European Commission

Best Available Techniques (BAT) Reference Document
for the

Intensive Rearing of Poultry and Pigs

Industrial Emissions Directive 2010/75/EU
(Integrated Pollution Prevention and Control

JOINT RESEARCH CENTRE
Institute for Prospective Technological Studies
Sustainable Production and Consumption Unit
European IPPC Bureau

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This document is one from the series of foreseen documents listed below (at the time of writing, not all documents have been drafted):

Best Available Techniques Reference Document...	**Code**
Ceramic Manufacturing Industry	CER
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Emissions from Storage	EFS
Energy Efficiency	ENE
Ferrous Metals Processing Industry	FMP
Food, Drink and Milk Industries	FDM
Industrial Cooling Systems	ICS
Intensive Rearing of Poultry and Pigs	*IRPP*
Iron and Steel Production	IS
Large Combustion Plants	LCP
Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers Industries	LVIC-AAF
Large Volume Inorganic Chemicals – Solids and Others industry	LVIC-S
Large Volume Organic Chemical Industry	LVOC
Management of Tailings and Waste-rock in Mining Activities	MTWR
Manufacture of Glass	GLS
Manufacture of Organic Fine Chemicals	OFC
Non-ferrous Metals Industries	NFM
Production of Cement, Lime and Magnesium Oxide	CLM
Production of Chlor-alkali	CAK
Production of Polymers	POL
Production of Pulp, Paper and Board	PP
Production of Speciality Inorganic Chemicals	SIC
Refining of Mineral Oil and Gas	REF
Slaughterhouses and Animals By-products Industries	SA
Smitheries and Foundries Industry	SF
Surface Treatment of Metals and Plastics	STM
Surface Treatment Using Organic Solvents	STS
Tanning of Hides and Skins	TAN
Textiles Industry	TXT
Waste Incineration	WI
Waste Treatments Industries	WT
Wood and Wood Products Preservation with Chemicals	WPC
Wood-based Panels Production	WBP
Reference Document...	
Economics and Cross-media Effects	ECM
General Principles of Monitoring	MON

Electronic versions of draft and finalised documents are publicly available and can be downloaded from http://eippcb.jrc.ec.europa.eu/.

PREFACE

THE PREVIOUS VERSION OF THE STANDARD TEXT INCLUDED IN DRAFT 1 OF THE REVISED IRPP BREF HAS BEEN SUBSTITUTED BY A NEW VERSION REPORTED BELOW, APPROVED BY THE IED ART. 13 FORUM

1. Status of this document

Unless otherwise stated, references to 'the Directive' in this document refer to the Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (integrated pollution prevention and control) (Recast).

This document is a working draft of the European IPPC Bureau (of the Commission's Joint Research Centre). It is not an official publication of the European Union and does not necessarily reflect the position of the European Commission.

2. Participants in the information exchange

As required in Article 13(3) of the Directive, the Commission has established a forum to promote the exchange of information, which is composed of representatives from Member States, the industries concerned and non-governmental organisations promoting environmental protection (Commission Decision of 16 May 2011 establishing a forum for the exchange of information pursuant to Article 13 of the Directive 2010/75/EU on industrial emissions (2011/C 146/03), OJ C 146, 17.05.2011, p. 3).

Forum members have nominated technical experts constituting the technical working group (TWG) that was the main source of information for drafting this document. The work of the TWG was led by the European IPPC Bureau (of the Commission's Joint Research Centre).

3. Structure and contents of this document

Chapters 1 and 2 provide general information on the intensive rearing of poultry and pigs and on the industrial processes and techniques used within this sector.

Chapter 3 provides data and information concerning the environmental performance of installations (farms) within the sector, and in operation at the time of writing, in terms of current emissions, consumption and nature of raw materials, water consumption, use of energy and the generation of waste.

Chapter 4 describes in more detail the techniques to prevent or, where this is not practicable, to reduce the environmental impact of installations (farms) in this sector that were considered in determining the BAT This information includes, where relevant, the environmental performance levels (e.g. emission and consumption levels) which can be achieved by using the techniques, the associated monitoring and the costs and the cross-media issues associated with the techniques.

Chapter 5 presents the BAT conclusions as defined in Article 3(12) of the Directive.

Chapter 6 presents information on 'emerging techniques' as defined in Article 3(14) of the Directive.

Concluding remarks and recommendations for future work are presented in Chapter 7.

4. Information sources and the derivation of BAT

This document is based on information collected from a number of sources, in particular through the TWG that was established specifically for the exchange of information under Article 13 of the Directive. The information has been collated and assessed by the European IPPC Bureau (of the Commission's Joint Research Centre) who led the work on determining BAT, guided by the principles of technical expertise, transparency and neutrality. The work of the TWG and all other contributors is gratefully acknowledged.

The BAT conclusions have been established through an iterative process involving the following steps:

- identification of the key environmental issues for the sector;
- examination of the techniques most relevant to address these key issues;
- identification of the best environmental performance levels, on the basis of the available data in the European Union and worldwide;
- examination of the conditions under which these environmental performance levels were achieved, such as costs, cross-media effects, and the main driving forces involved in the implementation of the techniques;
- selection of the best available techniques (BAT), their associated emission levels (and other environmental performance levels) and the associated monitoring for this sector according to Article 3(10) of, and Annex III to, the Directive.

Expert judgement by the European IPPC Bureau and the TWG has played a key role in each of these steps and the way in which the information is presented here.

Where available, economic data have been given together with the descriptions of the techniques presented in Chapter 4. These data give a rough indication of the magnitude of the costs and benefits. However, the actual costs and benefits of applying a technique may depend strongly on the specific situation of the installation concerned, which cannot be evaluated fully in this document. In the absence of data concerning costs, conclusions on the economic viability of techniques are drawn from observations on existing installations.

5. Review of BAT reference documents (BREFs)

BAT is a dynamic concept and so the review of BREFs is a continuing process. For example, new measures and techniques may emerge, science and technologies are continuously developing and new or emerging processes are being successfully introduced into the industries. In order to reflect such changes and their consequences for BAT, this document will be periodically reviewed and, if necessary, updated accordingly.

6. Contact information

All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

European Commission
Institute for Prospective Technological Studies
European IPPC Bureau
Edificio Expo
c/Inca Garcilaso, 3
E-41092 Seville, Spain
Telephone: +34 95 4488 284
Fax: +34 95 4488 426
E-mail: JRC-IPTS-EIPPCB@ec.europa.eu
Internet: http://eippcb.jrc.ec.europa.eu

Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry and Pigs

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SCOPE

THE PREVIOUS VERSION OF THE STANDARD TEXT INCLUDED IN DRAFT 1 OF THE REVISED IRPP BREF HAS BEEN SUBSTITUTED BY A NEW VERSION REPORTED BELOW, WHICH STRUCTURE HAS BEEN APPROVED BY THE IED ART. 13 FORUM.
OTHER RELEVANT INFORMATION PRESENT IN THE "OLD TEXT" HAS BEEN INCORPORATED IN THE MOST APPROPRIATE SECTIONS OF THIS DOCUMENT

This BREF for the intensive rearing of poultry or pigs covers the following activities within the scope of Annex I of Directive 2010/75/EU.

- Section 6.6. Intensive rearing of poultry or pigs:
  a. with more than 40 000 places for poultry
  b. with more than 2 000 places for production of pigs (over 30 kg), or
  c. with more than 750 places for sows.

In particular, this document covers the following processes and activities:

- Nutritional management of poultry and pigs
- Storage of animal feed and feed additives
- Milling and grinding of feed
- Rearing (housing) of poultry and pigs
- Collection and storage of manure
- On–farm processing of manure
- On-farm treatment of manure
- Landspreading of manure
- Storage of animal carcasses.

This document does not address the following activities:

- Animal slaughtering and disposal of animal carcasses covered by the Reference Document on Best Available Techniques for Slaughterhouses and Animal By-products Industries (SA).

Other reference documents which are of relevance for the sector covered in this document are the following:

Reference documents	Activity
Waste Incineration (WI)	Incineration of animal carcasses
Emissions from Storage (EFS)	Storage and handling of raw materials and products
Energy Efficiency (ENE)	General energy efficiency
Economics and Cross-media Effects (ECM)	Economics and cross-media effects of techniques

The scope of the BREF does **not** include matters that only concern safety in the workplace or the safety of products because these matters are not covered by the Directive. They are discussed only where they affect matters within the scope of the Directive.

1 GENERAL INFORMATION

This chapter provides general information on pig and poultry production in Europe. It briefly describes the position of Europe on the world market and developments in the internal European market and those of its Member States. It introduces the main environmental issues associated with intensive pig and poultry farming.

For the purpose of this document, the term '**farm**' is used as synonymous with '**installation**' that may consist of one or more stationary technical units (plants) and of all the directly associated activities. Other terminology used in this document include:

- Rearing of poultry: the rearing cycle for the production of eggs or for the production of meat from chickens, turkeys, ducks, guinea fowls, etc., including parental lines and pullets
- Rearing of pigs: the rearing of animals of the porcine species, of any age, kept for breeding or fattening
- Rearing of sows: the rearing of female pigs including mating, gestating and farrowing sows (including offsprings) as well as replacement sows (selected or purchased as replacement breeding stocks) and gilts. However, some member States do not consider gestating and maiden gilts as sows but as production of pigs.

1.1 Intensive livestock farming

Animal production represents 41.3 % of EU agricultural output by value. [4, Eurostat 2009]

Farming has been and still is dominated by family-run businesses. Until the mid-70s, ~~sixties and into the early seventies, poultry and pig production were only part of the activities of a~~, ~~where~~ crops were grown and different animal species were kept in mixed farming systems. Feed was grown on the farm or purchased locally and ~~residues of the animal~~ manures were returned to the land as fertiliser. ~~Very few examples of this type of farm still exist in the EU.~~

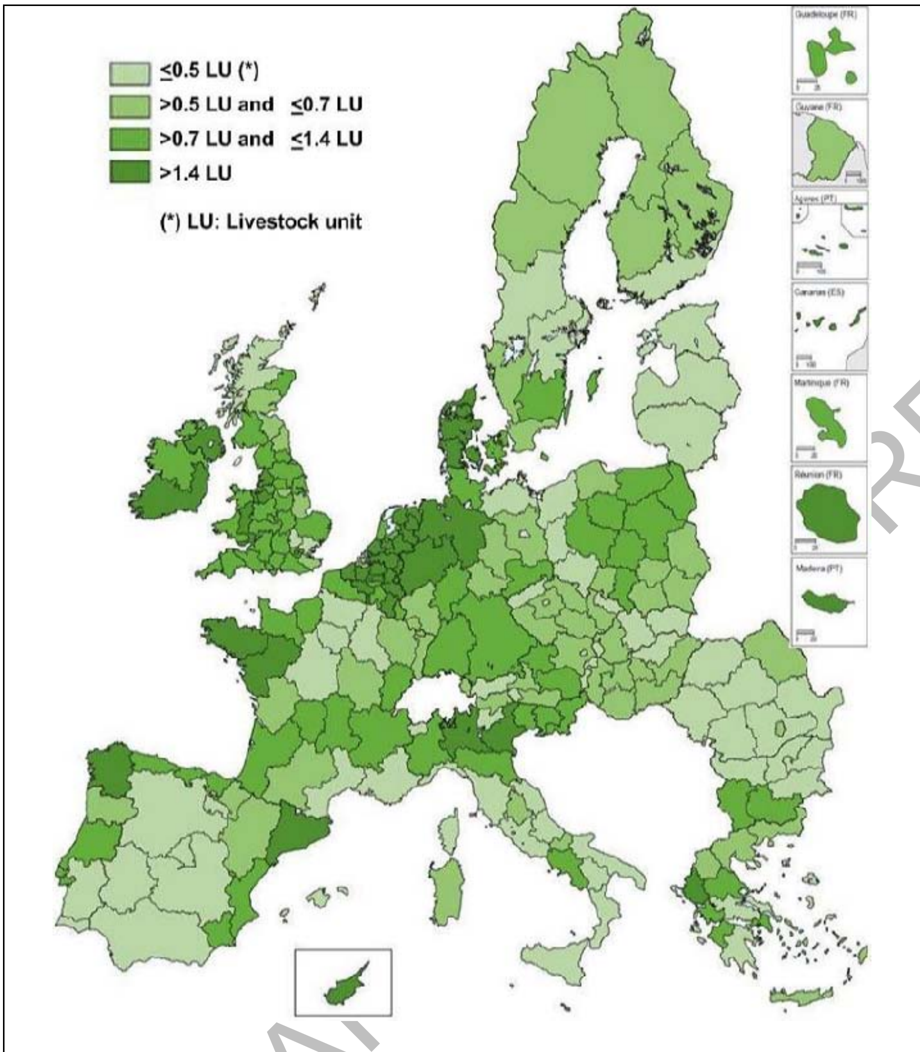
Since then, increasing market demands, the evolution of breeds due to ~~the~~ genetic ~~material~~ selection, the development of farming equipment and the availability of a wide range of feedstuff ~~relatively cheap feed~~ encouraged farmers to specialise. As a consequence, animal numbers and farm sizes increased and intensive livestock farming started. Some regions specialised in animal production; scale and agglomeration economies appeared, leading hence to high animal density areas. ~~Feeds were often~~ The feed market opened up and raw feed started to be imported from outside the EU~~, since the amounts and types needed could not be produced locally~~. Intensive farming thus led to significant imports of nutrients, that were then returned to soils in different ~~lands than~~ areas to that where the feed was produced, in the form of manure, sometimes in excessive loads.

~~that were not returned to the same land (via manure) that had produced the crops that provided the feed components. Instead The manure is was hence applied on the available land, being. However, in many intensive livestock regions there is insufficient land available. In addition, higher nutrient levels were fed to the animals (sometimes more than was strictly necessary) to ensure optimum growth levels. These nutrients, and especially those that were fed in excess, were consequently partly excreted in natural processes, thus increasing the level of nutrients in the manure and in the fields even more.~~

~~Intensive livestock farming coincides with high animal densities.~~ Animal density is itself considered a rough indicator of the amount of animal manure produced ~~by livestock. A high density usually indicates that~~ and therefore of the nutrient ~~mineral~~ supply to the land, which ~~that might~~ can exceed~~s~~ the requirements of the agricultural area to grow crops or to maintain grassland. Hence, data on the concentration of livestock production at a regional level are considered ~~to be~~ a good indicator of areas with potential environmental problems (e.g. nitrogen pollution).

~~on the management of nitrogen pollution [77, LEI, 1999],~~ The term livestock units (LU = 500 kg animal mass) can be ~~is~~ used in ~~a~~ reports to present the total size of the livestock population, allowing a summation of animal species according to their feed requirements. The meaning of the term 'intensive livestock farming' in Europe is illustrated by using animal density expressed in the number of livestock units per hectare of utilised agricultural area (LU/ha).

Figure 1.1 shows animal density of all farmed livestock (in LU/ha) at a ~~the~~ regional level~~s~~ in 2007. ~~Animal density exceeds 2 LU/ha in most of the Netherlands, parts of Germany (Niedersachsen, Nordrhein-Westfalia), Brittany (France), Lombardy (Italy) and some parts of Spain (Galicia, Cataluña). A stocking density of 2 LU/ha is considered to be close to the amounts of nitrogen from livestock manure that may be applied in accordance with the Nitrates Directive.~~ The picture ~~also~~ illustrates that for nearly all Member States, the environmental impact of intensive livestock farming is a regional issue, but for a few countries like the Netherlands and Belgium it can almost be considered a national issue. The ~~picture's~~ maximum definition for the legend is 1.5 LU/ha, but higher densities over 2 LU per hectare are recorded in 21 of the 257 regions in the map. This ratio exceeds 4 LU in Malta, in four Dutch regions and in two Belgian regions. [2, Eurostat 2009]. Table 1.1 shows the variation of ~~the~~ animal density for the years 2003, 2005 and 2007 in the EU and for each Member State, expressed in livestock units per hectare of utilised agricultural area.



Source [2, Eurostat 2009].

Figure 1.1: Animal density in the European Union expressed as number of livestock units per hectare of utilised agricultural area 2007

Table 1.1: Animal density in the European Union expressed as number of livestock units per hectare of utilised agricultural area for the years 2003, 2005 and 2007 over time

Country	2003	2005	2007	Country	2003	2005	2007
EU-27	0.82	0.79	0.78	Lithuania	0.47	0.46	0.39
EU-15	0.89	0.88	0.88	Luxembourg	1.24	1.22	1.22
Belgium	2.84	2.80	2.75	Hungary	0.61	0.58	0.56
Bulgaria	0.56	0.49	0.40	Malta	4.53	4.50	4.80
Czech republic	0.63	0.58	0.58	Netherlands	3.07	3.26	3.35
Denmark	1.71	1.69	1.72	Austria	0.77	0.75	0.77
Germany	1.10	1.07	1.06	Poland	0.77	0.72	0.72
Estonia	0.41	0.38	0.35	Portugal	0.63	0.56	0.58
Ireland	1.47	1.47	1.42	Romania	0.52	0.47	0.43
Greece	0.66	0.62	0.64	Slovenia	1.20	1.08	1.13
Spain	0.56	0.58	0.57	Slovakia	0.45	0.42	0.38
France	0.84	0.82	0.82	Finland	0.53	0.51	0.50
Italy	0.76	0.75	0.77	Sweden	0.59	0.57	0.57
Cyprus	1.64	1.61	1.68	United Kingdom	0.90	0.90	0.86
Latvia	0.31	0.27	0.28	*Source:* [6, Eurostat 2009]			

In the pre-accession period, between 2003 and 2007, the new Member States recorded significant falls in livestock population.

The areas with high livestock densities typically have many intensive pig and poultry farms, each with a large number of animals. For example, the share of pigs and poultry exceeds 50 % in most of these regions and poultry accounts for more than 20 % of the regional livestock population in parts of France (Pays de la Loire, Bretagne), Spain (Cataluña) and the United Kingdom (East England). In some Member States; there is a decline in the actual number of farms, but the remaining farms now tend to keep more animals and have higher production. In only a few Member States (e.g. Spain) are new enterprises being started or large facilities being installed. [77, LEI, 1999] Based on data submitted by Member States during the first half of 2008, information on the number of installations farms falling under point 6.6 of the IED Directive is given in Table 1.2.

Table 1.2: Summary of existing installations farms requiring a permit by category of activities in Annex I to Directive 2010/75/EUE (reference period 2007 – 2008).

Member State	Total	Poultry 6.6 (a)	Pigs Sows 6.6(b)	Sows Pigs 6.6 (c)
Belgium ([1])	518	322	179	17
Flanders	*575*	*328*	*224*	*23*
Wallonia	*40*	*26*	*13*	*1*
Bulgaria	80	38	22	20
Czech Rep.	418	222	135	61
Denmark	NA	NA	NA	NA
Germany	1 321	720	395	206
Estonia	40	6	34	NA
Ireland	209	120	89	NA
Greece	42	31	7	4
Spain	1 732	277	1 206	249
France	2 813	2 504	284	25
Italy	1 424	749	580	95
Cyprus	61	27	34	0
Latvia	32	8	22	2
Lithuania	45	17	24	4
Luxembourg	1	0	1	0
Hungary	502	213	241	48
Malta	2	2	0	0
Netherlands	1 781	925	639	217
Austria	4	4	0	0
Poland	594	472	116	6
Portugal	196	98	83	15
Romania	169	111	49	9
Slovenia	25	16	8	1
Slovakia	113	70	38	5
Finland	131	107	14	10
Sweden	274	157	102	15
UK	1 179	965	177	37

NA = Not available
([1]) In Flanders, the number of farms requiring a permit for the reference year 2009 was in total 575, of which 224 were for pigs, 23 for sows and 328 for poultry.
Source: [7, DG Env 2009] [45, Flanders 2010]

1.2 The poultry production sector in Europe

By far the majority of poultry farms are part of the production chain for ~~chicken~~ eggs or for chicken broilers. A comparatively small number of farms produce turkey~~s~~ (meat) and duck~~s~~ (for meat, foie gras or eggs). Very little is known yet about the production of guinea fowl, with France being the most important producer with 926 farms ~~Guinea fowl~~. Sections 1.2.1, 1.2.2 and 1.2.3. ~~The following sections~~ describe briefly the poultry sectors in Europe with an ~~the~~ emphasis on chicken production.~~ as only limited information has been submitted on the other production sectors. More detailed statistical data can be found in the annual reports of the European Commission (DG Agriculture and Eurostat).~~

The table below has been moved to Section 1.2.1

~~Table 1.4: Global and EU egg production over time.~~

~~Year~~	~~Production (1000t) World~~	~~EU-27 (*)~~	~~EU (%) Share~~
~~t2002~~	~~59 724~~	~~7423~~	~~12.4~~
~~2003~~	~~61 447~~	~~7168~~	~~11.7~~
~~2004~~	~~63 085~~	~~7469~~	~~11.8~~
~~2005~~	~~64 782~~	~~7404~~	~~11.4~~
~~2006~~	~~66 532~~	~~7154~~	~~10.8~~
~~2007~~	~~68 000~~	~~7236~~	~~10.6~~
~~(*) Figures consider all 27 Member States data even before EU-27 realisation~~ ~~Source [9, Windhorst H.W. 2008]~~			

Poultry production data vary by ~~per~~ poultry species and poultry breed and also somewhat by ~~per~~ Member States, depending on market demands. Breeds are either selected for their egg producing capacities or growing (meat) potential.

Table 1.3 shows some typical production data for poultry species under the scope of the Directive ~~IPPC~~ (figures can be seen in connection with data in Table 3.2).

Table 1.3: ~~Some~~ Typical poultry breeding data

Types of animal production	**Production cycle (days)**	**Live weight (kg)**	**Density (kg/m²)**
Laying hens	350 – 450	1.1 – >2.0	12 – 36
Standard broilers	33 – 42	1.5 – 2.6	30 – 37
Heavy broilers	45 – 63	2.2 – 3.2	38 – 50
Male turkey	~~up to~~ 84 – 150	10 ~~12~~ – 21	58
Female turkey	63 – 120	3.5 – 15	52
Duck Pekin	48 – 56	2.8 – 3.75	20 – 55
Duck Barbary	85	3.9	55 ([1])
Guinea fowl	77	1.63 – 1.78	24 – 30 ([1])
([1]) Values calculated from data provided by [328, CORPEN 2006] and [418, ITAVI 2010] *Source:* [328, CORPEN 2006] [383, France 2010] [418, ITAVI 2010] [500, IRPP TWG 2011]			

~~Types of technical elements~~	~~Laying hens~~	~~Broilers: Standard broilers~~	~~Broilers: French broiler~~	~~Turkey: Male~~	~~Turkey: Female~~	~~Duck~~
~~Production cycle (days)~~	~~350 385 – 450~~	~~39 – 45~~	~~35 – 62~~	~~115 – 150133~~	~~90 98 – 133~~	~~42 – 86 49~~
~~Weight (kg)~~	~~1.85 – 2.0~~	~~1.85 – 2.15~~	~~1.3 – 3~~	~~1214.5 – 15~~	~~6 7.5 – 15~~	~~2.3 – 3.89~~
~~Feed conversion ratio~~	~~1.77~~	~~1.85~~	~~1.7 – 2.2~~	~~2.4 – 2.72~~	~~2.37 – 2.4~~	~~2.5 – 2.77~~
~~Weight (kg)/m²~~	~~No data~~	~~30 – 37~~	~~35 – 52~~	~~70 – 75~~	~~70 – 75~~	~~20 – 55~~
~~*Source:* [8, Portugal 1999], [506, TWG ILF BREF 2001], [383, France 2010].~~						

1.2.1 Egg production

Worldwide, Europe is the second largest producer of hen eggs, ~~with about~~ producing around ~~19~~10 % of the world total (see Table 1.4), equalling 6 619 ~~7346~~ thousand tonnes ~~148688 million~~ eggs ~~per~~ in the year 2009 ~~2007~~. It is considered that 1 tonne equals around 16 020 eggs. Production and consumption data are displayed in Table 1.5.~~ (1998)~~, ~~and it is expected that this production will not change significantly in the coming years.~~ ~~In 1999, the EU-15 had about 305 million layers producing 5342 million tonnes of eggs, or, at an average of about 62 grams per egg, approximately 86161 million eggs. This means that on average about 282 saleable eggs per hen per year were produced (the actual number will be slightly higher, as some eggs will be lost due to cracks and dirt). Egg production follows a cyclical pattern as production is increased/reduced after periods of favourable/ low prices [203, EC, 2001].~~

Table 1.4: ~~Global~~ World and EU-27 egg production for consumption ~~over time~~

Year(s)	Production (1 000 tonnes)		EU-27 share
	World	EU-27	(%)
1999 – 2001	55 140	6 702	12.2
2003 – 2005	59 939	6 704	11.2
2007	64 303	6 630	10.3
2008	66 103	6 773	10.2
2009	67 408	6 619	9.8
Source: [566, FAO 2010]			

Eggs for human consumption are produced in all Member States. In the year 2009, the top EU producer states were France (918 Mt), Spain (802 Mt), Italy (724 Mt), and Germany (698 Mt). In 2011, the main exporters of eggs for consumption ~~states~~ were the Netherlands with 53 % of the total EU-27 export, (~~318 Mt~~), Germany (13.1 %), Poland (10.6 % ~~86.4 Mt~~), Spain (6.8 % ~~135 Mt~~) and France (5.9 %). ~~Germany (306.6 Mt) is the leading importer in the EU (33.6 %) and also on a global level.~~ The main importers from Third Countries for the year 2011 were Greece with 47.8 % of the total import into the EU-27, United Kingdom (19.8 %) and Denmark (12.9 %).

Table 1.5: Balance sheet for poultry meat and egg production in the year 2008 ~~2007~~

Productions	Eggs	Poultry Meat
Gross internal production (1 000 t)	7 067 ~~7346~~	11 640 ~~11459~~
Import (1 000 t)	24 ~~44~~	864 ~~829~~
Export (1 000 t)	187 ~~167~~	905 ~~811~~
~~Other uses (1000 t)~~	~~735 (1)~~	~~5(2)~~
Internal ~~food~~ consumption (1 000 t)	6 903 ~~6488~~	11 599 ~~11472~~
Per capita consumption (kg/head)	12.3 ~~13.1~~	23.35 ~~23.2~~
~~(1) Other uses eggs: hatching eggs, losses, industrial use.~~ ~~(2) Other uses poultry meat: import of live animals.~~ *Source:* [10, CIRCA 2009 (Bilan oeufs - Balance sheet eggs), (Bilan volaille - Balance sheet poultry)] [567, AGRI-C4 2012]		

The transition to ~~the~~ full compliance ~~to~~ with the Council Directive 1999/74/EC ‘laying down minimum standards for the protection of laying hens’ encountered ~~ongoing with~~ difficulties as reported in the ‘Communication from the Commission on the various systems of rearing hens’ of 8 January 2008. Member States shall ensure that the provisions of the Directive 1999/74 concerning rearing in the cages are fully applied from 1 January 2012, as stated in Article 5 (2)

~~compliance with Article 10~~ of this Directive. In Europe, in 2008, 278 million hens were reared in cage systems, of which only about 7 % were in enriched cages ~~colonies~~.

Information provided in the Communication from the Commission SEC(2007)1750, based on a number of independent scientific and socio-economic studies, supports the ~~upcoming~~ ban on unenriched cages. It also confirmes that unenriched cages present serious animal welfare problems and that there are clear benefits in changing to enriched caging or alternative systems. It was reported that the cost of production in enriched cages ~~should be~~ were around 10 % more than in unenriched cages, but it also stated that 57 % of EU citizens ~~stated to be~~ were prepared ~~ready~~ to pay more for eggs sourced from animal-welfare-friendly production [20, EC 2008].

~~The majority of laying hens in the EU are still kept in conventional cages, although by January 2012 they must be abandoned. particularly~~

In northern Europe, non-cage egg production has gained ~~in~~ popularity, since the end of the ~~years~~ 1990s. ~~over the past ten years. For example, the United Kingdom, France, Austria, Sweden, Denmark and the Netherlands have increased the proportion of eggs produced in systems such as barn, semi-intensive, free range and deep litter.~~ In Austria, conventional cages were prohibited at the end of 2008, and enriched colonies will also be banned by 2020, whilst in Germany, all conventional cages should have been abandoned by the end of 2009. In Sweden conventional cages ceased to be used by the end of 2002 and enriched colony systems are permitted. In the United Kingdom, ~~from the~~ around 30 million egg laying hens were reared in 2007, from which 62 % of eggs were produced in battery cages (versus ~~against~~ 85 % in 1997 ~~ten years before~~), 4 % in barn systems and 34 % in free-range systems. Barn production systems are also widespread, accounting for more than 15 % of the flocks in Cyprus, Hungary and Germany, and 41 % in the Netherlands. [5, The Poultry Site 2009].

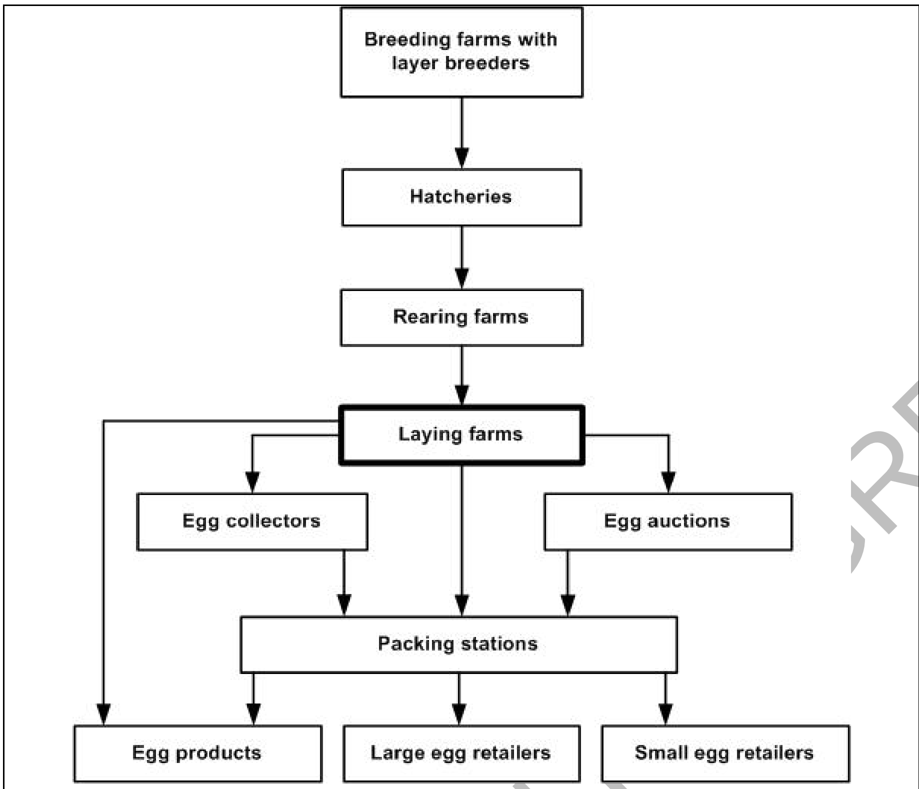
Most of the EU-produced consumption eggs (about 95 %) are consumed within the European Community itself. The average EU-27 annual consumption per capita in ~~2000 was about 12.3 kg~~ 2007 was about 13.1 kg (see Table 1.6).~~Compared with 1991, consumption levels show a slight decline~~

Table 1.6: Gross human apparent consumption per capita of eggs and poultry meat ~~some animal products~~ (availability for human consumption) for the year 2007

Country	Poultry meat (kg)	~~Pork (kg)~~ *Moved to Section 1.3.2*	Eggs (kg)
Belgium	21.1	~~51.8~~	12.7
Bulgaria	19.0	~~21.0~~	NA
Czech Republic	2.3	~~NA~~	NA
Denmark	21.7	~~52.1~~	17.0
Germany	16.6	~~53.9~~	12.7
Estonia	18.0	~~36.0~~	NA
Ireland	31.0	~~38.5~~	10.9
Greece	19.3	~~28.4~~	10.3
Spain	32.1	~~60.9~~	18.0
France	23.0	~~34.4~~	15.2
Italy	15.3	~~39.0~~	11.1
Cyprus	45.0	~~72.0~~	NA
Latvia	NA	~~NA~~	NA
Lithuania	11.8	~~26.1~~	NA
Luxembourg	11.5	~~44.1~~	NA
Hungary	29.0	~~46.0~~	NA
Malta	22.9	~~33.0~~	NA
Netherlands	18.6	~~42.4~~	13.5
Austria	18.7	~~57.0~~	14.2
Poland	19.8	~~48.1~~	NA
Portugal	29.8	~~44.2~~	8.5
Romania	19.0	~~33.0~~	NA
Slovenia	26.0	~~42.0~~	NA
Slovakia	19.0	~~34.0~~	NA
Finland	16.2	~~33.7~~	9.3
Sweden	13.9	~~36.1~~	12.1
United Kingdom	29.8	~~21.6~~	11.2

NA = Not available.
NB: Gross human apparent consumption: quantity of products made available for human consumption in all forms (See Glossary).
Source:[1, Eurostat 2008] [3, Eurostat 2009].

The production chain of the egg production sector is a sequence of different activities, each representing one breeding or production step (see Figure 1.2). The breeding, hatching, rearing and egg laying often take place at different sites and on different farms to prevent the possible spread of diseases. Layer farms, particularly the larger ones, often include the grading and packing of eggs, after which the eggs are delivered directly to the retail (or wholesale) market.



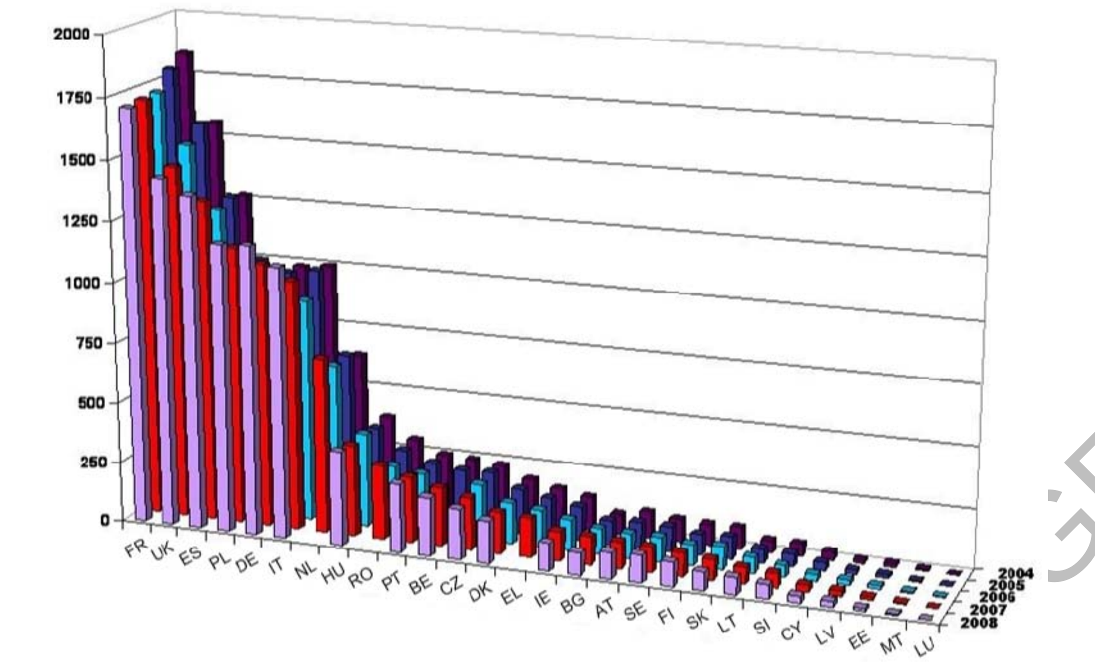
Source: [24, LNV 1994]

Figure 1.2: Example of the production chain of the egg production sector

The other egg-producing sectors (in particular ducks)~~. They~~ represent ~~form~~ only a very small portion of the rearing activity in comparison with the chicken egg production sector. Little information ~~Not very much is known yet on~~ is available in relation to the structure, position and development~~s~~ of these sectors.

1.2.2 Poultry meat ~~Broiler~~ production

~~According to DG Agriculture unit D2, the total production of poultry meat in the EU-15 was 8.784 megatonnes for the year 2000, of which 8.332 megatonnes were consumed within the EU. The balance, 0.452 megatonnes (5.1 %) was net export. [203, EC, 2001]~~
Poultry meat production is relatively stable. In 2008, the total production of poultry meat in the EU-27 ~~in 2007~~ was around 11.7 ~~11.4~~ million tonnes ~~megatonnes~~ (see Table 1.5). Data related to ~~at~~ the EU-27 production ~~level~~ are reported in Figure 1.3, for each Member State. ~~of which 8332 megatonnes were consumed within the EU. The balance, 0.452 megatonnes (5.1 %) was net export~~ In the year 2009, the biggest producer of poultry meat in the EU-27 ~~15 in that year (year 2000)~~ was France (~~26~~15.3 % of EU production), followed by the United Kingdom (~~17~~12.9 %), ~~Italy (12 %) and~~ Spain (~~11~~11.8 %), and Poland (10.2 %). Production in these Member States, as well as in Germany and Italy, was around or above ~~of over or around~~ one million tonnes, in 2009.~~ are reached in these Member States as well as in Poland and Italy~~.

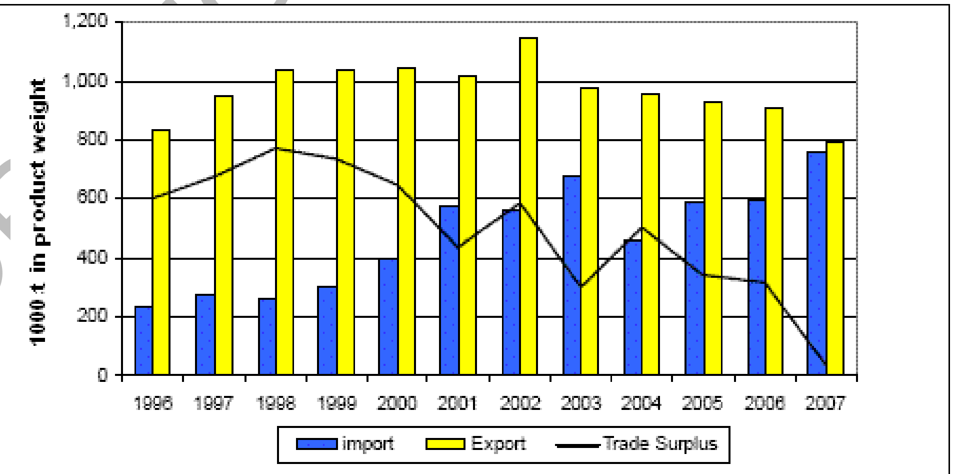


Source: [12, Eurostat 2009], [382, VEPEK 2009]

Figure 1.3: Slaughtered animals for poultry meat production (1 000 t carcass weight)

~~Production of poultry meat has been increasing since 1991 by an average of 232000 tonnes per year. The largest EU producers (France, UK, Italy and Spain) all showed an increase in their poultry meat production.~~

Some countries are clearly export-oriented, such as the Netherlands and Denmark, where ~~63 %~~ nearly half of the production is not consumed within the country, ~~as well as Denmark,~~ or France and Belgium where nearly one-third ~~51 %, 51 % and 31 % respectively~~ of production is exported~~are not consumed within the own country~~. On the other hand, some countries such as Germany, Greece and Austria have higher consumptions than their own production.~~ in those countries, 41 %, 21 % and 23 % respectively of total consumption is imported from other countries. [203, EC, 2001]~~ At the EU level, the trade balance of poultry meat over ~~in the~~ time is described in Figure 1.4.



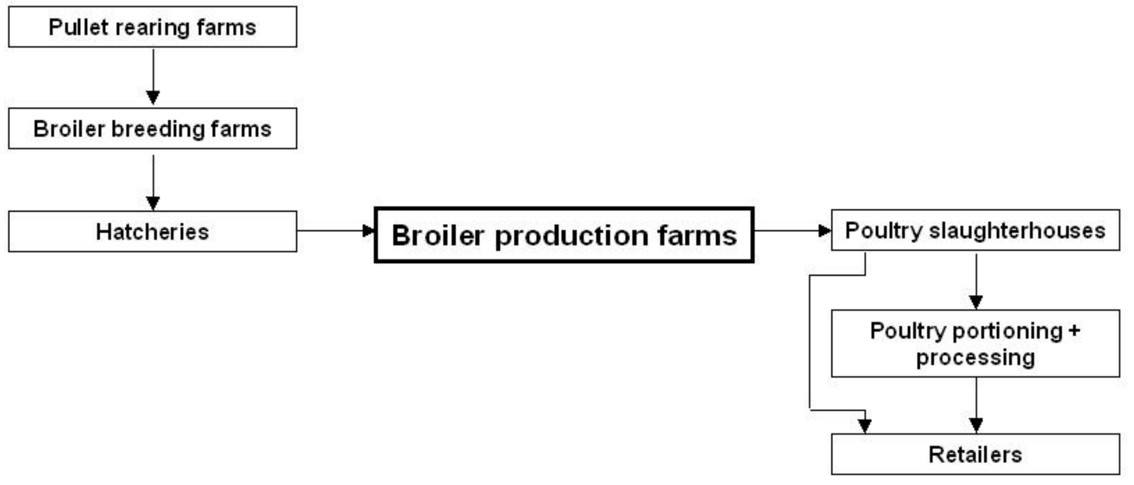
Source: Comext in [12, Eurostat 2009].

Figure 1.4: EU import and export of poultry meat ~~over time~~

In 2007, Spain recorded the highest per capita apparent consumption of poultry meat: the two Iberian Member States, as well as Ireland and the United Kingdom all recorded annual apparent consumption of poultry meat averaging approximately 30 kg per capita. The Czech Republic recorded by far the lowest apparent consumption, just 2.3 kg per capita (see Table 1.6).

EXISTING FIGURE 1.4 AND TEXT REPORTING DATA FOR THE REFERENCE PERIOD 1991 – 1999 HAVE BEEN DELETED

The production of broilers for meat is a specialised part of the broiler production chain. The different steps in the broiler chain are shown in Figure 1.5. This document addresses, in particular, the broiler production farms. Broilers are generally not housed in cages, although cage systems exist. The majority of poultry meat production is based on an all-in, all-out system applying littered floors. Broiler farms with over 40 000 bird places are quite common in Europe. The duration of a production cycle depends on the required slaughter weight, feeding and the condition (health) of the birds, and varies between five 5 weeks (Finland) and eight 8 or nine weeks, [26, Finland 2001] after which the broilers are delivered to the slaughterhouse. After every cycle, the housing is fully cleaned and disinfected. The length of this period varies from one day [500, IRPP TWG 2011] 1 week up to two (Finland, UK) or even three weeks (Ireland).



Source: [24, LNV 1994].

Figure 1.5: Example of the production chain of the broiler production sector

A type of production that has so far been specific to France involves the so-called 'red label' broiler. The broilers have permanent access to the open range and are slaughtered at the minimum age of 80 days, at more than 2 kg live weight (LW). This type of production is gaining popularity and represents to date (year 2000) close to 20 % of the French broiler consumption. [506, TWG ILF BREF 2001]

The turkey production sector is the largest of the other poultry meat producing sectors. It is an important sector in four Member States (France, Italy, Germany and the UK). Since 1991 the production in the EU has increased by 50 % [203, EC, 2001]. Annual patterns of turkey poult (young turkey) placings in the EU show similar patterns with four peak placings in February-March, June, August-September and November-December.

The European production of guinea fowl is approximately 45 million guinea fowl per year, 86 % of which is produced in France and 13 % in Italy.

1.2.3 Economics of the poultry sector

The majority of poultry farms are family-run enterprises. Some farms belong to large integrated companies ~~holdings~~ carrying out all the ~~that~~ activities ~~that are part~~ of a production line, from production to retail and including animal feed supply. ~~The investment in livestock and production items (equipment, housing) is linked with the farms' net margin.~~ The net margin of poultry farms varies in each Member State and depends on production costs and product price. Production costs may consist of:

1. costs for chicks ~~(except in integrated systems)~~
2. feed costs
3. water costs
4. litter costs
5. cleaning and disinfecting costs
6. manure management costs
7. veterinary costs
8. labour costs
9. energy costs
10. maintenance of equipment and buildings
11. depreciation costs for equipment and buildings
12. interest.

The cost of egg production is also clearly related to production factors such as the stocking density. Production costs are lowest in multi-bird cages; costs increase with increasing space allowances in cages and with the use of non-cage systems. The production of free-range eggs is considerably more costly than any other non-organic system.

The reductions in stocking density realised to comply with ~~the~~ Council Directive 1999/74/EC resulted in decreased production in several Member States. In the United Kingdom and in Germany, egg production decreased by 121 000 t and 81 000 t respectively, as a consequence of the decision of several food chains in the UK not to ~~list~~ stock cage eggs any longer, and of an animal protection act in Germany, which prohibited conventional cages from 2009 onwards ~~on~~ [9, Windhorst H.W. 2008].

Enriched colonies require higher capital investment, lower animal densities and a slightly higher labour input, implying an additional cost per hen of around 10 %. However, consumers regard free-range and organic eggs in a positive manner, and this generates higher market prices. ~~that enriched colonies do not provide~~ ([5, The Poultry Site 2009])

Estimated economic figures for different laying hens rearing systems in Europe are reported in Table 1.7.

EXISTING TABLE 1.6 REPORTING PRODUCTION DATA FOR THE REFERENCE PERIOD 1996 HAS BEEN DELETED

Table 1.7: EU level weighted average of production parameters and ~~technical~~ costs for each system to keep laying hens

	Unit	Traditional cage	Barn	Free range	Organic	Average
Laying cycle	Days	388	382	378	354	387
Empty period	Days	22	25	23	26	22
Feed/bird/year	kg	38.82	41.84	43.99	43.19	39.33
Feed/bird/day	g	112	121	126	127	113
Eggs/bird/year (collected)		280	269	261	246	278
kg feed/kg eggs		2.21	2.49	2.70	2.81	2.27
Mortality	%	6	9.1	10.4	12.8	6.5
No of hens managed/labourer		36 714	17 420	11 031	5 031	33 694
No of hens housed/m^2 of house		79	8	8	7	70
Space allowance/hen	cm^2	534	1 271	1 247	1 443	630
Pullet cost	EUR	3.17	3.63	3.77	4.64	3.25
End-of-lay hen weight ~~at end of lay~~	kg	1.53	1.21	1.51	1.19	1.51
End-of-lay hen price ~~at end of lay~~	EUR	0.18	0.18	0.11	0.43	0.17
Source: [25, AGRA CEAS 2004].						

The gross income of a farm depends on the number of eggs or kg of live weight that can be sold and the prices the farmer receives (including the price of end-of-lay hens). The prices of poultry products are not guaranteed or fixed and fluctuate with price fluctuations ~~on~~ in-the market. In some Member States (FR, DE, UK, IT), contracts are stipulated between farmers and buyers to reduce prices fluctuations. This market is in turn affected by the dynamics and the structure of the large grocery retailers (15 in 1999), who are the main outlets for the poultry products and are therefore responsible for the majority ~~part~~ of the annual turnover of poultry products.

From ~~Starting in~~ the 1990s, average prices for eggs and poultry meat ~~began to~~ have encountered peaks and troughs ~~ups and downs~~. The average price for eggs for consumption ranged from EUR 86.33/100 kg in 2004 to EUR 119.89/100 kg in 2009 ~~113.21/100 kg in 2008~~ and dropped to 112.09/100 kg in 2010. The average price for broiler meat ~~slightly~~ increased from EUR 138.11/100 kg in 2002 to 180.93/100 kg in 2008 and fell to 171.30/100 kg in 2010. [10, CIRCA 2009]

EXISTING TEXT REPORTING PRICE DATA FOR THE REFERENCE PERIOD 1991 – 1999 HAS BEEN DELETED

An example of production costs for the poultry meat sector is shown in Table 1.8, where French national averages for the year 2009 are displayed. Production costs before slaughter are calculated (plucking and bleeding are excluded) on the basis of technical and economic data weighed on production volumes. The calculations include investment costs, fixed costs (heating, electricity, water, etc.), variable costs (feeding, chicks, etc.) for fully equipped housing.

Table 1.8: Average performance data and production costs for meat poultry species in France for the year 2009

Parameter	Broiler			Turkey		Duck		Guinea-fowl
	Standard	Heavy		Male	Female	Male	Female	
		'Certified'	'Label'					
Stocking density at start (animals/m^2)	22.8	17.9	11.0	7.9		14.9		17.1
Production cycles per year	6.51	4.88	3.27	2.53		3.44		3.74
Age at slaughter (days)	37.7	58.5	87.6	120.7	88.0	84.4	70.2	77.2
Live weight at slaughter (kg)	1.9	2.22	2.3	12.9	6.5	4.6	2.5	1.7
Feed conversion ratio	1.8	2.16	3.2	2.4	2.4	2.8	2.8	2.8
Mortality (%)	4.18	2.64	3.60	6.87		4.1		5.5
Production cost (EUR/kg live weight)	0.831	0.938	1.607	1.137		1.271 – 1.299		1.593
Source: [418, ITAVI 2010]								

THE FORMER TABLE 1.8, ALREADY CROSSED OUT IN DRAFT 1, HAS BEEN DELETED

1.3 The pig production sector in Europe

1.3.1 Dimension, evolution and geographical distribution of the pig production sector in Europe

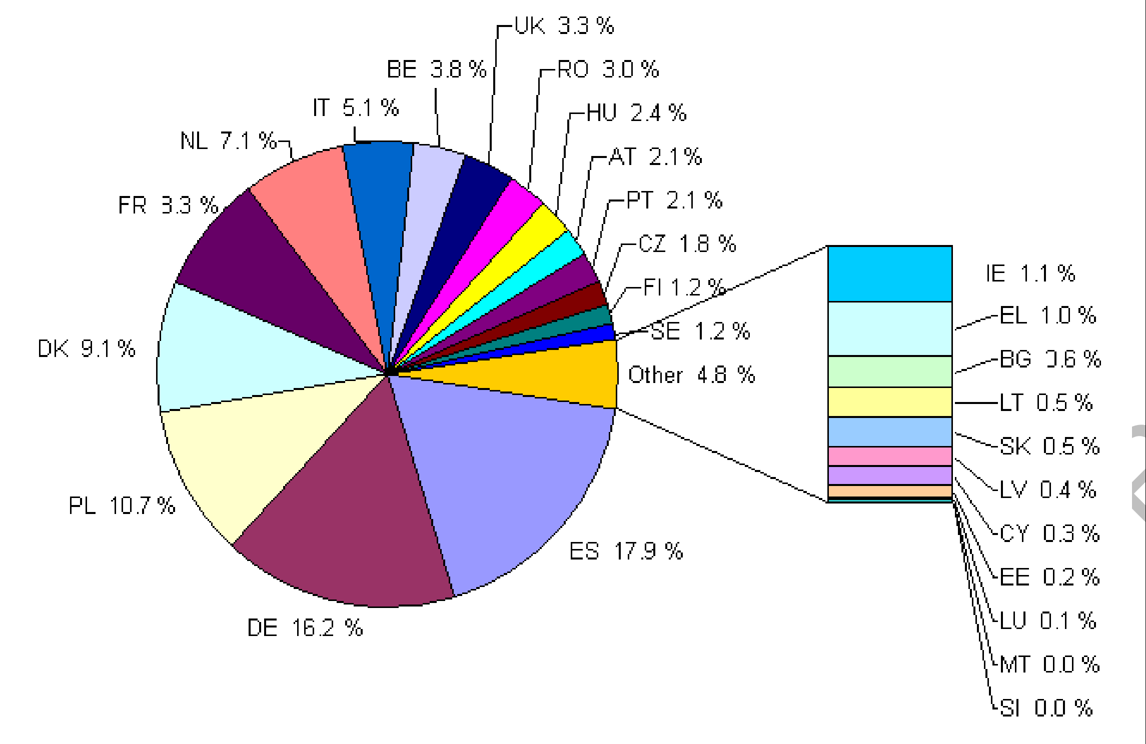
In 2007, the pig population in the EU-27 consisted of an estimated 42.1 million piglets (<20 kg), 36.1 million growers (>20 kg and <50 kg), 58.1 fattening pigs (>50 kg) and 15.2 million breeders (>50 kg), of which 0.3 million were boars and 14.9 million were sows. [3, Eurostat 2009].

In the former EU-15 countries, ~~the~~ population patterns that were recorded at the end of the previous century remained the same: in some MSs, pig numbers continued growing (Spain, Denmark, the Netherland), others continued in a slow decrease (UK, Ireland, Belgium, France) or a moderate decrease (Portugal, Sweden). Hence, the overall EU-27 pig population has slightly decreased, as shown in Table 1.9. Pig production decreased in the new Member States in the pre-accession period.

Table 1.9: ~~Total number of~~ Pig population in the EU-27, EU-15 and new EU Member States ~~over time~~ in millions

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2005–2008
EU-27	157.3	158.2	160.4	159.0	158.6	159.1	161.9	160.0	153.1	-3.80 %
EU-15	122.2	122.7	122.2	121.7	122.7	122.2	124.5	124.7	123.0	0.62 %
New MSs	35.1	35.4	38.2	37.3	35.9	36.9	37.5	35.4	30.1	-18.44 %
Source [3, Eurostat 2009].										

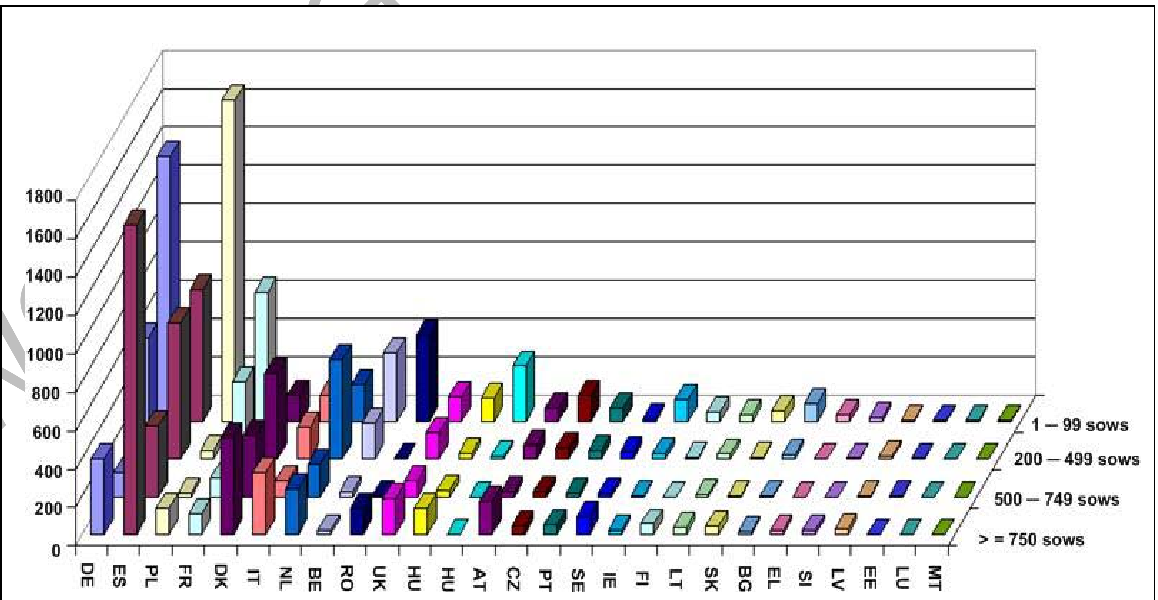
The major pig breeding Member States in 2007 were ~~are~~ Spain, Germany, Poland, Denmark, France and the Netherlands with a combined share of ~~71~~69.3 % of the breeding sows of the EU-27 ~~in 1998~~ (See Figure 1.6).



Source: [3, Eurostat 2009]

Figure 1.6: Distribution of breeding sows in Europe for each Member State in 2007

Pig farms vary considerably in size. The most recent figures on unit size available for all 27 Members States relate to 2005 (see Figure 1.7) ~~1997~~. ~~The~~ Farms rearing less than 10 pigs in Romania, Poland, Bulgaria, Hungary and Lithuania ~~are~~ account for more than 70 % of the total fattening farms in the EU-27. Among these Member States that joined the EU from 2004 and 2007, there was a period of land restitution in the run-up to accession to the EU. This led to the dividing up of formerly large state farms and replacing them with private individuals farms, leading to a substantial rise in the numbers of farms, and especially in smaller ones (except in Poland where many small farms existed in the socialist period). [14, Eurostat 2008] [383, France 2010]



Source [14, Eurostat 2008].

Figure 1.7: Number of sows (head × 1 000) in different sized units in 2005 ~~(1997)~~

In the UK, approximately 40 % of the total 438 thousand breeding sows are reared outdoors in rotational systems. This type of rearing scheme is not included in the statistics of the permitted farms given in Table 1.2.

~~The majority of~~ About three-quarters of the pigs for fattening ~~(81 %)~~ are reared on units of 200 pigs or more (see Table 1.10) ~~and 63 % of them on units of more than 400 pigs~~. The industry in Spain, Germany, Denmark and Italy ~~United Kingdom and Ireland~~ is characterised by units of more than 1 000 fattening pigs: in these farms throughout the EU-27, almost 60 % of fattening pigs are reared yearly, of which nearly 1 million are in Spain. Germany, Poland, Spain, France and Austria ~~the Netherlands~~ have significant proportions of pigs in units of between 50 and 400 fattening pigs.

Table 1.10: Number of ~~pig~~ farms for fattening pigs in 2005 in EU Member States in different size units (No of heads).

Member State	Total herds	Herds with fewer than 10 heads	Herds with 10 – 99 heads	Herds with 100 – 999 heads	Herds with 1 000 heads or more
Belgium	7 390	1 330	650	4 190	1 220
Bulgaria	175 670	173 680	1 790	140	60
Czech Republic	13 770	10 780	1 740	900	350
Denmark	8 890	610	1 450	3 960	2 870
Germany	83 780	30 960	24 840	24 040	3 940
Estonia	3 290	2 940	220	80	50
Ireland	690	240	80	150	220
Greece	31 380	27 660	3 160	450	110
Spain	95 610	78 840	5 120	7 230	4 420
France	38 910	23 660	2 730	10 480	2 040
Italy	100 900	89 250	7 850	2 080	1 720
Cyprus	520	380	50	20	70
Latvia	36 350	34 610	1 570	140	30
Lithuania	135 850	130 980	4 680	140	50
Luxembourg	160	70	30	50	10
Hungary	304 610	286 130	17 670	530	280
Malta	130	0	30	100	0
Netherlands	9 550	970	1 420	5 480	1 680
Austria	51 000	37 390	7 340	6 220	50
Poland	577 430	374 930	189 490	12 700	310
Portugal	68 210	65 790	1 410	760	250
Romania	1 393 280	1 373 930	19 000	290	60
Slovenia	32 900	30 420	2 180	290	10
Slovakia	40 890	39 500	870	390	130
Finland	3 010	320	960	1 600	130
Sweden	2 540	550	670	980	340
United Kingdom	9 710	4 820	2 030	1 920	940
Total	**3 226 420**	**2 820 740**	**299 030**	**85 310**	**21 340**
Percentage (%)	*100.00*	*87.43*	*9.27*	*2.64*	*0.66*
Source: Eurostat [15, Eurostat 2010].					

THE FORMER "FIGURE" 1.9 (REFERENCE YEAR 1997) ALREADY CROSSED OUT IN DRAFT 1, HAS BEEN DELETED

The most dense concentrations of pigs ~~is~~ are found in Belgium (in such regions as West and East Flanders, Antwerp and Limburg), in the Netherlands (from Limburg in a sweep across the south of the country) and the German regions of western Lower Saxony (districts of Cloppenburg and Vechta) and the northern parts of North Rhine-Westfalia. These concentrated areas of pig farming ~~is~~ are probably explained by the coexistence of arable land on which the pig slurry can be spread and the availability of grain imports via the ports of Rotterdam and

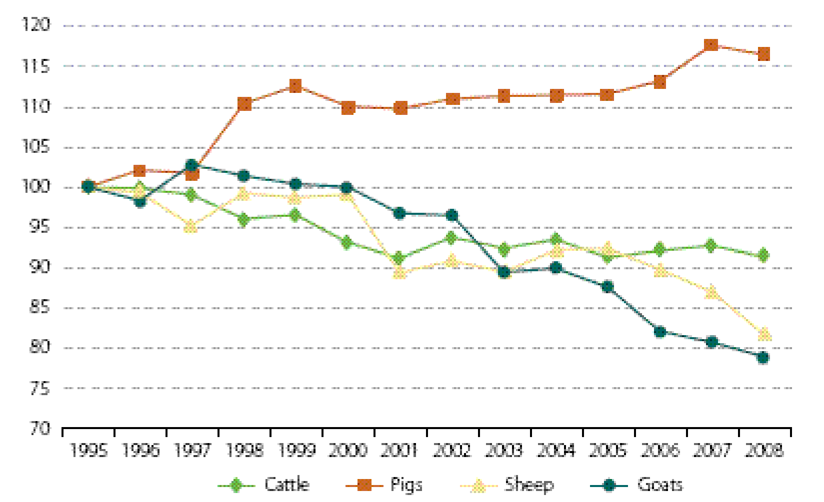
Antwerp. Brittany in France, Denmark, Malta, Catalonia and Murcia in Spain, Lombardy in Italy and Greater Poland Voivodeship are also regions of intense pig-rearing ~~raising~~ [4, Eurostat 2009]. As a consequence, some countries have developed specific legislation for the pig sector including instruments that are based on environmental and sanitary approaches, like maximum farms sizes or minimum distances from residencial areas.

THE EXISTING TEXT WITH DATA ON SPATIAL DENSITY OF PIG PRODUCTION (REFERENCE YEAR 1994) ALREADY CROSSED OUT IN DRAFT 1, HAS BEEN DELETED

1.3.2 Production and consumption of pork

The EU-27 accounts for 22.8 % of the world pork production, with ~~as the~~ 22.7 million tonnes of slaughtered carcass weight ~~relate to the~~ against nearly one hundred million tonnes produced in the whole world (99 532 328 t). [17, FAO 2009] For comparison, ~~the~~ pork production totals ~~this was~~ more than twice the carcasse weight of beef and veal ~~slaughterings over the same period of time [153, Eurostat, 2001].~~

Figure 1.8 shows the decreases registered for the slaughter of cattle (-8.6 %), sheep (-18.2 %) and goats (-21.0 %) since 1995, whilst at the same time the increase in the total weight of pigs slaughtered ~~has increased by~~ is 16.5 %, leading to ~~still expand the~~ overall expansion in meat production within the EU.



Source: [16, Eurostat 2009]

Figure 1.8: Slaughter index (in tonnes) by species in the EU-27

The average weight to which pigs are finished and their average carcasse weight vary throughout the EU. This has a significant impact in relation to the period of time that the pigs are housed, the quantity of feed consumed, and the volume of effluent produced. For example in Italy, heavy pigs are reared to an average live weight of 156 kg, yielding a carcasse weight of 112 kg. ~~Generally, carcase weights higher than average (in excess of 80 kg) are also produced in Austria, Germany and Belgium. (finished 117 kg/carcase 93 kg) (see Figure).~~

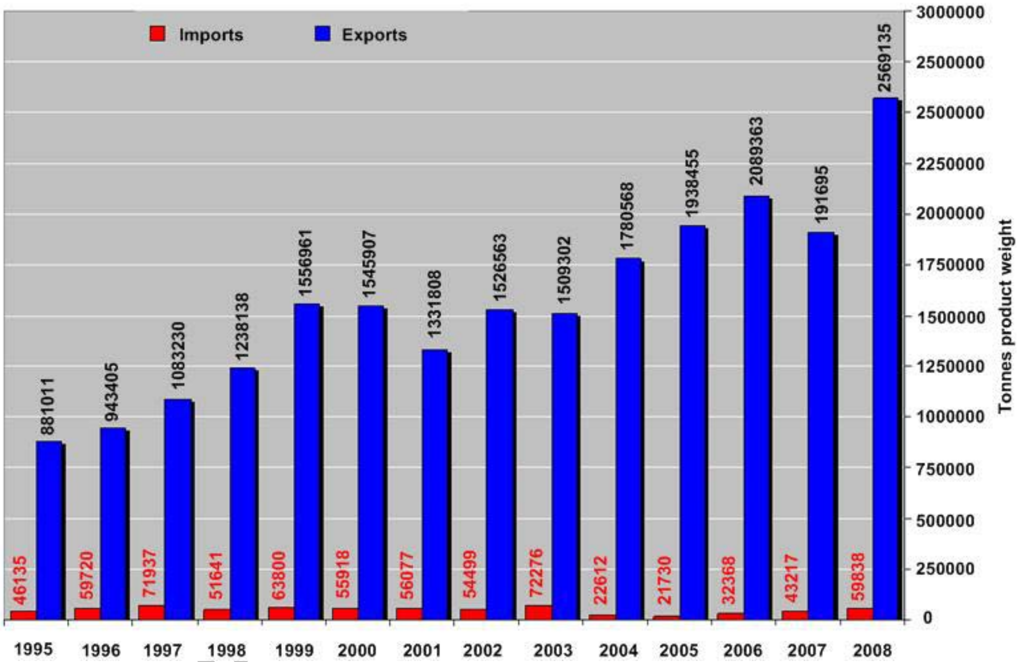
These types of pig production carried out in the EU are listed below ~~can be~~:

- Italian heavy pig. ~~In Italy,~~ Standard pigs are also produced in Italy
- Continental pig, ~~that is~~ produced in Germany, the Netherlands, Austria, Belgium and France, with a carcass weight at around 90 kg

- British pig, with 90 – 105 kg live weight and 79 ~~60 – 70 kg of~~ average carcass weight
- Danish and Spanish pigs, intermediate between continental and British types. [383, France 2010]

THE EXISTING TEXT AND FIGURE CONCERNING CARCASS WEIGHT (REFERENCE YEAR 2001), ALREADY CROSSED OUT IN DRAFT 1, HAVE BEEN DELETED

Not all of this production is consumed in the Member States themselves. As a whole, the EU is a net exporter of pork, importing only a very small amount (see Figure 1.9). Not every major producer is an exporter, for instance Germany is a major producer but still imports~~ed~~ about twice as much as it exports~~ed in 1999~~. Denmark, the Netherlands, Belgium and Spain are large exporters. Italy and UK are net importers, and Germany and France are exporters to a lesser extent ~~in small amounts~~. [383, France 2010].



Source: [19, CIRCA 2009]

Figure 1.9: EU-27 pork trade ~~over time. Pigmeat trade by European Member States~~

With varying live weights at the end of the finishing period, the period of time needed for rearing a pig also varies in the EU~~-15~~. Many factors influence this, such as the feeding, farm management and market demands requiring a certain quality pork. ~~As an example, some production data are shown describing production in the UK.~~

Table 1.11 presents the physical performances data concerning the production of pigs for a selected sample of EU countries.

Table 1.11: Summary of physical performance data for the production of pigs for selected EU countries (year 2009). ~~General production levels in pig farming in the UK~~

Performance	DK	FR	DE	UK	IT	NL	ES	SE	EU Average
Pigs weaned per sow per year	27.45	26.16	23.9	22.25	22.64	27.19	23.71	23.19	24.32
Pigs sold per sow per year	25.63	24.7	22.47	21	21.69	26.03	21.81	22.11	23.01
Litters per sow per year	2.25	2.33	2.3	2.23	2.22	2.38	2.32	2.2	2.28
Sow replacement rate (%)	53.8	45.4	43.2	48.1	34.0	42.0	52.7	51.3	45.5
Lactation period (days)	31	25	27	28	27	25	23	34	27
Post weaning ([1]) daily liveweight gain (g/day)	460	475	440	492	450	362	285	437	423
Post weaning feed conversion ratio	1.70	1.69	1.70	1.80	2.02	1.54	1.70	1.97	1.78
Average number of days in post weaning unit	52	51	51	60	61	51	45	48	53
Transfer weight to finishing unit (kg)	31.4	31.57	29.9	36.6	35	25.1	19	31	30.03
Finishing daily liveweight gain (g/day)	898	785	753	819	640	792	643	876	767
Finishing feed conversion ratio	2.66	2.85	2.92	2.77	3.68	2.71	2.71	2.83	2.89
Average number of days in finishing unit	84	107	119	81	205	116	134	98	116
Finishing pigs feed consumption (kg) per pig	203	243	265	187	483	250	236	242	256
Finishing ration average energy content (MJ ME/kg)	13.32	12.8	13.2	12.96	12.7	13.8	NA	12.32	11.83
Finishing mortality (%)	4.10	3.60	3.10	3.20	0.70	2.40	4.80	2.40	3
Pigs per pig place per year (finishing)	4.06	3.19	2.89	4.13	1.72	2.93	2.59	3.49	3.14
Average live weight at slaughter (kg)	107	116	120	103	166	117	105	117	117
Average carcase weight - cold (kg)	81	89	93	78	128	90	79	87	90
Carcass meat production per sow per year (kg)	2 064	2 189	2 084	1 643	2 781	2 349	1 729	1 924	2 062
Average lean meat percentage (%)	60.2	60.1	56.5	62.0	47.0	56.4	58.0	57.7	58

NA = Not Available
([1]) Post weaning: the fattening phase after weaning and before finishing. See Glossary: 'fattening period'
Source: [415, Park J. 2010]

Depending on the final slaughter weight, the castration of male piglets is a practice still in use to avoid boar taint. While alternatives to castration are being investigated, the debate on the ~~relations of the~~ practice in relation to ~~with~~ the production systems and efficiency, and ~~on~~ the use of anaesthetic ~~and eventually on production systems~~ is ongoing. As an example, in the UK, over 90 % of British pigs are produced on farms which are members of a recognised quality assurance scheme that does not allow the castration of male pigs.

THE EXISTING TEXT AND FIGURE CONCERNING PIG MEAT CONSUMPTION (REFERENCE YEAR 2001), ALREADY CROSSED OUT IN DRAFT 1, HAVE BEEN DELETED

The annual apparent consumption for pork products averages over 40 kg per capita, a level that is higher than the combined total of poultry, cattle, sheep and goats. Consumption values for the year 2007 are presented in Table 1.12. Spain has one of the highest overall consumption of meat in the EU, just over 60 kg per capita, although ~~it has been remarked that~~ ~~the~~ its annual 50 ~~30~~ million tourists may contribute to this high amount. Austria, Germany, Denmark and Belgium reported averages in excess of 50 kg, while the United Kingdom, Lithuania, Bulgaria and Greece recorded per capita averages below 30 kg (see Table 1.6).

Table 1.12: Gross human apparent consumption per capita of pork meat for the year 2007

Country	Pork (kg)
Belgium	51.8
Bulgaria	21.0
Czech Republic	NA
Denmark	52.1
Germany	53.9
Estonia	36.0
Ireland	38.5
Greece	28.4
Spain	60.9
France	34.4
Italy	39.0
Cyprus	72.0
Latvia	NA
Lithuania	26.1
Luxembourg	44.1
Hungary	46.0
Malta	33.0
Netherlands	42.4
Austria	57.0
Poland	48.1
Portugal	44.2
Romania	33.0
Slovenia	42.0
Slovakia	34.0
Finland	33.7
Sweden	36.1
United Kingdom	21.6

NA = Not available
NB: Gross human apparent consumption: quantity of products made available for human consumption in all forms. (See Glossary)
Source:[1, Eurostat 2008] [3, Eurostat 2009].

1.3.3 Economics of the pig sector

The economics of pig production are largely dictated by the availability of feed and ~~or by~~ access to suitable markets, as is the case in ~~for~~ Belgium and the Netherlands. This has led to regional development of the industry, for example in the Po Valley (Italy), where pig production has developed in association with cereal growing and dairy production, and also due to the easy access to transport.

The economy of European pig production is driven by the choices of the Common Market Organisation (CMO), for which the key factor is competitiveness, even if there are small 'niche' markets. Prices reflect mostly the situation of ~~are ruled by~~ supply and demand, while the EU Common Agricultural Policy only indirectly affects the pig sector by shifting crop production. Market crises are recurrent and there is very little public support for the European pig production ~~and few 'niche' markets exist~~. For more efficiency, the trend is towards concentration in larger farms and in specialised regions (economy of scale and agglomeration). The efficiency of the whole chain, and not only of the farm, is important. [383, France 2010]

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~~In the UK, parts of the pig production were moved to straw bedded systems to meet the desires of pork customers, particularly on welfare grounds. This change especially applies to loose housed dry sows (as in the Netherlands) and eventually raised discussions about conflicts of animal welfare with environmental protection~~

In the UK, many of the pigs that are fattened on straw are sourced from outdoor sow herds, giving an example of a niche market with an integrated supply chain from producer to retailer.

More recently, environmental constraints within this farming activity have led to a link between production and the availability of land for ~~the irrigation of effluent,~~ spreading wash waters and manure. Manure (solid, slurry) has a nutrient value for crops and when used in accordance with crop requirements is a fertiliser. When spread on land; it adds nutrients (nitrogen and phosphorus) to the soil which can leach into ground and surface waters. This can be a problem where there are concerns over eutrophication of water bodies and/or nitrate levels in drinking water sources. Where sufficient land for spreading is available, manure can be applied without a potential risk of water pollution by nitrate. In this respect, differences exist across countries.

In Denmark, ~~has a definite advantage over pig producers in the Netherlands and several other countries in that it's the~~ pig population is spread across the entire country, and therefore ~~by~~ it has only a relatively low density of pigs associated to the ~~in relation to~~ cultivated land area. ~~and~~ The mixed ~~farming~~ systems of livestock and arable farming that are used in Denmark and Germany also allow for the use of effluents with reduced environmental risk ~~hazard~~. ~~Same mixed farming exists in Germany. The Danish farm system generally combines pig production with mixed farming; allowing effluent to be used in a manner that lessens the environmental hazard. The association with mixed farming also provides benefits in terms of feed costs. A similar situation exists in the concentrated pig production areas in Germany, where pig production is associated with mixed farms, again facilitating a control of the feed inputs and irrigation of the effluent.~~ In contrast, in some Member States (e.g. the Netherlands) little land area is associated to livestock farms, and the quantities of manure produced are so large that farmers pay to have it removed. In some others, the manure has sufficient value that farmers can sell it or at least give it to other farmers. [204, IMPEL 2009]

Pig density in Spain as a whole is very low, but there is a concentration of intensive pig farming and other agricultural activity in the northern autonomous communities (e.g. in Catalonia ~~Cataluña~~).

Where manure transportation is possible, ~~it~~ wider spreading areas are reached, even though at higher costs. ~~There are still many areas where manure can be applied without a potential risk of water pollution by nitrates. It has been stated that the application of animal manure to land is of great agronomic interest to Spain as, along with the savings on chemical fertilisers, it can also improve the structure and fertility of most Spanish soils and can contribute significantly to the fight against desertification. These favourable circumstances support the growth of the sector and even the setting up of foreign companies. [89, Spain, 2000]~~

Generally, pig production in the EU does not tend to show the level of vertical integration found in the poultry sector, for instance the breeding and finishing of pigs are often carried out in separate facilities. In recent years, there has been a tendency towards a more integrated approach with an individual or company-based control of feed supply, pig production and slaughtering capacities. There is also a trend that even in situations where breeding and finishing are undertaken ~~on~~ at separate sites, these may be owned by a single producer. The most developed integrated production systems are in Denmark and fall under the guidance of the Federation of Danish Pig Producers and Slaughterhouses (Danske Slagterier).

THE EXISTING TEXT ON ECONOMIC CONSIDERATIONS (REFERENCE YEAR 2001), ALREADY CROSSED OUT IN DRAFT 1, HAS BEEN DELETED

Where investments are made, there are a variety of reasons why farmers might decide to invest in environmental techniques. Often, national legislation pushes them towards the application of certain techniques, but also the requirements of the large grocery retailers can affect the choice and operation of production techniques, as happens in egg production. Increasing attention is being paid to animal welfare issues, such as the use of straw and access to an outdoor area. It should be borne in mind that techniques applied under the scope of animal welfare legislation are not always associated with the best environmental performance.

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In the UK, some producers in the pig production sector ~~parts of the pig production were~~ moved to straw ~~bedded~~ bedding systems to meet the desires of pork customers, particularly on welfare grounds. This change especially applies to loose-housed dry sows (as in the Netherlands) and eventually raised discussions about the environmental disadvantages that may be occasionally introduced by some practices (e.g. use of straw). ~~conflicts of animal welfare with environmental protection~~

Some Member States set up public programmes for limited periods ~~exist in some many Member States~~ to encourage farmers to take actions or to purchase techniques for the protection of the environment. Hence, some farmers ~~can~~ were able to access financial assistance to invest in improved manure management techniques. [26, Finland 2001] [35, Finland 2001] [36, Italy 2001] [37, BOE España 2009]

The economic viability of techniques or combinations of techniques is related to the economic profitability of the sector or installation, where profitability depends on production costs and sales incomes. Table 1.13 shows the financial performance data for the year 2009, together with the variability of production costs across the EU.

Table 1.13: Summary of financial performance in year 2009 in selected countries in EUR per 100 kg pig meat (*)

Type of costs	BE	DK	FR	DE	UK	IE	IT	NL	ES	SE	EU
Feed	65.2	59.8	61.3	64.7	66.6	72.4	87.2	60.2	71.3	52.6	65.5
Other variable costs	8.8	8.2	9.0	13.6	7.1	9.4	10.8	10.8	11.7	9.2	10.3
Total variable costs	74.0	68.0	70.3	78.3	73.7	81.7	98.0	71.0	83.0	61.8	75.8
Labour	13.2	5.6	12.2	11.3	12.2	10.9	12.1	11.5	10.4	13.1	11.8
Building, finance and misc.	26.2	30.4	25.1	34.5	29.7	23.3	25.7	30.0	22.8	39.1	28.4
Total fixed costs	37.0	42.7	37.3	45.8	41.9	34.2	37.8	41.5	33.2	52.1	40.2
Total	**111.0**	**110.7**	**107.6**	**124.0**	**115.6**	**115.9**	**135.7**	**112.5**	**116.2**	**114.0**	**115.9**

NB: Figures may not total due to rounding.
(*) Values in EUR as per exchange GBP/EUR = 0.88.
Source: [415, Park J. 2010]

The European Commission and Member States are progressively introducing rules to enforce industry and farmers to commit to minimising Greenhouse Gas (GHG) emissions as part of the actions implementing the Kyoto Protocol. Provisions that could be introduced may become a significant driver in the future and may affect the costs of production. In the UK, the strategy on low carbon emissions (Low Carbon Transition Plan) moved the English pig industry to organise an action plan on greenhouse gases (Roadmap and Greenhouse Gas Action Plan).

1.4 Environmental issues of intensive poultry and pig farming

Environmental issues have only been on the agricultural agenda for a relatively short period of time. It was not until the 1980s ~~eighties~~ that the environmental impact of intensive livestock farming really became an issue.~~, although~~ ~~there was already an~~ Awareness of the implications of farming activities such as ~~contamination of soil due to~~ excess manure application and its impact on soil and water quality and ~~of~~ odour nuisance have increased over the years, ~~increasingly becoming an issue~~ due to an increasing population in ~~the~~ rural areas.

The growing concerns about climate change focused ~~raised~~ ~~the~~ attention on ~~of~~ the emissions from the entire livestock sector. According to the FAO, about 12 % of greenhouse gas in the world is related to livestock production. [18, FAO 2006] On a global scale, the greater contributions come from enteric fermentation ~~of~~ by ruminant animals and deforestation related to feed crops, whilst emissions from pigs and poultry farms contribute to a smaller extent.

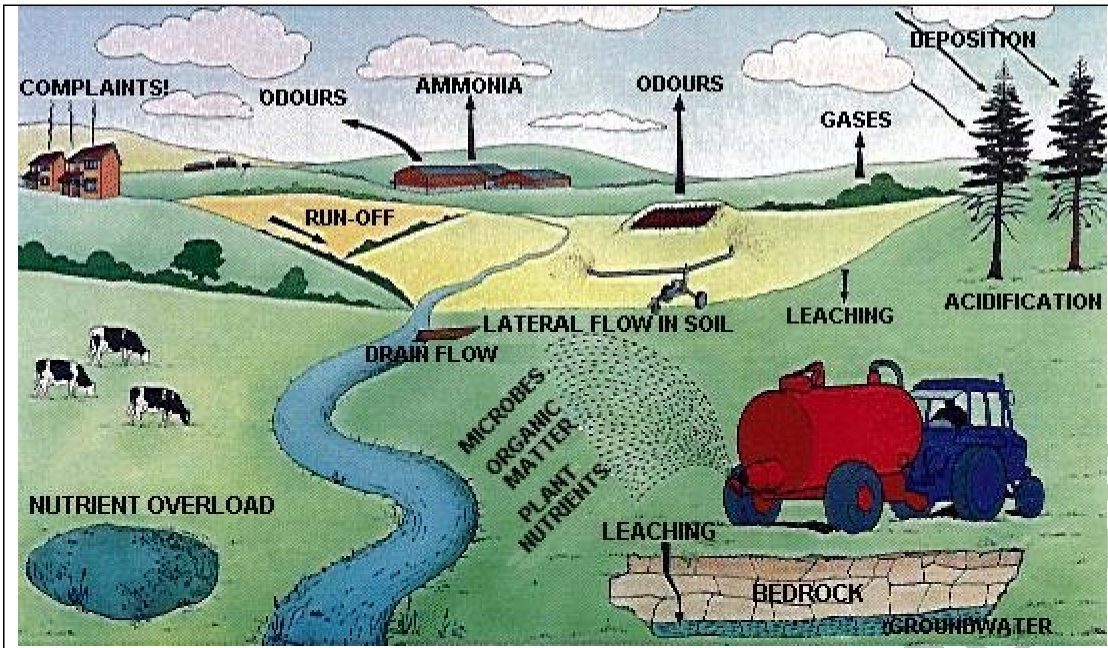
The existence of livestock farms near areas of particular protection or interest (e.g. sites of specific scientific interest, wildlife and geological areas or where vegetation is very sensitive) may lead to stricter local, regional and/or national legal requirements and additional improvement conditions. This may be the case for the EU Natura 2 000 sites, in the vicinity of residential areas, or for the closeness to other farms where, a cumulative impact of dust and odour may occur.

~~Significant Notable advances have been achieved in a the relatively short period of time in the pig and poultry sectors. Environmental and welfare awareness of with legal obligations have encouraged impulsed technical improvements that renewed the production means to dramatic unprecedented environmental performances.~~

One of the major challenges in the modernisation of poultry and pig production is the need to balance the reduction or elimination of the polluting effects on the environment with increasing animal welfare demands, while at the same time maintaining a profitable business. Food security has become a real concern ~~in~~ for the public ~~opinion~~. The European agriculture industry has to operate in the global food market with technological advances which simultaneously aim to achieve economic efficiency, safeguard animal and consumer health, and protection of the environment. ~~technical tools that at once aim to comply with economic efficiency, animal and consumer health safeguarding and environmental protection~~.

Potentially, agricultural activities on intensive poultry and pig farms ~~can~~ contribute to a number of environmental phenomena (see also Figure 1.10):

- surface water and ground water pollution (e.g. NO_3^- and NH_4^+)
- acidification (NH_3 mainly, ~~SO_2,~~ H_2S, NO_X, etc.)
- eutrophication (N, P)
- ~~reduction of ozone layer (CH_3Br)~~
- airborne pollution, in particular ammonia (NH_3), N_2O, NO, dust (PM_{10} and $PM_{2.5}$), photochemical ozone formation, bio-aerosols, etc.
- increase of the greenhouse effect (CO_2, CH_4, N_2O, etc.)
- desiccation (groundwater use)
- local disturbance (odour, noise)
- diffuse spreading of heavy metals, ~~and~~ pesticides and toxic substances
- spreading of pathogens including antibiotic-resistant pathogens
- residues of pharmaceuticals in waters.

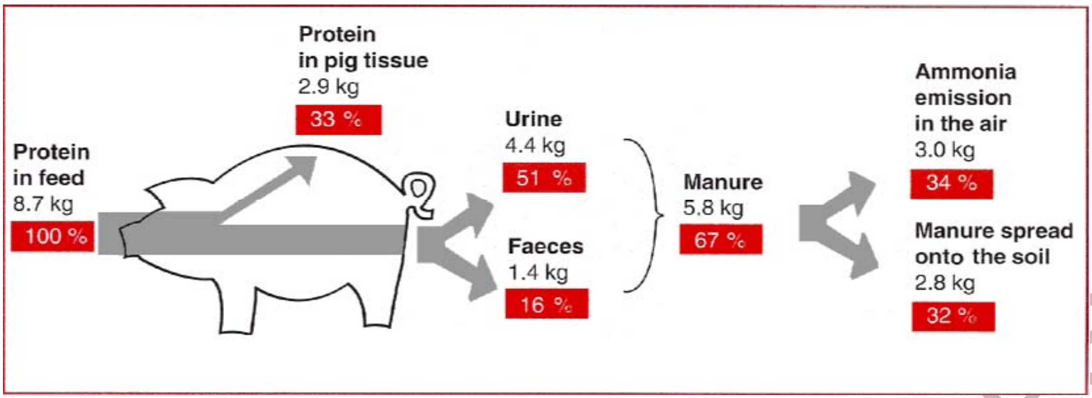


Source: [29, Pahl 1999]

Figure 1.10: Illustration of environmental aspects related to intensive livestock farming

~~Increasing the knowledge of the different sources responsible for these environmental phenomena has increased the attention paid to a number of environmental aspects associated with the intensive rearing of poultry and pigs.~~ The key on-farm environmental aspect of intensive livestock production is related to the natural living processes, i.e. that the animals metabolise feed containing nutrients absorbed by the feed crop. Part of the nutrients are then retained in the animals, while the other part is ~~and the excreted nearly all the nutrients are nearly all eliminated~~ excreted via manure. The quality and composition of the manure and the way it is stored and handled are the main factors determining the emission levels of intensive livestock production.

From an on-farm environmental point of view, the efficiency with which pigs, for example, convert feed for maintenance, growth speed, and breeding is important. The pigs' requirements will vary during different stages of their life, e.g. during the rearing and growth periods or during different stages of their reproductive life. To be sure that their nutritional requirements are always met, it has become customary to feed nutrients at levels in excess of the animals' requirements. At the same time, emissions of N into the environment can be observed which are partly due to this imbalance. The process of N consumption, utilisation and losses in the production of slaughter pigs is quite well understood (see Figure 1.11).



Source: **[34, Ajinomoto 2000]**.

Figure 1.11: Consumption, utilisation and losses of protein in the production of a slaughter pig with a final live weight of 108 kg

Modern approaches are used to investigate emissions in livestock production, considering all environmental impacts that occur in relation to the production. A recent study [416, EC-JRC 2010], based on an internationally agreed methodology for the accounting of emissions, was used for estimating the net emissions of greenhouse gases and ammonia from the livestock sector in the EU-27. The methodology takes into account all on-farm emissions related to the livestock rearing, as well as the emissions associated with the production of feed and emissions caused by input of mineral fertilisers, pesticides, energy and land for the production of feed.

From the study, the total amount of ammonia per kg of produced pork is equivalent to 27.69 g nitrogen. Based on this value, the total ammonia emissions for the whole European pig sector are estimated to be around 60 000 tonnes of N per year. Table 1.14 presents all the emission sources considered in the study for the estimation of net emissions from the livestock sector.

Table 1.14: Emission sources considered in estimating greenhouse gases and ammonia from the livestock sector

Emission source	Livestock rearing	Feed production	Gases
• Enteric fermentation	X		CH_4
• Livestock excretions			
▪ Manure management (housing and storage)	X		NH_3, N_2O, CH_4, NO_X
▪ Depositions by grazing animals	X		NH_3, N_2O, NO_X
▪ Manure application to agricultural soils	X		NH_3, N_2O, NO_X
▪ Indirect emissions, indirect emissions following N-deposition of volatilised NH_3/NO_X from agricultural soils and leaching/run-off of nitrate	X		N_2O
• Use of fertilisers for production of crops dedicated to animal feeding crops (directly or as blends or feed concentrates, including imported feed)			
▪ Manufacturing of fertilisers	X		CO_2, N_2O
▪ Use of fertilisers, direct emissions from agricultural soils and indirect emissions		X	NH_3, N_2O
▪ Use of fertilisers, indirect emissions following N-deposition of volatilised NH_3/NO_X from agricultural soils and leaching/run-off of nitrate		X	N_2O
• Cultivation of organic soils		X	CO_2, N_2O
• Emissions from crop residues (including leguminous feed crops)		X	N_2O
• Feed transport (including imported feed)		X	$CO_{2\text{-eq}}$
• On-farm energy use (diesel fuel and other fuel electricity, indirect energy use by machinery and buildings)		X	$CO_{2\text{-eq}}$
• Pesticide use		X	
• Feed processing and feed transport		X	CO_2
• Emissions (or removals) of land use changes induced by livestock activities (feed production or grazing)			
▪ Carbon stock changes in above and below ground biomass and dead organic matter		X	CO_2
▪ Soil carbon stock change		X	CO_2
▪ Biomass burning		X	CH_4 and N_2O
• Emissions or removals from pastures, grassland and cropland	X	X	CO_2
Source: [416, EC-JRC 2010]			

1.4.1 Emissions to air

Emissions to air from the intensive rearing of poultry and pigs ~~livestock production~~ systems can be summarised as given in Table 1.15 ~~follows~~.

Table 1.15: Emissions to air from the intensive rearing of poultry and pigs ~~livestock production~~ systems

Air	Production system
Ammonia (NH_3)	Animal housing, storage, treatment ~~of manure~~ and landspreading of manure
Odour ~~(e.g. H_2S)~~	Animal housing, storage of manure, landspreading of manure and slurry
Dust	Milling and grinding of feed, feed storage, housing of animals, solid manure storage and application
Methane (CH_4)	Animal housing, storage of manure and manure treatment
Nitrous oxide (N_2O)	Animal housing, ~~manure~~ storage, treatment and landspreading of manure
NO_X ($NO + NO_2$)	Animal housing, storage and spreading of manure, heaters in buildings and small combustion installations
Carbon dioxide (CO_2)	Animal housing, energy used for heating and transport on farm~~,~~ ~~burning of waste~~ and biogenic CO_2 that may be emitted in the field
~~Dark smoke/CO~~	~~Burning of waste~~
CO, dust, NO_X, SO_2, HCl, HF, heavy metals, dioxins and furans	Incineration of residues and by-products

The 1979 Geneva Convention on Long-range Transboundary Air Pollution is an important measure ~~means~~ for protecting the world environment against air pollution. ~~One of the Protocols that extend from the Convention is~~ The 1999 Gothenburg Protocol that originated from the Convention is aimed at reducing ~~to abate~~ acidification, eutrophication and ground-level ozone. Annex IX to the Protocol gives ‘Measures for the control of emissions of ammonia from Agricultural Sources’.

Ammonia ~~N-related~~ emissions

Most attention has been paid to the emission of ammonia from animal housing, as ~~it~~ this is considered an important compound for the acidification of soil and water.

Ammonia gas (NH_3) has a sharp and pungent odour and in higher concentrations can irritate the eyes, throat and mucous membranes in humans and farm animals. It is slowly volatilised ~~rises~~ from the manure and spreads through the farm building and is eventually removed by the ventilation system. Factors such as the temperature, ventilation rate, humidity, stocking rate, litter quality and feed composition (crude protein) can all affect ammonia levels. Factors that influence the rate of ammonia emissions are presented in Table 1.16. For example in pig slurry, urea nitrogen represents more than 95 % of the total nitrogen in pig urine. As a result of microbial urease activity, this urea can rapidly be converted into volatile ammonia. The rate of conversion depends on the pH of the manure and other environmental parameters (e.g. temperature).

High ammonia levels also affect working conditions for the farmer and in many Member States workplace regulations set upper limits for the acceptable ammonia concentration in working environments.

Table 1.16: Schematic overview of processes and factors involved in ammonia release from animal houses

Processes	Nitrogen components and appearance	Affecting Factors
1. Faeces production	Uric acid/urea (70 %) + undigested proteins (30 %)	Animal and feed
2. Degradation	Ammonia/ammonium in manure	Process conditions (manure): e.g. T, pH, A_w, airflow at floor level, urease activity etc.
3. Volatilisation	Ammonia in air	Process conditions, ~~and~~ local climate, exposed surface and contact time of manure/slurry with the air
4. Removal ~~Ventilation~~	Ammonia in animal ~~poultry~~ house	Ventilation ~~Local climate (air)~~: T, RH, air velocity
5. Emission	Ammonia in environment	Air cleaning
NB: T= temperature, pH= acidity, A_w= water activity, RH= relative humidity.		

The generation of gaseous substances in the animal housing also influences the indoor air quality and can affect the animals' health and create unhealthy working conditions for the farmer.

Furthermore, NH_3 reacts with atmospheric acids forming secondary particles that contribute significantly to the burden of particulate matter. [337, Webb et al. 2005]

Greenhouse gases

Greenhouse gases have an effect on global warming in relation to their potential for trapping heat in the atmosphere (GWP: global warming potential). Methane (CH_4) and nitrous oxide (N_2O) are the most important greenhouse gases associated with animal farming and their GWP for a time horizon of 100 years is 25 (CH_4) and 298 (N_2O) times greater than CO_2 (IPCC data).

Emissions of CH_4 and N_2O from livestock production are regulated as part of the Kyoto Protocol under the United Nations Framework Convention on Climate Change. The EU reduction target for GHG is 9 % by 2008 to 2012, with reference to 1990, with a proposed further reduction target of 20 % by 2020.

The anaerobic processes that decomposeing organic matter in livestock manure are a net source of methane ~~(CH_4)~~. ~~Methane is the second most important greenhouse gas, having an effect of trapping the atmosphere heat 21 times greater than CO_2.~~ Methane emissions from pig and poultry manure management in Western Europe have been calculated by the FAO at 1.52 and 0.09 million tonnes, respectively, in the year 2004 [18, FAO 2006].

Soil microbial processes (denitrification processes) produce nitrous oxide (N_2O), and nitrogen gas (N_2) which. ~~Nitrous oxide is one of the gases responsible for the 'greenhouse effect', whilst nitrogen gas~~ is harmless to the environment. Both can be produced from the breakdown of nitrate in the soil, whether derived from manure, inorganic fertilisers or the soil itself, but the presence of manure encourages this process. Livestock housing itself, particularly littered systems, is an additional source of N_2O emissions.

Most of the N_2O in livestock systems occurs through microbiological transformation of N and this involves three main processes: nitrification, denitrification and autotrophic nitrifier denitrification. For denitrification to occur, anaerobic conditions are necessary, while nitrification occurs under aerobic conditions. Not much is known about the nitrifier denitrification pathway, but it is believed to be similar to denitrification. Under partial or transient anaerobic conditions, the denitrification reaction is uncompleted, resulting in the production of NO and N_2O. Apart from the lack of oxygen availability, denitrification is also favoured by the presence of an available carbon source and warm temperature, among others. Because of this dependence upon such site-specific factors, emissions of N_2O exhibit a rather high degree of spatial and temporal variability. [551, Oenema et al. 2005]

~~N_2O can be produced by denitrification and by nitrification. From denitrification, high quantities of nitrous oxide can be released in low-oxygen environments. Nitrification is an oxidation of ammonium addressed by aerobic bacteria where N_2O is formed through the decomposition of the intermediates between NH_4 and the final NO_2. [232, Huijsmans et al. 2009]~~

The IPCC factor [550, IPCC 2006] for direct N_2O-N emission from mineral/organic fertilizer, crop residues and N mineralised as a result of soil C loss is 0.01 kg N_2O-N/kg N applied. [500, IRPP TWG 2011]~~The IPCC (International Panel for Climate Change) considers the release of N_2O from the total nitrogen applied for fertilising use as the result of a factor of 0.0125 kg N_2O-nitrogen (total nitrogen weight in N_2O form) per kg of nitrogen.~~

On average, the EU-27 emits 7.5 kg of $CO_{2\text{-}eq}$ per kg of pork. The total fluxes of greenhouse gas emissions for the pig production have been estimated on the basis of available factors and are presented in Table 1.17.

Table 1.17: Total fluxes of greenhouse gas emissions for the EU-27 pig production

	kg of CO_2 equivalent factor per kg of produced pork	Total EU emissions in 1 000 tonnes of CO_2
CH_4	0.74	16 277
N_2O	1.71	37 317
CO_2 related to energy consumption	2.01	43 951
Source: [417, EC JRC 2010]		

Other gases

Among other gas emissions related to livestock rearing, NO_X and N_2 need to be mentioned. NO_X are normally associated with combustion processes, while N_2 derives from nitrification/denitrification processes but, notoriously, is not an environmental concern.

Odour

Odour is a local problem but is an issue that is becoming increasingly important as the livestock industry expands and as ever increasing numbers of rural residential developments are built in traditional farming areas, bringing residential areas closer to livestock farms. The increase in number of farm neighbours is expected to lead to increased attention to odour as an environmental issue.

Odour can be emitted by stationary sources, such as from storage, and can also be an important emission during farm activities, such as landspreading, depending on the spreading technique applied. Its impact increases with farm size. Dust emitted from farms contributes to odour transport. In areas with a high density of pig production, plumes from one farm can potentially transfer diseases to other farms.

Odour emissions, especially from large poultry farms, can give rise to problems with neighbours. Emissions of odour are related to many different compounds, such as mercaptans, H_2S, skatole, thiocresol, thiophenol and ammonia, ~~but~~ although not all compounds that are involved have been identified yet ~~to identify~~. [30, Spain 2001]

Dust

In the past, dust was ~~has~~ not ~~been~~ reported as an important environmental issue ~~in the~~ for the intensive livestock sector. ~~surroundings of a farm, but it may cause some nuisance during dry or windy weather.~~ Nowadays (2013), in some areas, where farms are close to housing, there may be concerns over local air quality. A distinction is often made between dust and fine dust particles (PM_{10}), with PM_{10} being considered a major environmental risk to health and dust more of a nuisance.

The airborne particles that can be generated in livestock buildings range from non organic substances (e.g. soil material) to organic particles from plants and animals, including dead and living microorganisms that are usually named 'bioaerosols'.

Dust is a major health ~~sanitary~~ concern inside the animal house, since it ~~dust~~ is known under certain circumstances to be a contaminant that can affect both the respiration of the animals and the farmer, such as in broiler houses with high dry matter ~~litter~~ contents.

Between the factors that affect dust emissions there are:

- ventilation
- activity of the animals
- type and quantity of bedding
- the type and the consistency of feedstuff
- humidity in the animal house.

The type and quality of litter has a great influence on emissions. Finely structured material (e.g. chopped straw) releases more particles than coarse material (long straw, wood shavings).

The indoor dust concentration depends very much on the animal activity. Housing techniques which offer the animals only little freedom of motion (e.g. small group housing of laying hens) emit less dust than those which provide more freedom of motion (e.g. large group housing, aviary housing, floor husbandry).

In pig housing, airborne particulate matter also depends on the feeding technique and human presence. During feeding time and when the animals are disturbed (e.g. during inspection rounds), higher concentrations are measured than at night and in resting phases.

1.4.2 Emissions to soil, groundwater and surface water

Emissions from housing, slurry storage facilities and manure storage areas that contaminate soil and ground or surface water occur because of inadequate facilities or operational failures and should be considered accidental rather than structural. Adequate equipment, frequent monitoring and proper operation can prevent leakage and spillage from slurry storage facilities.

Emissions to surface water can occur from a direct discharge of the waste water arising on a farm but normally, only direct emissions from slurry treatment systems such as ~~the~~ lagoon systems are permitted. Little quantified information is available on these emissions; ~~to surface water.~~ however, it is known that these emissions contain N and P, and normally increased levels of BOD and total suspended solids (TSS). [364, Portugal 2010]. Waste water arising from dirty water collected from the farmyard, manure collection areas, household and agricultural activities might also be mixed with slurry to be applied onto land, although mixing is not allowed in many Member States ~~MSs~~.

The quality of waste water produced from intensive livestock farming is generally affected by the feeding regime, animal manure, the litter used and other supplementary substances such as pharmaceuticals or disinfectants. Waste water is usually the result of manure run off, wash water after cleaning of animals, cleaning and disinfecting of buildings and farmyards, waste water from flue-gas treatment by wet scrubbing. In addition, polluted precipitation water may be infiltrated into the drainage via storage and manipulation, as well as from the roof surfaces. [373, UBA 2009]

~~Waste water discharged directly into surface water can come from various sources but, normally only direct emissions from slurry treatment systems such as the lagoon systems are permitted. Emissions to surface water from these sources contain N and P, but increased levels of BOD may also occur; in particular in dirty water collected from the farm yard and from manure collection areas.~~

However, ~~from~~ of all the sources, landspreading is the key activity responsible for the emissions of a number of components to soil, groundwater (see Table 1.18) and surface water (and air, see Section 1.4.1). Land fertilisation with untreated manure/slurry or with matters that are derived from manure/slurry treatments are good agronomical practices as long as they are correctly managed and the side-effects are minimised. ~~Although manure treatment techniques are available, the application of manure onto land is still the most favoured technique. Manure can be a good fertiliser, but where it is applied in excess to soil capacity and crop requirements it is a major agricultural source of emissions.~~

Table 1.18: Main emissions to soil and groundwater from intensive rearing of poultry and pigs ~~livestock production~~ systems

Soil and groundwater	Production system
Nitrogenous compounds	Landspreading and manure storage (indoor/outdoor)
Phosphorus	
K and Na	
(Heavy) metals	
Antibiotics	

Most attention has been given to the emission of **nitrogen** and **phosphorus**, but other contaminants, ~~elements,~~ such as ~~potassium, nitrite, NH_4^+,~~ (heavy) metals (e.g. Cu and Zn), microorganisms, antibiotics, metabolics and other pharmaceuticals may end up in manure and their emissions may cause negative effects in the long run.

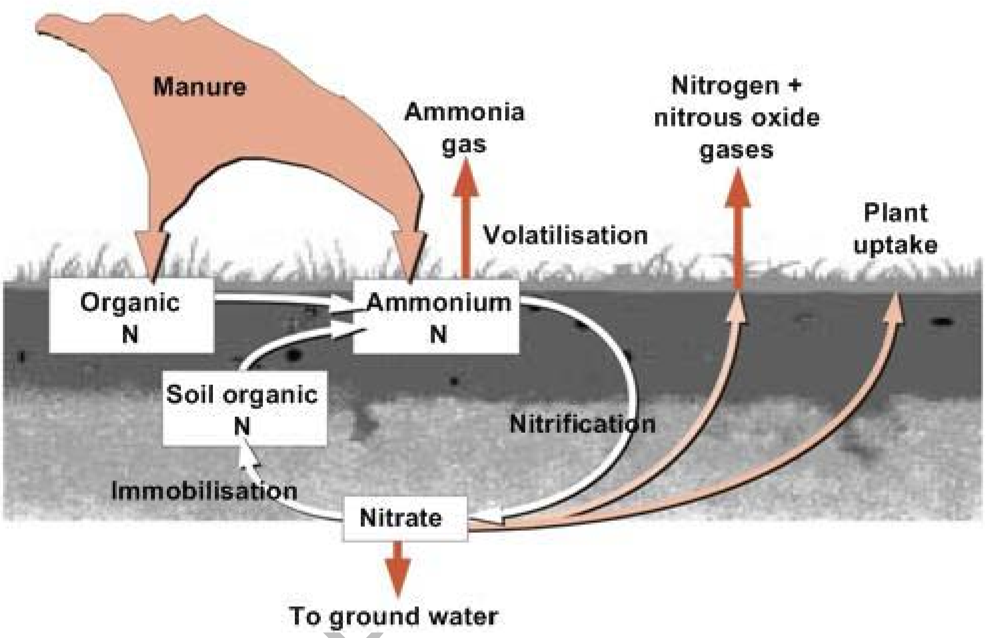
Contamination of waters due to nitrates, phosphates pathogens (particularly faecal coliforms and salmonella) or heavy metals is ~~the~~ a main concern. Excess application to land has also been associated with an accumulation of copper in soils, but EU legislation starting in 1984 significantly reduced the level of copper allowed in pig feeds, thereby reducing the potential for soil contamination when manure is correctly applied. While improved design and management can lead to the elimination of potential pollution sources on site, the existing spatial density of pig production in the EU raises particular concern with regard to the availability and suitability of land for spreading pig slurry. Increased environmental regulation of the spreading of manure has sought to address this problem. Indeed, in the Netherlands and the Flemish region of Belgium, exports of surplus manure ~~are now~~ occurr~~ing~~.

Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy or, in short, the EU Water Framework Directive, was adopted to provide coordinated sets of objectives and tools to protect water bodies. The directive establishes an innovative approach for water management based on river basins, the natural geographical and hydrological units. In this framework, Member States put various initiatives in place to address diffuse pollution from agriculture, ~~as are~~ such as the Codes of Good Agricultural Practice (COGAP), or more specific initiatives, as in England is the Catchment Sensitive Farming Delivery Initiative in UK.

For On the Baltic and Mediterranean seas, eutrophication concerns arose, as they are characterised by longer water retention times. The objective of the Council Directive 91/676/EEC (the nitrates Directive) is to reduce these risks via a reduction and limitation of organic nitrogen application per hectare of arable land.

Nitrogen

For nitrogen, the various emission routes are well illustrated in Figure 1.12. Through these reactions, losses of 25 – 30 % of nitrogen as excreted in pig slurry have been reported. Depending on the weather and soil conditions, this can be 20 – 100 % of the ammoniacal nitrogen, if slurry is surface spread. The ammonia emission rate tends to be relatively high in the first few hours after application and decreases rapidly during the day of application. It is important to note that the ammonia release is not only an unwanted air emission, but also a reduction of the fertilising quality of the applied manure.



Source: [31, MAFF 1999]

Figure 1.12: Nitrogen cycle showing the main transformations and losses to the environment

To comply with the Nitrates Directive, Members States are obliged to identify zones, that drain into waters which are vulnerable to pollution from nitrogen compounds and that require special protection; i.e. the Nitrate Vulnerable Zones. In these zones, landspreading is restricted to a maximum level of 170 kg N/ha per year.

Of the whole EU-27 area, 39.6 % (based on data for the year 2007) has been designated as vulnerable zones, including the area of Member States that apply a whole territory approach. As compared to the previous reporting period, the total area in the EU-15 designated as vulnerable zones or subject to the whole territory approach has increased by 1 %, representing now (2013) 44.6 % of the total EU-15 area. [427, EC 2010]

Fewer problems arise from landspreading in areas where sufficient land appropriate for application is available for the amount of manure that is produced. The intensive rearing of poultry and pigs is sometimes affected by little land area associated to productive installations. livestock production and related nitrogen pollution are concentrated in different countries and in various regions in the EU. Nitrogen surpluses are observed to be most critical on pig and poultry farms.

Phosphorus

Phosphorus (P) is an essential element in agriculture and plays an important role in all forms of life. In natural (i.e. unfarmed) systems, P is ~~recycled to soil in litter and natural and vegetative residues, where it remains. In such ecosystems P is fairly efficiently recycled.~~ efficiently recycled as it remains in the ecosystems, transforming in cycles across vegetation, residues and soil. In agricultural systems, P is removed by the crop and eventually by the animal product, so ~~However, in agricultural systems P is removed in the crop or the animal product and~~ further P has to be imported to sustain productivity.

Manure applications that comply with the nitrogen load allowed by the Nitrate Directive (max 170 kg N/ha per year) normally provide an excess of P fertilisation. ~~Referring to the quantities of nitrogen and phosphorous that are uptaken by the crops from soils, and to the quantities that can be brought to fields by manure application, surpluses of P can be reached with much smaller amounts of manure than those that are allowed by the Nitrate Directive.~~

As only part of the P is taken up by the soil (5 – 10 %) large and ~~amounts were are~~ often ~~applied in~~ excessive ~~of what is needed, by the addition~~ applications of manure and inorganic fertiliser ~~or increasing amounts of manure~~ were common in the past ~~in addition to which increasing amounts of P-containing manure are added~~. Increased awareness on farmers on environmental and economic aspects induced a change in farm practices for a better use of nutrients.

The importance of manure as a source of phosphorus has increased to the point at which it is estimated that 50 % of the input to EU surface waters from leaching and penetration into soil can be attributed to the application of animal manure [32, SCOPE 1997]. Concentrations of 20 – 30 micrograms P/l in lakes or slow rivers can cause water eutrophication, with the danger of a growth of toxic blue algae (cyanophytes) in fresh water, which are P limited [33, DG Env 2002].

1.4.3 Other emissions

~~**Noise**~~

The intensive rearing of poultry and pigs ~~livestock farming~~ can generate other emissions such as **noise** and emissions of bioaerosols. Like odour, ~~is of~~ they are local problems, and disturbances can be kept to a minimum by properly planning activities. The relevance of this problem may increase with expanding farms and with the growth in rural residential developments in traditional farming areas.

~~**Bioaerosols**~~

Bioaerosols are important for the role they can play in the spread of diseases. The type of feed and feeding technique can influence the concentration and emission of bioaerosols. The feeding of pellets or mealy feed mixes via liquid feed systems and through the addition of feed fats, or oils in the case of dry feed systems, can reduce dust development. Mealy feed mixes are better when combined with oils as binding agents. Liquid feed installations are regarded as desirable. A dry feed system may only be implemented on the basis of automatic slop/raw slop feeders. The high quality of the raw materials can be ensured through dry harvesting and storage. This will then prevent ~~avoid~~, in particular, microbial and fungal contamination.

Regular cleaning of the housing equipment and all the housing surfaces will remove dust deposits. This regime is assisted by the all-in, all-out rotation method, as following the removal of all the livestock, careful cleaning and disinfecting of the housing is necessary.

As a general rule, in non-litter housings, less dust occurs than in the case of litter-based housings. In litter-based housings, care must be taken to keep the litter~~,~~ clean and dry~~,~~ under all circumstances~~,~~ and free of mould/fungus. Low air velocities in the floor area can reduce the dust content in the air.

2 APPLIED PRODUCTION SYSTEMS AND TECHNIQUES

This chapter describes the major activities and production systems used found in intensive poultry and pig production, including the materials and equipment used and the techniques applied. It attempts to present the techniques that are generally applied throughout Europe and to create a background for the environmental data presented in Chapter 3. It also describes those techniques that can serve as a reference or benchmark for the environmental performances of the reduction techniques presented in Chapter 4., without This chapter does not seek to givinge an exhaustive description of all existing practices., nor can it give a description of all combinations of techniques that may be found on IPPC farms. Because of historical developments and climatic, economical and geophysical differences, farms will vary in the kind of activities that take place are applied, as well as in the way in which these activities are carried out, namely in the combinations of techniques that may be applied. Nevertheless, it this chapter should give the reader a general understanding of the common production systems and techniques applied in Europe in the production of poultry products and pork products pig meat.

2.1 Introduction

Livestock production mainly consists of transforming feed into meat or eggs, and is usually performed in different phases, stages is concerned with the processing of feed into a form that is suitable for human consumption. The the objective of which is to reach achieve a high efficiency in the feed utilisation (feed conversion rate, FCR), whilst respecting animal welfare and avoiding as well as to use production methods that do not cause emissions that are harmful to the environment or to people. It is important to note that the good environmental farm management is more likely to be carried out if it is complementary to product quality rather than at the expense of it, since the economic profitability and the customer satisfaction are the main drivers for the activity.

In general, the production systems commonly applied do not require highly complex equipment and installations, but they increasingly require a high level of expertise to properly manage all the activities of the farm. and to balance the production aims with the animals' welfare.

The animal housing system, where animals for meat or egg production are reared, fed, grown and finished, is the main determinant of the activities of the farm, and This system (see Sections 2.2 and 2.3) includes the following elements:

- the way the animals are stocked (cages, crates, free);
- the system to remove and store (internally) the produced manure;
- the equipment used to control and maintain the indoor climate;
- the equipment used to feed and water the animals.

Other important essential elements of the rearing farming system are:

- the storage of feedstuffs feed and feed additives;
- the storage of manure in a separate facility;
- the storage of carcasses;
- the storage of other residues;
- the loading and unloading of animals.

Additionally, on egg-producing farms, the selection and packaging of eggs is quite a common activity, but this is outside it is out of the scope of this document. the IRPP BREF.

Equipment to run the following A number of activities may also be encountered on rearing of poultry and pigs livestock production, depending on the structure of the farm: farm can be part of the farming system, but these vary between farms for reasons such as the availability of land, farming tradition, or commercial interest. The following activities or techniques:

- manure application on farming land;
- on-farm manure processing and treatment, including, e.g. biogas production, manure separation, composting, etc.;
- feed milling and grinding;
- waste water treatment;
- residues treatment, such as carcasses incineration.

Schematically, farm activities for the reaing of poultry and pigs this can be illustrated as in Figure 2.1.

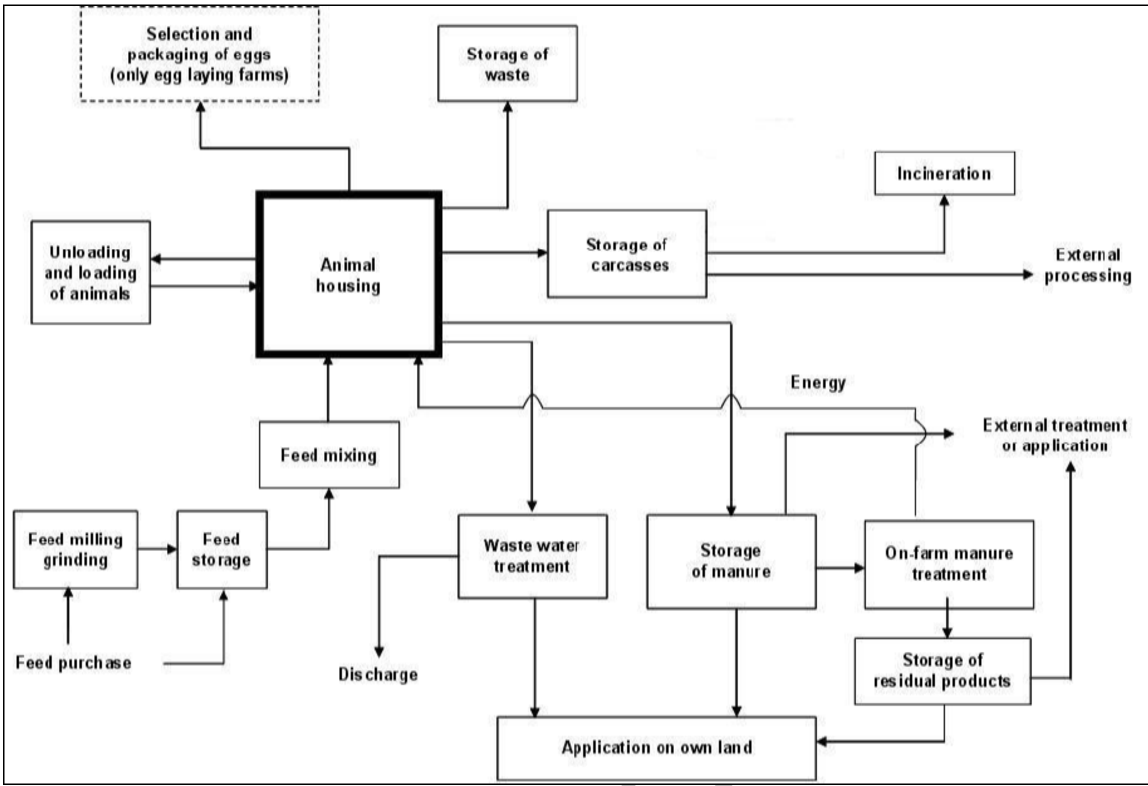


Figure 2.1: Schematic representation of activities, carried out on farms for ~~on~~ intensive rearing of poultry and pigs ~~farms~~

2.2 Poultry production

2.2.1 Production of eggs

Council Directive 1999/74/EC of 19 July 1999 lays down minimum standards for the protection of laying hens. The ban on conventional battery cages was confirmed in 2008, hence by the year 2012, non-enriched cages will have to be phased out completely, and the standards laid layed down in Articles 4 and 6 of the Directive will be mandatory. Only enriched cages or non-cage rearing systems will be allowed to be in service, according to the minimum requirements set in the Directive. The term 'furnished' is also used to mean enriched cages.

Intensive egg production usually takes place in closed buildings made of various materials (e.g. stone, wood, steel with sheet cladding). The building can be designed with or without a light system, but always with ventilation. The equipment in the housing can vary from hand operated systems to fully automated systems for indoor air quality control (see Section 2.2.4), feeding and drinking (see Section 2.2.5), manure removal and egg collection. Close to the housing or immediately attached are the feed storage facilities.

New developments in housing systems sometimes make it difficult to distinguish between cage and non-cage systems. If the system is operated from outside and workers do not enter the system, it is defined as a cage. [21, EFSA 2005]

The number of birds per surface area varies between housing systems. WhereThe formerly commonly used cage systems allowed a stocking density, depending on tier arrangement, of up to 30 – 40 birds/m^2 (corresponding to the available ground area). and severely restrict the birds in their freedom of movement, Modern applied alternative Rearing systems currently allowed by regulation have much lower densities, in the range of 7 birds/m^2 (littered floor) to 12 – 13 birds/m^2 (in each enriched cage floor area) and 18 birds/m^2 (in an aviary system).

EXISTING TEXT REFERRING TO CONVENTIONAL CAGES (PHASED OUT) HAS BEEN DELETED

In non-cage systems, hens can walk around freely, such as in the barn systems, and the 'free-range' systems in which the hens also have continuous daytime access to open-air runs.

Cages are enclosures made from by welded wire mesh with sloped floors to allow the eggs to roll to the front side of the cages, where they are removed by hand or on a transport belt.

The cage battery systems can be described as a combination of the following elements:

- building construction
- cage design and placement
- manure collection, removal and storage.

For commercial egg production, poultry chicken laying breeds are used that resulting from selection and breeding programmes that optimise their genetic potential for high egg production. Usually, they have small bodies that make them undesirable as meat producers. The smaller bodies allow benefit these breeds because very few nutrients are wasted in producing great body mass. Instead, they to direct more of their dietary nutrients into egg-production, rather than producing greater body mass. The egg producing breeds are also selected to lay further divided into birds that produce white shelled eggs or coloured brown shelled eggs.

Laying birds kept in cages have one laying period of about 12 – 15 months measured from the end of the (after around 16 – 20 weeks of growing period). The laying period can be extended by a if forced moulting is initiated between the 8th and 12th month of lay,. This takes advantage of hence a second laying period of that can add at least another seven months is can be added. on the end of the forced moulting period, taking the laying up to 80 weeks. [39, Germany 2001

]. In non-cage systems, the laying period lasts from about 20 weeks to 15 months, but no forced moulting is initiated. Moulting is a natural process, but in commercial egg production it is sometimes still induced by feed modification deprivation or light alteration, hence it is argued that it is not a welfare-compatible practice. Moult induction by feed or water deprivation is prohibited (Directive 98/58/EC concerning the protection of animals kept for farming purposes), whereas changing feed composition (e.g. reducing the energy content by increasing bran percentage) or controlling feed (instead of *ad libitum* provision) is allowed. Studies are ongoing to find a more acceptable alternative method of inducing moulting in laying hens to prolong the laying period.

2.2.1.1 Cage battery systems for laying hens

Directive 1999/74/EC phases phased out conventional cages as of 31 December 2011, and therefore they are not described in this document. The cage systems described below corresponds to modern cages that are referred to as 'enriched', or 'furnished', or 'colony systems'. All systems comply with the minimum requirement for space allowances and additional equipment that are detailed in Directive 1999/74/EC.

Enriched cages Modern cages are equipped with structural features to stimulate species-specific behaviour. These elements are nests, perches, litter, and increased cage height. Nest boxes can be placed at the front of the cage and are normally darkened by plastic curtains to encourage laying offer a comfortable place to lay eggs. Nests can be adapted outfitted to keep hens out at night, with gentle expulsion systems or automatic doors that allow animals to exit but not to enter the nest.

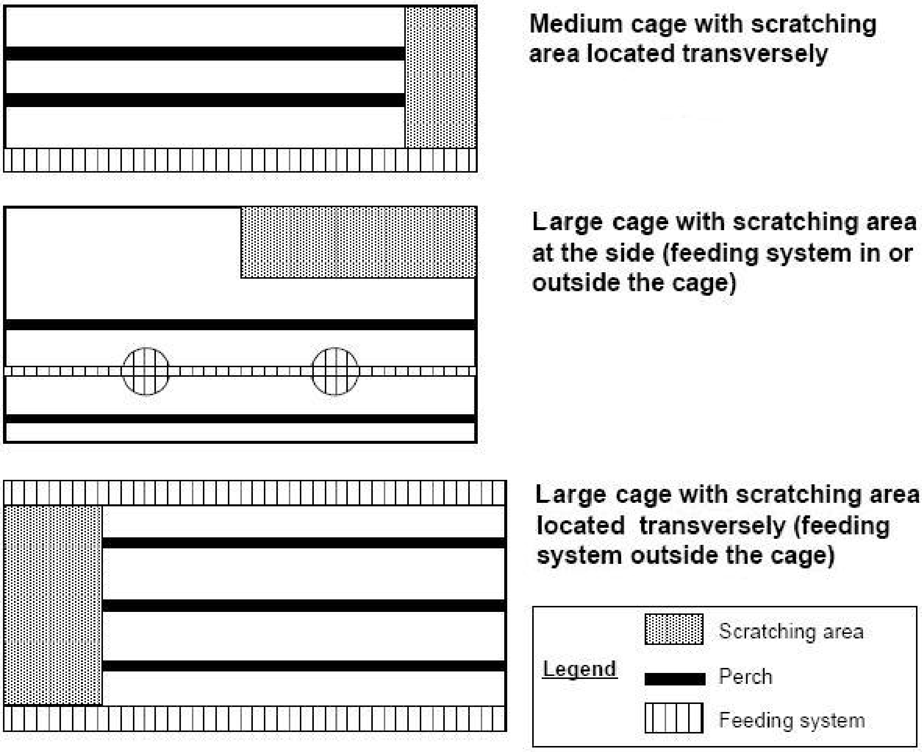
In furnished cages, the area in which eggs are laid can be relatively small, and collisions occasionally occur between eggs in the nest box, which in turn can damage the eggshell.

Perches are arranged to give around 15 cm per hen, and are designed to strengthen animals' legs. Wing flapping is made possible due to a cage height of at least 45 cm. Sand-bathing and scratching needs are allowed possible in separated areas, which are equipped with automated distribution of sand, shavings, or other materials, plastic mats, or many other kinds of litter. Claw shorteners are provided as perforated plates, abrasive stones, ceramics, plates or strips, and are frequently placed in the baffle plates behind the feed troughs. All these features can be placed in different relative positions in the cage, as it shown in Figure 2.2.

In Table 2.1, a summary of the main characteristics of enriched cages is presented.

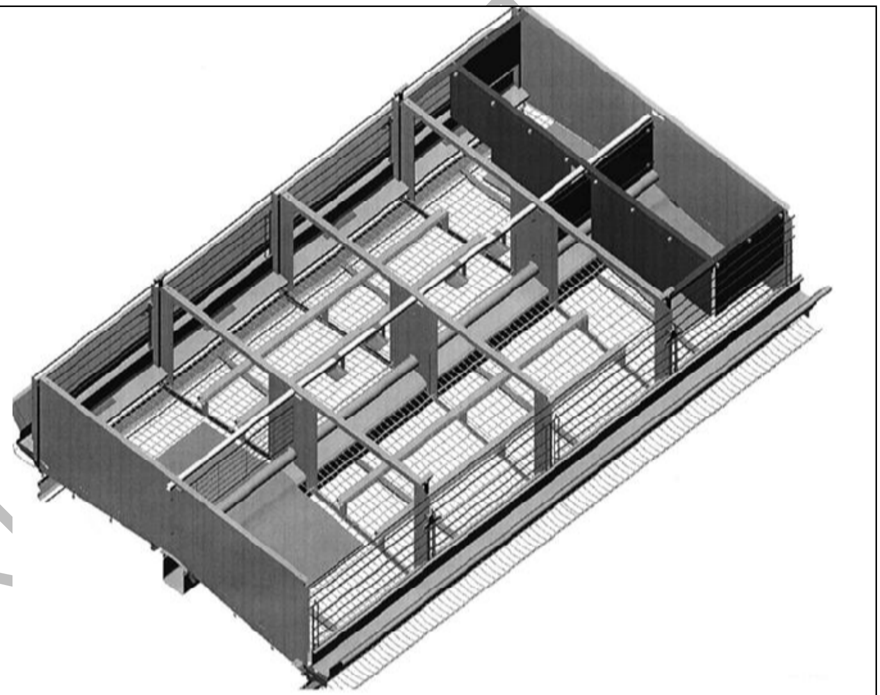
Table 2.1: Summary of the main characteristics of enriched cages

Minimum cage area per hen	At least 750 cm^2, of which 600 cm^2 shall be usable
Minimum total area per cage	2 000 cm^2
Length of feed trough	12 cm per hen
Minimum height	45 cm: headroom between levels in the usable area 20 cm, (at least) in the remaining area of the cage
Drinking system	Two nipple drinkers or two cups must be within reach of each hen
Length of perches	At least 15 cm per hen
Levels and droppings	No more than four levels, arranged to prevent droppings falling on the levels below
Additional features	A nest: litter such that pecking and scratching are possible



Source: [46, Netherlands 2010]

Figure 2.2: Possible placement of the equipment in enriched cages



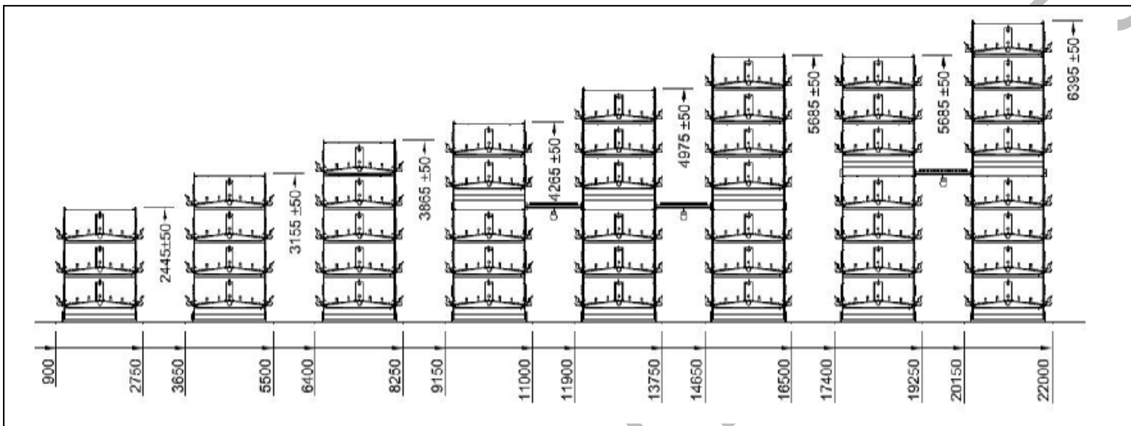
Source: [21, EFSA 2005]

Figure 2.3: Schematic drawing ~~picture~~ of ~~a possible design of an~~ two large enriched cages

~~Groups of~~ Hens are reared in enriched cages in a wide variety of group sizes. ~~in each cage~~. Groups of up to 10 – 12 birds are generally referred to as a 'small group', while, 15 to 30 birds could be regarded as a medium sized group and above this number would be regarded as a 'large group'. At the time of writing (2013), larger cages may house up to 60 birds. Neither the maximum nor the optimum number of birds is yet defined. [38, ASG Lelystad 2006]

~~are reared in each cage, that are usually called 'small' if the number of animals is up to 15, 'medium', if the number is from 15 to 30 hens, and 'large' with 60 hens or more.~~
Cage dimensions are related to the group size and may influence bird inspection and depopulation. [21, EFSA 2005] In Germany, the so-called small-group housing system that has been developed exceeds the EU requirements for an enriched cage and allows for better hygiene performances.

Cages are produced in modules of 1 to 4 – 5 levels (or 'tiers'), and can be stacked to give many overlapped levels (see Figure 2.4).



Source: (Victorsson AB)

Figure 2.4: Examples of combinations of enriched cage modules

EXISTING TEXT REFERRING TO CONVENTIONAL CAGES (PHASED OUT) HAS BEEN DELETED

The manure is collected on manure belts that are situated under each ~~tier (or~~ cage level~~)~~. At the end of the belt, a cross conveyor further transports the manure ~~further~~ to the outside, normally to ~~an the~~ external storage. Closed manure storage can pose a sanitary risk; hence, manure is also transported directly to field heaps or external storage, or to other uses (e.g. direct application to compatible cultivations, manure processing or treatment, etc.). The manure belts are made of smooth, easy-to-clean polypropylene or trevira and no residue sticks to them ~~these belts. With modern reinforced belts, manure can be removed from very long runs of cages~~. Some drying takes place on the belts, especially ~~in~~ during the summer season ~~conditions~~, and manure may be held on the belts for up to a week.

Frequently, the manure on the belts is dried by blowing air over the droppings through pipes that are placed above or along the belts (see Figure 2.5). The air can be preheated and the manure is removed at least once a week at a dry matter content of at least 40 – 60 %. ~~at least 50 %~~. ~~In improved belt systems, air is blown over the manure to achieve faster drying of the manure. The air is introduced just under each tier of cages, usually via rigid polypropylene ducts. Another~~ A benefit for the animals is the introduction of fresh cooling air immediately adjacent to the birds. Further improvements consist of the introduction of conditioned ~~preheated pre-warmed house~~ air and/or the use of heat exchangers to condition ~~preheat pre-warm~~ incoming outside air.

Source: (Valli S.p.a.)

Figure 2.5: An air duct over manure belts in enriched ~~colony~~ cages, where air is blown through holes over the droppings

EXISTING TEXT REFERRING TO THE DEVELOPMENT OF ENRICHED CAGES FOR THE SUBSTITUTION OF CONVENTIONAL CAGES (PHASED OUT) HAS BEEN DELETED

2.2.1.2 Non-cage housing systems for laying hens

Laying hens are also kept in systems which Directive 1999/74/EC refer to as 'alternative systems'. They are also commonly called 'non-cage housing systems'.

In alternative housing systems, hens are reared on a litter covered solid floor in combination with a slatted floor. Often the floor is made of concrete, but other materials can be used as well. Manure accumulates either on the solid floor or under the slatted area for the 14-month laying period.

Article 4 of Directive 1999/74/EC regulates features for these systems, such as:

- feeders and drinkers availability;
- positioning and dimensioning of nests, perches and litter;
- the number and the height of the floors where the hens can move freely;
- the prevention of droppings from falling on levels below;
- the dimensions and the availability of pop-holes giving access to open runs;
- the general characteristics of the open runs;
- the stocking density.

These features, ~~added to the reduction of emissions achievable by means of the frequent manure removal with belts or scrapers,~~ allow for a more comfortable housing. ~~better indoor climate.~~ However, higher ammonia and dust emissions may arise compared to cage systems, due to the presence of litter material and to increased animal activity, though this can be mitigated by the frequent removal of manure with belts or scrapers.

What these housing systems all have in common is that the birds have more space or can move around more freely within the building, and that operators ~~keepers~~ can enter them~~ to operate~~.

The housing construction ~~in which the birds are kept~~ is similar to that of the cage systems~~. The layer house is a traditional building~~ with respect to walls, roof and foundation. Birds are kept in large groups with 2 000 to 10 000 bird places per housing facility, where the air is replaced and emitted passively by natural ventilation or by forced ventilation with negative pressure. Thermally-insulated poultry houses have forced ventilation, either windowless or with windows for natural daylight.

Various housing designs are applied ~~in different Member States~~, such as variations of the basic schemes of:

- the deep litter system, also referred to as ~~or~~ the single-tier non-cage system or single level system;
- the aviary system, also referred to as ~~or~~ the 'perchery' or multi-level system.

These indoor systems can be combined with either one or both of the following additional structures: verandas and/or forecourt free ranges (see Section 2.2.1.2.5).
~~In Directive 1999/74/EC two non-cage systems are defined: the barn and the free-range system.~~

2.2.1.2.1 Barn, or deep litter (or single-tier) system ~~for laying hens~~

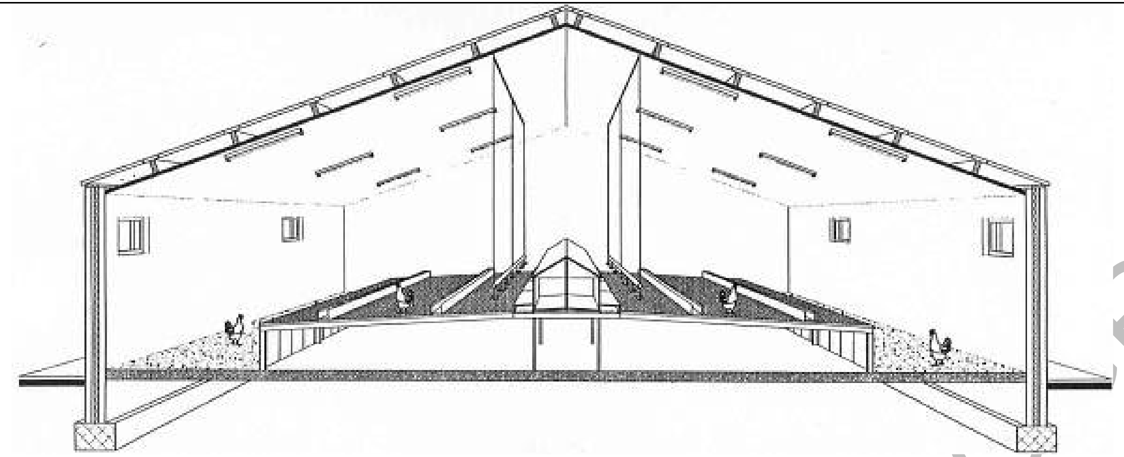
In ~~the~~ single-tier systems, the ground floor area is fully or ~~usually~~ ~~made up~~ partly covered with ~~of~~ litter and may be combined with variable ratios of partly-slatted floor.~~ in variable ratios~~. In accordance with EU Egg Marketing Standards currently in effect, at least one-third of the floor area (concrete floor) must be covered with bedding (chopped straw or wood shavings used as litter material). The remaining area ~~and two thirds arranged as droppings (manure) pit slightly raised. The pit~~ is covered with slats that are mostly made of plastic (see Figure 2.6), ~~or artificial material (~~wire mesh~~ing~~ or wood. ~~lattice).~~ Underneath the slats, a manure pit or a manure removal system is placed that is made of scrapers or belts, with or without aeration. Usually the slatted floors are in the middle of the hen house, but they can also run alongside both walls, whereas litter is in the middle of the house. The pit is formed by the raised floor or can be sunk into the ground (see Figure 2.7). ~~The manure in the a pit below the slats is collected during the laying period (13 – 15 months).~~ Droppings are removed from the pit at the end of a ~~given~~ laying period, or may be removed intermittently~~, with the aid of (aerated) manure belts~~. At least one-third of the used-air volume stream is drawn off via the droppings pit. In single-tier systems, there is only one level for the birds at any one point, even if this level might be stepped.

Source: SKA S.r.l.

Figure 2.6: Typical plastic floors for layer rearing

Variations are possible also ~~in the sense that~~ in wider houses, where ~~more~~ rows of laying nests can be placed, or in the same house, two stacked compartments can be arranged on ~~the~~ different levels of the house. [70, Netherlands 2010]

Laying nests, feed installation and the water supply are usually placed on the slats to keep the litter area dry. Perches are available and are usually placed in A-frames on the slatted floor. The automatic supply of feed and drinking water, with long troughs or automatic round feeders (feeder pans) and nipple drinkers or round drinkers are installed above the pit area. Individual or community nests are provided for laying; automatic egg collection is also possible. Lighting programmes to influence the performance/rate of laying, and crude protein-adapted feeding may be applied. [38, ASG Lelystad 2006], [39, Germany 2001], [44, Netherlands 2000].



Source: [38, ASG Lelystad 2006] ~~[128, Netherlands, 2000]~~

Figure 2.7: Schematic cross-section of a single-tiered non-cage system

2.2.1.2.2 Aviary system with non-integrated nest boxes

~~In~~ This type of poultry house ~~is a construction with thermal insulation and forced ventilation, either windowless, or with windows for natural daylight and artificial light for applying lighting programmes; houses that~~ can be combined with a range and an outside scratching area. ~~Birds are kept in large groups and enjoy freedom of movement over the entire house area.~~ The housing space is subdivided into different functional areas: feeding and drinking, sleeping and resting, scratching and egg-laying ~~area~~. The available surface area is increased by means of elevated floors combined in stacks (at some point across the system, there will be at least two levels available for birds), ~~The birds can use several house levels that~~ allowing for ~~higher stocking densities compared to the commonly used floor regime (deep litter). stocking~~ a density of up ~~is maximised~~ to 9 birds per usable m^2 or up to 18 ~~15.7~~ birds per ~~ground surface (in~~ m^2~~)~~ of ground space.~~, with~~ ~~Hence~~ Houses can accommodate ~~accommodating between 2000 and 20 000~~ up to 80 000 birds ~~(bird places)~~.

The elevated floors usually have slight slopes to allow eggs to roll towards one side. Under each floor a manure belt is positioned to prevent the manure from falling to the lower levels, and to transport manure out of the hen house. The nest boxes (individual or group nests) can be lined up in one row or in multiple rows above one another (see Figure 2.8, A).

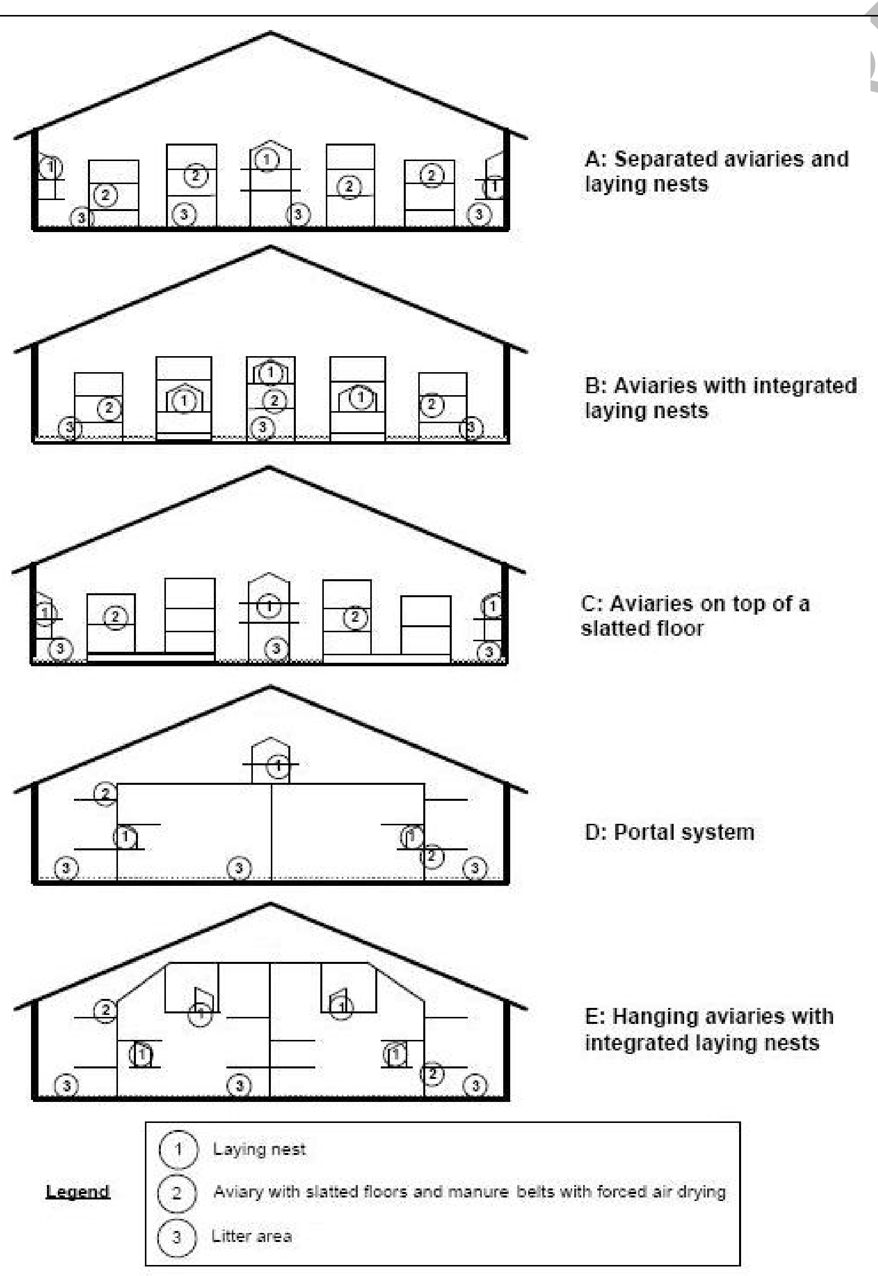
On the elevated floors, water and feed is provided. Water is usually provided through nipple drinkers, but cups are also possible. Feed can be provided by means of chain feeders or feeding pans. The top floor usually has many perches; the lower floors often have only perches along the sides of the floors.

Litter is provided on the bottom of the hen house. In some systems, birds cannot use the space underneath the stacks; in other systems they can, the lowest floor being elevated to at least 45 cm, as required by law. [38, ASG Lelystad 2006]

EXISTING FIGURE 2.1 (REFERENCE YEAR 2000) AND RELATED INTRODUCTION HAVE BEEN DELETED

2.2.1.2.3 Aviaries with integrated nest boxes

The use of a system with integrated nest boxes is an evolution of the ~~one~~ system previously described of non-integrated nests, as the stacks of elevated floors have units of nest boxes integrated into the same stack. Often, stacks with integrated nest boxes are alternated with stacks without nest boxes. Between the different stacks of floors, an aisle covered with litter is positioned to enable operators/keepers to walk through the system and to provide litter to the hens. The nest boxes (individual or group nests) are usually lined up in two rows connected to the back of the nests, [38, ASG Lelystad 2006] but many ~~schemes~~ configurations are possible (see Figure 2.8).



Source: [47, Netherlands 2010]

Figure 2.8: Aviary configurations ~~Schemes of aviaries~~ normally in use

2.2.1.2.4 Portal system

A further evolution of aviaries is the portal system, where units of nest boxes are integrated into the same stack. On top of two of these stacks, a single level system is placed to connect the two stacks, as can be seen in Figure 2.8 (configuration D ~~fourth from top~~). Litter is provided on the entire floor of the hen house and birds can walk underneath the elevated floors. ~~Workers~~ Operators/keepers can usually access the aisles both ouside the stacks and under the floor that connects them. [38, ASG Lelystad 2006]

2.2.1.2.5 Additional structures for non-cage housings

Covered veranda (Winter garden ~~Wintergarten~~)
This consists of an outside covered area, which is available to the birds during daylight hours. Covered verandas are connected to the hen house and can be built as additional elements to the house, or as a part of the total construction, covered by a roof extension. Verandas are often closed by shutters or a curtain that can be lifted to provide hens access to the free- range area. If there is no free range, curtains are replaced by fences of wire mesh preventing animals from ~~going~~ getting out, but ~~letting~~ allowing ~~the~~ fresh air to blow freely through the area. In this case, the climate is similar to that outside, except for the rain, which is prevented from entering the area by the use of ~~Only some~~ protective devices. ~~can be made to prevent rain from entering the area~~ The floor of the covered veranda is usually littered. [38, ASG Lelystad 2006]

Forecourt/free range
Free ranges can be covered with grass. The birds have access to this area from houses via pop-holes in the wall and in the covered veranda, if present. They ~~animals~~ will use the area if they feel there is sufficient shelter. The shelter may be trees or bushes, but it can also be artificial shelter (elevated nets, tents). ~~and~~ Also, a fence is used as cover to walk along. Providing water, feed or a sand bath is another way to attract poultry to use these facilities. Areas near the house may be covered with free draining material, in order to maintain good hygiene both outside and inside the house [38, ASG Lelystad 2006]. Protection is also necessary from wild avifauna for biosecurity reasons, e.g. due to the risk of avian flu.

2.2.1.3 Pullet rearing

Success in the laying period will greatly depend on effective housing and management in the rearing period. In order to facilitate a smooth start to the laying period, it is advisable to rear the pullets of laying hens ~~are normally reared~~ in systems that are very similar to the ones they will be housed in during the laying period ~~production system~~. ~~The similarity of the systems is necessary for minimising~~ This procedure, together with a transfer well before the onset of laying, minimises ~~the~~ stress due to the transfer into a new ~~producing~~ facility and, consequently, ~~to~~ promotes layer production.

The ~~phase of~~ rearing phase for ~~the~~ chicks up to 17 or 20 weeks is normally run in separate~~d~~ facilities because the microbial conditions of the adult environment would be too dangerous for young chicks. The space provided in small group housing is about 0.035 – 0.045 m^2 per animal.

Normally, only management details differentiate ~~the~~ pullet rearing from the laying period. For instance, in rearing, more care is paid ~~to provide~~ in providing heat to the few-days-old animals, ~~to encourage~~ in encouraging them in feeding and drinking after arrival, and ~~to synchronise~~ in synchronising their activity ~~by~~ with lighting programmes.

Pullets destined ~~to~~ for alternative systems need to learn to fly and jump at a young age, ~~and this~~ but these can happen in similar structures.

Pullets can also be reared in simple deep litter housings on a bedded solid floor in closed, well insulated houses with forced ventilation and without functional areas. The manure is stored with the bedding and ~~it~~ is removed at the end of the rearing period, which is about 16 – 18 weeks.

The system is relatively animal friendly and provides a space of 0.05 to 0.07 m^2 per head (whilst in aviaries, 0.017 m^2 per head is usual). However, ~~On the contrary~~ high ammonia, dust and odour emissions arise due to the long-term indoor manure storage.

A slatted floor ~~over~~ covering not more than two-thirds of the area, can be placed, ~~making~~ allowing a deep pit underneath. In this case, the removal of the manure is done at the end of the rearing period.
~~and the ammonia emissions are estimated to be around 0.17 – 0.21 kg of ammonia per animal per year.~~ **DATA ALREADY REPORTED IN CHAPTER 4, TABLE 4.35.**

2.2.2 Production of broiler meat

Broiler meat is produced by growing meat-type breeds of chicken. A very limited number of international companies produce hybrid varieties (strains) out of combinations of many different breeds. ~~The combinations of breeds are selected to produce a variety (strain) with meat characteristics that the producer desires most. Some breeds grow faster and larger while others emphasise~~ Traits that are mostly considered in the genetic selection are: ~~like larger~~ breast meat yield, ~~more efficient~~ feed conversion, reproduction efficiency, and ~~or more~~ disease resistance. ~~Strains are often named after the breeding companies that genetically develop them. Obviously, these strains are not as well suited to laying eggs as the laying breeds.~~

This text belongs to the previous 2003 IRPP BREF and was moved in this position from section 4.3.1

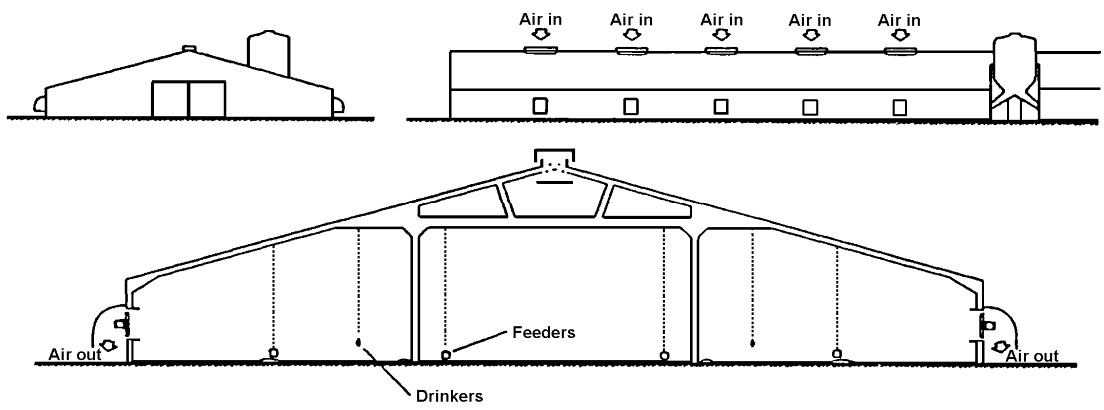
However, it should be noted that genetic selection towards better feed-conversion is also linked with an increased growth rate. However, high growth rate can lead to increased lameness in broiler chickens as well as to systematic underfeed parent breeds (the *ad libitum* feeding of parents creates reproductive difficulties). As a consequence, a proper balance between better growth rate and potential welfare problems is aimed for.

Directive 2007/43/EC, laying down miniumum rules for the protection of chickens kept for meat production, establishes rules for the protection of animals, aiming for a balance between animal welfare, health, economic and social considerations, and environmental impacts.

The traditional housing of intensive broiler production is a simple, closed-building construction of concrete or wood with natural light, or windowless with a light system, thermally insulated and force ventilated. Forced ventilation (negative pressure principle) is applied by way of fans and air inlet valves.Buildings are also used that are constructed with open side walls (windows with jalousie-type curtains) and naturally ventilated. Open houses ~~must be~~ are placed ~~located~~ so that they are freely exposed to a natural stream of air and are positioned at a right angle to the prevailing wind direction. Additional ventilating fans operate via ridge slots; ~~and~~ gable openings may also apply. ~~This is intended to provide the in-house broiler area with extra air circulation during hot spells in summer.~~ Wire mesh ~~Mesh wire~~ screens along upper sidewalls keep wild birds out. ~~(see Figure 2.13).~~

Houses can be combined with free range (made accessible from the 20th day of the bird's age onward) and/or a veranda.

Modern housings are maily equipped with controlled ventilation systems that allow climate control for animals, litter drying, and ~~eventually~~ ultimately for air channelling to air treatment devices. The air flow direction ~~is a consequence of~~ depends on the position of inlets and outlets that can be placed equally on the roof ridge, on side walls or gable ends. Hence the air can be drawn from the sides up to the ridge, or from the top down to the sides (cross ventilation), or all along the length of the house from one gable side to the other (tunnel ventilation). In housings fitted with cross ventilation, the litter moisture ~~can~~ may be less homogenous and can be around 10 % higher. [91, Italy 2010] Directing the ventilated air in a precise direction also allows for channelling it entirely to an air treatment system, without leaving any air flows out of control.



Source: [400, Silsoe Inst. 1997]

Figure 2.9: Example of schematic cross section of a commonly applied broiler house

2.2.2.1 Deep litter

Traditionally, broilers are kept on litter, mainly made up of chopped straw or wood shavings, but also of ~~or~~ shredded paper or other matter, which needs to comply with the provisions (dry and friable) of Directive 2007/43/EC. Litter is spread over the entire housing floor area ~~which, in turn,~~ that is usually built as a solid concrete slab, but which may also consist of a clay floor (in France, 93 % of buildings have non concrete floors). The bedding is spread uniformly at the beginning of each growing period and the manure is removed together with the litter at the end ~~of each growing period~~. Automatic, height-adjustable feeding and drinking systems (mostly tube feeders with round feeder pans and nipple drinkers with drip-water catch bowls) are provided ~~applied~~. Crude protein-adapted feed is given.

Closed buildings have oil- or gas-fired warm-air blowers for total room heating, when needed; heat exchangers (water-air, air-air) coupled to air blowers are increasingly used. Radiant heaters (mostly gas-fired) are used for zoned ~~zonal~~ heating ~~in houses built for open-air ventilation~~. Open climate and naturally ventilated houses are also in use.

Artificial lighting and/or artificial/natural daylight combination lighting systems are provided as required.

Broilers are kept at a stocking density of ~~18 to 24 birds per m^2.~~ 13 to 26 birds per m^2, depending on the duration of the fattening period and consequently of the live weight (LW) at slaughter:

- 34 days cycle and final weight of 1.5 kg LW per bird
- 40 days cycle and final weight of 2 kg LW per bird
- 45 – 55 days cycle and final weight of 2.1 kg LW female bird – 3 kg LW male birds.

Directive 2007/43/EC defines the maximum stocking density in a housing system ~~is also measured in kg live weight/m^2 (e.g. in Finland)~~ as 33 kg/m^2. Broilers can also be kept at a higher stocking density of 39 kg/m^2 and up to 42 kg/m^2 if Member States allow derogations, provided that the housing systems comply with certain welfare requirements.

, but this number is variable. New legislation is expected to limit the stocking density of broilers. Houses can stock (up to 60 000) between 20000 and 40000 birds.
More and more frequently, Sometimes (e.g. UK, Germany), houses are equipped with functional areas where animals can benefit from more locomotion exercise, outdoor air, and where they can express species-specific behaviours, like scratching. A veranda is an indoor littered space adjacent to the housing, in which the roof and open side wall are in full light. An outdoor space in full light, like a field or a large enclosed area of land for exercise, is correctly named a forecourt, but is frequently also called free range (see Section 2.2.1.2.5).

2.2.3 Other poultry production sectors

2.2.3.1 Rearing of broiler breeders (parental lines)

Broilers are born from by hatched eggs that are produced by the 'broiler breeders'. These parental lines are usually reared in similar housing to broilers, additionally equipped with nests where eggs are laid layed; or they are may be reared in colony cage systems.

At a very early stage, from 1 day-old to 7 – 10 days old, males and females are separated and brooded broodened until 10 – 20 weeks old, with adequate feeding in order to obtain the needed required different live-weights for the different genders. In the houses stables where reproduction is carried out run, 8 – 10 males are given provided to a hundred females, and one nest is provided for approximately every 5 layers.

2.2.3.2 Production of turkeys

Turkeys are kept for meat production and different production systems apply. The system It can be a two-phase age system (e.g. UK, Netherlands, Germany). The first period covers a brooding breeding period for all birds up to 4 – 6 weeks, up to when they reach an approximate weight of 2 kg, after which the birds Than Then the stags (males) are transferred shifted to a different housing for the rearing/fattening breeding period phase. is 19 – 20 weeks with an In general, the average slaughter weight for the stags is from 14.5 to 21 kg of live weight, with a fattening period that ends at 19 21 – 22 weeks, and for the hens, the slaughter weight is generally from 7.5 to 11 kg, with a fattening period between 10 and 17 16 – 17 weeks (see also Table 1.3). In Finland, four ages are distinguished relating to four different feeding rations, with stags being reared for 16 weeks and the hens for 12 weeks. The animals are kept in much higher densities at the beginning start, when they are still small. During the growing period, the birds are thinned, and after 22 weeks only a third of the birds may be left. For example in the UK, the hens are removed first and sold as oven-ready birds. Stags are used for further processing.

The most commonly applied turkey housing is a traditional housing construction, which is very similar to that used for the housing of broilers (Figure 2.9). Turkeys are housed in closed, thermally-insulated buildings with forced ventilation, or (more frequently) in open (outdoor-climate) houses with open side walls and jalousie-type curtains (unrestricted controlled natural ventilation). Forced ventilation (negative pressure) is applied by fans and inlet valves in fattening houses. Free open-air ventilation is created in rearing/brooding and fattening houses via automatically controlled jalousies or wall-mounted inlet valves. Open houses are aligned at right angles to the prevailing wind direction and located in such a way as to be exposed to natural airflow. Additional ventilation is applied via ridge slots and gable openings. Radiant gas heaters are applied for heating.

Closed buildings are used to house all young turkeys in the first rearing period, and to rear the females in their fattening phase. For the final breeding period, stags are more often reared in open houses, that can may also be fitted with outdoor free ranges.

Precautions are put in place to protect against emergencies like power cuts, extreme weather conditions or fire, since all animals in these large units will be at risk at once. ~~as per unit a large number of birds will always be at risk.~~ During peak summertime temperatures, additional measures are taken to minimise heat stress on the birds (by providing for larger-volume air exchange, operating extra fans for bird comfort in open houses, water fogging or roof sprinkling).

Wire meshing in the upper side wall section is applied to keep wild birds out. A floor regime is operated with litter material (chopped straw, wood shavings) spread over the entire housing floor area (built of concrete) at 5 – 7.5 cm depth, with layers topped up to during the rearing cycle to 20 – 55 cm ~~9 – 12 inches~~ ~~deep~~ depth. Manure removal and cleaning of the house takes place at the end of each respective growing period. All manure ~~litter~~ is removed by an excavator or front loader. Litter replenishment is applied as needed. Automatic height-adjustable bell ~~round~~ drinkers and feeders are provided ~~applied~~ during the growing/feeding period. Daylight length and light intensity can be controlled during brooding and, in closed houses, over the entire brooding/finishing period.

THE EXISTING SECTIONS 2.2.3.2.1 (CLOSED HOUSE SYSTEM) AND 2.2.3.2.2 (PARTIALLY VENTILATED LITTERED FLOOR SYSTEM) HAVE BEEN DELETED

2.2.3.3 Production of ducks

Ducks are generally kept for meat production. There are numerous breeds on the market, but popular breeds for commercial meat production are Pekin and Barbary; Rouen and Muscovy are both Barbary breeds. Different breeds are used for egg laying, although Pekins have a reasonable laying performance compared with the other breeds selected ~~breeds~~ for meat ~~types~~. Pekin account for about 80 % of meat production and Barbary for 20 %.~~The~~ Muscovy ducks are the heavier types. Drakes (males) are normally heavier than ducks (female). As with chickens, the selected meat breeds ~~types~~ are more heavily built than those selected for laying ~~the egg-type birds~~ (see Table 2.2).

Ducks are kept in housing, although in some Member States outdoor rearing is also allowed. There are three main housing systems for the fattening of ducks:

- fully littered floor, with or without water systems positioned above a gully
- partly-slatted/partly litter floor
- fully-slatted floor.

The commonly applied duck house is a traditional housing system and is similar to the broiler house (Figure 2.9). It has a concrete floor that is covered with litter. The house is equipped with a ventilation system (natural or mechanical) and, depending on the climatic conditions, heating is applied.

Table 2.2: Range of weights of duck breeds for meat and egg production

~~Meat breeds~~ ~~type~~	Adult drake (kg)	Adult duck (kg)
Meat breeds		
Pekin	3.00 ~~3.80~~~~4.00~~ – 4.50	2.80 ~~3.10~~ ~~3.50~~ – 3.75
Muscovy	4.50 – 5.50	2.25 – 3.00
Rouen	4.50 – 5.00	3.50 – 4.10
Barbary	4.65	2.55
Egg breeds ~~type~~		
Indian Runner	2.00 – 2.25	1.60 – 2.00
Khaki Campbell	2.25	2.00
Source: [506, TWG ILF BREF 2001] [365, France 2010]		

Production cycles will vary between Member States. In Germany, the production cycle for Pekin duck meat production is divided into a growing period of up to ~~day~~ ~~21~~ 16 days old; followed by a finishing period until day 40 – 42, and a final weight of 2.9 – 3.1 kg. ~~47 – 49.~~ Rearing and growing is done in separate houses ~~stalls~~. Manure is removed and houses ~~the stalls~~ are cleaned and disinfected during a service period of about 5 to 7 days, before they are stocked again. The maximum stocking density is 20 kg live weight/m^2 accessible floor area in both phases~~, with accessible areas typically measuring 16 m × 26 m for growing and 16 m × 66 m for finishing~~. Thus, the growing houses ~~stalls~~ can ~~house~~ accommodate approximately 20 000 young ducks and the finishing houses ~~stalls~~ about 6 000 ducks (see fact sheets in [39, Germany 2001]).

~~Commonly applied is~~ The fully littered system is commonly applied, using wheat or barley straw ~~or wood chips~~ (including wood shavings for the young ducks). The proper thickness of the bedding layer, taking into account that ~~is usually not too thick because~~ the manure of ducks is much wetter than that of chicken broilers, is crucial for the good health and conditions of the birds; a daily addition is normally necessary in order to avoid wet litter. It is reported that approximately 3 – 4 kg of straw per duck is needed, generating a triple quantity of manure, i.e. 9 – 12 kg litter per duck at 30 – 35 % total solid content.

Slats floorings are also used, ~~if applied, are usually~~ and are made out of plastic-coated wire, ~~wood~~ or synthetic material.

In France, ducks for meat are reared almost exclusively on slats, as ~~because~~ the highly diluted manure is considered to cause an excessive degradation of litters, expecially in winter, that eventually affects the birds sanitary state. Barbary ducks are raised ~~with~~ in mixed sexes, with a density of 14.5 ~~13.3~~ birds/m^2 until day 72, when females are then slaughtered. Males are reared until 85 days of age. [365, France 2010]

2.2.3.4 Production of guinea fowl

~~No specific information is available on the production of Guinea fowl in Europe. The general picture is that~~ Generally, this sector is thought to be quite insignificant compared to the production of other poultry species described above. Nevertheless, the European production of guinea fowl is approximately 45 million guinea fowl per year. In France, 86 % of the total EU production is raised in 926 farms ~~having~~ incorporating 1 345 buildings ~~for~~ and a total surface of 437 000 m². ~~Another 13 % of the production is carried out in Italy.~~ [365, France 2010]

Commercial breeding and the raising of ~~guinea~~ keets can be compared with that of turkeys. Guinea fowls ~~Guinea fowl is~~ are very different in their ~~its~~ behaviour from chicken and need~~s~~ a lot of space: in France they are reared at a density of 16.8 birds/m², until 78 days. ~~Somewhat dated information from US breeders and from the US Department of Agriculture (USDA) shows that guinea breeding stock is generally housed in free-range systems.~~ Breeders (approximately 350 000 guinea fowls in France) are raised in cages where artificial insemination is practiced systematically.

~~During the laying period the breeders are kept confined in houses equipped with wire floored sun porches.~~ It is an open question whether there are any farms in Europe rearing guinea fowl ~~Guinea fowl~~ intensively in such numbers so as to be under the scope of ~~IPPC~~ Directive 2010/75/EU.

2.2.4 Control of poultry indoor environment ~~housing climate~~

Houses for all poultry productions ~~species, housing systems~~ are normally equipped to maintain the indoor environment, and especially ~~climate, but~~ for broilers.~~ in particular climate, control has been studied extensively.~~ Factors that are important for ~~the climate~~ the indoor environment in poultry housing in general are:

- indoor air temperature and humidity (see Section 2.2.4.1)
- air composition and air velocity at the animal level (see Section 2.2.4.1)
- light intensity (see Section 2.2.4.2)
- dust concentration (see Section 2.2.4.3)
- stocking density
- insulation of the building.

Treatments applied to incoming air (principally for animal welfare reasons) generally comprise dust removal, cooling and/or humidification. [264, Loyon et al. 2010]

Adjustments are ~~is~~ usually made ~~done~~ by controlling the temperature, ventilation and lighting ~~illumination~~. Minimum health standards and production levels impose requirements on the indoor climate of poultry houses.

2.2.4.1 Temperature control and ventilation

Temperature control

The temperature in ~~the~~ poultry houses ~~are~~ is controlled by means of the following techniques:

- insulation of the walls
- local heating (deep litter systems) or space heating
- direct heating (e.g. infrared, gas/air heating, gas-convectors, hot air cannon)
- indirect heating (central heating-space, central heating-floor)
- cooling by spraying of the roof (practised in warmer climates and in summer)
- cooling by spraying water mist, also ‘fogging’
- wet filters, or pad-coolers.

~~Floors of~~ Housing flooring is ~~are~~ often made of concrete and is ~~are~~ normally not further insulated. Partly insulated floors are sometimes applied (e.g. Finland). There is a potential loss of heat from the housing by radiation to the soil underneath, but this is small and has not been reported as having an effect on ~~the~~ animals~~'~~ production. Heating is sometimes applied through heat recovery from the exhaust air, which is also used for manure drying. For layers, heating is hardly needed when the stocking density ~~in the cages~~ is high.

Generally, in winter, but also during the early stages of production (young birds), heating is applied to broilers. Local heating is usually provided by gas radiators that allow the animals to find their optimal temperature by displacement below the heater. Movement is sometimes restricted when the birds (of all species) are small, to keep them near the brooders.

The capacity of the heating equipment is related to the number of birds in the shed and the volume of the shed. For example, in Portugal, gas radiators with a capacity of 6 000 kJ are equal to 650 day-old ~~newborn~~ birds per radiator, and a capacity of 12 500 kJ ~~is equals~~ equates to 800 newborn birds. Some typical temperatures for the housing of broilers are shown in Table 2.3.

Table 2.3: Examples of required ~~indoor~~ temperature for broiler rearing ~~housing~~

Ages (days)	~~Indoor environment~~ Temperature (ºC)		
	Portugal ([1])	UK ([2])	France ([3])
1 – 3	37 – 38	30 – 34	31 – 33
3 – 7	35	32	30 – 32
7 – 14	32	28 – 30	28 – 30
14 – 21	28	27	26 – 28
Adults: 21 – 29	No heating	18 – 21	26 – 23
28 – 35			20 – 23
Over 35			18 – 20
([1]) [8, Portugal 1999] ([2]) [40, NFU/NPA 2001] ([3]) [339, ITAVI 1997]			

In turkey housing, the required temperature is higher (32 – 34 ºC) at the beginning of the rearing period, so heating may initially need to be applied; then, ~~When the birds grow,~~ the required ~~ambient~~ indoor-temperature is gradually decreased (see Table 2.4). ~~to 12 – 14 ºC~~. When ~~the~~ heating of ~~in~~ the turkey housing is ~~locally~~ applied, ~~as~~ more ventilation is needed ~~in these systems~~ and this results in higher energy consumption. On a number of farms in the Netherlands, recirculation of the air is practised, combining natural and mechanical ventilation. By operating valves, the airflow can be adjusted in such a way that the air is mixed properly, and less energy is then needed for heating.

Table 2.4: Indoor temperatures ~~that are provided in France~~ for rearing turkeys, applied in France

Age (days)	Temperature (°C)	Age (days)	Temperature (°C)
0 – 2	33.5–34	25 – 26	26.5
3 – 4	32.5–33.5	27 – 28	26
5 – 6	32–33	29 – 32	25.5
7 – 8	31.5–32.5	33 –34	24.5
9 – 10	31	35 – 36	24
1 – 14	29.5	37 – 38	23.5
1 – 16	29	39 – 40	23
17 – 18	28.5	41 – 42	22.5
19 – 20	28	43 – 44	21
21 – 22	27.5	+44	19 – 21
23 – 24	27		
Source: [339, ITAVI 1997]			

During the hot season it may be necessary to cool the indoor environment ~~to~~ for ensuring animal welfare purposes. Directive 2007/43/EC of 28 June 2007 provides that for outdoor temperatures higher than 30 °C, the interior temperature should not exceed the outside temperature by more than 3 °C.

The main techniques of cooling used in poultry farming are water fogging (see Section 2.2.4.1.1 ~~2.3.2.4~~) and wet filters (see Section 2.2.4.1.2). The common working principle is to evaporate water at the expense of air energy, ~~that~~ and hence the air is cooled down.

In practice, water may be added to the incoming air flow by the use of plates injecting water, at a pressure of 3 to 5 bar~~s~~. They are the least expensive and allow a cooling of maximum 3 – 5 °C. Wet filters system, or 'pad-cooling', uses corrugated paper supports for air/water exchange.

They produce strong cooling effects, but are sensitive to water quality and can develop pathogenic organisms on surfaces. [358, France 2010]

Ventilation

Poultry housing can be naturally and/or force-ventilated, depending on the climatic conditions and the birds' requirements. The building can be designed to force the ventilation air stream across, or longitudinally through, the building or from an open ridge in the roof downwards via fans below the cages. For both natural and forced ventilation systems, the prevailing wind direction may influence the positioning of the building, for instance it may increase ~~so as to enhance~~ the required control of the ventilation airflow, as well as ~~to~~ reduce emissions to sensitive areas in the vicinity of the farm.~~enterprise~~. Where low outdoor temperatures occur, heating equipment may be installed to maintain the required temperature inside the building.

Ventilation is important for the birds' health and will therefore affect production levels. It is applied when cooling is required, and for maintaining the composition of the indoor air at the required levels. Directive 2007/43/EC lays down minimum requirements for environmental parameters that need to be ensured, namely:

- NH_3 concentration not exceeding 20 ppm
- CO_2 concentration not exceeding 3 000 ppm
- indoor temperature, when the outside temperature measured in the shade exceeds 30 ºC, not exceeding this outside temperature by more than 3 °C
- indoor average humidity, measured over 48 hours, not exceeding 70 % when the outdoor temperature is below 10 °C.

Additional air parameters can be controlled. For example, for the composition of air in broiler housing, in Belgium ~~the~~ upper limit values are also set for H_2S at 20 ppm and for SO_2 at 5 ppm. ~~concentrations as shown in Table are advised, but these values vary by Member Statebetween MSs.~~

~~**Table 2.4Advisable limit values for different gaseous substances in the indoor air in broiler housing applied in Belgium**~~

~~**Parameter**~~	~~**Limit value**~~
~~CO_2~~	~~0.20 – 0.30 vol.-%~~
~~CO~~	~~0.01 vol.-%~~
~~NH_3~~	~~25 ppm~~
~~H_2S~~	~~20 ppm~~
~~SO_2~~	~~5 ppm~~
~~*Source:* [33, Provincie Antwerpen, 1999]~~	

For layers ~~housed in battery cages~~, the ventilation air flow ranges from 3 – 7 ~~5 – 12~~ m^3 per bird per hour in the summer (depending on the climate zone) and 0.5 – 0.8 ~~0.6~~ m^3 per bird per hour in the winter [39, Germany 2001].

Ventilation systems can be divided into natural and mechanical systems. Natural systems are comprised of openings in the ridges of the roof. Minimum outlet sizes are 2.5 cm^2/m^3 of housing volume, with a required inlet of 2.5 cm^2/m^3 on each side of the building. With natural systems, the design of the building is important to enhance ventilation. If width and height are not properly matched, ventilation may be insufficient and may give rise to increased ~~raised~~ levels of odour inside the housing.

Mechanical systems operate ~~with~~ under negative pressure and a net inlet of 2 cm^2/m^3 of housing volume. They are more expensive, but give better control of the indoor climate. Different designs are applied, such as:

- roof ventilation

- ridge-parallel ventilation
- side ventilation.

For example in the UK, approximately 40 % of broiler houses may have the ventilation on the roof. Another 50 % have reverse-flow ventilation, and 10 % have cross-flow ventilation.

Longitudinal flow Long flow ventilation is now common, also named 'tunnel ventilation'. is an emerging technique, but no further information has been is made available. In general, broiler-housing facilities are equipped with thermometers at various places to control indoor air temperatures.

For broilers, generally, a maximum the ventilation capacity of 4 to 6 about 3.6 m^3 per kg live weight is applied in the design of the ventilation systems. The air speed at the bird level varies by with temperature, and speed levels of 0.1 to 0.3 m/s have been reported [8, Portugal 1999]. The ventilation capacity changes with the outside air temperature and relative humidity (RH) and with the age and live weight of the bird (CO_2, water and heat requirements).

The relationship between ventilation needs and the different variables were found to be as follows was reported on a study conducted in Belgium. With an outside air temperature of 15 °C and a RH of 60 %, the ventilation was determined by the CO_2 balance in the first three days, by the water balance in the period up to 28 days, and after this by the heat balance. With lower outside air temperatures, CO_2 balance and water balance become more important. From a temperature of 15 °C, the heat balance becomes more important in combination with lower RH and heavier chickens. It was concluded that a minimum ventilation requirement for broilers should be set at 1 m^3 per kg live weight, to be prudent on the safe side [509, Province Antwerpen 1999].

2.2.4.1.1 Fogging

Fogging systems are a way means of controlling indoor temperature, humidity and dust. The key characterisation parameters that characterise for the equipment are pressure and design.

High pressure fogging at around 1 000 psi or more (1 psi = 0.07307 kg/cm^2) produces droplets as fine as around 10 microns. These droplets absorb the heat present in the atmosphere and evaporate, becoming water vapour or gas. Evaporation takes place very quickly, so that walls or animals are not moistened. The operation of these systems at lower pressure (100 – 250 psi) produces droplets around 200 microns in size, and is called 'misting'. The heavy droplets drop to the floor relatively quickly and may cause wetness, hence it is less suitable in livestock production.

Line systems cool the air around misting lines that are positioned along the internal perimeter of the houses. Water is forced through specially designed nozzles to spray droplets of water into the surrounding air. In fan systems, the mist cooling is combined with the convective cooling: the mist cools the air and fans, that are placed immediately behind the nozzles, create an air flow that intensifies the cooling effect.

The benefits of this technique are recognised as being the following:

- cooling effect
- dust abatement (see Section 2.2.4.3)
- transportation means for additive products that are sprayed simultaneously with water, such as for anti-odour or sanitary products
- cleaning of slatted floors, where present, is easier.

2.2.4.1.2 Pad cooling

Pad cooling systems are used to cool down the incoming air in poultry houses by a water evaporation effect. The system is most effective at high temperatures and low relative humidities.

The pads are cellulose or plastic panels with a large specific surface and are continuously kept soaked. The warm incoming air flows through the moist pads (by negative pressure), taking up humidity and cooling down in turn. Excess water is recirculated.

The residual salinity of the circulating water and the possibility that pathogenic organisms can develop on the wide surfaces are the main difficulties encountered with the management of these systems.

2.2.4.2 Lighting ~~Illumination~~

Poultry housing may use only artificial light or may allow natural light to enter (sometimes called ‘daylight housing’). Laying activity and laying rate can be influenced by the use of artificial lighting.

Directive 2007/43/EC enforces that all buildings for the rearing of chickens for meat production shall have lighting with an intensity of at least 20 lux at bird eye level during the lighting periods, and illuminating at least 80 % of the usable area (temporary reduction may be allowed following veterinary advice). The lighting must follow a 24-hour rhythm, with darkness lasting at least six hours in total and with at least one uninterrupted period of darkness of at least four hours, except for the initial 7 days from the time when the chickens are placed in the building and the last 3 days before the foreseen time of slaughter.

~~Illumination is also important for poultry production.~~ Different light schemes are applied with alternating periods of light and darkness. A couple of examples are ~~An example is~~ shown in Table 2.5.

Table 2.5: Examples of lighting programmes requirements for poultry production ~~as practised in Portugal~~

Age of birds (days)	Hours of light per day	
	Example 1	Example 2
1 – 3	23	23
4 – 10	8	18
11 – 15	12	8
16 – 21	16	12
22 – 35	18	16
36 – 42	23	18
Source: The Poultry Site		

In turkey rearing ~~housing~~, lighting ~~illumination~~ is particularly important during the first few days of life (1 – 7 days), when programmes with a light intensity of at least 10 lux or more (up to 50 lux) and 2 – 3 hours of darkness are applied. Afterwards, the light intensity is ~~After which it can be~~ reduced. Light schemes can vary from continuous to 14 – 16 hours a day.

2.2.4.3 Control of dust

Controlling dust at ~~the~~ source not only reduces emissions to the external environment, but ~~it~~ also helps to maintain a better housing environment for animals and a better working environment for workers. Animal activity is normally a factor increasing dust emission. ~~The~~ Dust levels may also increase if the form of the feed is initially dusty, such as with some non-pelleted feeds for laying hens. Broiler feed is less dusty as it contains a higher level of fat. The equipment in which feed is administered can also increase the amount of airborne dust. Automatic feeders can generate dust when the feed is dropped into the troughs.

Dust emissions are generally ~~up to five times~~ higher in houses using bedding than in enriched cages with wire floors. Spraying oil is an inexpensive and effective abatement method, ~~with up to 90 % of~~ removing airborne dust ~~removed~~ by binding it to oil in the litter or the bedding (see Section 4.8.4); however, cleaning of the houses can be more difficult and the quality of the litter can be affected.

Dry filters can be fitted to internal air recirculation units. Negative ions can also be artificially circulated (i.e. ionisation, see Section 2.3.2.5) to charge airborne particles and collect them by electrostatic attraction onto room surfaces (see Figure 2.10).

Source:[377, NL 2010]

Figure 2.10: Effect of dust attraction caused by ionisation on the roof of a poultry shed

High pressure fogging (Section 2.2.4.1.1) produces small droplets that absorb airborne particles and fall on the floor. It is important that the size of water and dust particles be similar, in the range of microns. If the sprayed droplets are too large, the dust particles flow around the droplets and are not absorbed, ~~so that~~ as little or no contact occurs.

2.2.5 Poultry feeding and drinking supply ~~watering~~

2.2.5.1 Poultry feed formulation

Feeding is very important, as the quality of feed determines the quality of ~~the~~ products. In particular, the broiler growth (reaching the required weight in only 5 to 8 weeks) depends largely on feed quality. The way feed is obtained varies from the purchase ~~purchasing~~ of ready-to-use feed mixtures to ~~the~~ on-farm milling and preparation of the required mixtures, which are often stored in silos adjacent to the birds~~'~~ housing. The formulation of the poultry feed is very important to meet the requirements of the animals; ~~and~~ the production aims and to ensure the right level of energy and essential nutrients, such as amino acids, minerals and vitamins.

The indispensable (essential) amino acids (AA) are those that the animal metabolism cannot provide or can only provide in small quantities. Therefore, essential amino acids must be supplied through the diet in sufficient quantities to cover the animal requirement. The essential AA are methionine (+cystine), lysine, threonine, valine, isoleucine, leucine, tryptophan, arginine, histidine and phenylalanine (+tyrosine).
~~for poultry are supplied, as their metabolism cannot supply them. They are: arginine, histidine, isoleucine, leucine, lysine, methionine (+cystine), phenylalanine (+tyrosine), threonine, tryptophan and valine.~~

Cystine is not an essential amino acid *per se*, but methionine can only be made from cysteine and thus they are always linked. ~~As a result of the current ingredients in~~ With current formulations of poultry feed, the most frequent amino acid deficiencies ~~detected in feed mix~~ are sulphur amino acids (methionine and cysteine) and lysine. Another quoted deficiency is typically threonine. [506, TWG ILF BREF 2001]~~[171, FEFANA, 2001]~~ However, recent developments in the production of amino acids, means more amino acids are now available for better poultry feed formulations.

~~Formulating feeds can require the use of linear programming to obtain the required mixtures. All species need sufficient amino acids, but~~
Layers, in particular, require sufficient Ca to produce the eggshell. P is important for its role in the storage of Ca in the bones and will either be fed as a supplement or made more readily available from feedstuffs used in the diet by, for example, ~~feeding on~~ adding phytase to the feed. Other minerals and trace elements in the feed~~s~~ can be more or less controlled as well: Na, K, Cl, I, Fe, Cu, Mn, Se and Zn, while others like S and F ~~Other elements are not usually added, as they~~ are already sufficiently available in the feed. ~~S and F~~.

Vitamins are not produced by the animals themselves, or are produced in insufficient quantities, and should ~~are~~ therefore be added to the daily ration. Vitamins are often part of a premix with minerals.

~~Feed formulation and~~The use of additives in animal feed ~~addition of feed~~ is ~~substances are~~ regulated at ~~on a~~ the European Union level (Commission Regulations 1831/2003 and 429/2008). Each additive is evaluated for safety, efficacy, as well as for the way it is used in animal nutrition. Only after a thorough risk assessment, ~~for~~ is each feed ~~substance~~ additive, ~~the relevant directives~~ authorised for its use and the conditions of that use, indicating the minimum and maximum dosage in feeds, for which species it is applicable, the appropriate age of the animal and whether a withdrawal period has to be observed.

There are environmental consequences of altering the feed formulation, for instance ~~are that there are observable~~ correlations have been reported ~~correspondences~~ between the ammonia emission from houses and the actual total protein intake of the animals in them. Highest emissions are registered for the house where the highest total protein diet is consumed, and generally the lowest for the house with the lowest protein intake.
[149, Robertson et al. 2002]

The composition of poultry feed varies considerably – also between Member States ~~MSs~~ –, as it is a mixture of different ingredients, such as:

- cereals grains, their products and by-products ~~residuals;~~
- oil seeds, oil fruits, their products and by-products ~~residuals;~~
- tubers, roots, their products and by-products
- other seeds and fruits, their products and by-products
- milk products and fish, other marine animals, their products and by-products

Meat and bone meal is ~~still~~ banned in Europe. In Spain~~, for example,~~ pork lard is added to the feed because of the lack of the enzyme lactase, but milk products are not included. ~~And~~ In the UK, 'bulbs, tubers and roots or root crops' are not fed to poultry, and neither is bone meal. In

France, animal fats are not used. In Danish broiler production, whole wheat is added to the broiler feed at the farm, from day 10. The share of whole wheat in the total feed is initially 2 % at day 10 and is then continuously increased up to 30 – 35 % at the end of the production cycle.

~~The inclusion of the last category of components has now been called into serious question, where there are indications that this practice (feeding processed animal proteins) may have been an important cause of the development of BSE. See also Commission Decision 2000/766/EC. [201, Portugal, 2001]~~

Different substances ~~Elements~~ can be added to poultry feed for different reasons, e.g.:~~as described below. There are substances that:~~

- Some substances are added in small amounts, but can have a positive effect on growth, by increasing the gained weight and improving the feed conversion ratio (FCR). ~~Others (e.g. antibiotics) can have a regulating effect on potential harmful gut flora. [201, Portugal, 2001]~~ Enzymes, herbs, essential oils, immunostimulants and organic acids are examples of substances used (compounds of copper and zinc may also be included in this category).
- Some substances raise the quality of the feed (e.g. vitamins).
- Some substances have a quality-raising effect on feed, e.g. ~~so called~~ technological additives, such as those that can improve the pressing of feed into granules.
- Some substances balance the protein quality of the feed, therefore improving the protein/N conversion (pure amino acids).

~~In several Member States, MSs the use of antibiotics in feed is under discussion. In several countries feeding without antibiotics is carried out, such as in Sweden, Finland and the UK (only poultry feed), as these have a total ban on the use of all feed antibiotics (including the ones authorised in the EU). See also Section 2.3.3.1 on the use of antibiotics in pig feed.~~

The use of antibiotics as feed additives in animal feed for growth promotion is prohibited under EU Regulation No 1831/2003/EC. Coccidiostats and histomonostats may be added to prevent the development of parasites. Such products are regulated as additives in animal nutrition.

Apart from the feed formulation, to match the feed closer to the requirements of the birds, ~~also~~ different types of feeding regimes are also ~~given~~ adopted during production cycles. For the different categories, the following number of feeds are most commonly applied:

- layers 2-phase (feeding up to laying, during laying)
- broilers 3 – 4 phases (early weeks growing, finishing)
- turkeys 4 – 6 phases (more types for stags than for hens)
- ducks 2 – 3 phases.

Layers can also have a 6-phase feeding, 3 phases up to laying and 3 phases during laying, or 2 to 3 phases up to laying and 1 or 2 phases during laying. [40, NFU/NPA 2001] ~~[201, Portugal, 2001]~~ [506, TWG ILF BREF 2001].

2.2.5.2 Feeding systems

Feeding practices depend on the type of production and bird species. Feed is given in mashed form, crumbs, or pellets.

Layers are generally fed *ad libitum* [40, NFU/NPA 2001] [30, Spain 2001]. Meat species, such as broilers and turkeys, are also fed *ad libitum*. Hand feeding is still applied, but in large enterprises, modern feeding systems are applied that reduce the spillage of feed and that allow accurate (phase) feeding.

Common feeding systems are:

- chain feed conveyor
- auger conveyor
- feeding pans ~~and;~~
- moving feed hopper.

Chain feed conveyors move feed from the storage area through to the feeding gutter. It is possible to influence the feeding pattern, spilling and rationing by adjusting the velocity of the conveyor. Chain feed conveyors are common in floor systems and are also applied in cage systems.

In the auger conveyor, feed is pushed or pulled through the feeding gutter by a spiral. Spillage is low. Application is common in floor systems and aviary systems.

Feeding pans or bowls are connected with ~~the~~ supply via the transport system. The diameter varies from 300 to 400 mm. Feed is transported by a spiral, chain or a steel rod with small scrapers. The system is designed with a lifting device. They are applied in floor systems (e.g. broilers, turkeys and ducks). In the case of bowls, one bowl feeds approximately 65 – 70 birds. For the feeding of turkeys, feeding pans are used in the earlier life-stage, but at a later stage, feeding barrels (50 – 60 kg) are also used. Feed is supplied in large buckets or square feeding troughs. Tube feeding systems are increasingly applied to reduce spillage.

A feed hopper is a moving system ~~applied in battery systems. It~~ that moves ~~alongside the cages~~ on wheels or a rail, and is equipped with a funnel-shaped hopper. Moved by hand or electrically, this system fills the feeding trays or gutters.

Examples of feed space allowances (in the UK) for meat poultry are as follows:

• Broiler, pan feeders	1 linear metre per 100 birds
• Broiler, chain feeders	0.75 linear metre per 100 birds
• Turkeys, pan feeders	1 linear metre per 100 birds
• Ducks, trough space	50 cm per 100 birds from one day old to 8 weeks of age 60 cm per 100 birds from 8 weeks of age and over.

2.2.5.3 Drinking water supply systems

For all poultry species water has to be available without restriction. Techniques applying restricted watering have been tried, but for welfare reasons this practice is no longer allowed (except for breeders). Various drinking systems are applied. Design and control of the drinking system aims to provide sufficient water at all times and to prevent spillage at the same time and further wetting of the manure. There are different drinking systems:~~ basically three systems [24, LNV 1994]:~~

- ~~nipple drinkers;~~
- high capacity nipple drinkers (80 – 90 ml/min)
- low capacity nipple drinkers (30 – 50 ml/min)
- round ~~drinkers~~ or bell drinkers
- water troughs
- drip cups (cups and mini-cups).

Nipple drinkers have various designs, and have a pressure control system ~~is~~ installed at the beginning of each pipe, with a water gauge to measure ~~the~~ consumption. Pressure regulation in water lines is in fact a critical aspect.

Usually, nipple drinkers ~~they~~ are made of ~~a combination of~~ plastic and steel, and ~~The Nipples~~ are placed underneath the water supply pipe. High capacity nipple drinkers have the advantage that the animal quickly receives a proper amount of water, but ~~has~~ have the disadvantage of leaking water during drinking. To catch this leakage, small ~~little~~ cups are installed underneath the nipples (drip cups).

~~The~~ Low-capacity nipple drinkers are not affected by leakage, but may cause animals to take more time to drink. ~~do not show the problem of leaking water, but it takes more time for an animal to drink enough water.~~ In non-cage ~~aviary~~ systems, ~~the~~ drinking hens may block other ~~the path of the~~ hens on their way to the nest, so that eggs may be laid in incorrect places. ~~and subsequently the eggs can end up in the litter instead of in the nest.~~ [407, Netherlands 2002]

In floor housing, low pressure drinking lines are lifted up to allow for ~~the nipple drinker system can be installed in such a way that it can be lifted out (for example for~~ cleaning and mucking out.~~). It works with low pressure.~~

Round drinkers, or bell drinkers, are the oldest systems but are still widely used in turkey and duck rearing. They incur a ~~imply~~ notable waste of water because even a minimal movement of an animal's head leads to wasting water. Stabilisers are also applied to prevent tipping over ~~counteract hustles~~. [357, France 2010]

Round drinkers are made of strong plastic and have different bell-shaped designs depending on the type of bird or the system they are applied to. They are usually attached to a winch~~ed~~ line and can be pulled up. They work on low pressure and are easily adjustable.

Water troughs are placed on or below the water supply pipe. There are two designs that either automatically have water in the cup or that supply water when a metal strip is touched. One trough is placed for every 100 animals.

Drip cups ~~or mini-cups~~ are placed in groups or in lines and can minimise stagnant water. They are suitable for young poultries that can not force valves to open; ~~but~~ however, they might be more complicated to keep clean.

~~In most layer housing systems automatic watering systems are applied using nipple drinkers.~~
In the Netherlands, 90 % of the water supply systems for layers are nipple drinkers and 10 % are round drinkers [407, Netherlands 2002]. The ~~use~~ share of the different drinking systems ~~in France~~ is shown in **Table 2.6**.

Table 2.6: Standard drinking systems ratio (number of animals for each type of equipment) ~~in France~~

Species	Starter	Ratio	Grower/Finisher	Ratio
Broiler	Round drinker	100 – 150	Round drinker	100 – 130
	Nipple drinker	10-20 ~~15 – 18~~	Nipple drinker	15 – 18
	Drinker with cup	200 – 250	Drinker with cup	200 – 250
	Large cup	60		
Turkey	Round drinker ~~Water source~~	50 – 200	Round drinker	100 –120 ~~150~~
	Mini-cup	20	Mini-cup	20~~40 – 50~~
	Large cup	100	Large cup	100
	Nipple drinker	8 – 10 ~~15 – 18~~	Nipple drinker	100 – 120 ~~15 – 18~~
	Drinker with cup	200 – 250	Drinker with cup	135
Duck	Round drinker ~~Water source~~	50	Round drinker, wide channel ~~Water source~~	120 – 150
	Nipple drinker ([1])	5 – 7	Nipple drinker ([1])	5 – 7
Guinea fowl	Round drinker ~~Water source~~	50	Round drinker	100 – 130
	Nipple drinker	15	Nipple drinker	15

([1]) When nipple drinkers are provided as drinking source, then an additional water source must also be provided, such as troughs, bell drinkers, baths or showers.
Source: [357, France 2010] [500, IRPP TWG 2011]

However, minimum standards on drinking systems for the protection of laying hens are laid down in Directive 1999/74/EC.

In broiler houses, watering points are installed in many places, frequently by a combination.~~ A commonly used system consists~~ of round drinkers and nipples drinkers. The round drinker design gives every bird easy access to water and aims at ~~minimum~~ minimising spillage, to prevent wetting the litter. ~~With cups, 40 animals are served and with drinking nipples 12 – 15 animals per nipple is applied.~~ Each cup can serve 40 birds, ~~animals~~ whilst a nipple is applied for every 12 – 18 birds.

In the UK, nipple drinkers are more commonly applied to broilers than round drinkers. ~~but~~ In the Netherlands only 10 % of the water supply systems for broilers are nipple drinkers and 90 % are round drinkers. [40, NFU/NPA 2001] [407, Netherlands 2002]

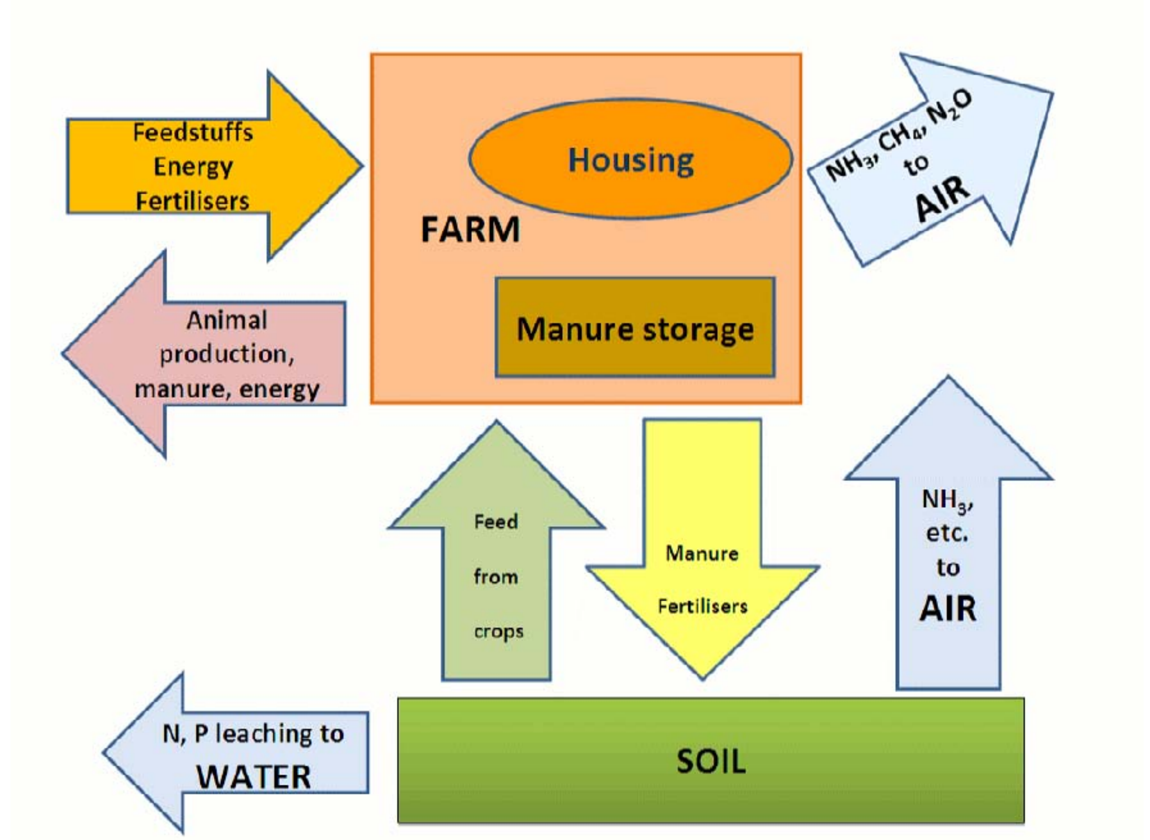
Drinking water for turkeys is supplied using round drinkers~~, bell drinkers~~ or water troughs. Round drinkers and troughs can differ in size according to the stage of production (smaller or larger birds). Nipple drinkers are generally not applied, as turkeys do not use these effectively.

For duck rearing, a minimum water drinker space of 60 cm per 100 birds should be provided. The most used source is the bell drinker. Trough type drinkers should be placed at a maximum height of 25 cm, with a minimum width of 15 cm and a water depth of 10 cm. Where nipple drinkers are provided as the drinking source, then an additional water source should also be provided, such as troughs, bell drinkers, baths or showers.

2.3 Pig production

Pig farms produce impacts on the environment depending on the pathways of the flows of chemicals and energy that occur in the production chain (see Figure 2.11). Mass balances can be sketched for each ~~of the~~ production stage~~s~~ but, since they ~~that~~ are linked to one another, and as emissions are interdependent, based on the chemical flows between stages. Therefore, the correct accounting of the environmental impacts should consider mass and energy balances along the whole production chain.

THE EXISTING FIGURE 2.11 HAS BEEN SUBSTITUTED WITH THE NEW ONE PRESENTED BELOW



Source: Elaboration from [204, IMPEL 2009]

Figure 2.11: Environmental accounts related to a pig farm

~~Chemical accounts can be considered at different scales.~~ Separate mass ~~nitrogen~~ balances for housing and ~~another one~~ for manure storage may be performed ~~differentiated~~, both contribute~~ing~~ to the ~~global~~ overall farm balance. At the field level, accounts can be assessed for chemical substances such as agronomic inputs and outputs. ~~Thus, in assessing the processes in and around a farm, it is important to understand the environmental impacts.~~ Only by the full accounting of energy and mass flows ~~then~~ can conditions for the authorisation be set and can compliance be assessed. [204, IMPEL 2009]

2.3.1 Pig housing and manure collection

THE EXISTING INTRODUCTORY PART OF THIS SECTION HAS BEEN REMOVED SINCE IT WAS OUTDATED (REFERENCE YEAR 1998)

Pig production is commonly divided into breeding sows (dry or mating, pregnant or gestating and farrowing sows) and fattening pigs where post-weaning (from 4 – 6 weeks of age up to 20 – 30 kg of live weight), growing (to around 60 kg) and finishing phases can be distinguished. Sows are group housed until farrowing when commonly they are individually penned: they can be equally kept on slatted or bedded floors, hence producing liquid or solid manure. Growing pigs are more often reared on slats in groups of 10 to 200 20 to 100, producing liquid manure. Buildings are increasingly modern and forced ventilation is used with dedicated heating for the very young piglets. [264, Loyon et al. 2010]

For all systems, variations in flooring consist of the application Housing systems vary mainly based on the proportions of fully-slatted (FSF), partly-slatted (PSF) or solid (concrete) floors (SCF) and on the use of straw or other litter, forming two main categories of production systems, those based on liquid manure (slurry) and those based on solid manure. The main common characteristics of both systems, for all animal types (sows, weaners, fattening pigs) are given below.

Techniques based on slurry
Partly or fully-slatted floors are used in the housing systems; slats can be made of concrete, metal (mostly iron) or plastic and have different shapes (e.g. triangular), although, the use of composite materials is increasing. The area of open surface is approximately 20 – 30 % of that of the slatted surface. One critical component for the efficient use of slatted floors is the dimension of the gap between slats in relation to the dimensions of the animal feet at any given age.

Directive 2008/120/EC of 18 December 2008 lays down minimum standards for the protection of pigs and, among other things, imposes a maximum width of openings in concrete slatted floors according to the type of pigs. The maximum width of the openings must be 11 mm for piglets, 14 mm for weaners, 18 mm for rearing pigs and 20 mm for gilts after service and sows. [158, EU 2008] Directive 2008/120/EC also determines the minimum slat width that is 50 mm for piglets and weaners, and 80 mm for rearing pigs, gilts after service and sows.

THIS PARAGRAPH HAS BEEN MOVED FROM BELOW.

Concrete slats have proved to be more durable than other materials, such as metal and plastic, and smooth finishes ensure that no slurry builds up, as they are easier to clean. The base and walls of the under-slat slurry tank are preferably built of concrete blocks and sealed with a waterproof plaster coating. The tank base is sometime preferred to be flat, as V-channels are considered to cause the liquid element of the slurry to run off faster, leaving the solids behind, causing the build-up of ammonia. [175, Ecodyn 2010]

Systems for removing manure and urine are related to the flooring system and as such are described in the context of housing systems. These systems may varying from deep pits with a long storage period to shallow pits and manure channels through which the slurry is removed, frequently by gravity and valves or by flushing with a liquid.

At the time of writing (2011) almost all Member States have implemented Directive 2008/120/EC (25 out of 27 Member States). A limited number of countries have formulated stricter or additional demands than the EU legislation with respect to floor area, floor design and group housing or provision of natural light. [201, Mul M. et al 2010] In Denmark and the Netherlands, requirements for continuous solid floor space are usually greater than those mentioned in the EU Directive, and the maximum drainage opening is smaller. In Sweden, the ban has been carried out on fully-slatted floors in all pig housing, and in Germany, houses for pig rearing pig are required to have at least 50 % continuous solid floor. In general, there is an increasing attention on the provision of manipulable materials to animals, in order to provide them the opportunity to exhibit natural behaviours (nesting, play etc.).

Techniques based on solid manure

Solid floors with bedding materials that absorb animal excretion are used in the housing systems.

Bedding materials should be comfortable to lie on, non-abrasive, non-slippery, highly absorbent and have low levels of environmental bacteria and mycotoxin contamination.

Straw and other materials, such as wood shavings, sawdust and peat (in Finland), are ~~is~~ used to increase animal welfare and to reduce NH_3 losses. Due to the great surface and the high C:N ratio, straw can reduce emissions of NH_3, but conversely, may also result in the composting of the bedding in situ and, hence, in increased bedding temperatures and increased NH_3 emissions. Therefore, effectiveness at reducing NH_3 emissions from pig buildings is achieved only by more frequent mucking out, hence at an additional cost. [252, IGER 2005] Compared to slurry management, straw bedding may lead to largely enhanced emissions of greenhouse gases. Nevertheless, CH_4 emissions from the straw-based sow-housing systems are reported to be not greater than the emissions from the slurry-based systems as it seems that CH_4 produced in deeper anaerobic layers of the litter bed on solid floors for pigs is readily oxidised to CO_2 in the surface layer, due to aeration by the rooting and foraging behaviour of the pigs. [441, Webb et al. 2011]

Straw is a manipulable and rootable material and also provides thermal insulation and physical cushioning; moreover, it presents good thermal properties and a moderate absorption capacity making it an effective bedding material. The viability of straw (availability and cost) is affected by plant harvests and competition from different uses (e.g. biofuel). In the UK, pig farms typically use wheat and barley straw and occasionally oat straw.

Bedding materials have different capacities to absorb humidity, in proportion to their dry weight. The absorbency and characteristics of different bedding materials are presented in Table 2.7.

Table 2.7: Absorbencies and characteristics of different bedding types

Bedding material	Mean absorbency factor (kg water absorbed/kg material	Remarks
Sawdust (1)	2.60	Coarse sawdust is extremely absorbent. Fine sawdust is not a suitable bedding material due to potential health problems for workers and animals
Barley straw (1)	1.91	Commonly used with pigs; soft and does not contain much dust. The least absorbent of all straw types
Wheat straw (1)	2.14	The most commonly used material with pigs; quite brittle, not as soft as barley. The least palatable of all the straws
Oat straw	2.86	Softer than wheat straw and, therefore, more absorbent than all other straws. It can be expensive due to its feeding value. Highly palatable; however, very light and fluffy so will blow away quite easily
Triticale straw (1)	1.97	Similar to wheat straw, although a little harder. It produces a 30 % larger volume of straw compared with the equivalent yield of wheat or barley straw
Cornstalks	2.70	Only available when the cob is combined-off for animal feed rather than when the whole plant is used for silage
Shredded paper (1)	2.08	Dust-free, very absorbent and costs little. Excellent bedding material especially for farrowing sows. Light to handle and easy to transport

(1) Values calculated on the basis of the information reported in reference [388, BPEX 2011]
Source: [388, BPEX 2011]

For litter-based systems, even though there are a number of designs and layouts of the animal house and different practices for manure management, ~~there are~~ two main modes of litter management can be distinguished:

Littered floor system or 'scraped straw'
When straw is used as bedding material, the manure is frequently scraped or manually removed, with a typical frequency of ~~about~~ once or twice per week up to a daily frequency. Topping up with fresh dry litter is frequently and regularly provided in order to prevent the litter from becoming too wet; this operation replaces ~~and replaced by~~ the same amount of ~~fresh~~ straw removed with the manure. Animals are provided with modest amounts of litter which serves as an absorptive and play material. The smaller the amount of litter applied the higher will be the risk of an increase in humidity and ammonia emissions. Floors can be sloped to one ~~an~~ end to allow the collection of the manure resulting from ~~by~~ the mixture of dung and straw.

Deep litter or 'accumulated straw'
~~Alternatively~~ The litter is accumulated on the floor and a permanent thick bedding is provided to the pigs as a rest and residence area. Fresh straw is frequently added upon necessity (usually every week) over accumulating manure that is removed at the end of the rearing period or can remain for longer periods (removal after successive ~~the end of the~~ production cycles). This period ranges from some weeks (piglets, sows) to some months (fattening pigs, sows). After the bedding material is spread, litter may need to be stirred, since pigs tend to defecate in the same spot. The abundance of bedding provides protection against low temperatures.

In the case of sawdust used as a bedding material, only a deep litter system is used, this can be a thick (60 – 80 cm) or thin (15 – 20 cm) bedding. Deep sawdust litter is introduced at the start-up of the production cycle. [262, France 2010]

Additives may be used with bedding to alter the manure characteristics (see Section 2.7.6).

The housing construction itself shows a variation comparable to that of the flooring systems. Houses can be constructed of durable material and brick-built to withstand cold temperatures, but much lighter material and open constructions are also used. In some Member States artificial heating is commonly applied to all classes of stock including dry sows.

In the following Sections 2.3.1.1, 2.3.1.2, 2.3.1.3 and 2.3.1.4, technical descriptions are presented of the commonly applied housing systems for sows, weaners and growers/finishers. The environmental performances and other characteristics are described and evaluated in Chapter 4. The overview aims to be representative of the currently applied techniques, but can never be exhaustive given the observed variation in systems and their adapted designs.

2.3.1.1 Housing systems for mating and gestating sows

Sows are housed in different systems depending on the phase of their reproduction cycle. they are in. Mating sows are kept in systems which facilitate easy contact between boars and sows. After mating, the sows are usually moved to a separate part of the housing for their gestating period. Directive 2001/88/EC initially imposed restrictions to individual housing. The gestating sows must be kept in groups from 4 weeks after service to one week before the expected time of farrowing, for new or rebuilt houses from 1 January 2003, and from 1 January 2013 for existing housing. [262, France 2010] For animal welfare, tethers for breeding sows were prohibited from 1 January 2006.

In the UK non-lactating sows should be kept in groups and there is no exception for 4 weeks after service. In Sweden sows and gilts should always be housed in groups, except farrowing sows and sows one week before farrowing. In the Netherlands sows and gilts should be kept in groups starting from 4 days after service until one week before farrowing, instead of from four weeks after service. In Denmark, the pen size has to be at least 3.0 m in length, instead of 2.8 m. [201, Mul M. et al 2010]

Directive 2008/120/EC, laying down minimum standards for the protection of pigs, Article 3.2.a, gives provisions for continuous solid floors and maximum drainage openings for serviced gilts and pregnant sows: at least 0.95 m^2 per gilt and at least 1.3 m^2 per sow must be a continuous solid floor of which a maximum of 15 % is reserved for drainage openings.

In [202, EAAP 1998] the following observations were made on the housing of sows. Mating and gestating sows are housed individually or in groups. Each method has its advantages and disadvantages for both the animal and the farmer. The differences between individual and group housing are in:

- animal behaviour
- health
- welfare
- labour intensity.

Individual housing systems generally score better on health and labour intensity. For example, since individually housed sows are limited in their movement, but they are easier to control and there is more tranquillity in the stall, which has a positive effect on the mating and in the early stages of gestation [202, EAAP 1998]. It is also easier to feed the sows in individual housing, where competition does not a play a role. On the other hand, housing sows in individual stalls, from the weaning period up to four weeks after mating, severely restricts their freedom of movement, causes frustration and does not allow sows to socially interact during a period of the reproductive cycle where they are highly motivated to do so. In addition, the lack of exercise has a damaging effect on the health of the limbs and muscular strength and leads to reduced bone strength and cardiovascular fitness. However, group housing seems to be better for reproduction. [494, EFSA 2007]

Housing sows in groups or in confinement is regulated by Council Directive 2008/120/EC of 18 December 2008, laying down minimum standards for the protection of pigs. In compliance with this Directive, from 1 January 2013, individual housing is permitted for sows and gilts only in the first four weeks after service and the last week before the expected time of farrowing. Directive 2008/120/EC also addresses the cases where group housing may have drawbacks, e.g. animals that are particularly aggressive, or that are sick or injured may be temporarily kept in individual pens, designed to allow the animal to turn around easily; it also imposes feeding systems for group housing that ensure that each animal can obtain sufficient food even when competitors for the food are present.

THE EXISTING TEXT CONCERNING INDIVIDUAL AND GROUP HOUSING FOR MATING AND GESTATING SOWS (OUTDATED) HAS BEEN REMOVED

In Austria, Germany, Denmark, Sweden and the Netherlands, the minimum unobstructed floor space requirement per gilt is greater than that demanded in the EU legislation. The minimum unobstructed floor space is dependent on group size. In the Netherlands, there are no extra demands for sows in groups as in Austria, Denmark and Sweden. Germany and Austria have very limited extra demands (for example 2.5 m^2 per sow instead of 2.475 and 2.05 m^2 instead of 2.025). [201, Mul M. et al 2010] In the UK, certified programs, mainly promoting and ensuring the production of quality food (farm assurance standards), can impose increased space allowances for animal welfare purposes. [419, Red Tractor 2011]

Dry sows are housed individually or in groups. Group housing seems more used in the northern Member States (SE, FI and DK). Partly-slatted floors are commonly applied throughout Europe, in association with liquid slurry management systems. The slurry is either stored underground in deep pits or it is removed frequently by a vacuum system. In the UK, most mating sows (85 %) are group housed and have access to straw (> 55 %), as a result of British welfare legislation requiring all sows to be loose-housed from weaning to farrowing by 1999. In countries where group housing is most common, production is also done on litter which is removed by scraping (e.g. SE, DK, CZ, CY, FI). In other systems like flush channels, gutters or pipes using fresh or treated slurry, reduced manure pits are only rarely applied. In the Czech Republic, a ‘Combined yard’ is cited as the most common method. In France, 4.4 % of the total gestating places for sows are on litter, almost as much as the service places on litter (4.9 %). [262, France 2010]

Due to the full entry into force of the pig welfare Directive 2008/120/EC, individual pens may only coexist along with grouped pens.

Buildings are generally well insulated, or, less frequently, partly insulated. Open climate housing is only rarely applied on IPPC IED farms. Heating, whether by electric or gas/oil, is applied locally above animals to a defined area, otherwise the incoming air into the house is preheated.

Only in some Member States (especially CY, DK, DE) is air conditioning or the pretreatment of incoming air to the housing, where cooling or water spraying is commonly applied. Pen ventilation is mostly driven by mechanical means (fans) and natural ventilation is not so widely applied. Outlet air treatment only seems to plays an important role in the Netherlands NL and Belgium BE-Wallonia, and it is also applied in Denmark and Germany but it is hardly used in the other EU Member States virtually not at all in the other states. [264, Loyon et al. 2010]

EXISTING OUTDATED TEXT HAS BEEN REMOVED

2.3.1.1.1 Individual housing with a fully- or partly-slatted floors for mating and gestating sows

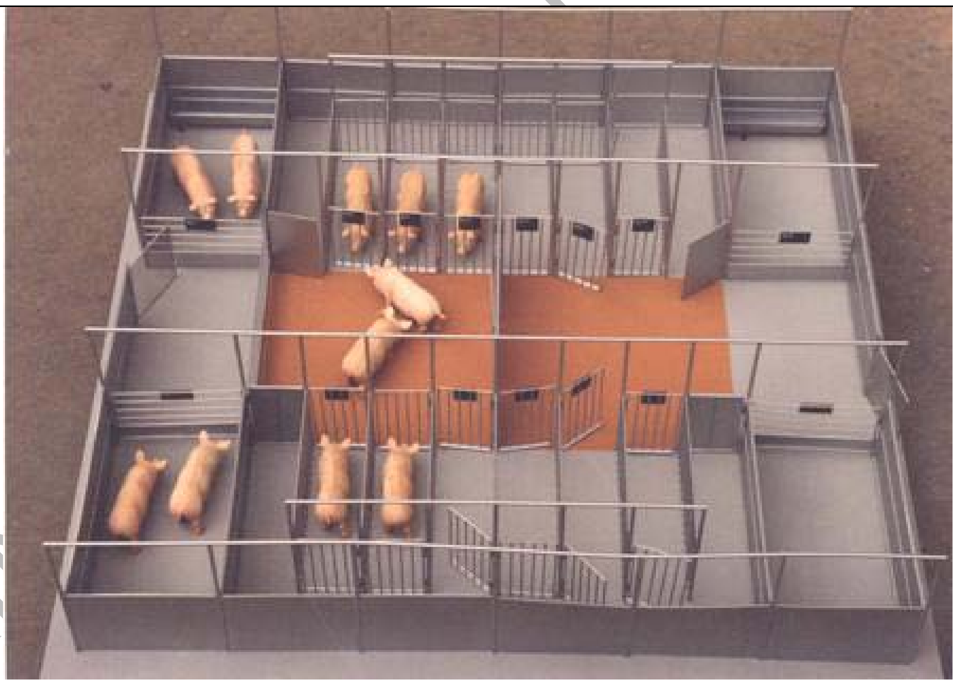
This way of housing mating and gestating sows is very common. The crates measure about 2 m × 0.60 – 0.65 m and the rear end is equipped with concrete or metal slats over a deep pit in which slurry and cleaning waters are stored. Feeding systems and drinkers are placed at the front end.

A central slatted alley runs between the rows of crates and a concrete-floored gangway runs on either side of the crates for feeding. In the mating house, there are pens for housing the boars (see Figure 2.12). These pens are absent in the housing section for gestating sows.

Slurry is collected under the slats and stored in a deep or a shallow pit. The slurry removal rate depends on the pit size. Natural or mechanical ventilation is applied and sometimes a heating system.

The use of fully-slatted floors for gestating sow has been prohibited since 1 January 2013.

The picture shows a common design for the mating section, but various other designs (with partly-slatted floors (PSF)) are applied to enhance intensive contact between boar and sows. Also, the sows may face the central alley with the troughs placed on the inner side and the slatted area will be at the side corridors.



Source: [‘Primefact’ NSW Dep. of Primary Industries, 2006, ISSN 1832-6668, Job number 6154]

Figure 2.12: Schematic view of a housing design for mating sows

2.3.1.1.2 Sow crates with a solid floor for mating and gestating sows

In this system mating and gestating sows are housed on concrete floors in a similar way to the design with the PSF, but there is a difference in the design of the floor and the removal of manure (see Figure 2.13). Again, feeding and watering are applied at the front of the crate. In the central alley there is a drain system for the removal of urine. Mucking-out of manure and ~~straw~~ litter (straw, wood shavings or other where ~~that is~~ applied) is done frequently.
[262, France 2010]

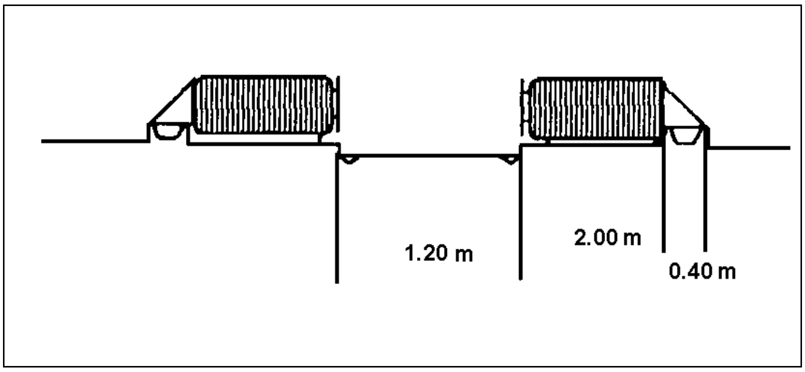
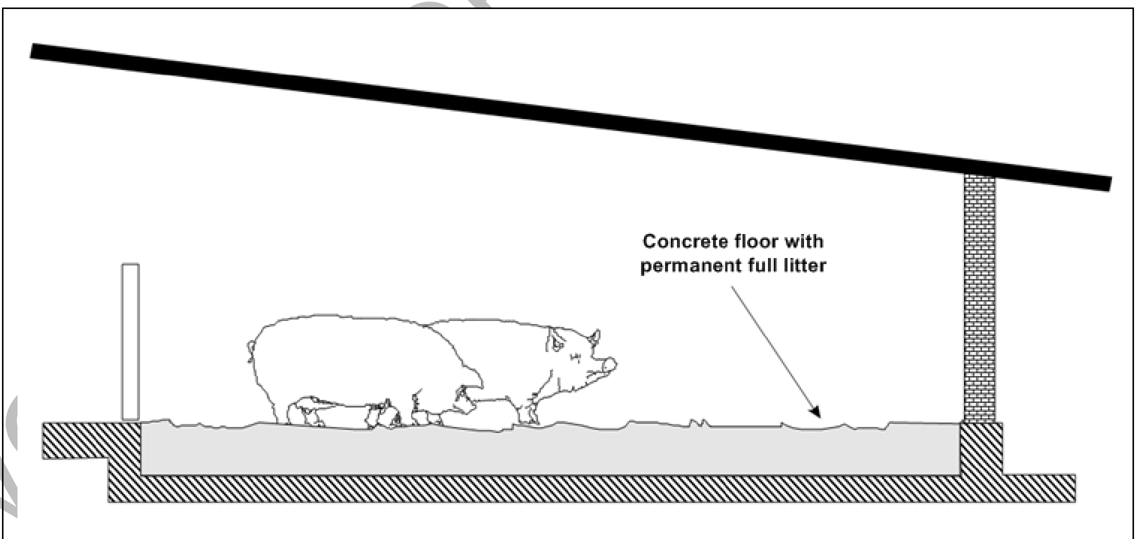


Figure 2.13: Floor design for sow crates with a solid concrete floor for mating and gestating sows

In these systems ventilation is natural when straw is applied, but mechanically-driven in insulated buildings where no straw is used.

2.3.1.1.3 Group housing with or without straw for gestating sows

Two basic designs for group housing of mating and gestating sows are applied. One system has a solid concrete floor with ~~deep~~ litter (accumulated or scraped, see Figure 2.14) and the other design has slatted floors at the defecating ~~dunging~~ area and the feeding stalls. The solid part is (almost) completely bedded by a layer of straw or other ligno-cellulosic materials to absorb urine and incorporate faeces. Solid manure is obtained and has to be frequently removed in order to prevent ~~avoid~~ the litter from becoming too moist, the~~. A~~ frequency of removal ~~of 1 – 4 times a year has been reported but this~~ dependings on the litter type, the depth of the bedded area and on the general farm management practices. ~~The frequency of complete litter removal can be higher in Italy, e.g. up to 6 – 8 times.~~ In addition, the partial removal of the moistened litter can be carried out weekly. In the case of one cleaning per year, it is spread directly onto the field. With more cleanings, the litter is generally stored, such as in a field clamp.

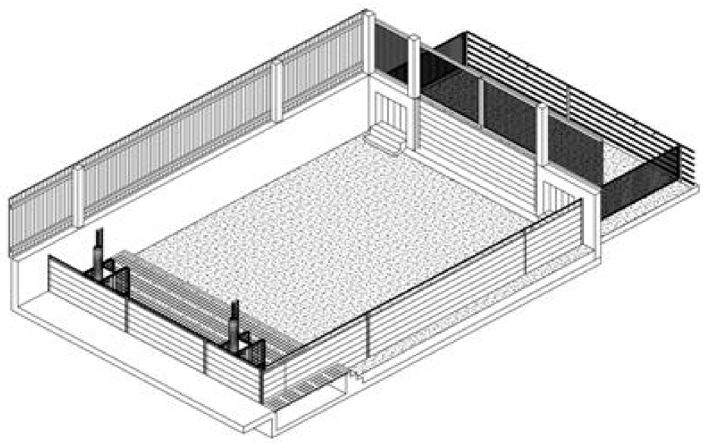


Source: [292, Italy 2001]

Figure 2.14: Example of group housing for gestating sows on a solid concrete floor with full litter

For the ventilation of this housing, the same principle applies as for the individual housing of sows. Natural ventilation is rather an option in new deep litter house systems. With the application of straw, heating is generally not applied as at low temperatures the sows are able to compensate by hiding in the deep litter. The design of this system can vary and may contain various functional areas. An example is shown in Figure 2.15.

Manure handling with this system has been described as follows. In units where bedding is used exclusively for rooting, the amount of litter is will be so limited that all the manure is handled in the form of slurry. In units with a slatted floor in the defecating dunging area, the manure is cleaned daily using underslat scrapers. In units with solid flooring, the manure is cleaned either daily with scrapers or 2 – 3 times a week using a tractor-mounted tyre scraper. In units with deep litter in the lying area, the litter is removed 1 – 2 times annually.



Source: [157, Germany 2010]

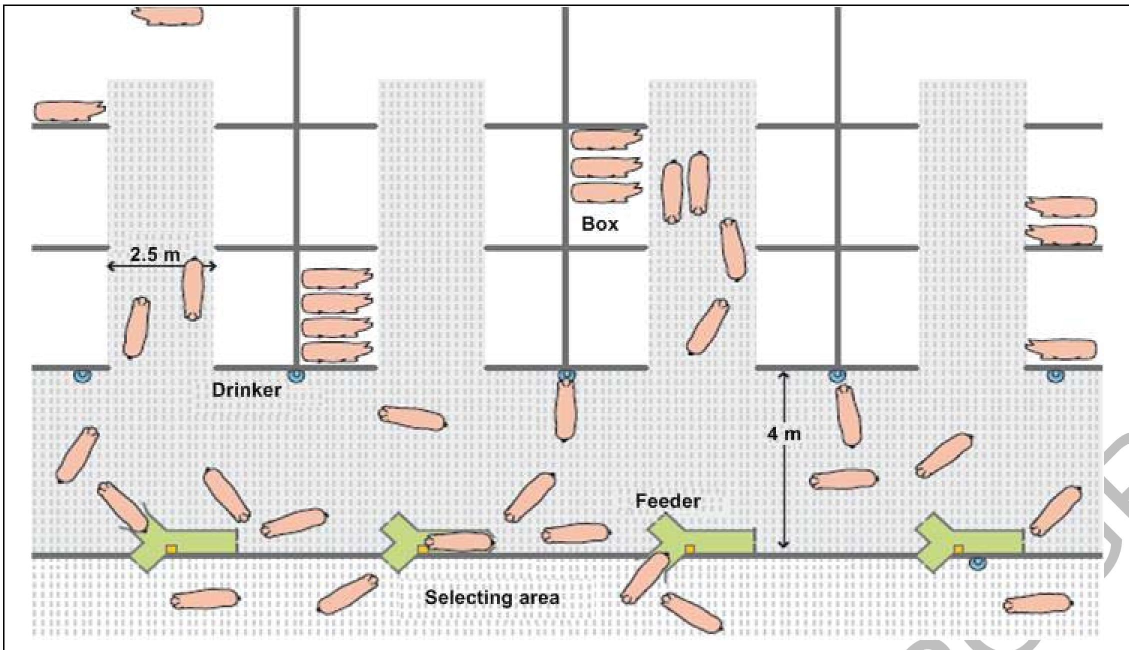
Figure 2.15: Example of a housing system with several functional areas for gestating sows

2.3.1.1.4 Group housing with electronic feeders

Sows may be fed by automatic equipment, the electronic sow feeder (ESF), that releases the exact amount of feed required for each individual sow. An electronic chip that is buckled onto an ear of each animal identifies the carrier sow which then receives a programmed feed ration by the electronic feeder. This system can be applied with or without straw on the floor.

The paddock layout is very important to place and manage large groups of sows fed this way, since ESFs allow a profit for a reduced space per head. Indeed, for groups of 40 animals or more, the minimal space is 2.025 m^2 per sow and 1.476 m^2 per gilt. Pens have a lying area, a defecating area and a feeding area where electronic sow feeders are placed. The laying areas are placed on solid concrete floors from which the manure is removed daily by a scraper tractor. Pens can be arranged on concrete slats or on straw.

The version on slatted floor allows an available surface per sow of 2.20 – 2.66 m^2. Separators may also be used to create boxes approximately 2 metres long. Crates Stalls or boxes can be are laid out at both sides of the corridors which are broad enough to allow two sows to cross each other (see Figure 2.16).



Source: [262, France 2010, Ramonet (2009) Loger les truies en groupes au DAC]

Figure 2.16 Layout of a pen for gestating sows fed with an electronic feeder (ESF)

The version with littered pens lays has a large area of 50 to 120 m^2 where sows can lie and that is opposite a feeding and defecating zone. The total surface per sow is between 2.3 and 3 m^2 and the minimal surface of the lying area is 1.2 – 1.4 m^2 per sow. Litter is added and removed every 7–10 days in quantities between 200 and 450 kg/sow per year (see Figure 4.4.1)

The feeding stations have one entrance but may have one or two exits, hence allowing the workers to drive animals to different areas as needed. [262, France 2010]

2.3.1.2 Housing systems for farrowing sows

Shortly before farrowing (about 1 week), gestating sows are moved to farrowing pens. There are different designs of farrowing pens. A common design has partly- or fully-slatted floors and generally no straw. The sows are often confined in their movement, but loose-housing is also applied. For example, straw-based and loose-housing can be found in the UK, whereas in France and Spain, breeding farrowing sows on litter seems to be marginal. [262, France 2010]

Fully-slatted flooring is applied widely in the EU, as it is considered to be more hygienic and labour efficient than partly-slatted or solid floors. In France, 93.6 % of the total capacity for sows, the most recently included, are fully-slatted floors. [262, France 2010] On the other hand However, Danish information indicates that partly-slatted systems are more energy efficient and a gradual increase in partly-slatted systems is being observed. In Austria, the fully-slatted floor systems are in decline [194, Austria, 2001].

General features of farrowing compartments are:

- applied minimum room temperature of 18 °C
- temperature for the sows of 16 – 18 °C
- distinct safe lying area for piglets with a temperature for the piglets of about 33 °C at start
- low airflow, in particular in the piglet area.

In Sweden, the farrowing pens must have a continuous solid floor area of at least 3 m^2, a total floor area of at least 6 m^2 and the farrowing pens should be constructed in such a manner as to allow nesting behaviour. [201, Mul M. et al 2010]

2.3.1.2.1 Housing for farrowing sows with confined movement

Farrowing pen sections generally contain not no more than 10 – 12 sows (pens) (e.g. in Belgium Flanders, 4 – 5 sows are normally hosted in each farrowing section). Pen sizes measure 4 to 5 m^2. Increasingly common are crates which can be opened out in such a way to allow the sow to move around more freely, including a full 360 degree of movement, while still protecting the piglets from being crushed.

Piglets are housed in these systems until weaning after which they are sold or reared in rearing pens (weaner housing). The floor can be fully or partly-slatted. Slats made of plastic or plastic-coated metal are increasingly used instead of concrete, as they are considered to be more comfortable (see Figure 2.17).

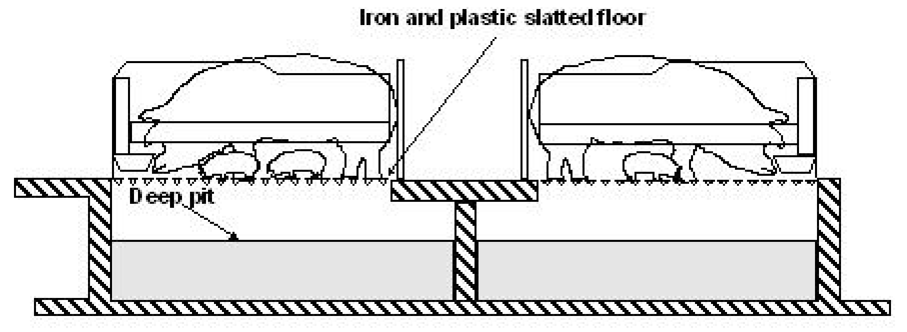
The slurry is stored under the slatted floor of the crates either in a shallow pit (0.8 m.), in which case it is removed frequently via a central system in the building, or in a deep pit, from which where it is removed only at the end of the lactating period or less frequently. A cross-section of a typical pen system for farrowing sows is shown in Figure 2.18.

There is a specific area for the piglets, usually positioned in the central alley (for easier observation) between the pens. This area is generally not slatted and is heated during the first days after birth by using a lamp or by warming the floor or both. The sow's is limited in her movement is limited to prevent her from crushing of the piglets.

Figure 2.17: Farrowing pen design with a fully-slatted floor (the Netherlands)

Forced or natural ventilation is applied in such a way that the airflow will not disturb the climate at the floor level (around sow and pigs). In modern closed housing, fully automatic climate control is applied, thereby maintaining the temperature and humidity in the farrowing section at a constant level.

The position of the sow is often as pictured in Figure 2.18, but the crates are also put the other way around may also be reversed with the sows facing the alley. In practice, some farmers have observed that this position makes the sows more relaxed, as they can more easily notice movements in the alley, whereas in the other position they cannot turn, which makes them more restless.



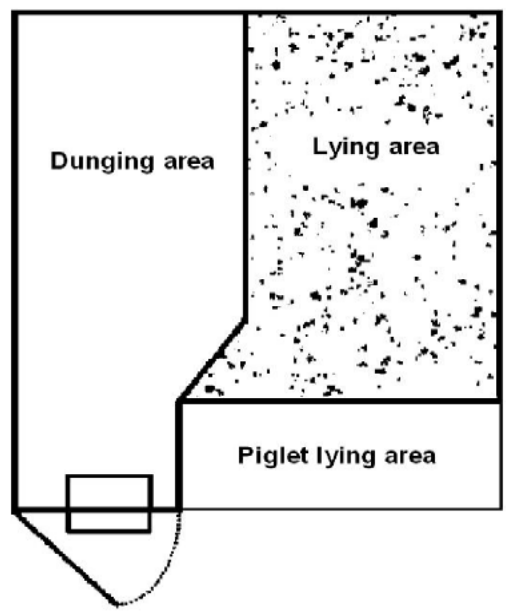
Source: [292, Italy 2001]

Figure 2.18: Example of confined housing of farrowing sows on a fully-slatted floor with a storage pit underneath

2.3.1.2.2 Housing of farrowing sows allowing sow movement

Farrowing sows are housed without being confined in their movement in systems with partly-slatted floors. A separate lying area for the piglets prevents them from being crushed by the sow (see Figure 2.19). This pen is sometimes used to raise the piglets from weaning until about 25 – 30 kg LW. This design requires more space than the design with restricted sow movement and requires ~~needs~~ more frequent cleaning. The number of pens or sows per compartment is generally less than 10.

Material for the floor system and heating and ventilation requirements for the sow and piglets are the same for this system. With free sow housing, the walls of the pen are slightly higher than for the pen with restricted movement.



Source: [202, EAAP 1998]

Figure 2.19: Example of an applied plan for a farrowing pen (partly-slatted floor) allowing sow movement

A series of different new designs for farrowing pens and management combinations is currently being tested in the UK under a specific project (PIGSAFE project, Piglet and Sow Alternative Farrowing Environment), with the objective of developing a non-crate system for indoor farrowing accommodation that reconciles the sows' behavioural needs with good piglet survival, farm practicality and easy daily management, at acceptable capital and running costs.

2.3.1.3 Housing systems for weaners

Piglets ~~Pigs~~ are weaned at no less than ~~at least approximately~~ 4 weeks and up to ~~(it ranges from 4 3 to~~ 6 weeks of age.~~, after which they are kept in small groups of the same litter (8 – 12 pigs per pen) up to 30 kg LW (range from 20 25 – to 35)~~.

In accordance with Directive 2008/120/EC ~~2001/93/CE~~, laying down minimum standards for the protection of pigs, piglets shall not be weaned from the sow at less than 28 days of age, unless the welfare or health of the ~~dam~~ sow or the piglets would otherwise be adversely affected. However, piglets may be weaned up to seven days earlier if they are moved into specialised houses which first need to be emptied and thoroughly cleaned and disinfected before the introduction of a new group and which are separated from houses where sows are kept, in order to minimise the transmission of diseases to the piglets.

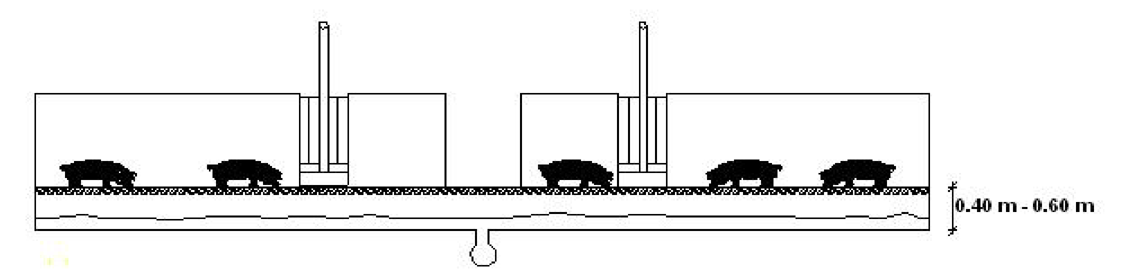
Piglets are commonly reared up to 30 kg ~~LW~~ live weight (range from 20 ~~25 –~~ to 35 kg) in small groups of the same litter (8 – 12 pigs per pen) or from two or more litters. In most European countries, the total number of animals for each small group is lower than 20; however, in other Member States (e.g. EE), larger groups of up to 100 animals or more are also common. [264, Loyon et al. 2010]

Weaners are reared in group-houses either in conventional pens or flat decks (raised pens). Rearing is ~~achieved~~ carried out both on completely slatted floors and on partial slats, which are mainly used in the EU ~~CZ, SE, FI, PL, DK and EE~~. For the storage of slurry, both systems: underground deep pit and frequent removal by channel systems are common. Systems with solid floor and deep litter s~~ystems~~ are not commonly ~~rarely~~ used, except in countries such as PL, UK, AT and EE. [264, Loyon et al. 2010] The use of solid floors with deep litter is increasing in the UK and is anticipated to become more widespread in the future because of animal welfare concerns.

The housing is equipped with mechanical ventilation, either a negative pressure or balanced pressures type. Ventilation is variable depending on the season and is around 20 m^3/h ~~$m^{3/h}$~~ per place in the cold season and around 40 m^3/h in the warmer season. [179, Spain 2010] ~~dimensioned at an output of maximum 40 m^3/h per place.~~ Auxiliary heating is also applied in the form of gas radiant heaters, electric fan or convection heaters or by a central heating plant with heating pipes.

Manure is handled in the form of slurry and is drained mainly through a pipe discharge plant, where the individual sections of the manure channels are emptied via plugs in the pipes (see Figure 2.20). The channels can also be drained via gates. The channels are cleaned after the removal of each group of pigs, often in connection with the cleaning of the pens, i.e. at intervals of 6 – 8 weeks.

The fully-slatted flooring is favoured, especially for sanitary reasons. Still manure over solid floor may disperse microorganisms affecting the digestive system.

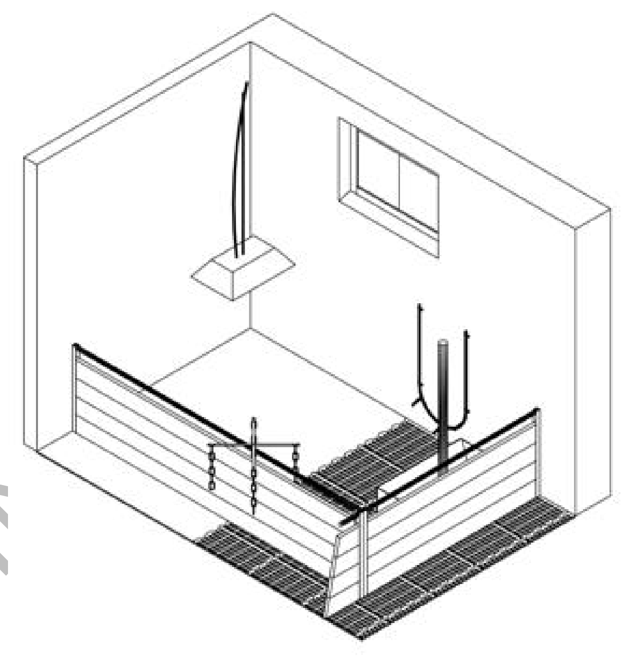


Source: [397, Denmark 2000]

Figure 2.20: Cross-section of a rearing unit with a fully-slatted floor and plastic or metal slats

~~In the partly-slatted design a covered lying area is applied which can be removed or lifted once the pigs have grown and need more ventilation (see Figure).~~ ~~The fully-slatted flooring is favoured specially for sanitary reasons. Still manure over solid floor may disperse microorganisms affecting the digestive system.~~

Partly-slatted floors are applied to add comfort areas with heated spaces (see Figure 2.21). Where litter is used, 10 to 15 kg of straw is used per piglet, on a surface of 0.5–0.6 m^2 per head, with a production of 30–50 kg of manure per piglet. [262, France 2010] In the partly-slatted design, a covered lying area is applied, which can be removed or lifted once the pigs have grown and need more ventilation.



Source: [184, Germany 2010]

Figure 2.21: Schematic picture of a weaner pen with a partly-slatted floor ~~(1/3) and a cover above the lying area~~

A ~~special design is the~~ typical housing design for ~~of~~ weaners ~~in~~ is the use of flat decks, ~~[133, Peirson/Brade, 2001]. Flat decks were initially developed in the late 1960s and early 1970s as a specialised housing system~~ that are intended to provide a controlled environment housing for piglets~~, weaned at~~ from 3 to 4 weeks of age, through to 15 – 20 kg live weight,.~~The concept has been extended and is also used to provide second stage housing from about 15 – 20 kg through~~

or even to weights of around ~~of up to 50 or~~ 60 kg, when pigs then make their final move into finishing pens.
~~The thermally insulated buildings used are often of a pre-fabricated sandwich construction with external wood or panel cladding, thermal insulation and panelled internal cladding. The internal layouts and structures have also been installed inside more permanent buildings.~~

Fully plastic or metal slatted floors are suspended over slurry channels or tanks. The floor level may be raised from the operating aisles or may be at the same level. ~~Flat decks are built around a batch system so that~~ Each room is stocked on an 'all-in, all-out' basis with piglets from a batch of sows farrowed in the same week.

Ventilation is almost exclusively provided by extractor fans. Indoor air might be preheated and radiant heaters above the pens (or underfloor heating) may be used to provide additional temperature/comfort control.

Feed is normally provided as dry pellets or meal offered in *ad libitum* hoppers on the front (passage) side of each pen. Phase feeding regimes are widespreaded for piglets.

Slurry is removed from the below-slat channels or tanks at the end of each stocking batch. Pens are power-washed between batches.

Room temperatures are maintained at 28 – 30 ºC for the first few days after weaning and are then reduced as the piglets grow. ~~Occupation is usually 4 – 5 weeks in the first-stage pens, and by the end of this period temperatures would have been reduced to 20 – 22 ºC.~~

The flat deck system evolved with the addition of features like solid (and possibly littered) floored lying areas that may be provided to help improve pig comfort and welfare. Underfloor heating has become a more common feature and group sizes have tended to increase ~~and the system is slowly evolving into a "nursery" room system with groups of up~~ to around 100 pigs. ~~in a group in a partially solid-floored pen (around one third of the floor area solid) and no access passageways.~~

2.3.1.4 Housing of growers/finishers

With ~~From~~ an average ~~LW~~ live weight of 30 kg (20 ~~25~~ 35 kg), pigs are moved to separate sections to be grown and finished for slaughter. It is not uncommon to house growers (e.g. up to 60 kg) and finishers (from 60 kg onwards) in separate sections, but the housing facilities are very much the same.

The growing-finishing housing is a brick-built, open or closed, insulated construction for 100 to 200 pigs. It is usually divided into compartments for 10 – 15 pigs (small groups) or up to 24 or more pigs (large groups). The pens are arranged either with the aisle on one side or in a double row with the aisle in the centre. In the pens with a solid concrete floor, movable covers can be ~~are~~ used to cover the lying area, at least during the first stage of the growing period.

Feed distribution is usually automated and can be sensor-controlled. Liquid or dry feeding is applied *ad-libitum* or may be restricted. ~~and~~ Multiphase (adapted N and P content) feeding regimes are commonly applied for fattening pigs, as well as the use of feed additives, with the aim of reducing the amount of manure. The design of feeding troughs and drinkers depends on the type of feeding.

In most EU countries, fattening pigs are generally reared in groups of less than 20 animals (as weaners), but larger groups are also common in some ~~several~~ countries, and groups ~~even~~ larger than 100 animals are used in EE. Partly-slatted floors are the most used in NL, CZ, IT, SE, CY, FI, PL, DK and PT. In DE ~~and BE~~, ~~flooring is essentially~~ fully-slatted floors prevail and in ES both types of floor are used with the proportion of partial to total slatted being ~~is~~ 60: 40. In BE, fully-slatted floors are prevalent in old housings or new houses and they are equipped with a chemical scrubbing system. In the UK, straw bedding is common. Both systems for the storage of slurry are common: underground deep pit and frequent removal by channel systems. Deep litter systems are rarely used ~~practised~~, with only a few examples in IT. [264, Loyon et al. 2010]

Buildings are, in general, well insulated and usually heated (depending on the country's climate). Heating is mostly provided by electricity, gas or oil and sometimes by a mixture of all sources of energy. Wood, straw and other renewable sources are also used as a fuel, especially in Nordic countries. Heating is either applied locally within the housing or by hot air. Mechanical ventilation of buildings is the main option in ~~effectively~~ nearly all countries. Nonetheless, the use of controlled natural ventilation is still important in some countries, including IT, DE, CY, PL, PT and FR. In ES, FI and DK, air conditioning is commonly applied; in the other states only rarely. Ventilation with pretreated air is used in ES, PL and DK. With the exception of DK, outlet air treatment is only rarely applied. [264, Loyon et al. 2010]

2.3.1.4.1 Housing of growers/finishers on a fully-slatted floor

Housing systems with fully-slatted floors are widely used throughout the EU. In these systems, slats cover the entire pen area, usually to maintain hygiene and cleanliness by allowing for a quick removal of faeces and urine from the immediate environment of the animal, and thus favouring the conditions for a dry lying area. In addition, slatted floors are generally associated with lower airborne and toxin concentrations than litter-based systems, due to the potential bacterial contamination of straw and other litter materials.

Slatted floors should have a sufficient perforation in order to keep the pen clean from manure and urine; on the other hand, the gap between slats should not endanger the animals, in accordance with Directive 2008/120/EC, which lays down minimum standards for the protection of pigs.

The fully-slatted floor housing system is very common for small groups (10 – 15) pigs and large groups (up to 24) of growers/finishers. It is applied in closed, thermally-insulated housing with mechanical ventilation, as well as in houses with natural ventilation. Windows allow daylight in, but electrical light is also used. Auxiliary heating is applied only when necessary, as the pigs' body heat is usually capable of satisfying the heat requirement (see Figure 2.22).

The pen is fully-slatted and has no physical separation of the lying, eating and defecating ~~dunging~~ areas. The slats are made of concrete or (plastic-coated) metal ~~iron~~. Manure is trodden through and urine mixes with the manure or runs off through urine/liquid manure channels. The slurry is collected in a manure pit under the fully-slatted floor. Depending on the depth of the pit, it may provide for an extended storage period (thus high ammonia levels in the house) or it is emptied frequently and the slurry is stored in a separate storage facility. A frequently applied system has the individual sections connected by a central drain, into which they are emptied by lifting a plug or a gate in the pipe.

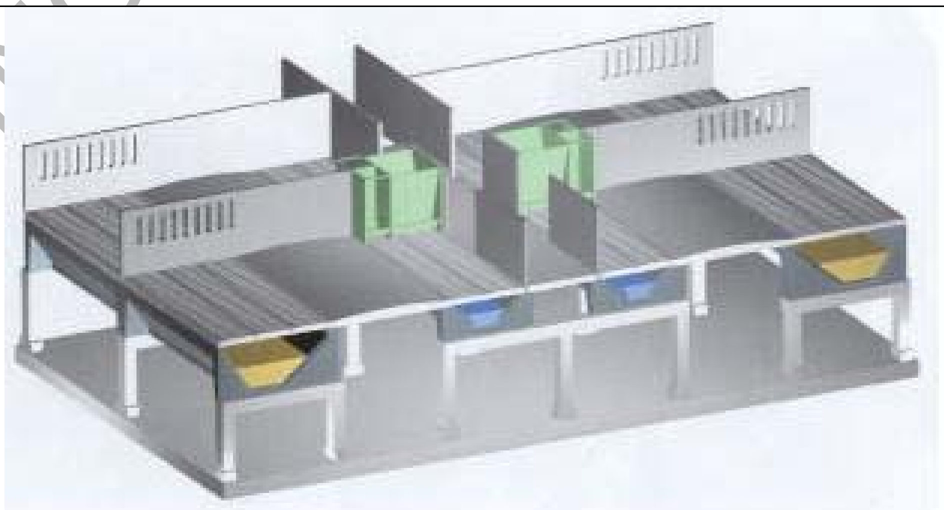
Source: KTBL

Figure 2.22: Scheme and layout of fully-slatted floored pens in a fattening farm

Point 4 of Annex I, Chapter I of the Directive 2008/120/EC concerning the welfare of pigs, states that "pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals"; the provision of such material may be somewhat difficult in the case of housing systems with fully-slatted floors. A Scientific Opinion issued by EFSA concludes that "stocking density, associated with lack of enrichment and fully-slatted floors, is a significant risk for tail biting". It is scientifically considered that tail biting may cause very poor welfare, and tail docking is likely to be painful. [495, EFSA 2007]

2.3.1.4.2 Housing of growers/finishers on a partly-slatted floor

Partly-slatted floor systems are applied in similar buildings to those used for fully-slatted floor systems. The floor is divided into a slatted and a solid/non-slatted section. There are basically two options: to have the solid concrete floor on one side or in the centre of the pen. The solid part can be flat, convex (see Figure 2.23) or slightly inclined (see description below).

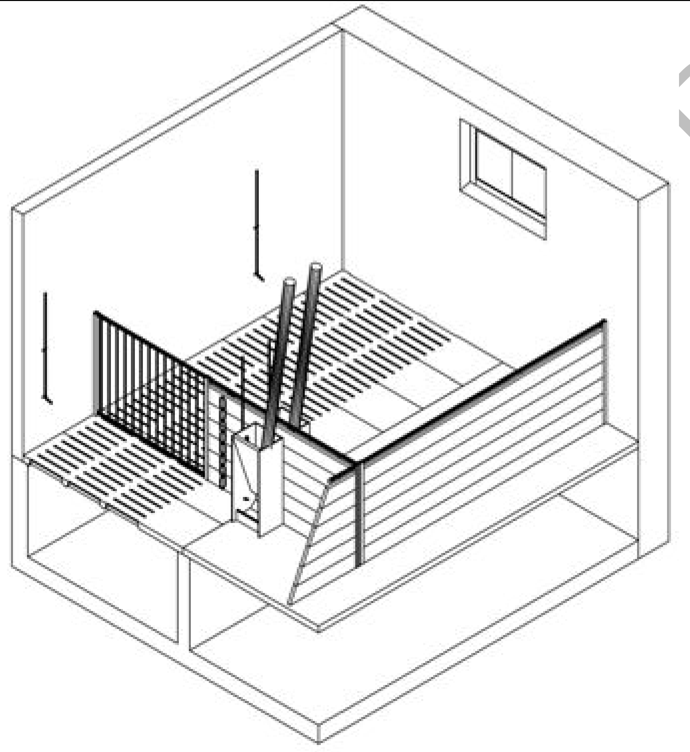


Source: [265, BE Flanders 2010]

Figure 2.23: Pen design for growers/finishers with partly-slatted (convex) floor and solid area in the centre

The solid part usually functions as a feeding and resting place and the slatted part is used for defecating dunging. The slats are made of concrete or (plastic coated) metal iron. Manure is trodden through and urine mixes with the manure or runs off through urine/liquid manure channels. The slurry is collected in a manure pit under the fully-slatted floor. Depending on the depth of the pit, it may provide for an extended storage period (thus high ammonia levels in the house) or it is emptied frequently and the slurry is stored in a separate storage facility. A frequently applied system has the individual sections connected by a central drain, into which they are emptied by lifting a plug or a gate in the pipe.

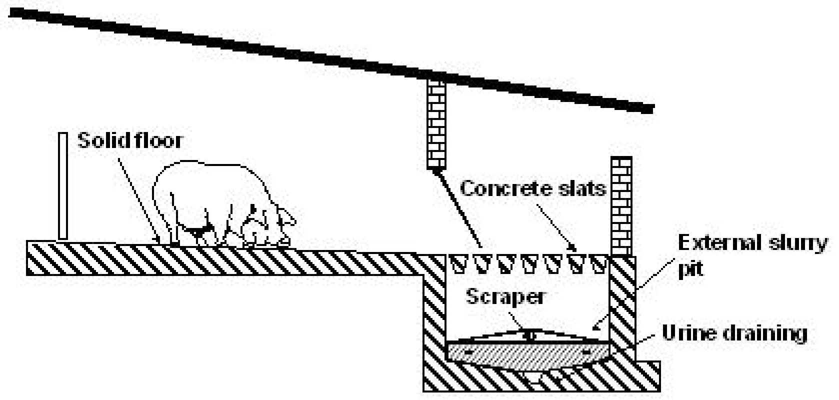
Restricted amounts of straw are is applied in the partly-slatted pen that is designed with a concrete floor and one slatted area (solid/slatted: 2: 1, see Figure 2.24). Straw is given in straw racks that are filled manually, and from which the pigs bring take the straw in themselves. The solid floor has a slight incline and slurry and straw are moved towards the slats by the pigs' activity; therefore, this system is also called a straw-flow system. Manure is removed several times a day.



Source: [192, Germany 2010]

Figure 2.24: Design of a partly-slatted floor system with restricted straw use for growers/finishers

A partly-slatted design is applied in Italy with a solid concrete floor and an external slatted alley adjacent to a manure channel (see Figure 2.25). In each pen, the pigs have their housing and feeding area inside the building, but an opening with a shutter allows them to reach the external defecating dunging area with the slatted floor. The pig activity moves the manure through the slats into the manure channel, which is emptied once or twice a day with a scraper. The manure channel runs parallel to the pig building and is connected with a slurry storage facility. This system is also used for mating and gestating sows in group housing.



Source: [391, Italy 1999]

Figure 2.25: Solid concrete floor with slatted external alley and scraper underneath

2.3.1.4.3 Housing of growers/finishers on a solid concrete floor and straw

In the housing systems for growers/finishers with a concrete floor, straw is applied in restricted amounts for reasons of animal welfare or as big-bale supply to serve as bedding (see Figure 2.26). These systems are applied in closed buildings or in open-front houses. The open-front designs are equipped with wind barriers (netting or spaceboards), but also straw bales are used for insulation and for protection against the wind.

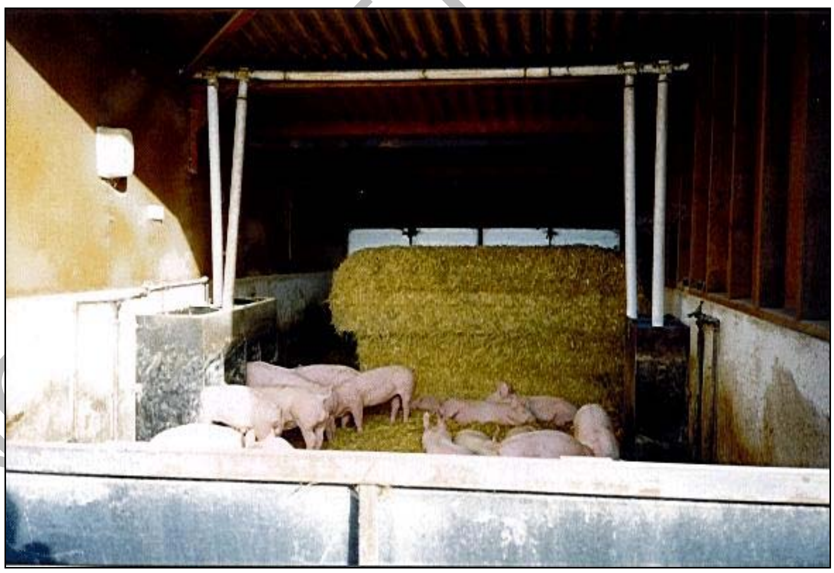


Figure 2.26: Open-front design using straw bales for protection (UK)

In France, pigs are ~~can be~~ fattened on a thin litter of wood grain or sawdust in houses where ~~if~~ the walls and the roof ~~of the building are perfectly~~ are well insulated. [262, France 2010]

Pen designs can vary, but usually there is a lying area with straw and a feeding area, which may be elevated and accessible by steps (see Figure 2.27). The lying area may be covered. The pens may be positioned on one side of the building or on either side of a central aisle. Defecation ~~Dunging~~ takes place in the littered area. Mucking-out and cleaning are usually done with a front-end loader after each batch. Group size may be 35 – 40.

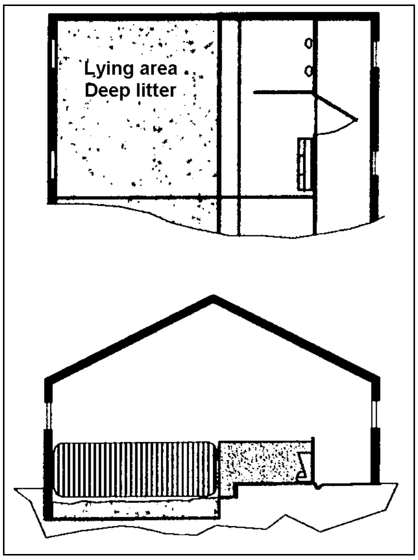


Figure 2.27: An example of a solid concrete floor system for growers/finishers ~~[202, EAAP 1998]~~

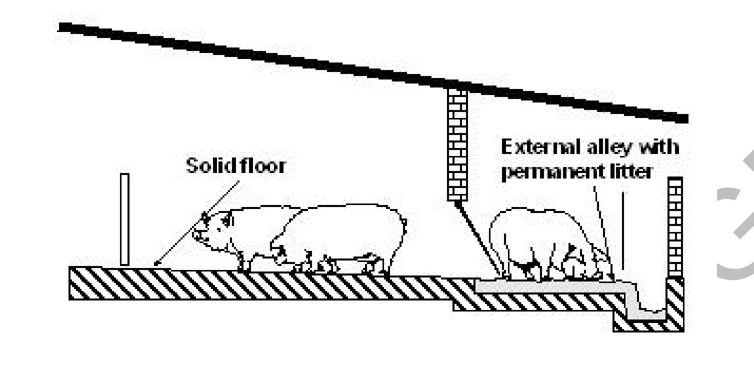
Bedding can be provided and managed in different ways. The 'accumulated straw' is a deep layer of bedding that is used for several batches. ~~Details for some usual~~ Litter management is detailed in Table 2.8, as reported by France.

Table 2.8: Manure and bedding management in litter-based systems for fattening pigs (from 30 to 115 kg live weight).

Litter management	Building features and management of bedding and manure	Surface (m^2/pig)	Bedding use (kg/pig/cycle)	Manure result (kg/pig/cycle)
Accumulated straw	- High raised bedded area and feeding platform - Straw provision at cycle start-up - Fresh straw addition over the accumulated manure: 2 to 3 times per week - Manure removal at end of cycle	1.3	50 – 80	200 – 300
Scraped straw	- Straw in comfort area, scraper corridor and feeding platform - Removal manure and fresh straw addition: 2 to 3 times per week	1.0	30 – 50	No data
Deep sawdust bedding	- High raised bedded area and feeding platform - Litter of 60 – 70 cm used for few batches - Only the surface layer is removed at the end of each cycle	1.2	50 – 60	No data
Thin sawdust bedding (20 cm)	- Insulated ~~Isolated~~ building on walls and roof with ~~and~~ dynamic ventilation - Straw provision at cycle start-up - No sawdust added - Removal manure at the release point of animals	1.3	20 – 40 (90 % DM)	100 – 200 (40 – 30 % DM)
Source: [420, Ramonet 2003] ~~[262, France 2010]~~				

Straw is also used in combination with bare solid floors, where the animals' activity over the slight slope of the floor pushes the straw towards the dunging area at one end of the pen (e.g.

Austria, UK). [519, Amon et al. 2007] As with the partly-slatted design, a solid concrete floor system is applied In Italy, the bedded area is with a littered external alley, that is similar to the solution with partly-slatted floors (see Figure 2.28). The indoor pen area inside is used for lying and feeding and has very little or no straw. The outside defecation dunging area is littered and connected with a manure channel. Manure and straw are moved into the channel by the pigs' activity. Manure is removed once or twice daily by a drag chain or a scraper to an outside manure storage.



Source: [391, Italy 1999]

Figure 2.28: Solid concrete floor with external littered alley and manure channel

2.3.2 Control of indoor environment in pig housing systems

The indoor environment of the pig housing systems has to be adequately controlled to ensure:

(a) the evacuation of harmful gases (CO_2, CH_4, NH_3), whilst providing oxygen necessary for the breathing of the animals;
(b) maintainance of an adequate temperature adapted to the physiological stage of the animal rearing, to ensure a good performance, in good health and without behaviour disorders.

The indoor climate in pig housing systems is important, as ammonia, combined with dust, is known to be a frequent cause of pig respiratory diseases, including atrophic rhinitis and enzootic pneumonia. Since stock workers can also be subject to respiratory health issues [98, FORUM, 1999], it is doubly important that pig housing is sufficiently ventilated.

Minimum (qualitative) requirements are laid down in Directive 91/630/EEC [132, EC, 1991] Council Directive 2008/120/EC, where minimum standards for the protection of pigs are given, including for the control of the pig housing climate. Temperature and humidity of air, dust levels, air circulation and gas concentrations must be below harmful levels. For example, the limit value concentrations shown in Table 2.9 are advised, but these values vary between MSs.

A good indoor environment atmosphere in the house can be achieved by:

- insulation of the buildings;
- heating;
- ventilation.

Table 2.9: General indicative levels of indoor environment for pigs

Indoor environment factors	Level/occurrence
CO	Below measurable value
H_2S	Below measurable value
Relative humidity (H)	Pigs up to 25 kg: 60 – 80 % Pigs 25 kg upwards: 50 – 60 %
NH_3	Maximum 10 ppm
Air velocity	Farrowing pens and weaners: <0.15 m/s Mating and gestating sows: <0.20 m/s
CO_2	Max. 0.20 volume %
Source: [44, IKC 1993]	

The performance of the applied system is affected by:

- design and construction of the building;
- position of the building in relation to wind directions and surrounding objects;
- application of control systems;
- age and production stage of the pigs in the housing.

Insulation can be applied to reduce heat losses through walls, the ground and the roof by interposition of layers of materials that slow down the ~~transportation~~ transfer of heat in and out the building. Different degrees of insulation are achieved by various materials. Two coefficients are generally used to define this insulation: the coefficient of thermal conductivity (λ) and the coefficient of thermal transmission (U), which is the coefficient most commonly used and is expressed in W/m^2 per °C. [345, France 2010]

In all circumstances, the building must be as air-tight as possible. It is important to verify regularly the air sealing of doors and windows, and that neither water condensation on walls nor undesired air flows are established. When air leakage occurs, openings are usually sealed by polyurethane foam spraying.

Treatments may be applied to incoming air (mainly for animal welfare reasons), primarily being dust removal, cooling and/or humidification. [264, Loyon et al. 2010]

2.3.2.1 Heating of pig housing

The need for temperature control in pig housing depends on theclimatic conditions, construction of the building and the stage of production of the animals (see Table 2.10). In general, in colder climates or climates with periods of low temperatures, buildings are insulated and equipped with mechanical ventilation. In warmer regions (Mediterranean latitudes), high temperatures have ~~are~~ a greater influence on welfare and productivity of adult pigs than low temperatures. Usually there is no need to install heating systems; the animal body heat is generally sufficient to maintain welfare temperatures within installations. In this context, climate control systems are mainly designed to guarantee good air circulation.

In some housing systems for sows and growers/finishers, large amounts of straw help the animals to maintain a comfortable temperature. However, the most important factors are live weight, age and production stage. Other factors that affect temperature requirements are:

- individual or group housing;
- flooring system (fully or partly-slatted or solid floors);
- amount of feed (energy) the animals get;
- use of bedding (concrete or concrete + straw).

Table 2.10: Example of applied temperature requirements for the calculation of heating capacity in heated housing for different pig categories under ~~in~~ healthy conditions

Farrowing pen	Weaned pigs	Mating and gestating sows	Growers/finishers
Room and sow location, ~~1st week~~ up to 20 – 22 °C	7 kg up to 25 °C	Mating up to 20 °C	20 kg up to 20 – 22 °C
	10 kg up to 24 °C	Early gestation up to 20 °C	30 kg up to 18 °C
Piglet area, first days after birth, ~~up to~~ 28 – 30 °C	15 kg up to 22 °C	Middle gestation up to 18 °C	40 kg up to 16 °C
	20 kg up to 20 °C	End of gestation up to 16 °C	50 kg up to 15 °C
	25 kg up to 18 °C		
Source: [44, IKC 1993] [261, France 2010]			

Pig housing can be heated by various systems. Heating is applied as local heating or room heating. Local heating has the advantage that it is aimed at the place where it is most needed. Systems applied are:

- floors equipped with heating elements;
- heating elements above the pig places radiating heat onto the animals, as well as onto the floor surface.

Room heating ~~ventilation~~ is applied by two methods:

- by preheating: incoming air is preheated by leading the air through a central corridor to warm it to a minimum temperature, to reduce temperature fluctuations and to improve air movement in the housing area
- by post-heating: heating is applied to the air once it has entered the housing area, to reduce temperature fluctuations and to reduce heating cost.

Heating can be direct or indirect. Direct heating is accomplished by applying installations such as:

- gas heat radiators: infrared, gas air heaters and gas-fuelled radiation convectors
- electric heat radiators: special light bulbs or ceramic radiators
- electric floor heating: on matting or under ~~in~~ the floor
- floor heating with warm water (water is heated by boilers of various types or by the techniques reported below)
- combined heat and power systems (CHP)
- heat pumps
- heat exchangers
- ~~heaters/~~blowers.

Indirect heating can be compared to central heating in domestic applications. The installations applied can be:

- standard boilers (efficiency: 50 – 65 %)
- improved efficiency boilers (improved efficiency: 75 %)
- high efficiency boilers (high efficiency: 90 %).

Boilers can be open or closed design. Open designs use indoor air for the burning process. Closed designs draw air from outside the building and are particularly suitable for dusty areas.

2.3.2.2 Ventilation of pig housing

Ventilation systems vary from manually controlled natural systems to fully automated fan-based systems. The following basic systems are examples of commonly used ventilation systems:

- Dynamic (or mechanical) systems:
  - exhaust ventilation: ventilation in depression under negative pressure
  - pressure ventilation: ventilation in overpressure
  - neutral ventilation with manual or automatic control.

- Natural systems:
  - hand controlled ventilation
  - automatically controlled natural ventilation (ACNV).

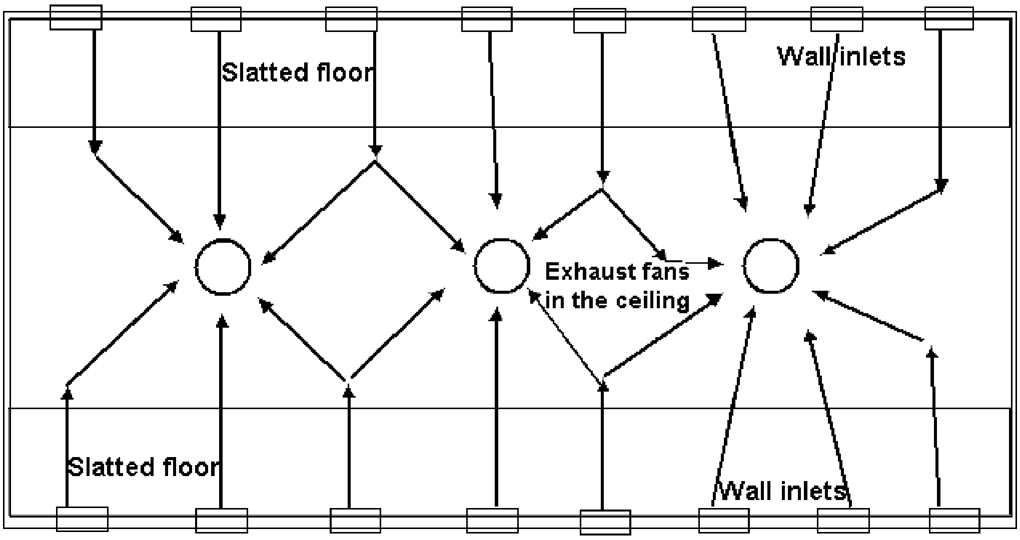
With dynamic mechanical systems, the distribution of air can be accurately adjusted by means of valves, positioning of the fan(s) and the diameter of the air inlets. Natural ventilation depends more on the natural fluctuations of the outside air temperature and on the wind. With fans, more even airflow in the housing can be achieved. This is important when considering the application with housing systems, as the interaction between the housing (flooring) system and the ventilation system affects the air currents and temperature gradients in the house. For example, partly-slatted floors may combine better with mechanical ventilation than with natural ventilation, whereas with fully-slatted floors, natural ventilation may be equally applied. [120, ADAS, 1999]

The volume of the housing area and the air inlet and outlet openings have to correspond to create the required ventilation rate at all times. Irrespective of the production stage and the ventilation system, a draught stream close to the animals must be avoided. Until recently, the majority of ventilation and heat supply systems were installed independently, but in new installations (e.g. in Denmark), it is common to apply integrated installations that match heating and ventilation requirements. [397, Denmark 2000]

Operators can monitor by computer the ventilation parameters and remotely apply correction measures for precision control. Control and adjustment of ventilation are important and can be carried out in different ways: Control parameters may include temperature, relative humidity and carbon dioxide concentration. Electronic equipment is applied to measure the fan revolutions per minute. A measuring fan in a ventilation tube can be used to measure the air velocity in the tube, which is related to a certain pressure and revolution rate.

The following principal Some ventilation techniques that are mostly can be applied in pig housing are described below. [44, IKC 1993] [26, Finland 2001]

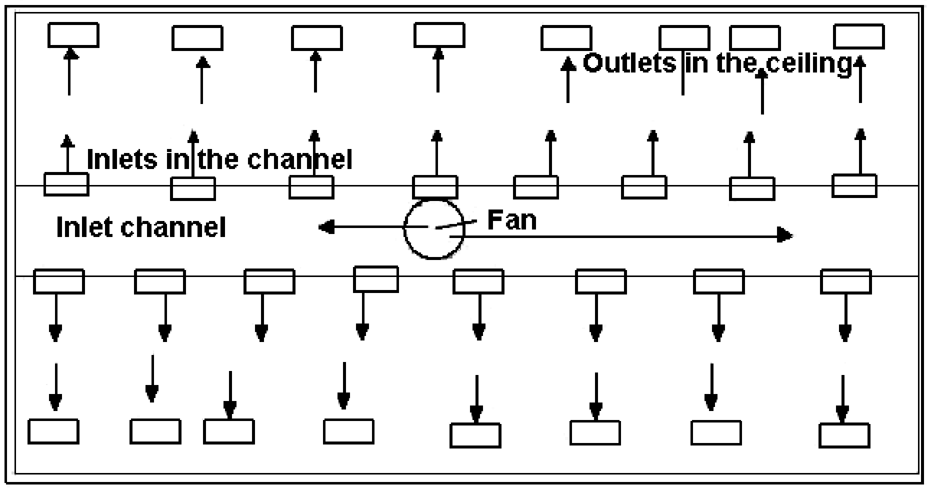
Exhaust ventilation in pig housing uses is ventilation by running fans in the side walls or in the roof (see Figure 2.29). Adjustable ventilation openings or windows allow fresh air to be drawn in. Fans exhaust air outside, usually through the ceiling at one or more points. This creates under-pressure, and creates fresh airflows into the building through the inlets. The fresh air inlets are usually on the wall, close to the ceiling or on the ceiling, so that the air flows from between the roof and the ceiling to the outlet. It is typical in an exhaust ventilation system for the air pressure inside the building to be lower than that outside. Exhaust ventilation works well when it is warm outside, and it is therefore a very popular and appropriate system in countries with warmer climates. On growing-finishing pig farms, heating costs may be relatively low when exhaust ventilation is used, provided that it is properly adjusted.



Source: [26, Finland 2001]

Figure 2.29: Schematic view ~~picture~~ of airflow in an exhaust ventilation system

In buildings with a pressure ventilation system, fans are used to blow air into the building, which means that the air pressure inside the building is higher than outside. Due to the difference in the pressure, air flows out of the building through outlets (see Figure 2.30).



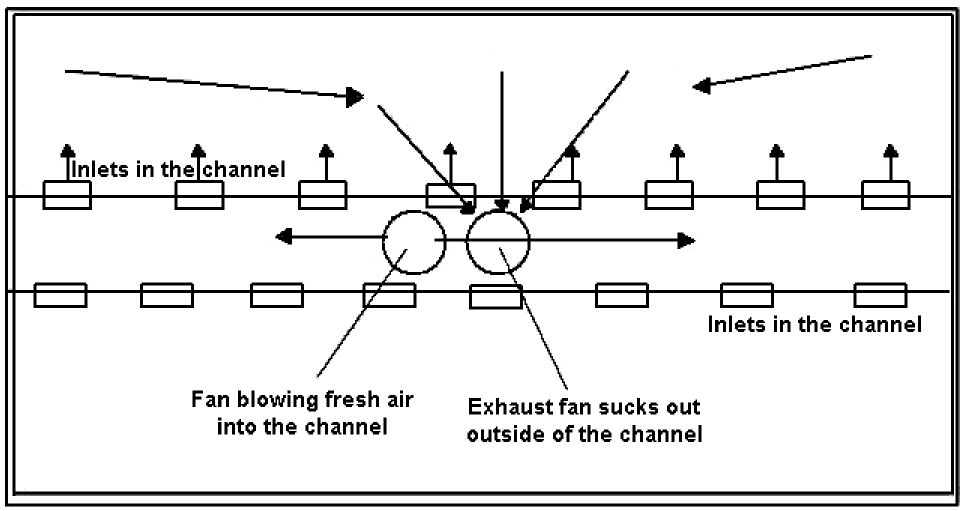
Source:[26, Finland 2001]

Figure 2.30: Schematic view ~~picture~~ of airflow in a pressure ventilation system

When using pressure ventilation, the air entering the building can be preheated, and thus part of the heating in the winter can be done by means of ventilation. The main problem in this system is that the airflow is quite uneven when only one blowing point is used. Airflow is rapid and the air is cold close to the fan, but the airflow slows down rapidly when moving further away from the fan. Blowing channels may be used to avoid this problem. Blowing channels are usually placed in the middle of the pig house.

Air is blown into a channel, which spreads it throughout the building. The airflow, distribution and direction of the blow are controlled by means of nozzles. Sometimes humidity is a problem, which, due to the higher pressure inside compared to ~~than~~ outside, leads to condensation on the surfaces of the channels when the air is not preheated. This is why pressure ventilation is not very common in colder climates. It is only be used in concrete buildings, as the humidity can damage insulating materials and structural timbers.

A neutral ventilation system is a combination of the exhaust and pressure ventilation systems (see Figure 2.31). As with exhaust ventilation, the exhaust air is drawn out of the building by means of a fan. However, the replacement air does not flow into the building, because of negative pressure in the building, but air is drawn in through a channel. Thus, the difference between the air pressure inside and outside the building is much smaller than in the case of exhaust or pressure ventilation. In neutral ventilation, a heat exchanger can be used to reduce the need for additional heating. Neutral ventilation uses more energy than exhaust or pressure ventilation, because the air is drawn in and blown out. Investment costs are also higher, as twice as many blowers and blowing channels are needed as for the other systems.



Source:[26, Finland 2001]

Figure 2.31: Schematic view of airflow in a neutral ventilation system

Natural ventilation systems are based on the difference in density and air pressure between warm air and cold air due to wind, temperature and the ~~so-called~~ ‘chimney effect’ that causes warm air to rise and cold air to replace it. The ‘stack (chimney) effect’ depends on the relationship between the opening and the position of air inlets and outlets and the inclination of the roof (25°; 0.46 m per metre stall width). Obviously, design and construction of the building are very important with natural ventilation. As the effect is based on temperature differences, it is clear that the effect is largest when the ventilation requirement is at its lowest (in winter).

The naturally created negative pressure is relatively small; even in winter in Finland it is reported~~ly~~ as less than 20 Pa, and so in summer, ~~may have to be assisted by~~ exhaust pressure ventilation is sometimes used to boost the air flow. Thus, combinations of ventilation systems are applied that work alternately, depending on the indoor and outdoor air temperatures. In countries such as the Netherlands, wind is the prevailing factor that influences natural ventilation.

Automatically adjustable valves in the air inlets can be applied to control natural ventilation (ACNV). Sensors at the pig level send a signal to the system ~~that~~ adjust the opening of the inlets and thus increases or reduces the airflow.

Ventilation by drawing air from the manure pit in slatted floor systems is also applied and is considered an efficient way to reduce concentrations of manure gases in the house. This system has specific requirements of length and diameters of the air channels.

The combination of heating and ventilation constitutes the crucial factor in environment management. Each of the two factors has an antagonistic action on the other, hence the best compromise needs to be determined.

In France, recommended temperatures for preheated and non-preheated ventilated air are shown in Table 2.11.

Table 2.11: Recommended air temperatures for heated or non-heated pig rooms

Heated rooms	**Farrowing sows**	**Weaners**
Beginning of cycle	24 °C	27 °C for weaning 28 d 28 °C for weaning 27 d
End of cyle	22 °C	24 °C
Non-heated rooms	**Mating/gestating sows**	**Growers/finishers**
Winter	20 °C	22 °C
Summer	22 °C	24 – 25 °C
Source: [261, France 2010]		

The minimum ventilation capacity is the flow necessary to evacuate the steam produced in cold weather by the youngest animals for the ~~given~~ physiological stage considered, e.g. for animals entering a room in cold weather (less than 5 ºC. The maximum capacity is the flow applied in hot weather to the heaviest animals for the ~~given~~ stage considered, to counteract the temperature rise inside the building. ~~French~~ Reference values from the Netherlands and France are reported in Table 2.12.

Table 2.12: Ventilation capacity and temperature references by type of animal production

Type of production	**Minimum ventilation m^3/h per animal place**	**Maximum ventilation m^3/h per animal place**	**Temp (ºC)**
Mating sows	14 – 20	120 – 150	22
Gestating sows	18 – 25	120 – 150	20
Gestating sows 1 week before birth	18 – 25	150 – 200	20
Farrowing sows during birth	18 – 25	160 – 200	22 – 24
Farrowing sows 1 week after latest birth	35 – 50	200 – 250	20
Farrowing sows end	35 – 50	200 – 250	20
Weaned piglets start (7, 5 kg)	2 – 3	10 – 12	26 – 28
Weaned piglets day 21	4 – 6	15 – 18	24
Weaned piglets day 42	6 – 9	20 – 30	22
Fattening pigs day 1 (23 kg)	6 – 8	20 – 30	25
Fattening pigs day 5	6 – 8	20 – 30	23
Fattening pigs day 50	11 – 15	40 – 55	22
Fattening pigs day 100	14 – 20	60 – 80	21
Source: [345, France 2010][421, Netherlands 2011]			

~~**Ventilation characteristic**~~	~~**Farrowing sows**~~	~~**Gestating sows**~~	~~**Weaned piglets**~~	~~**Fattening pigs**~~
~~Minimum capacity~~	~~35~~	~~25~~	~~3~~	~~8~~
~~Maximum capacity~~	~~250~~	~~150~~	~~30~~	~~65~~
~~Ratio max/ min capacity~~	~~7~~	~~6~~	~~10~~	~~8~~
~~NB: Values are in m^3 per animal per hour.~~ ~~*Source*: [261, France 2010]~~				

The optimum air flow significantly contributes to the control of the indoor concentrations of ammonia, dust and germs. Deterioration of the indoor air quality living environment (i.e. increase in content of CO_2, NH_3, dust and germs) can affect the pig food feed intake by approximately 160 g/d, decreasing as a consequence the daily weight gain of 75 g. [261, France 2010]

Irrespective of design or the principle applied, ventilation systems have to provide the required ventilation rate, which varies with the different production stages and the time of year. Air velocity around the animals must be kept below 0.15 – 0.20 m/s, to avoid a sense of draughts.

Mating and gestating sows have relatively low temperature requirements. In Spain and Italy, many farms apply only natural ventilation, with air entering from outside directly into the animal housing area. Nevertheless, in large installations, with a high density of animals, ventilation requirements are met by means of fan ventilation.

Extractor fans are commonly used, but, e.g. in Spain there is a trend towards pressure ventilation systems linked to evaporative refrigeration (cooling systems), as these enable not only ventilation but also air temperature reductions inside the building.

Throughout Europe, in farrowing and weaning houses it is common to control the indoor climate by operating automatic (sensor controlled) ventilation systems with the heating of the air. The air inlet is usually via a central corridor (indirect) and the design of the ventilation system in the units is such that a draught near the animals is avoided.

Extra local heating is applied to the piglets during their first weeks. Often, a heating lamp (gas or electric) is installed above the solid (non-slatted) lying area. The lying surface itself can also be heated, by running hot water through tubes or a reservoir underneath the floor surface.

Weaners still have temperature requirements that require control of temperature and ventilation. Heating may be required during cold weather. The following heating systems are used: radiating radiant heating lamps, electric heating (thermal bedding with a resistance wire heating) and also hot water heating systems (under the floor or through aerial tubes).

Heating the housing of growing and finishing pigs is not common, as their body heat is usually sufficient to create a comfortable environment. In pens with growers, removable covers are sometimes applied to create a more comfortable lying area in the early weeks. The majority of houses for growers/finishers are naturally ventilated with air inlet directly into the pen area, but extractor fans are also used. Mechanical ventilation is also applied (e.g. for most growers/finishers houses in Belgium Flanders).

Some farms, located in zones where summer temperatures are extremely high, use mist evaporative cooling systems to decrease reduce the housing temperature.

2.3.2.3 Lighting Illumination of pig housing

Light requirements for pigs are laid down in Directive 2008/120, stating that pigs must be kept in light with an intensity of at least 40 lux for a minimum period of eight hours per day. 91/630/EEC stating that pigs may never be permanently kept in the dark and need light comparable with normal daylight hours. Light must be available for good control of the animals and does not have a negative influence on pig production. Light can be artificial or natural entering through the windows, but additional electric light is normally applied.

Additional requirements are stipulated in some Member States. Austria, Belgium, Sweden and Germany require that pigs have access to daylight through wall or roof (BE and DE; AT if there is no outdoor access) or through windows (SE). Germany requires that pigs are housed under 80 lux for at least 8 hours per day.

Different lamps are used with different energy requirements. Fluorescent lights are up to seven times more efficient than filament bulbs, but they are also generally more expensive to buy. LED lights are entering the market and are characterised by lower energy consumption and heat output, by smaller sizes than traditional bulbs, by the possibility of dimming bulbs without effect on the spectral sensitivity, and by the minimal flicker. [422, Taylor N. 2010]

Lighting installations should conform to ~~with~~ normalised standards for safe operation and must be water resistant. Lights are installed in such a way that sufficient radiation (light level) is assured to allow the required maintenance and control activities to be carried out.

2.3.2.4 Fogging

In warmer climates or in warmer seasons, heat stress can affect animal performances. Spraying fine particles of water into the indoor environment is a technique that produces a cooling effect, and has a positive effect on dust control, as described in Section 2.2.4.1.1.

Active products having an effect on odour substances can also be added to the water and transported by the diffused microdroplets. When these products come in contact with olfactory pollutants (gaseous or dust-conveyed), reactions occur and the pollutants are inactivated.

2.3.2.5 Ionisation

Electric forces can be used to reduce emissions of stable gases and dustiness from the environment in a house. ~~stable~~ In an ionisation process, an electrode creates ions that are introduced into the indoor space in the direction of the potential gradient. The room surfaces are used as opposite electrode and there, the charged particles are collected. The collection efficiency is affected by the dust spatial distribution, air flowrate, scattering of collected particles, and thickness of the particle layers accumulated on the surface (see Figure 2.10).

2.3.3 Pig feeding and drinking supply ~~watering systems~~

2.3.3.1 Pig feed formulation

The feeding of pigs is aimed at supplying the required amount of net energy, essential amino acids, minerals, trace elements and vitamins for growth, fattening or reproduction. The composition and supply of pig feed is a key factor in the reduction of emissions to the environment from pig farming.

Pig feed formulation is a complex matter, combining many different components in the most economical way. Different factors influence the composition of a feed. Components used for feed formulation are determined by the location. For example in Spain, cereals are more commonly used inland, whereas in the coastal zones, cereals may be partially replaced by cassava. It is now common for different feeds to be applied, enabling formulation closer to the requirements of the pig. For example, two-phase feeding is applied for sows and three-phase for finishers. This section can only give a short overview of the essential elements that are combined in pig feed.

An important feature of a feed is its energy content and in particular the amount of energy that is actually ~~really~~ available to the pig, the net energy. ~~The~~ Net energy ~~of a feed indicates the maximum amount of energy that can be stored as fat tissue and~~ is expressed in MJ/kg.

The indispensable (essential) amino acids (AA) are those that the animal metabolism cannot provide or can only produce in small quantities. Therefore, essential amino acids must be supplied through the diet, and in sufficient quantities to cover the animal requirement. The

essential AA are methionine (+cystine), lysine, threonine, valine, isoleucine, leucine, tryptophan, arginine, histidine and phenylalanine (+tyrosine).
~~for poultry are supplied, as their metabolism cannot supply them. They are: arginine, histidine, isoleucine, leucine, lysine, methionine (+cystine), phenylalanine (+tyrosine), threonine, tryptophan and valine.~~

Cystine is not an essential amino acid *per se*, but methionine can only be made from cysteine and thus they are always linked. As a result of the current ingredients in poultry feed, the most frequent amino acid deficiencies detected in feed mix are sulphur amino acids (methionine and cysteine) and lysine. Another quoted deficiency is typically threonine. [506, TWG ILF BREF 2001]~~[171, FEFANA, 2001]~~ Due to recent developments in the production of amino acids, more amino acids are now available for proper poultry feed formulations.

The indispensable (essential) amino acids are those that cannot be synthesised by the animal organism, or can only be in small quantities. They must, therefore, be supplied through the diet, which has to provide the indispensable AA in sufficient quantities to cover the animal's requirements. The essential AA for pigs are the same as for poultry, but the order of deficiency is not the same. In pigs, lysine is the first limiting amino acid, followed in general by methionine (+cystine), threonine, tryptophan, valine, isoleucine, histidine and the others.
~~Essential amino acids for pigs are supplied, as their metabolism cannot supply them. The principles are the same for poultry (see Section 2.2.5.1) and common deficiencies as well. They are: arginine, histidine, isoleucine, leucine, lysine, methionine (+cystine), phenylalanine (+tyrosine), threonine, tryptophan and valine. Concerning the two sulphur-containing amino acids, methionine and cystine, the last one is not essential, but as methionine is a precursor of cystine (two molecules of cystine produce one molecule of methionine), they are always linked. The first limiting amino acids are: lysine, methionine (+ cystine), threonine and tryptophan. To prevent deficiency, pig feed has to meet minimum requirements by selecting the right components or by adding synthetic amino acids. [172, Denmark, 2001] [201, Portugal, 2001]~~

The pigs' requirements for minerals and trace elements is a complex matter, even more so due to the interactions between them. Their doses in feeds are measured in g/kg (minerals) or mg/kg (trace elements). The most important are Ca and (digestible) P for bone tissue. Ca is also important for lactation and P is important for the energy system. Often their functionalities are related and so therefore attention must be given to their ratio. The minimum requirements vary for the different production stages or purposes. For early growth (including weaners) and lactation, more Ca and P is required than for growing and finishing. Mg, ~~K~~, Na and Cl are usually given at levels sufficient to meet the requirements.

The requirements of trace elements are defined as minimum and maximum levels, as the elements are toxic above certain concentrations.

Important trace elements are Fe, Zn, Mn, Cu, Se and I. The requirements can usually be met, but Fe is given by injection to suckling piglets. ~~Copper and zinc~~ Cu and Zn can be added to the feed ration of pigs in a quantity higher than the actual production requirements, ~~needs~~ in order to make use of the pharmacological effects and the positive effects on production performance (auxinic effect). However, European (i.e. Directive 85/520/EEC and Regulation 1334/2003)and national rules have been adopted, establishing maximum concentration levels in livestock feeds; for example in Italy, regarding additives in feeds, which place~~s~~ limits on the addition of copper and zinc, in order to reduce the quantity of these two metals in animal slurry.

Vitamins are organic substances that are important for many physiological processes, but can usually not (or not sufficiently) be provided by the pig itself and therefore have to be added to the pig's feed. There are two types of vitamins:

- fat soluble vitamins: A, D, E, K
- water soluble vitamins: B, H (Biotin) and C.

Vitamins A, D, E and K are supplied on a regular basis, but B-vitamins, H and C are supplied daily, as the animal cannot store them (except B12). There are minimum requirements for the concentration of vitamins in pig feed, but the requirements of pigs are affected by many factors, such as stress, disease and genetic variation. To meet the varying requirements, feed producers apply a safety margin, which means that usually more vitamins are supplied than necessary.

Other substances might be added to pig feed to improve:

- production levels (growth, FCR): zootechnical additives e.g. antibiotics and growth promoting substances
- quality of feed: e.g. vitamins and trace elements
- technological characteristics of feed (taste, structure)
- the environmental impact of animal production: digestibility enhancers, gut flora stabilisers and additives that favourably affect the environment.

Organic acids and acid salts can be added for their effect on digestibility and to allow a better use of the feed energy.

Enzymes are substances that enhance the chemical reactions of the pigs' digestive processes. By improving digestibility, they increase the availability of nutrients and improve the efficiency of metabolic processes. [201, Portugal, 2001] [506, TWG ILF BREF 2001].

The use of antibiotics as a feed additive in animal feed for growth promotion is prohibited in the EU (Regulation No 1831/2003/EC).

Most concern about the environmental importance of feed additives in intensive animal production is related to the use of the antibiotics, and the potential risk of the development of drug-resistant bacteria. Their application is therefore strongly regulated and registration of these substances is organised at a European level. Authorised antibiotics and growth promoters might be used through the entire growing period, as they are not considered to leave any residues in the body as their metabolites do not cross the intestinal barrier. [201, Portugal, 2001]
A report has been drafted on the aspects of the use of antibiotics in the animal production sector by the European Commission, [385, EC 1999] and summarised in a note by Dijkmans [32, Vito, 1999]. It that reports that the resistance of disease-spreading bacteria against a wide range of antibiotics is a growing problem in human medical science. The growing resistance is caused by the increased application of antibiotics in human health science, in veterinary science, and as a feed additive in animal breeding and even for plant protection.
Due to the use of antibiotics in feed, antibiotic-resistant microorganisms might develop in the gastrointestinal tract of animals. Potentially these resistant bacteria can infect infest humans on or in the vicinity of the farm. The genetic material (DNA) can be taken up by other bacterial human pathogens. Potential routes for infection of humans are the consumption of contaminated meat or water, or food contaminated by manure. There may also be a risk of infection of people living near the farm. In several countries, feeding without antibiotics is carried out, such as in Sweden, which has a total ban on all feed antibiotics (including the ones authorised in the EU) and in Denmark which has a total ban on the use of antibiotics in pig feed. In other MSs proposals are under discussion for the total ban on the use of antibiotics. The true effects of antibiotics on feed conversion rates FCRs and on manure production are not agreed internationally. Similarly the environmental effects of antimicrobials are also unknown, e.g. such as the resistance of soil and water, and the consequences for soil and water ecology. Antibiotics still might be administered directly to animals in all MSs, even although they are not used in feeds. [40, NFU/NPA 2001]

2.3.3.2 Feeding systems

There are no uniform systems practised across the whole of Europe for pig feeding. Feeding systems can be linked to with the feeding practice and feeding practice is normally linked to

~~with~~ pig production type. For example in the UK, there are weaner producers who produce pigs of 30 kg from their own sows, fatteners who buy the 30 kg pigs and finish them ~~at about 90 kg~~ and breeder-feeders who have their own sows, breed their own piglets and rear them up to a slaughter weight of 90 – 105 kg ~~finish them at about 90 kg~~. [28, FORUM 2001]

The design of the feeding installation depends on the structure of the pig feed. Liquid feeding is most common, but for example in Spain and Belgium, dry feeding is applied in most ~~98 %~~ of the farms, and mixtures are also applied. Regimes are *ad libitum* or restricted. For example in Italy the following variations apply ~~applies~~ [412, Italy 2001]:

- on mating/gestating sows: 80 % of farms operate liquid feeding; the other 20 %, dry feeding;
- farrowing sows and weaning piglets are (it is assumed) given dry feed;
- growing/finishing pigs are liquid-fed on 80 % of farms, 5 % are fed with wetted feed, feed supplied as dry plus drinkers on 5 %, and dry-fed on 15 %.

~~As far as feeding systems are concerned, descriptions are were given in [44, IKC 1993] and [26, Finland 2001].~~

The feeding system consists of the following parts:

- feeding trough
- storage facility
- preparation
- transport system
- dosage system.

Feeding can vary from fully hand-operated to fully mechanised and automated systems. Troughs of different designs are used and provisions are made to prevent pigs from lying in the trough. Feed is often delivered dry ~~and~~ or mixed with water. Different dry feeds are purchased to allow a mixture close to the required nutrient content. Dry feed is usually transferred from the storage to the mixing machines by augers.

Distribution varies with the type of feed. Dry feed can be transported by a feeding cart or mechanically through tubes or spiral feeders in the same way as liquid feed. Liquid feed is pressed through a plastic tube system, in which the pressure is built up by the pumping system. There are centrifugal pumps, which can pump large amounts and can achieve about 3 bar. Displacement pumps have a lower capacity, but are less limited by pressure build up in the system.

Liquid feeders consist of a mixing container, where the feed is mixed with water, and tubes to distribute it to the animals. The rationing of the mixture can be done automatically based on weighing the exact amounts or can be computer controlled, mixing according to the feeding plan and substituting feed when necessary. Liquid feeding can also be operated manually by weighing and mixing the required amounts. In Austria, fatteners are fed with a ‘soup’ of water and 30 % of dry matter coming from maize, soy, mineral raw materials and a raw fibre carrier called ‘pig fibre’. [373, UBA 2009]

Feed can be delivered to animals by using mechanical drops with calibrated boxes (drop-feeding) that are fed by auger. The system is used for group-housed animals and for individual housing (crates). Group-housed sows can be individually fed with computerised sow feeders (see section 2.3.1.1.4) that identify the animals by an electronic identifier (chip) clipped at the ear or neck. ~~In some loose-housing for mating and gestating sows, feeding machines consist of a central feeding station detecting a label around the neck of the sow. The machine identifies the animal and supplies the required amount.~~ The amount and supply are adjusted to allow the sow to eat as much and as often as it needs.

Individual feeding stalls are frequently provided in pens for group housing. Animals are free to roam in pens and enter the feeding stations, where they are individually fed, in order to reduce aggression between animals at feeding time. Self-locking or manual locking individual feeding stalls can be used for activities such as vaccination, estrous detection, artificial insemination, etc.

With trickle feeding, feed is delivered via a top auger to individual feeding points, in small portions, at regular intervals over the feeding period. The feed is delivered at a speed similar to the eating speed of animals (typically 80 – 180 g/minute), to discourage changes of feeding position, with consequent differences of feed intake within the group ('bullying'). Short stalls (at shoulder) normally equip the troughs.

The choice of feeding system is important as it can influence daily weight gain, FCR and percentage feed loss [39, Germany 2001]. In Table 2.13, the effect of different feeding systems on the feed conversion rate (FCR) and daily gain of pigs is reported.

Table 2.13: Effect of feeding system on weight gain, FCR and feed losses

Feeding system	Daily weight gains (g/day)	Feed conversion per kg LW	Losses %
Dry feeding	681	3.05	3.23
Automatic mash dispenser	696	3.03	3.62
Liquid feeding	657	3.07	3.64
Source: [39, Germany 2001]			

Liquid feeding has the potential to reduce production costs by a net amount of around EUR 0.15 (GBP 0.135) per kg of dead weight and is an effective management tool for controlling the presence of salmonella in pigs at slaughter, but has no significant effect on measures to reduce the environmental impact. [289, MLC 2005] [290, Univ. of Newcastle 2002]. On the other hand, the variability of ingredients in liquid feeding could make it difficult to guarantee the ingestion of properly balanced feed.

2.3.3.3 Drinking water supply systems

For the supply of drinking water, a great variety of drinker systems are available. Drinking water can be obtained from deep wells or from the public supply system. The quality of the water is the same as that for human consumption. In some MSs, installations have a main reservoir with a large capacity and possibilities for disinfecting treatment; inside each house or sector there may be smaller reservoirs to allow water distribution along with medicines and/or vitamins. Different water supply systems are used, such as pipettes, shells or canals. [413, Portugal 2001]

Inadequate water intake can lead to reduced feed intake, poor daily gain and poor feed conversion. Significant losses may occur due to a recreational use of water. In turn, water waste may significantly increase the volume of produced slurry. [423, Gill P. 1989]

Drinking water can be distributed to the animals in different ways:
- ~~by nipple drinkers in the trough~~
- ~~by nipple drinkers in a cup~~
- ~~by a biting nipple~~
- ~~by filling the trough.~~

- nipple drinkers and bite drinkers
- push-tube drinkers
- trough with bowl and pallet

- trough on constant levels.

Animals easily learn how to use nipple and bite drinkers. Notable waste can occur, but they are easily kept clean. Push-tube drinkers generally match wet feeders or can be laid above small troughs. Troughs allow fast animals adaptation and limited waste, but, since the contained water is easily contaminated, are not very widely used.

The drinkers functionality depends essentially on:

- the design
- the capacity
- the number of animals per drinker system
- the height from the ground. [357, France 2010]

By pressing a nipple with its nose, the pig can make water run into the trough or the cup. Minimum requirement capacities vary from 0.75 – 1.0 litres per minute for piglets and 1.0 - 4.0 litres per minute for sows.

A bite ~~biting~~ nipple gives water when the pig sucks on it and opens a valve. The water will not run into a trough or cup. The capacity of the bite nipple is 0.5 – 1.5 litres per minute.

Watering the animals by filling the trough can vary between a simple tap to a computerised dosing system measuring exactly the required volume.

2.4 End-of-pipe techniques for air cleaning ~~treatment~~

A group of techniques that have recently become of frequent use in some Member States consists of ~~the~~ ‘end-of pipe’ air cleaning systems ~~treatment of the air~~ applied in mechanically ventilated animal housings. Air cleaners operate on different removal principles (physical, biological and/or chemical). Currently, different types of wet scrubbers and biofilters are applied, individually or in combinations, for the removal of pollutants from the exhaust air of animal housings; they differ in applicability and removal performance (see related data in Table 4.120).

2.4.1 Wet scrubbers

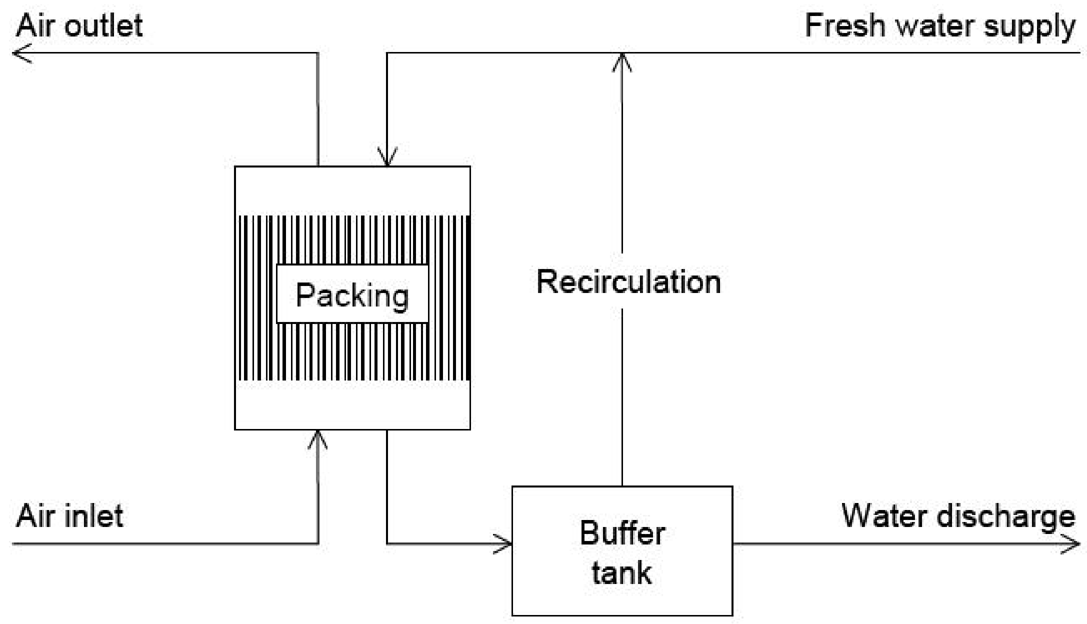
To TWG: Some information has been moved from this section to Section 4.9

These techniques have the potential to achieve a combined removal of ammonia, odour and particulate matter with high removal efficiencies that are not achievable with other techniques.

Modifications to the feed formulation and adaptation of the housing system may prevent from meeting increasingly stringent emission regulations and targets. This can be seen as a driving force for the development and use of air cleaning systems; even if these techniques do not improve the indoor climate of the animal houses.

~~The adaptations of feed and of housing system seem to be unable to meet the increasingly stringent emission regulations and targets that livestock operations must comply with. This can be seen as a driving force for the development and the use of air treatment techniques.~~

The basic principle of wet scrubbers is that a spray of water cleans the air that streams at 90 degrees through a filter (see Figure 2.32)



Source:[13, Melse 2009]

Figure 2.32: Schematic representation of an air scrubber

The main purpose for the use of scrubbers in livestock rearing is ammonia abatement, but scrubbers also have a positive effect on dust ~~reduction a lesser effect~~ and odour (except in the case of acid scrubbers), also with reduction efficiencies that have been proven (e.g. German test results for air cleaning technologies). [424, VERA 2010]

Two types of wet scrubbers and their combinations are mainly used: 'acid scrubbers', or 'bio trickling filters' (bioscrubbers) and their combinations, e.g. 'multi-stage air cleaning systems', 'combined scrubbers' where different steps are run in a series. Manufacturers deliver either premade modules or custom-made installations to treat 3600 to 7200 cubic metres of air per hour for each cubic metre of filter package. **MOVED TO SECTION 4.9**

In the Netherlands, the wording 'combi-scrubber' is legally used to refer to systems that obtain reductions higher than 70 %, regardless of if these levels are achieved by one single step, or by combining different technical steps.

A wet scrubber, or trickling filter, is a reactor where the air is filtered through a bed of inert material that has a high porosity and a large specific area and is continuously kept wet. The contaminated air is blown through the filter either horizontally (cross-current) or upwards (countercurrent), to produce intensive contact between air and water, enabling the soluble contents to be exchanged from a gas to a liquid phase. A fraction of the trickling water is continuously recirculated, whereas another fraction is discharged and replaced by fresh water. The discharge is automatically managed on the basis of the water conductivity and allows for the removal of nitrogen compounds. Filter thickness varies from 50 cm to 2 metres.

The most important compound that is the object of abatement in exhaust air from animal farming is ammonia. The alkaline properties of ammonia are neutralised by acids, hence in animal farming no alkaline scrubbing is performed, with the consequence that the acid scrubbers are also commonly simply called 'chemical' scrubbers.

In an acid scrubber, the pH of the circulating liquid is kept at low levels by the addition of acid, usually sulphuric acid; the ammonium salt that is formed is removed from the system with the discharge water.

In a bioscrubber or biotrickling filter, the ammonium is removed by bacterial conversion to nitrite (or nitrous acid) and nitrate (or nitric acid). The bacterial population mainly grows as a film on the packing material and is partly suspended in the recirculating water.

Microbes in the biological system need to be regularly fed with oxygen, heat and nutrients (ammonia) to work in optimal conditions. The 'all-in, all-out' production cycles that are typical in animal rearing, apply resting periods between cycles. In these periods, the nutrient supply to the microbes is missing. Eventually, an entire poultry house is generally emptied, but in pig housing, all the sections are emptied at the same time less frequently, hence biological scrubbers are more suitable for pig farms than poultry farms. In addition, poultry houses are typically charged with more dust, litter and feather residues that may lead more frequently to clogging filters
[51, BE Flanders 2010]

Air scrubbers are required in some Member States to comply with maximum air emissions, but they are still costly installations. **MOVED TO SECTION 4.9**

In practice, scrubbers should be designed for treating the maximum exhaust air flowrate. Since maximum airflows do not occur very frequently, scrubbers can alternatively be dimensioned for lower ventilation rates, so that the part of the exhaust air that exceeds the system's maximum load is allowed to be vented untreated through bypasses. In this way, the scrubber size and cost are significantly decreased. Removal efficiency is kept very high and emission loads are only slightly affected; on the other hand, the efficiency of odour removal drops significantly. However, the efficiency of the ammonia removal system also depends on other parameters, including the thickness of the filter package.

An acid scrubber needs approximately 90 litres of water and 3 litres of sulphuric acid to remove 1 kg of ammonia from the air [55, Denmark 2010]. The chemical principle is the following:

~~Ammonium absorption:~~ $2 NH_3 + H_2SO_4 \rightarrow 2 NH_4^+ + SO_4^{2-}$

On average, the odour removal efficiency is considered to be 30 % for acid scrubbers and 45 % for biotrickling filters, where mostly well-soluble, easily biodegradable (in bioscrubbers), or alkaline (in acid scrubbers) compounds are removed.

In addition, particulate matter removal has been reported from air scrubbers at efficiencies ranging from 62 to 93 % for PM_{10} and from 47 to 90 % for $PM_{2.5}$. On the contrary, methane removal is considered negligible. [13, Melse 2009]

The air that is treated in wet scrubbers typically leaves the systems with high levels of humidity, over 95 %. In order to avoid aerosol discharge, drip separators are normally used at the outlets [121, Germany 2010].

Scrubbers can be installed in existing houses ~~stables~~, under the condition that the air should be completely channelled towards a single outlet point and that fans be verified to meet the extra (forced) ventilation capacity that is required to overcome the extra flow resistance that inevitably is introduced by the presence of the scrubber. [51, BE Flanders 2010] The adaptation of existing houses will be difficult and expensive in most cases. In existing houses, the ventilation system is rarely adequate to support a scrubber, since they normally have multiple outlets and an unsuitable original fan design and capacity. The resulting operating costs are also expected to be higher (compared to new houses), because of the difficult optimisation of the modified system.

Periodic maintenance and controls need to be carried out on equipment, workbooks and electronic logs in order to keep the abatement effectiveness, and to allow inspection.

The nitrogen compounds that result from both chemical and microbial processes can be reused as fertilisers in on-field applications. The outgoing water from a bioscrubber can be processed with a further stage of denitrification, where microbial populations convert nitrate compounds into N_2 gas. The reason for this process is to reduce the amount of discharged water, avoiding the production of nitrogen compounds to be eliminated. On-field applications are still developing.

2.4.2 Biofilters

A commonly applied method of treating the exhaust air of animal housings is the use of biofilters. The entire air flow is humidified and led through a filter bed of organic material, such as compost, root wood or wood chips. The filter material is also kept always moist, so that high microbial activity occurs on the film that is formed. The wet microbial film oxidises and degrades the gaseous compounds (ammonia) that are blown through the filter. Odour and dust emissions are considerably reduced. As a side effect, greenhouse gases develop due to the microbial activity; therefore, in general, this technique is suitable to be used in combination with other air cleaning techniques.

2.5 Processing and storage of animal feed

Many on-farm activities involve the processing and storage of feed. Many farmers obtain feed from external producers that~~. It~~ can be readily used or that need only very limited processing. ~~However, On the other hand,~~ Production of the basic feed ingredients is a specialised activity; however, some large enterprises produce the majority ~~part~~ of the basic ingredients themselves and also purchase ~~some additives to produce the feed mixtures~~ premixtures of additives to manufacture their compound feed; this may also be the case for some small and medium-sized enterprises (e.g. in Belgium-Flanders).

The processing of feedstuff consists of grinding or crushing and mixing. Mixing the feedstuff to obtain a liquid feed is often done shortly before feeding the animals, as this liquid cannot be stored for a long period of time. Grinding and crushing are time consuming and require a lot of energy. Other energy-consuming parts of the installation are the mixing equipment and the conveyor belts or air pressure generators used to transport the feed.

Feed processing and feed storage facilities are usually located as close as possible to the animal housing. Feed produced on the farm is usually stored in silos or sheds as dry cereals; gas emissions are then limited to the emission of carbon dioxide from respiration.

Industrial feed can be wet or dry. If dry, it is often pelleted or granulated to allow for easier handling. Dry industrial feed is transported in tanker lorries and unloaded straight into closed silos, therefore dust emissions are usually not a problem.

Driveways and trucks are preferably kept in a zone separate from the animal houses, in order to avoid trucks entering the clean zone and, therefore, reducing the risk of contamination (biosecurity measure).

There are many different designs of silos and materials used. They can be flat at the bottom to stand on the ground or conical, resting on a supporting construction (see Figure 2.33). Sizes and storage capacities are numerous. Nowadays, they are often made of polyester or similar material and the inside is made as smooth as possible to prevent residues from sticking to the wall. For liquid feed, materials (resins) are applied to resist low pH products or high temperatures.

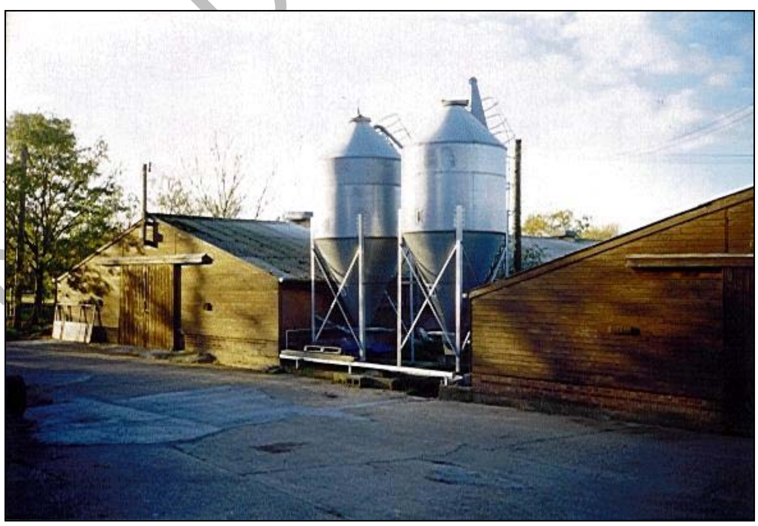


Figure 2.33: Example of silos built close to the broiler houses (UK)

Silos are usually a single construction, but there are (Italian) designs on the market that can be transported in parts and assembled in the farmyard. Silos are usually equipped with a manhole for internal inspection and a device for air venting or for relieving overpressure during filling.

Equipment is also applied for aeration and the stirring of the contents (especially soya) and to allow smooth transport of the feed out of the silo.

2.6 Collection and storage of manure

Manure is an organic material, which supplies organic matter to soil, together with plant nutrients (in relatively small concentrations compared to the mineral fertilisers). It is collected from animal housing and stored either as ~~liquid~~ **slurry** or as a **solid manure**. Manure from pig housing and dried poultry manure are ~~intensive livestock is~~ not necessarily stored on-farm and particular care is taken ~~in broiler units,~~ because of the risk of spreading disease.

Slurry consists of excreta produced by livestock in a yard or a building, mixed with rainwater and wash water and, in some cases, with waste bedding and feed. Slurry may be pumped or discharged by gravity.

Solid manure includes farmyard manure (FYM) and consists of material from litter-covered ~~straw~~ yards, dried poultry manure from belt removal systems in hen housing, excreta with a lot of straw in it, or solids from a mechanical slurry separator. Most poultry production systems produce solid manure, which can generally be stacked. Pig manure is often handled as slurry.

Slurry can be stored for long periods of time in a deep pit storage ~~facility under the animal house~~ within the housing (e.g. Belgium-Flanders, UK, Ireland), but in general, inside storage is temporary and slurry ~~manure~~ is regularly removed to an outside storage facility in the farmyard for further management ~~processing~~.

Storage facilities are usually built with ~~have~~ a minimum capacity to guarantee sufficient storage until further manure handling is possible or allowed (see Table 2.14), due to regulations implementing the Nitrate Directive 91/676/EC. The required minimum storage capacity and prohibition period (for landspreading of manure) differ between Member States, but also depend on the soil texture and manure management system. For slurry storage, in particular, the required capacity has to allow for a minimum freeboard, ~~and for rainfall, depending on the type of slurry storage applied~~ to take into account the addition of atmospheric precipitations. The capacity depends on the climate, on the regulatory requirements ~~in relation to with the periods in which the application to land is not possible or not allowed in relation to with~~ on the size of the farm (animal numbers) and the amount of slurry/manure produced and is expressed in months rather than in m^3. The storage time depends on the field crops, fertiliser requirements, vegetation period, and storage capacity. The field crops and fertiliser requirement differ between farms and management options and may change every year.

The storage time can range from some days to some months depending on the management system. Across Europe, a storage capacity of 4 – 6 months is generally applied for solid manure. In the northern regions (SE, FI), even larger storage capacities may be applied.
A storage capacity of 6 months seems to be a common standard in Europe for slurries; although, shorter (CZ, ES, PL) and even longer storing times are also common (NL, DK, DE, SE, FI).
[264, Loyon et al. 2010]. A ~~commonly used storage period is 6 months and~~ large slurry tank can easily contain 2 000 m^3 and up to 5 000 m^3 ~~or more~~.

Table 2.14: Storage times of poultry and pig manure in a number of Member States

EU Member State	External manure storage capacity ([1]) (in months)	Climate
Belgium	~~4 – 6~~ **3** (farmyard manure) **9** (slurry) **9** (poultry manure when birds are kept indoor all the time	Atlantic/Continental
Luxembourg	**5**	Atlantic/Continental
Denmark	**6 – 9**	Atlantic
Finland	**12** (except for deep litter)	Boreal
France	**3 – 4** **6** (Brittany)	Atlantic
Germany	**2 – 4** (solid manure, according to good agricultural practice) **6 – 10** (slurry, depending on soil and climatic conditions)	Continental
Austria	**6** 4	Continental
Greece	**4**	Mediterranean
Ireland	**6**	Atlantic
Italy	**3** (solid manure) **5** (slurry)	Mediterranean
Portugal	**3 – 4**	Mediterranean
Spain	**3** or more	Mediterranean
Sweden	**8 – 10**	Boreal
Netherlands	**7** ~~6~~ (slurry) length of production cycle (poultry)	Atlantic
UK	4 **6**	Atlantic
Slovenia	4 or 6 (depending on the region)	Continental

([1]) Deep litter of loose-housed poultry systems is considered ~~as~~ storage space.
Source: [537, EC 1999] ~~[~~. [500, IRPP TWG 2011] [574, Umweltbundesamt 2011]

Table 2.15 reports examples of national regulations implementing the Nitrate Directive 91/676/EEC, which bans manure application during certain periods of the year.

Table 2.15: Examples of national regulations prohibiting manure application during certain periods of the year

EU Member State	Regulation for manure application
Germany	Ban for slurry application between 01.11 and 31.01 on tillage land, and between 15.11 and 31.01 on grass land
Austria	Ban for slurry application between 15.10 and 15.02 on soils without vegetation, and between 15.11 and 15.02 on soils with vegetation
Netherlands	Ban for slurry application between 01.09 and 31.01 on sandy and loosen soils, and between 15.10 and 31.01 on clay and peat soils under grass
Ireland	Ban for slurry application between 15.10 and 12.01 till 31.01, depending on the region
France	Ban for slurry application between 01.11 or 15.11 to 15.01, depending on the type of cultivation
UK	Ban for slurry application between 01.09 and 31.12 for sand and shallow soils under grass, and between 01.08 and 31.12 for sand and shallow soils under tillage; in other soils, between 15.10 and 15.01 under grass, and between 01.10 and 15.01 under tillage
Denmark	It is not allowed to spread slurry between 15.10 and 01.02

Source: ([1]) [442, Hansen et al. 2008] [574, Umweltbundesamt 2011]

Manure can have a relatively high dry matter (DM) content ~~dm-content~~ (dried poultry manure and litter-based manure) or can be a mixture of manure, urine and cleaning water ~~called~~ (slurry). Facilities for the storage of manures are normally designed and operated in such a way that the substances they contain cannot run out ~~escape~~.

In France, compact solid pig manures are stored or composted on bare land or a dungheap pit after a short storage period (2 months) in order to minimise risks of leaches. A dungheap may be obligatory, depending on the water protection regulation. [259, France 2010] In other countries (e.g. Denmark), solid pig manure must be stored on impermeable surfaces (concrete etc.) with a liquid collection system and covered.

The design and the building material for the manure storage facilities to be used often have to be chosen in accordance with the specifications and technical requirements laid down in guidance notes or in national or regional regulations (e.g. Germany, UK, Belgium). The regulations are often based on water regulations and their objective is to prevent any contamination of ground or surface water. They also include provisions for maintenance and inspection and procedures to follow in case of an escape of slurry, liquid manure which could pose a risk of damage to water resources.

Spatial planning of on-farm manure storage is regulated for the protection of water sources and to protect sensitive objects (surface or underground water bodies) in the vicinity of the farm against odour. Regulations prescribe minimum distances, depending on the number of animals and on site-specific features, such as prevailing wind direction and the type of neighbouring objects.

The following types of manure storage systems are commonly applied:

- storage for solid and litter-based manure
- aboveground or underground slurry tanks
- earth-banked stores or lagoons (waterproofed with an impermeable liner: clay or plastic a geomembrane).

The storage of FYM on floors made of concrete (with or without side walls) is the most common option applied throughout Europe. However, field storage is still often practised. Measures for leakage control and a separate storage of seepage water are applied only in few countries (CZ, IT, DE, FI). Slurries, or the liquid fraction of slurry after separation, are usually stored in tanks made of concrete or steel panels above or below ground. Also deep pit storage within the housing and external lagoons is still are commonly in common used. Only in some Member States (e.g. NL, DK) the storage facilities are generally covered by tents or roofs. Open storage is still very widespread along with the use of natural or artificial crust forming. [264, Loyon et al. 2010].

2.6.1 Poultry manure

Most **solid manure** is produced in buildings and may be temporarily stored in the same building. until The manure is cleared out approximately once a year for laying hens in systems without frequent removal, and after at the end of the rearing production cycle, i.e.: for broilers and other poultry raised for meat.

- approximately annually for laying hens in deep pit and deep litter systems
- every 6 weeks or so for broilers (Table chickens)
- every 16 to 20 weeks for turkeys, and every 50 days for ducks.

For example, in the Netherlands the majority (89 %) of layer and pullets poults houses have a storage capacity of 1 week, the rest having 10 % have a capacity of 1 year and 1 % of up to 3 years (deep pit systems).

Some (laying hen) egg production systems allow for more frequent, almost daily removal of manure.

For free range systems, birds have access to the outside environment and some droppings will be deposited in fields.

Laying hens produce droppings with typical moisture contents of 80 – 85 %., ~~reducing to around 70 – 75 % with regular daily mucking out.~~ The initial moisture content is likely to be mainly influenced by nutrition, whilst the drying rate is affected by the external climate, house environment, ventilation and the manure handling system. ~~Some systems enable manure to be dried to lower moisture contents in order to reduce ammonia emissions. Some laying hens use a litter-based system similar to broilers.~~ In-house manure collection and storage systems are described in Section 2.2.1. Different types of manure can be obtained:

- Wet manure. This has a dry matter content of approximately 30 – 35 % % and is produced with regular daily removal.
- Pre-dried manure, with a dry matter content of up to 35 – 50 %. This can be produced, for example, in systems where manure belts are fitted with pre-drying ventilation.
- Dry manure or littered manure. These are produced in houses with deep pits or from littered houses. The manure has a high dry matter content of up to 80 %.

Where manure belts are used, manure collection is rather frequent (usually every 1 to 3 days) because the weight of the accumulating droppings may hamper the performance of the removal system.

In large installations, it is not unusual for the collection, further off-farm storage and management of the manure to be done by contracted third parties.

In Table 2.16, factors for dimensioning the storage for manure from laying hens production in France, ~~that are in use in France, are~~ simply related to rearing surfaces ~~and~~ are reported.

Table 2.16: Factors for calculating the storage dimensions of laying hen manure in France

Manure collection	Characteristic of manure		Characteristics of storage			Storage 4 months		Storage 6 months	
	Type of manure	**Dry matter (%)**	**Storage type**	**Wall height (m)**	**No of walls**	**Surface (m^2)**	**Volume (m^3)**	**Surface (m^2)**	**Volume (m^3)**
Gutters	Slurry	< 20	External pit				23.3		35.0
Belt, no drying	Wet droppings	20 – 27	External pit				23.3		35.0
Belt, no drying	Wet droppings	20 – 27	Covered flat deck	1.5	4	20.0		24.0	
Belt, no drying	Wet droppings	28 – 35	Covered flat deck	2	4	11.2		14.0	
Belt, no drying	Pre-dried droppings	36 – 65	Covered flat deck	1.5	3	6.7		10.0	
Belt, drying	Pre-dried droppings	> 65	Covered flat deck	No		6.7		10.0	
Belt, drying	Pre-dried droppings	> 65	Covered flat deck	1.5	3	4.7		7.0	
Belt, drying	Pre-dried droppings	> 65	Covered flat deck	3.0	3	3.3		5.0	
None	Droppings	< 20	Pit below building			Storage surface = surface of the building			
None, air drying	Pre-dried droppings	35 – 65	Pit below building			Storage surface = surface of the building			
Source: [257, France 2010]									

In Belgium-Flanders, the factors used for estimating the manure storage capacity for the rearing of pullets and laying hens are the following [255, BE Flanders 2010]:

- pullets (wet manure): 10 m^3/1 000 animal places
- laying hens (wet manure): 30 m^3/1 000 animal places.

Moved from Section 4.11.2.1

Broilers ~~(Table chickens)~~ are typically bedded on wood shavings, sawdust or straw which, when combined with bird droppings, produces a fairly dry (around 60 % dry matter) friable manure, usually ~~often~~ referred to as poultry litter. Sometimes shredded paper is used as a bedding material. Peat is the most used litter material for broilers and turkeys in Finland. Poultry litter quality is affected by temperature and by ventilation, drinker type and management, feeder type and management, stocking density, nutrition and bird health. Systems are described in Section 2.2.2.

Turkeys are typically bedded on wood shavings or straw (also mixed together) to about 75 mm depth, which produces a litter of around 60 % dry matter, similar to broiler litter. Systems are described in Section 2.2.3.

Ducks are normally bedded on straw applying the greatest ~~highest~~ amounts of ~~in~~ finishing accommodation. A lot of water is spilled and this results in a litter relatively low in dry matter (around 25 ~~30 %~~ dry matter). [425, Defra 2010] Systems are described in Section 2.2.3. However, in France, meat ducks are mainly raised on fully-slatted floor, where slurry is produced. ~~and~~ ~~Storages~~ Stores are dimensioned in relation to the surfaces where the ducks are reared, with a capacity of 300 m^3 or 450 m^3 per 1 000 m^2 of surface, for storing times of 4 or 6 months respectively. ~~as in Table 2.15.~~ [257, France 2010]

~~**Table 2.15: Storage dimension for duck slurry**~~

~~Duck production~~	~~Type of manure~~	~~Storage type~~	~~Storage: 6 months~~	~~Storage: 6 months~~
~~Foie gras (1000 places)~~	~~Slurry (less than 40 l of water per duck)~~	~~Pit~~	~~200 m^3~~	~~300 m^3~~
~~Meat (1000 m^2)~~	~~Slurry~~	~~Pit~~	~~300 m^3~~	~~450 m^3~~
~~*Source*: [257, France 2010]~~				

To store broiler manure for four months, which comes out of a building of 1 000 m² (150 tonne of manure/year), a surface between 48 and 80 m² is needed, depending on the height of the side walls and their number (3 or 4). [259, France 2010].

Poultry droppings, with dry matter over 65 %, are also simply stored (France) on land close to where they will be spread. A waterproof cover, but permeable to gases, must be applied.

2.6.2 Pig manure

Slurry may be stored beneath fully-slatted or partly-slatted floors of livestock buildings. The storage period can be quite short but may extend to several weeks, depending on design. In-house manure collection and storage systems are described in Section 2.3. Where further storage is required or where treatment is applied, slurry is usually sluiced by gravity or pumped to collection pits and/or directly to slurry stores. ~~In some cases a~~ Slurry tankers are also ~~is~~ used.

The factors used in Belgium-Flanders for calculating slurry storage volume, corresponding to a storage period of six months, are presented in Table 2.17.

Table 2.17: Factors used for calculating storage dimensions for pig slurry, for a storage period of six months, in Belgium-Flanders

Animal physiological state	m^3 per animal place ([1])
Fattening pigs	0.8 (0.6 if water saving devices are used)
Farrowing sows	2.3
Empty sows, pregnant sows, boars	2.0
Gilts	1
Piglets	0.2 – 0.4
([1]) For a storage period of 9 months, the values are increased by half. *Source*: [255, BE Flanders 2010]	

Differences in similar factors are common because the amount of manure or slurry produced is variable due to the following aspects:

- yields and efficiency of the animals;
- amount and type of bedding;
- spillage of drinking water, depending on the type of drinkers;
- water used for cleaning and sprinkling;
- differences in diet that may cause a higher consumption of drinking water and thus also higher urine production.

Where significant quantities of straw are used for bedding, **solid manure** is created which may be removed from buildings regularly (every 1, 2 or 3 days) or (in deep-strawed buildings) after batches of pigs are moved every few weeks. Solid manure and FYM are typically stored in concrete yards or on field on sites ready for spreading to land.

Many pig farms produce both **slurry** and **solid manure**. There is a tendency to collect the excreta and urine separately to reduce ammonia emissions from housing (see Chapter 4). They may be mixed again in storage if further treatment of the slurry and/or the solid manure is not required ~~[201, Portugal, 2001]~~. [506, TWG ILF BREF 2001]

Over the entire chain of operations that are carried on the farm, the benefits and disadvantages deriving from the choice of one system or another are compared in Table 2.18.

A ~~piggery~~ pig farm of 550 fattening places, producing 1 tonne of manure/place per year (460 kg/m^3 approximately), will need a 400 m² dungheap pit with 3 walls 1 m high to store the manure for four months. [259, France 2010]

Table 2.18: Advantages and limitations of solid manure and slurry-based systems

	Straw-based systems	**Slurry-based systems**
General Pros	• More flexible long-term use of houses • May reduce odour problems • Perceived as more animal friendly	• Generally more easily mechanised • Lower labour inputs during housing
General Cons	• More floor space required per animal • Straw not always easily available/high cost • Potentially higher ammonia and GHG emissions, due to the straw • Higher dust emissions associated with litter	• Specialised storage and handling equipment required
Transport and storage	• Flexible, as almost any farm bulk trailer or lorry can be used to transport solid manure • Manure can be stored simply in field heaps, until land is available for spreading • Few straw-based units produce only 'solid' manure	• Almost always at the unit itself and must be in dedicated facilities • Slurry is usually moved in purpose-made tankers or via piped systems • High work rates can be achieved by pumping slurry through pipelines and trailed umbilical or hose-reel irrigation systems
Fertiliser value and spreading attributes	• FYM provides a greater amount of added organic matter, as well as plant nutrients • Spreading is generally favoured on uncropped land or to grass-land before re-seeding, because of potential smothering problems • No 'closed' spreading periods in NVZs	• Slurry can more readily be applied to growing arable crops and grassland in early spring and summer • Greater supply of nitrogen available to plant in the season of application
Animal welfare	• Straw is widely perceived to enhance the welfare of pigs • Provides thermal insulation, thermal comfort 'buffering' and a more 'natural' environment • Specific welfare concerns about outdoor production systems with straw-bedded shelters, despite the (apparent) natural pig-friendly image • Straw must be of good quality, without presence of fungus	• European welfare directives increasingly discourage fully-slatted systems. • ~~However, there is little confidence that~~ Poor management of partly-slatted rearing systems ~~can be used universally in the UK, because~~ entails problems of fouled lying areas • Fully-slatted systems have been outlawed as new accommodation in some EU Member States
Industry image	• The perception of better pig welfare provides some pig-meat marketing advantages • Little evidence that a higher price is achieved	• Producers see slatted floor housing as the most cost-effective way to produce
Labour requirements	• Advanced mechanisation of straw and solid manure handling • Activity involved in straw procurement and additional manual tasks • Typically, one extra full time workman is required for a straw-based breeder/finishing pig unit of about 250 – 300 sows	• Slurry-based housing systems have lower labour requirements at all stages of production • General husbandry tasks are generally more readily accomplished in housing layouts associated to slurry
Flexibility of buildings	• Straw-based houses are more flexible, but reconversion to a slurry system would be costly • Many buildings could readily be adapted to other farm uses (simple modifications to general purpose farm buildings)	• Most slurry-based pig buildings have low internal ceiling heights, and could not be readily adapted to mechanised straw-based manure handling • Natural ventilation could also be difficult to provide in many houses, because of lack of head room
Source: [253, ADAS 2002]		

2.6.3 Storage systems for solid and litter based manure (FYM)

Solid and litter-based manures Manure collected in solid form is normally transported by frontloader or (chain) belt systems and stored on an impermeable concrete floor that is placed outdoors in the open or in closed barns.

The storage system store can be equipped with side walls to prevent slurry or rainwater from leaking away. These constructions are often attached to an effluent tank to store the liquid fraction separately. The tank may be emptied regularly or the contents may be moved to a slurry storage store. Two-story Double storey constructions are also applied that allow the liquid fraction of manure and rainwater to drain into a basin underneath the manure storage area (Figure 2.34).

Figure 2.34: Storage of littered manure with separate containment of the liquid fraction (Italy)

Temporary field heaps are created prior to field application. They may remain in place for a few days or for several weeks. up to several months and Since soil and water contamination can occur, depending on the rainfall and the length of storage, heaps should be located sited where there is no risk of direct run-off entering watercourses or infiltration of liquid fractions seeping from heaps to groundwater. Member States regulate temporary heaps in different ways by requiring covers (NL, FI, FR), regulating the length or the season of the storage (NL, BE, UK), the quantity and maturity of the manure (AT), or demanding a yearly rotation of the place of storage (NL, AT, UK, FR). Some examples of the requirements applied in different Member States for temporary field heaps are presented in Table 2.19.

Table 2.19: Examples of requirements applied for temporary field heaps in different Member States

Member State	Requirements
Austria	No requirement to cover manure heaps. Storage is only permited for manure treated at high temperatures (after a period of about 3 months) and the amount should correspond to the fertilising demand of the site (about 25 t per ha). Mandatory yearly change of the the storage place
Belgium	From 2013, solid manure may not be stored on the field during the closed period for landspreading (November 15th – January 15th) and for a maximum of one month (prior to spreading) outside the closed period
France	Location of temporary manure stacks must change every year and, in this case, there is no need of solid impermeable floor with drains. Mandatory cover only for poultry manure
Netherlands	For temporary manure storage of two weeks or more, an absorbent layer of at least 0.15 metres, with at least 25 % of organic matter (e.g. peat) is requested. Contact with rainwater has to be prevented as much as possible (in practice this means the use of a plastic sheet). Requirements may be applied at local level for temporary manure heaps of less than 2 weeks. (same protection as for older heaps)
Denmark	Solid manure heaps must be covered and have to be stored on sites with impermeable surface covers (concrete etc.) and liquid collection facilities
United Kingdom	Covering of the heaps is not always required. Criteria as to where, and for how long, temporary field heaps may be located are normally applied.
Source: [500, IRPP TWG 2011]	

~~Only one Member State (Finland: General Agricultural Environment Protection Scheme under their Agri-Environment Programme to which about 90 % of farmers belong) currently requires farmers to provide a cover for such heaps.~~

2.6.4 Storage systems for slurry

2.6.4.1 Slurry storage in tanks

Slurries are pumped from the slurry pit or slurry channel inside the housing to an external slurry storage. Slurry is transported via a pipeline or by means of a slurry tank, and can be stored in slurry tanks above or below ground.

Slurry storage systems consist of collection and transfer facilities. Collection facilities are structural-technical facilities (channels, drains, pits, pipes, slide gates) for the collection and piping of liquid manure, slurry and other effluents, which may include ~~including~~ the pumping station. Valves and sliding gates are important devices to control (back) flow. Although single valve designs are still common, double valve (sliding gate) designs or the blocking of valves are recommended for safety reasons.

The structural-technical facilities intended for homogenisation and transfer of liquid fractions ~~manure~~ and slurry are called transfer facilities.

Emissions of gases are produced by the slurry stores surface and are released into the atmosphere at varying rates, partly dependent on the air flow across the surface. Slurry stores may be covered to reduce the emissions that escape to the atmosphere at a rate that depends on the level of tightness that covers provide. Other options for reducing emissions from slurry stores include the reduction of the surface area (appropriate store design), the use of floating covers (different types), and the formation of a natural crust on the slurry store surface.

Underground ~~Below-ground~~ tanks and reception pits are often used to store small amounts of slurry and can act as reception pits to collect slurry before it is pumped to a larger slurry storage system ~~store~~. They are usually square constructions built from rendered reinforced blocks, reinforced concrete made on site, ready-made concrete panels, steel panels or glass fibre-reinforced plastic (GRP). With blocks or bricks, extra attention is paid to the impermeability by applying elastic coating or lining. Occasionally, larger storage systems ~~stores~~ are constructed with reinforced concrete or block-work, or concrete panels; they may be aboveground or partly underground ~~below ground~~, and are often rectangular in shape.

Underground ~~Below-ground~~ tanks made of reinforced concrete elements ~~with capacities up to 3000 m^3~~ are the most common storage systems for slurry in cold regions. They are built with a common capacity of 5 000 m^3 or circular and partly underground of up to 3 000 m^3 in ~~like~~ Finland. ~~[188, Finland, 2001]~~

Aboveground silos are storage tank concrete constructions; the base plate is *in situ* concrete cast; walls are concrete or steel (corrosion-resistant coating or painting). The structure may have a covering lid. Manure flows are made over the rim and below the slurry surface, and unloading pipes are fitted with at least two safety devices. Sliding gates and pumps are easily accessible.

A typical size is 1 500 m³, within the range of 500 – 5 000 m³ and is ~~realised by~~ made up of round buildings of 20 m of diameter or by boxed buildings with a height of 5.2 m. A freeboard of at least 0.5 metres is always left when filling the store ~~storage~~.

Underground silos are built *in situ* with the same characteristics as the aboveground concrete silos, but obviously the base is not observable from the outside.

THE DELETED TEXT (BELOW) HAS BEEN MOVED TO SECTION 4.12.5

~~In Germany, leakeage checks are mandatory, but construction in areas under water protection is not allowed. The investment that is needed is greater than aboveground and is in the range of EUR 45 – 60 per m^3.~~

~~In some Member States (DE, DK, BE) Germany a cover is mandatory and as a minimum can be a floating crust whilst other cover designs depend on the building construction and can be made of granules, a floating plastic sheet, a membrane, a roof or a tent.~~

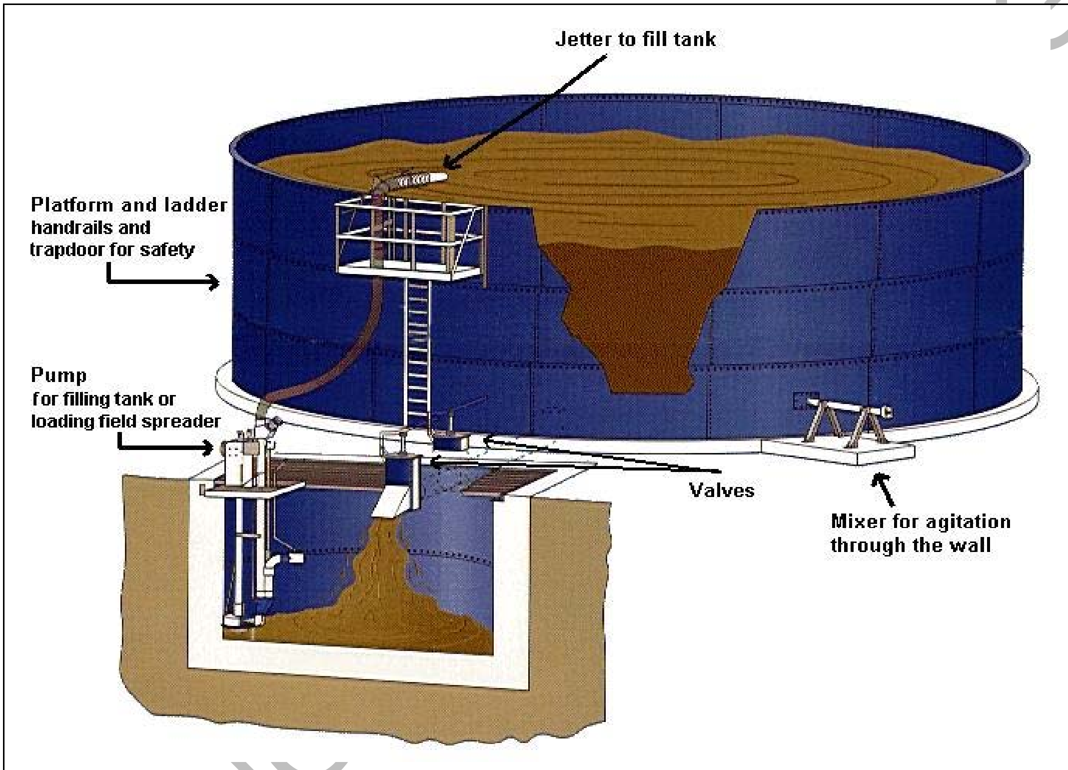
~~Building costs vary from EUR 30 to EUR 39 per cubic metre. The durability of buildings is considered to be around 30 years, hence yearly total costs are around EUR 3.2/m^3 per year. [426, Germany 2010]~~

~~Buildings in water protection areas need a periodical leakage control below the base plate (circumferential drainage system). Then, the responsibility of the operator manager is the regular checking of the density of containers (10–12 years), pipes, and fittings and of the operativeness of the control equipment. In these cases, costs increase to EUR 35 – 45 for investment and EUR 3.0 – 3.5 for the total annualisation, due to the additional control measures. [214, Germany 2010]~~

Aboveground circular stores ~~storage systems~~ ~~stores~~ are normally made from curved steel panels or concrete sections. Steel panels are coated to protect them from ~~against~~ corrosion, usually by coating them with paint or a ceramic layer. Some concrete panel stores may be partly ~~below~~ underground. Normally, all stores ~~storage systems~~ ~~stores~~ are built on a properly designed reinforced concrete base. In all tank designs, the thickness of the base plate and the suitability of the seal at the joint of the wall and the tank base are very important features to prevent slurry from leaking ~~away~~. A typical system has a reception pit with a grid cover next to the main store. A pump is used to transfer slurry to the main stores ~~storage system store~~; the pump can be fitted with an extra outlet to allow slurry to mix ~~mixing~~ in the reception pit. Aboveground slurry tanks are filled via a pipe with an opening above or below the slurry surface. Since gas and odour emissions are different if the slurry is pipe-loaded from above or below the surface of the stored slurry, authorisations (e.g. Finland) may require that tanks are filled by a pipe below the slurry surface. Prior to discharge or being stored ~~filling~~, slurry ~~liquid manure~~ is normally thoroughly mixed with hydraulic or pneumatic stirring systems to agitate sediment and floating matter and to obtain an even distribution of the nutrients. Slurry mixing can be carried out using propellers, either mounted through the side of the store ~~storage store~~ or suspended from a gantry over the top of the store ~~storage~~ ~~store~~. Stirring can cause sudden releases of large quantities of noxious gases and proper ventilation is required, particularly if done in housing.

The main store ~~storage~~ ~~store~~ may have a valve outlet to allow for emptying back to the reception pit, or alternatively it can be emptied using a pump located in the store ~~storage~~ ~~store~~ (Figure 2.35).

Slurry tanks can be open or may be covered with a natural or artificial layer of floating matter (such as granulated materials, straw chaff or floating membrane) or with a firm cover (such as a canvas or concrete roof) to keep rainwater out and to reduce emissions.



Source: [404, Tank manufacturer 2000]

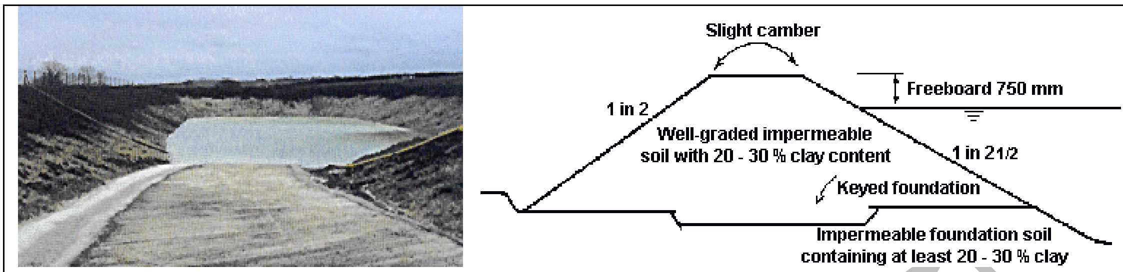
Figure 2.35: Example of aboveground slurry tank with an underground ~~belowground~~ receiving pit

2.6.4.2 Slurry storage in earth-banked ~~storages~~ stores or lagoons waterproofed with a geomembrane liner

Earth-banked walls or lagoons are commonly applied in many MSs to store slurry for extended periods of time. Their design varies from simple ponds without any provisions to relatively well monitored storage facilities with thick plastic sheets (e.g. polythene or butyl rubber) on the bottom, protecting the soil underneath. The capacity of a lagoon depends on the slurry production of the enterprise and the operational requirements. ~~There are no specific measures characterising a typical lagoon when it is constructed only for storage purposes [201, Portugal, 2001].~~ Slurry can be mixed using pumps or propellers.

The soil used to construct an earth-banked store ~~storage~~ ~~store~~ needs special properties to ensure stability and low permeability, which usually means a high clay content. These stores ~~storages~~

~~stores~~ are built below, above or partly-below/partly-aboveground level. Earth-banked stores ~~storages stores~~ also include a minimum allowance for freeboard (see Figure 2.36). These installations are not authorised in some Member States if they are not equipped with a system of a ~~waterproofing~~ geomembrane liner (i.e. double-layered plastic geomembrane) and with leakage control. [257, France 2010]



Source:[402, ADAS 2000]

Figure 2.36: Example of geomembrane-lined ~~waterproofed~~ earth-banked slurry store, and design features

In case the slurry is not transported by pipelines but by ~~or with~~ a vacuum tank, ~~and for this~~ earth-banked stores can be equipped with an access ramp. The earth-banked store is often fenced off to prevent accidents.

On some farms located in Mediterranean countries ~~(e.g. in Italy and Portugal)~~, a multiple earth-banked store ~~storage store~~ or lagoon system is used. In Portugal, these systems are normally designed and operated to comply with treatment requirements; although, due to legal restrictions on the discharge of treated slurry, a considerable number of farms use lagoons to storage the slurry before spreading it on land as fertiliser. ~~Nevertheless, as the slurries have to remain in these systems for a considerable period of time, the lagoons can also serve as storage [201, Portugal, 2001]~~. In each store, ~~storage store~~ slurry is held for a certain period of time for aerobic or anaerobic degradation. ~~Finally, slurry is removed from the last slurry storage store for further processing.~~ Transport between the different stores ~~storages stores~~ can be done mechanically or by gravity, using the natural height differences of the site. Under the agroclimatic conditions that are typical in Spain, large storage capacities are required (storage for more than 6 months). The size of the storage system does not allow the installation of abatement techniques for the control of gaseous emissions.

2.6.4.3 Slurry storage in flexible bags

For the short-term storage of relatively small amounts of slurry, flexible bags are used. They may be moved from site to site (when empty). Larger bags may be sited more permanently in earthworks to provide longer-term storage. Such stores ~~storages stores~~ are filled and emptied via ~~by~~ pumps and the larger stores ~~storages stores~~ can ~~be provided with~~ have mixing tools installed. ~~mixer units~~.

2.7 On-farm manure processing

To reduce nitrogen (and phosphorus) losses from livestock manure, it is important to manage the manure effectively so as to improve utilisation of the nutrient content, thereby reducing mineral fertiliser requirement.

Currently, where farmers have insufficient land to accommodate the manure being produced they are encouraged to export manure to their neighbours or look to reduce livestock numbers, in order not to exceed the limits imposed by the Nitrate Directive (91/676/EEC) concerning the amount of nitrogen that can be applied on-farm. Movement of manure is an added cost and a potential source of odours and problems with biosecurity, odour and road safety, whilst but at the same time, reduction in livestock numbers may not be economically viable.

Some countries have opted to encourage the treatment of livestock manure so as to improve its manageability and utilisation. It is important that such manure treatments do not increase losses of gaseous forms of nitrogen (NH_3, N_2O, NO_X), or the formation and release of other (greenhouse) gases: CO_2 and CH_4. [203, ADAS 2005]

FYM is not often treated, but in some cases it is composted, dried and or treated anaerobically. The treatment of slurry is of minor importance if we look on Europe as a whole. In some southern countries (e.g. IT, CY, PT), solids separation in pig slurry is seems of practical importance, possibly because of the value ascribed to the organic matter recovered. Amongst all other treatment techniques, anaerobic and (to a lesser extent) aerobic treatments have some use. Interest in anaerobic digestion has increased due to the rewards of biogas production. [264, Loyon et al. 2010]

In general, treatment techniques for liquid fractions have little or no relation with the rearing of poultry.

Manure treatment prior to or instead of landspreading may be performed for the following reasons:

1. to recover the residual energy (biogas) in the manure;
2. to reduce odour emissions during storage and/or landspreading;
3. to separate the solid phase of slurry;
4. to decrease the nitrogen content of the manure to prevent groundwater and surface water pollution as a result of landspreading, and to reduce odour;
5. to allow easy and safe transportation to distant regions or to other sites for application in other processes;
6. to reduce the gaseous N and C losses from manure at housing, storage and landspreading.

The latter two systems are implemented in regions with a nutrient surplus.

1. Using the energy value of manure: Organic compounds are converted to methane by the anaerobic biological digestion of manure. The Methane can be recovered methane is normally and used as a fuel in combined heat and power production systems (CHP) for the production of electricity to sell in the public network and of heat to use at the farm or in the neighbourhood.

In this way, the use of fossil fuels that would be needed to produce electricity and/or heat can be reduced.

2. Reduce odour emissions during storage and/or landspreading of manure: Manure may give rise to Odour nuisance that occurs during or after the storage of manureThis can, in some instances, be reduced by aerobic or anaerobic treatment or by additives. [506, TWG ILF BREF 2001] [174, Belgium, 2001]

3. Separation of the solid fraction: The solid phase, which is rich in phosphorus, can be separated from the liquid phase, which is rich in nitrogen, allowing for a more adequate and environmentally balanced use of nutrients, especially in order to avoid over-fertilisation with phosphorus.

4. Reduction of the nitrogen content of manure: Nitrogen compounds in manure (organic, ammonium, nitrites and nitrates) can be converted to the environmentally-neutral nitrogen gas (N_2). Techniques to reduce the nitrogen content of manure are:

- incineration: oxidises nitrogen compounds to nitrogen gas and to NO_X;
- biological nitrification/denitrification: bacteria convert organic and ammonium nitrogen to nitrites and nitrates (nitrification) and further still to nitrogen gas (denitrification);
- chemical oxidation: supplementing manure with oxidising chemicals and increasing the temperature and pressure also results in the oxidation of nitrogen compounds.

On the other hand, reducing the N content of manure also means that there is less N to be used as a fertiliser (compared to raw manure). This amount of N that can no longer be provided by manure then has to be supplied through the addition of mineral fertilisers, with consequent indirect emissions associated with the production of the mineral fertiliser, including N_2O emissions.

5. Processing of manure for the marketing of manure compounds and/or easy and safe transportation: The water content and volume of the manure are can be reduced. In addition, pathogenic microorganisms present in the manure can be deactivated inactivated (this prevents the spreading of livestock pathogens to other regions), and odour emissions are is reduced. Sometimes different manure compounds are separated for market reasons. The following techniques given below are often used.

- Mechanical separationFiltration: separation of solid fractions (see above). (most of the P) and liquid (most of the N) fractions.
- Ammonia stripping: after pH adjustment, NH_3 is stripped from the manure fluid and captured.
- Membrane filtration: after pre-filtration, reverse osmosis is used to separate nitrogen, potassium and phosphorous salts from water.
- Chemical precipitation: addition of MgO or $MgCl_2$ and H3PO4 results in the precipitation of magnesium ammonium phosphate.
- Evaporation: liquid manure is heated or depressurised, the resulting vapours are then condensed and further treated.
- Drying: solid manure is dried by ambient air or animal body heat (see also Section 4.5), by burning fossil fuels, or by burning biogas from manure fermentation.
- Lime treatment: increasing the pH results in the separation of NH_3, an increase in temperature and a volume reduction.
- Lime treatment: lime (CaO or CaO-MgO) is added to the manure, with the aim of reducing the amount of pathogens. The resulting increase of increasing the pH and temperature also leads to an increased release results in the separation of NH_3 in the air an increase in temperature and a volume reduction.
- Composting: the volume of the solid pig manure fraction or poultry manure is reduced, and also many pathogens are inactivated by the temperature increase caused by the biological degradation of organic material. The (composting of poultry litter is, for example, used in the mushroom industry in Ireland). Under certain conditions, this technique increases the potential for NH_3, N_2O, CO_2 emissions.
- Pelletising: dried manure may be converted to fertiliser pellets, but with a notable expense for energy consumption.
- Nutrient recovery: processes can be applied to recovering both phosphorus and ammoniacal-N. The process is expensive and the commercial value of the final product is unlikely to cover the investment and operational costs. A modified precipitation process

~~has been considered where phosphorus is a serious local pollutant. In the Netherlands and Germany treatment plants have been set up.~~

- Reedbeds and constructed wetlands: there offer on-farm options to remove nutrients from livestock manure as it passes through the vegetative filter. There may be gaseous losses of N in various forms. ~~There are unresolved questions about the quality of the water filtering out of the system and also how long the system lasts without maintenance or replacement.~~ Some of these solutions may have limited effectiveness (with waters of variable quality) or may have a limited lifetime. They are relatively inexpensive to construct but may require a large area of land to provide an adequate level of treatment. [203, ADAS 2005]
- ~~Woodchip corrals are offered in Ireland and Scotland as a cheap and effective alternative to housing and concrete yards for overwintering cattle and sheep. Recent evidence, however, suggests that provision must be made to line the pads and collect the effluent arising following the percolation of dung and urine through the woodchip matrix.~~

6. Reduction of N and C losses from housing, storage and landspreading of manure: This is achieved by acidifying slurry with inorganic acids (mainly sulphuric acid). By regulating (reducing) the pH of slurry a reduction in both ammonia and methane emissions is achieved. If performed during in-house storage, slurry acidification prevents these emissions occurring in the slurry management chain.

In some EU countries, manure treatment is frequently done by mobile units run by contractors moving from farm to farm (e.g. Denmark, Belgium and France). [256, Lemmens et al. 2006] [259, France 2010] [533, Baltic Sea 2020 2011]

Other innovative techniques are ~~also~~ under study, with promising results. ~~and development is promising. and is seeking economic or environmental benefits.~~ These techniques are not yet available for on-farm ~~available~~ application at reasonable prices ~~yet~~, but are worth mentioning:
[256, Lemmens et al. 2006]

- Membrane filtration: after pre-filtration, reverse osmosis is used to separate nitrogen, potassium and phosphorus salts from water
- Struvite (magnesium ammonium phosphate) precipitation: the addition of MgO or $MgCl_2$ and H_3PO_4 results in the precipitation of magnesium ammonium phosphate, with the consequent possible recovery of both phosphorus and ammoniacal-N. In the Netherlands and Germany, treatment plants based on this technique have been set up
- Evaporation
- Algae culture
- Activated carbon filtration
- Ion exchange
- Activated carbon filters
- Wet oxidation.
- ~~lime treatment.~~

In the following sections some ~~of the~~ ~~treatment~~ techniques used for manure treatment are discussed in more detail, including also a description of the associated cross-media effects.

2.7.1 Mechanical separators

Natural settling is the easiest and cheapest way to achieve solid-liquid separation of liquid manure (slurry). It is performed in a thickener, in batch or continuous mode. Most thickeners consist of a container that is cylindrical at the top and conical at the bottom. Slurry is added to the top of a thickener and the solids settle at the bottom of the conical part from where they can be removed. The process is time consuming [203, ADAS 2005] Thickeners can also be operated continuous in mode, where the slurry is added continuously, while solid and liquid fractions are removed at the same rate. [594, Agro Business Park 2010]

Mechanical separation is the process that separates ~~from~~ the raw slurry into the solid fraction ~~(fibre)~~ (high concentration of organic matter and P at around 10 – 25 % of the mass) and the liquid fraction (high concentration of N at around 75 – 90 % of the mass) ~~that were around 10 % and 90 % of the initial volume respectively used on some pig farms to convert raw slurry into separated fibre/solids (ca. 10 % by volume) and a separated liquid (ca. 90 % by volume)~~.

Common techniques include:~~ are given below.~~ [219, Netherlands 2010]

Simple manure separators: These have a metal sieve mesh in either a flat (screen) or circular form (bow sieve, centrifuge). The sieve mesh is mechanically cleared ~~from~~ of solids using pressure rolls, brusher rolls or scrapers. The separation efficiency is mediocre, since only small amounts of solid manure are separated.

Screw and auger separators: These are equipped with a metal or plastic screw that forwards the liquid manure into a cylindrical metal housing fitted with small openings. The far end of the housing is closed using a piston that provides sufficient back pressure. A correctly set back pressure can ensure this process is capable of removing about 25 (pig ~~hog~~) to 40 % (cattle) ~~percent~~ of the phosphate from the liquid manure.

Sieve belt presses: These are large industrial separators ~~that~~ often used ~~find application~~ in waste water treatment plants. Manure is fed between two parallel conveyor belts, one of which is permeable to water (the sieve belt). By means of pressure rolls, the liquid fraction is separated from the solid fraction. To establish a reasonable separation efficiency (50 to 75 % phosphate removal), additives such as metal salts (i.e. $FeCl_3$) and/or charged polymers (polyamide and polyacrylamides) are applied. Sieve belt presses are designed to yield a clarified stream that is free of solids, which is important if the final goal of the purification is to discharge the effluent to the environment. Because of their size, sieve belt presses are suitable for regional/collective application and are not used as part of a mobile installation.

Centrifuges and decanters (vertically placed centrifuges): These operate on the principle of centripetal forces ~~that are~~ generated through the movement of the installed sieve drums. These separators are capable of efficiently removing small particles of high specific density, and are used to de-water sludge in waste water treatment plants. Without chemical additives, centrifuges can obtain phosphate removal efficiencies of 50 – 70 % for both hog and cattle manure. The drawback of these machines is the robustness, the capital cost and the high operating cost. Centrifuges can be incorporated in mobile equipment for the separation of manure.

Sieve belt presses, screw and auger presses and centrifuges are susceptible to large debris present in the manure that is treated. These separators, therefore, may need an additional pre-separator and/or cutting machine. Screw/auger presses and centrifuges are more susceptible to wear, ~~caused by~~ as a result of the presence of sand, than the other types of separators. All manure separation equipment have set points that can be manually adjusted, ~~leaving margin to optimise~~ allowing optimisation of the separation efficiencies.

In general, mechanical separation is performed as a first process step ~~often practiced~~ prior to the aerobic treatment of pig slurry, to reduce the oxygen requirement in the further treatment, and thus the energy needs and the economic costs.
[257, France 2010]

Composting ~~of~~ the solid fraction can be applied afterwards to enhance its ~~the~~ value~~ of the solid product~~. Aerobic treatment can be applied to further reduce nitrogen surplus in the remaining liquid fraction or this fraction is applied to land without further treatment. The solid fraction can also be treated by 'methanisation' (biogas production). Similar systems to those applied on-farm also exist for centralised facilities. [264, Loyon et al. 2010]

2.7.2 Aerobic treatment of liquid manure

On some pig farms, aerobic treatment is used to reduce odour emissions from pig slurry by a biological oxidation of volatile compounds, to improve the properties of liquid manure and, in some cases, to reduce its nitrogen content without drying and solidifying the manure.
~~Manure contains large quantities of nutrients for plants and micro-organisms, as well as microbes that are capable of utilising these nutrients.~~ The air conducted into liquid manure starts aerobic decomposition, which produces heat, and as a result of the aeration, bacteria and fungi which use oxygen in their metabolism multiply. ~~The main products from the activity of micro-organisms are carbon dioxide, water and heat. Liquid manure is composted by means of aeration (liquid composting) or by mixing it with an adequate amount of litter. The mixture can then be composted in a stack or drum. In aeration, aerobic treatment is used to improve the properties of liquid manure.~~

Aerobic digestion implies a biological oxidation of volatile organic compounds that enables a reduction of odour. The associated heat generation can also provide pathogen control. ~~creates a reduced odour and is pathogen-free. In theory the product is a more useable product but the operational costs are high, due to energy requirements.~~ Only well designed and well managed technologies, providing optimum aeration levels, can achieve effective odour and pathogen reduction. ~~Where aeration is excessive, ammonia might develop, whereas, at low pH and other sub-optimal conditions, methane and nitrous oxide may be produced.~~

The efficiency of the technique mainly depends on the retention time, the aeration intensity and whether the process is continuous or in batch mode. The variation of the raw slurry characteristics can highly affect the treatment efficacy. Inadequate control of the aeration process may lead to the increased release of sulphides and other odorous organic compounds, when anaerobic conditions resume, or to volatilisation of NH_3 when the aeration intensity is too high. In batch treatments of a short duration, the rapid increase in biological activity in the first days can exceed the aeration capacity, resulting in an excessive foam release and increased NH_3 loss. Following an incomplete aerobic treatment, anaerobic conditions can occur in the stored slurry, with a consequent formation of nitrous oxide or denitrification of nitrates to nitrogen gas (N_2); in this way, N losses in the range of 50 – 70 % are reported. [203, ADAS 2005]

Pilot schemes have been developed in France, the Netherlands and Portugal. In Norway and Germany, aerobic thermophilic stabilisation is ~~being~~ used to reduce pathogens and to lower C/N ratios in slurries. In the UK, aeration has been used to reduce odour and to homogenise slurry, but it is not common practice. Community facilities for aerobic digestion form an integral part of the NVZ Action Programme in parts of Brittany and Belgium. [203, ADAS 2005]

The main types of biological aerobic treatment system, that have been identified in France, are the following:

- intermittent aeration without any separation;
- intermittent aeration followed by sedimentation of aerated slurry;
- mechanical separation of raw slurry followed by intermittent aeration of the liquid fraction and sedimentation of aerated slurry;
- mechanical separation of raw slurry, followed by intermittent aeration of the liquid fraction, and the mechanical separation of the aerated slurry with the addition of chemical flocculating agents or polymers.

It is reported that the use of continuous aerobic treatments is declining in favour of intermittent processes (aeration in sequential batch reactors – SBR). The air supply is achieved mostly by surface aerators or by fine bubble diffusers. [264, Loyon et al. 2010]

Cross-media effects associated with the aerobic treatment of liquid slurry are linked to the effort of changing the conditions from anaerobic to aerobic by aeration, which is energy intensive. The temperature increase generated by aeration and the possible presence of anaerobic zones lead to a high risk of increased methane emissions, compared to a well covered conventional anaerobic storage. Moreover, if anaerobic/aerobic transition zones arise as a result of the process, N_2O emissions will occur.

In some cases, aerobic treatment is performed to slurry stored in lagoons.[204, IMPEL 2009]

2.7.3 Aerobic treatment of solid manure (composting)

The composting of solid manure is a form of controlled aerobic degradation ~~treatment~~ which can occur naturally in farmyard manure heaps, and that produces a more ~~stable matter~~ stable product, with consistent chemical properties than the initial ~~manure~~ material. A high porosity (30 – 50 %) is required for sufficient aeration. In addition, for manure to be composted has to contain a certain amount of water, to ensure the development of microorganisms. [257, France 2010]

Temperatures in the compost heap are between 50 and over 70 ºC and kill most of the pathogens, thus cleansing the product. A significant water loss also takes place at high temperatures, and compost with a dry matter of up to 85 % can be produced.

Suitability for application depends on the structure of the manure, but requires a minimum dry matter content of 20 %. On farm, the manure is usually arranged in windrows and monitored for temperature and moisture, ~~that~~ which cannot be excessive ~~which~~ as this would inhibit~~s~~ aeration. Effluent, dirty water or slurry can be added to dry windrows. The compost is turned regularly using a windrow turner or other available farmyard machinery. On the largest units, composting vessels can be used instead of windrows. For farmers, the main advantage of composting is the significant reduction in the volume of material to be transported and spread. Other advantages include efficient pathogen kill, the concentration of nutrients and a lighter, friable and more homogeneous product, which is easier to handle than untreated manure.

~~Typical FYM heaps do not satisfy the requirements for thorough composting. With controlled application, manure is composted in stacks of a size that suits the aerobic conditions and the use of machinery. Best results are obtained by using well-chopped straw and solid manure in the right proportions and by controlling temperature and moisture content in long narrow 'windrows'.~~

Composting can also be performed in a barn (e.g. pre-dried poultry manure). Specific systems have been developed that consist of a combination of tanks with aeration and stirring equipment to enhance the fermentation process and containers or boxes for further fermentation and drying. Co-composting is when solid manure is composted with ~~the~~ other wastes (green~~s~~ wastes usually) and, in general, it is applied to achieve an optimal C/N ratio of around 25 – 30, in order to ensure an efficient composting. The best results are obtained by using well chopped straw and solid manure in the right proportions in long narrow windrows. A biological inoculum can be added to start up the degradation.

~~Properly composted solid manure significantly reduces the volume of material spread to land and the amount of odour released. For easier handling, pelletising is applied in addition to composting.~~

~~Nitrate N is immobilised by bacteria in carbon compounds in the more stable, slowly released organic form. The organic fraction has a reduced odour and NH_3 emissions during landspreading, preventing mineral N from leaching into surface and groundwaters. [203, ADAS 2005]~~ **MOVED TO SECTION 4.12.4 (Environmental benefits)**

Generally the physical properties, the stability, and the organic form of the contained nitrogen make compost a good fertiliser and soil improver. ~~in general~~. **MOVED FROM SECTION 4.12.4**

However, during composting, NH_3 emissions will occur. The significant losses of ammoniacal nitrogen, as well as carbon, reduce the fertiliser value of the product with respect to the nutrient content.

Additionally during composting, there is a high risk of creating anaerobic zones in the mass, from where CH_4 and N_2O are released.

Composting installations handling animal manure, which is an animal by-product, must be approved under Regulation 1069/2009/EC, in accordance with Article 24. The requirements applicable to composting installation, concerning hygiene, operational parameters and standards of derived products are set out in Article 10 and Annex V of Regulation 142/2011/EC.

2.7.4 Anaerobic treatment

Anaerobic digestion ~~is used on some pig farms to reduce odour emissions from~~ of pig slurry~~. The process~~ is carried out in a biogas reactor in the absence of oxygen, and consists of the methanogenic anaerobic decomposition of organic matter. Most, but not all, organic matter can be decomposed via this fermentation process without chemical or physical pretreatment. It produces useful methane and a stabilised residue (digestate) that can be applied to land as a soil conditioner and a source of nutrients (e.g. N and P) with improved availability for the plants, compared to the raw slurry.

Processes can vary with temperature, process management, operating time and substrate mixing. In practice, the mesophilic process (at 33 – 45 °C) is most common for digestors at the farm scale. In large reactors, where the aim is generally to reduce the retention time (and thus the ~~needed~~ reactor volume required), the thermophilic ~~process is applied in large reactors~~ process is applied, which runs at a higher temperature (50 – 55 °C). In the case of joint biogas plants (shared by several farmers), the thermophilic process is also preferred, in order to ensure the return of better sanitised substrates. ~~less used but in theory,~~ It also reduces the time required for ~~of~~ digestion. [257, France 2010]

On the other hand, bacteria are very sensitive to temperature changes and this sensitivity increases with higher temperature. Moreover, higher temperature shifts the equilibrium of nitrogen towards more ammonia production, which renders the process vulnerable to ammonia inhibition (too much ammonia is toxic for methanogenesis bacteria).

Anaerobic digestion with biogas production has benefits in terms of manure treatment, as it reduces greenhouse gas emissions, producing a digested product with reduced pathogen levels and less odour during ~~on~~ spreading. ~~whilst~~ The resulting biogas (approximately 50 – 75 % methane and 30 – 40 % carbon dioxide) provides a source of renewable energy~~. The final products of digestion are biogas (approximately 50 – 75 % methane and 30 – 40 % carbon dioxide) and a stabilised treated slurry. The biogas~~ which can be used for heating, and/or for generating electricity. Application may include the use of mechanical separators, usually after digestion.

The anaerobic digestion can be carried out either in intermittent or continuous mode. Continuous systems are the most common. Here the digester is charged daily with fresh pig slurry, ~~matter~~ for an average residence time of the mass of 50 – 60 days, whilst an identical volume of degradated matter is expelled daily. The plant is in operation throughout the year; the accruing biogas is produced continuously and may be stored in gas bags and used in combined heat and power production units. The waste heat of the biogas engine is used to heat up the digester. The biogas can also be upgraded for a direct use into the natural gas grid, or for producing a fuel that can be used for mobile applications.

In discontinuous systems, the digester is charged with various substrates and it is hermetically closed. During the fermentation (2 to 4 weeks), the matter is degraded and the digester is then emptied. In this system; the volume of produced biogas and its composition are not constant over time. [257, France 2010]

Slurry tanks are used as pre-containers for the biogas facilities, but not all the contained manure may go to treatment, and some or all ~~otherwise~~ may be directly spread on land. [373, UBA 2009]

Slurry is ideally suited ~~apt~~ to anaerobic digestion, ~~because~~ as it is ~~of its~~ easy to transfer and use, ~~manipulation, mixability and~~ it has a high load of fresh bacteria, it is easily manipulated, it can be used to dilute other substrates, and it has a strong buffer effect (stabilises the pH), which facilitates the bacterial reactions and ensures an environment stability where the reaction takes place. Solid wastes and manures are conveniently used to raise the dry matter content (which increases the yield and reduces heating needs), but conversely incur an additional cost for the increase in energy use. ~~are more expensive and~~ A more difficult ~~to~~ mixing of ~~in~~ the mass has been reported for dry matters higher than 10 % in the digester. [257, France 2010]

High initial installation costs are a major deterrent~~, unless subsidised.~~ but can be overcome with targeted renewable energy incentives or other rewards for the multiple environmental benefits of the anaerobic digestion. ~~Around 2000 digesters in Germany and 45 farm digesters in Denmark have been reported. [203, ADAS 2005]~~

2.7.5 Anaerobic lagoons

The text of this section was reorganised and integrated, also taking into account information given in the original BREF.

~~The~~ Lagoons serve as a store for pig slurry and waste water, as well as for the biological anaerobic treatment of the slurry. Covered lagoons can also be used for biogas production, under ambient temperature conditions. Lagoon systems offer odour abatement, a long-term reservoir for liquid manure, and high flexibility for the timing of field applications of the manure.

The treatment system may involve mechanical separation of the solids and the subsequent separate treatment of solids and liquids. A mechanical separation of slurry before entering the lagoon system can avoid the capacity of the lagoon being reduced by sedimentation of sludge, and also reduces the organic matter in the liquid part. The liquid fraction is put into a settling basin or lagoon, from which it overflows or is pimped into the anaerobic lagoon system (often 3 to 5 earth-banked structures). The lagoons serve as storage for waste water, as well as for the biological treatment.

~~The treatment system may involve mechanical separation of the solids and subsequent separate treatment of solids and liquids.~~

The capacity of the lagoon that first receives the slurry is reduced over time by the sedimentation of the solid fraction, and needs to be desludged from time to time. A prior mechanical separation of the slurry can limit the content of solid fraction that is introduced into the system.

The liquid from the second lagoon is sometimes used for flushing the pits under the pig pens. It is usually believed that the second lagoon provides a certain degree of protection against disease-carrying organisms carried over from the first lagoon.

The anaerobic conditions inside the lagoon can lead to emissions of gases like methane and nitrous oxide that are related to the lagoon's surface size. The slurry and air temperature affect the biological activity in the lagoon, by changing the type of predominant methanogenic bacteria between psycrophilic and mesophilic. Methane emissions are also affected by the wind turbulence, that removes CH_4 from the lagoon surface and the atmospheric-boundary layer just above.

Large surfaces, especially in warmer climates, are subjected to high evaporation rates and a consequent increase of salt content in the slurry. This effect needs to be taken into consideration at the time of landspreading and for the relationship with the biological activity.

The solid fraction can be used for landspreading; ~~and~~ the liquid part after the anaerobic treatment ~~Waste water that comes out of the treatment~~ may be directly applied to land, but in a few cases it achieves ~~reaches~~ the required levels of acceptability to comply with local legal requirements for discharge into watercourses. [364, Portugal 2010]

~~This treatment~~ This technique is applied for pig slurry in warmer climates (e.g. Greece and Portugal). In Greece, all pig slurry must be treated to comply with local ~~certain~~ legal conditions, whereas in Portugal, legal conditions only apply to discharges to watercourses.

Designs are site-specific: for example, in Italy, covers are also used to collect biogas.

2.7.6 ~~Pig~~ Manure additives

Under the generic denomination of manure additives are a group of products made up of different compounds that interact with the manure, changing its characteristics and properties. These products are applied to the pig manure in the pits. The following effects are, the most common reasons for applying additives and are described to different degrees in the label of every product:

1. a reduction in the emission of several gaseous compounds (NH_3 and H_2S);
2. a reduction of unpleasant odours;
3. a change in the physical properties of the manure to make its use easier; ~~to its use~~
4. an increase in the fertilising value of the manure;
5. a stabilisation of pathogen microorganisms.

Usually, ~~the~~ items 1, 2 and 3 are the main reasons for their use at a farm level. Below, ~~the~~ techniques 1 – 5 are detailed.

1. Additives for reducing the emission of several gaseous compounds. The decrease in gaseous emissions achieved through its use (mainly NH_3 and H_2S) is one of the most interesting yet controversial points. It~~s~~ has been well documented that up to 90 % of the N produced by ~~the~~ pigs is in the form of ~~as~~ urea. When the urease produced by faecal microorganisms comes into contact with urea, the following reaction occurs:

$$CO(NH_2)_2 + 3\ H_2O \rightarrow 2\ NH_4 + HCO_3^- + OH^-$$

coupled with the following equilibrium reaction NH_3/NH_4^+:

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

One mole of urea may generate two moles of ammonia. The hydrolysis of urinary nitrogen (urea) to ammonia is rapid. Urea spread on a concrete floor starts releasing NH_3 in 2 – 2.5 minutes. [277, Ji-Qin et al. 2000].

This reaction is highly influenced by temperature and pH, for example, under 10 °C or at a pH below 6.5 the reaction stops. Acid addition to lower the pH and the addition of urease inhibitors to prevent the hydrolysis of urea both offer a strategy for significant control of ammonia emissions from livestock facilities, thus increasing the fertiliser value of slurry.

2. Additives for reducing unpleasant odours. Several types of additives, with different characteristics, may be employed for reducing odours from manure: masking, blocking, absorbing agents, microbiological agents, and chemical additives.

Odour results from the mix of different compounds under anaerobic conditions. More than 200 substances involved have been identified as causing odours, such as:

- volatile fatty acids
- alcohols (indol, skatole, p-cresol, etc.)
- H_2S and derivatives
- ammonia
- other N compounds (amines and mercaptans).

There is A huge variation in the proportion and concentration of odour agents exists, every substance depending on the type of farm, nutrition and nutritional management, and climatic conditions. This could explain why additive effectiveness is not always predictable at the farm level. in many instances the effectiveness of these compounds against odours could not be proven under farm conditions.

Unfortunately, confusion takes place between odour nuisance and ammonia.
Ammonia, due to its high perception threshold, contributes to the odours emitted by the livestock buildings, but odours may persist even in the total absence of ammonia. [257, France 2010]

The characteristics, advantages and disadvantages of each type of additives are summarised in Section 4.12.12.

3. Additives for changing the physical properties of the manure. The objective of these additives is to make the manure easier to handle by changing the physical properties of the manure, and result in an increase in manure flow and the elimination of superficial crusts. In particular, these additives may have an effect on dry matter content and viscosity of the manure; however, these effects were not demonstrated in every comparable case.
are probably the most used and their effects are well known. Their use results in an increase in manure flowing, an elimination of superficial crusts, a reduction of solved and suspended solids and a reduction in the stratification of the manure.

Their application might make the cleaning of the manure pits easier, and thereby might shorten the cleaning time required and allow a savings in water and energy consumption. Moreover, since the manure is more homogeneous, it eases improves the manure's agricultural use (better dosing).

4. Additives for increasing the fertilising value of the manure. As a consequence of the use of additives for reducing NH_3 emissions (e.g. pH modification), higher levels of N are retained in the manure.This effect is in fact derived from the reduction in NH_3 emissions, thereby keeping this N retained in the manure In many cases, this is through the an increased synthesis of the microbial cells (use of microbiological agents), giving higher levels of organic nitrogen.

5. Additives for stabilising pathogens microorganisms. There are many different microorganisms in manure, part of these contribute to the gaseous emissions and odours. It is also possible to find faecal coliforms and salmonella and other pig or poultry pathogens, viruses, eggs of flies and nematoda in the manure.

Usually, the longer the storage period, the higher the decrease in pathogens, because of the different requirements of temperature and pH. The pH decreases within the first month of storage (from 7.5 to 6.5 because of the microbial synthesis of volatile fatty acids) which has a negative effect on pathogen~~s~~ survival. Some of the manure additives have been designed to control the microorganisms ~~them~~, especially the eggs of flies.

THE TEXT ORIGINALLY PLACED HERE HAS BEEN MOVED TO SECTION 4.12.12, FOR COMPLEMENTING THE DESCRIPTION AND ASSESSMENT OF THE CANDIDATE BAT

<u>Overall efficacy of manure additives and farm use.</u> Nowadays, there are many manure additives on the market, with different characteristics and purposes; but their ~~the~~ efficacy has not been demonstrated in every case. Information concerning the performance and applicability of different additives is presented in Section 4.12.12. One of the main problems is the lack of standard techniques to test and analyse the results. Another problem with their use is that many trials have only been developed under experimental conditions in laboratories and not on-farm, where large ~~big~~ variations in nutrition, the management of nutrition, pH and temperature can be found. Besides this, there is also sometimes a huge volume of manure to be mixed with the additive in a pit or lagoon, and the results achieved often depend a lot more on the mixing efficiency than on the lack of efficacy of the additive. Improving the flow characteristics seems to be strongly related to ~~with~~ a good mixing.

Many products are offered for pig production (more than 80 according to a survey carried out by the IFIP), for indoor application, as well for external storage units and for spreading. Products for pig housings show results more or less controversial in term of efficiency in relation to ammonia, and the same is true for additives that are proposed for poultry breeding. <u>[257, France 2010]</u>

In the Czech Republic, manure additives are a national BAT, but ~~it is scientifically confirmed that~~ the efficacy of products must be validated on a case-by-case basis. <u>[287, Jelínek et al. 2007]</u>

Only recently have biological inoculums appeared on the market for use in broiler production. The product is pulverised directly on the litter. ~~, showing~~ These show interesting results in more flexible litter and lower releases of ammonia in the buildings. <u>[257, France 2010]</u>

The efficacy of every compound is highly dependent on the correct dosing, right timing and a good mixing. In some cases, a small effect has been observed of an increase in the fertilising value, but this effect is related to the type of crop, the time of application, and dosing.

It must ~~has to~~ be highlighted that in many cases the effects on human or animal health or other environmental effects by using additives are not known and this, of course, limits their applicability. <u>[405, Tengman C.L. et al. 2001]</u>

2.7.7 Impregnation with peat

Liquid manure can be converted into solid manure by mixing it with peat. There are mixers for this purpose, which makes this method quite usable in practice. Straw or sawdust can also be used as litter material, ~~but~~ although Finnish work has shown that peat absorbs water and ammonia more efficiently and also prevents the growth of harmful microbes. This method has been recommended, especially on farms in Finland where the storage capacity of the liquid manure tank is not adequate to accommodate all the liquid manure produced ~~but~~and where building a new tank is not considered profitable. Peat manure is a good soil improvement material for soil that is poor in humus. Liquid manure mixed with peat produces fewer odours than liquid manure alone; here the carefully mixed liquid manure is pumped into a machine which mixes liquid manure with peat into litter manure.

On the other hand, peat lands are important wetlands and natural ecosystems with a high value for biodiversity conservation and climate regulation. Inappropriate management may lead to their degradation, with major environmental and social impacts, such as major emissions of carbon gases (CH_4, CO_2) causing global warming, and a loss of biodiversity and freshwater resources [428, GEC 2008]

2.8 Manure application techniques

Depending on the cultivated field crops and the adopted management system, several applications of manure may can be performed till the end of the vegetation period. [574, UBA 2011]
In agricultural practice, a first application of slurry or solid manure will be performed in spring, with the start of the vegetation period and the increasing nutritional requirements of the plants.

A range of equipment and techniques are used to spread slurry and solid manure to land. These are described in the subsequent following sections. Formerly, Currently much of the slurry was is applied to land using machinery which broadcasts the material across the width of spread by throwing it into the air. In some countries (e.g. the Netherlands, Denmark and Belgium-Flanders), the use of band spreaders and injectors for slurry is required to reduce emissions. In many other countries, these techniques are also becoming increasingly popular. Solid manures are broadcast after being chopped or shredded into smaller pieces. Sometimes Manure should be, and often is, actually incorporated into soil by ploughing, discing or using other suitable cultivation equipment and, in some Member States, this is a legal requirement. Contractors are often used for manure spreading and manure is not always spread on the producer's own land.

Directive 91/676/EEC, the Nitrate Directive, lays down minimum provisions on the application of manure to land, with the aim of providing all waters a general level of protection against pollution from nitrogen compounds, and additional provisions for applying manure to land in designated vulnerable zones. is well established and is a reference for Nitrogen application rates and fertilisation methodology. The measures include nitrogen limits for organic manures, closed periods when some manures (high in available N) cannot be spread to grassland and arable land (on sandy and shallow soils), and the identification of other situations when manures should not be applied. In a number of countries (Ireland, Sweden, Estonia, Finland, Germany, Belgium-Flanders, Denmark, Lithuania, Latvia and Poland), the P-load is used as a limiting factor as well, either both as a legal constraint or as a recommendation only.

In other countries, Many countries have other legislation governing the landspreading of manures aims at balancing to try and balance the amounts of manure applied, with the nutrient requirements of the crop. Indeed, the Nitrate Directive is based on this approach, by requiring action programmes and codes of good agricultural practice, including measures for regulating the periods when land application is prohibited, in such a way that fertilisers (including manure) are spread only in periods when there is a crop available that can benefit from the nutrients applied to the field. Depending on legislation, weather conditions, and cultivation practices applied in different regions of Europe, there are different seasons for slurry spreading.

In France, the principle of balancing the fertilisation is envisaged, in order not to apply bring more nutrients than required by crops. In addition, the dates for spreading vary according to the type of product, classified according on the basis of the C/N ratio: type I with C/N > 8 (solid manure except poultry solid manure), or type II (C/N < 8 (solid manure of poultries and slurry).
[257, France 2010]

In other countries and areas, where landspreading is not controlled by specific legislation, reliance is placed on advice, often in spreading practices can rely upon published guidelines, such as codes of good practice (the UK). In other countries (i.e. Denmark), nitrogen quotas for each farmer have been introduced, in order to avoid unnecessarily high application levels of nitrogen per hectare of land.

Ammonia The volatilisation of ammonia after the application of the manure is influenced by the characteristics of the manure, of the weather, and of the soil, that are summarised in Table 2.20. The volatilisation rate over time is affected by air temperature, wind speed, and application rate, except for the deep placement of manure on arable land. With this technique, no factor affects the volatilisation rate except the time after application.

Table 2.20: Influence effects on the ammonia volatilisation rate after manure application

Factor	Grassland			Arable land		
	Surface spreading	Narrow band	Shallow injection	Surface spreading	Surface incorporation	Deep placement
Time (~~log~~ ln t)	–	–	–	–	–	–
Total (adjusted) Ammonia-N	○	+	○	+	+	○
Wind speed	+	+	+	+	+	○
Air temp.	+	+	+	+	+	○
Relative humidity	–	–	–	○	○	○
Incoming radiation	+	○	○	+	+	○
Grass/stubble height	–	–	○	○	○	○
Manure DM content	○	○	○	○	○	○

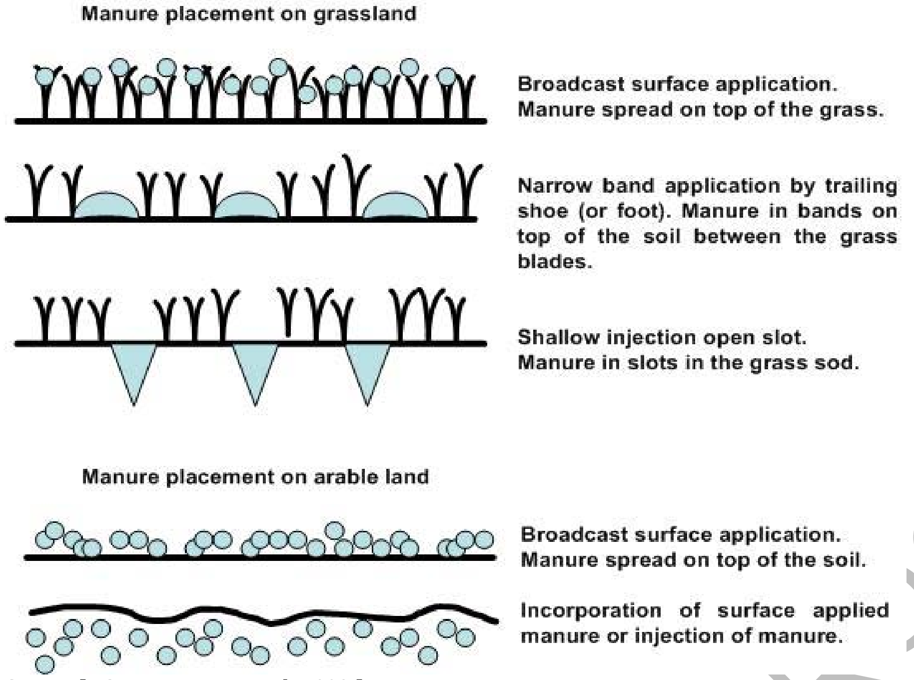
+ = positive correlation with volatilisation rate
– = negative correlation with volatilisation rate
○ = not significant effect
Source: [232, Huijsmans et al. 2009]

The viscosity of slurry, which is determined by the content of organic particles, and its tendency to stick to the soil have an influence on ammonia volatilisation. A slurry with a high viscosity will increase NH_3 emissions, by reducing the infiltration of liquid with dissolved TAN into the soil during application. It has been observed that e.g. digested slurry penetrates into the soil more easily and rapidly, not sticking to the surface as much as raw manure. For the same reason, this reduces ammonia emissions from field application, expressed in kg of contained ammonia in the manure. [517, Petersen et al. 2011]

For slurries, wind speed is one of the most important controlling variables, since each increase in wind speed of 1 m/s increases the NH_3 loss by 10 % (of the total applied nitrogen, TAN, applied). Rainfall immediately after distribution reduces the emissions from slurry, but has no effect on solid pig or poultry manure. [260, IGER 2001]

If properly applied, the landspreading of manure has benefits in terms of saving mineral fertiliser, improving ~~arid~~ soil conditions as a consequence of the addition of organic matter, and in reducing soil erosion. ~~It is complex to control and regulate manure application, as on many occasions the farmer who has an intensive livestock enterprise may not own the receiving land.~~

When manures are not properly applied, losses of the applied nutrients may occur by volatilisation, leaching through soil layers, and via run-off. Manure application techniques differ in their placement of the manure onto the grass or the soil surface. As can be seen in Figure 2.37, the grass contamination and the exposed surface of the manure is different from one application to another, which gives different dispersion in the environment.



Source:[232, Huijsmans et al. 2009]

Figure 2.37: Placement of the manure when applying manure with different application and incorporation methods

The conventional method of spreading slurry, surface broadcasting by a splash plate applicator, is rapid and inexpensive, but the distribution is typically uneven, especially under windy conditions. The diffusion of odours and the risk of pathogen spreading with drifting droplets are drawbacks of this technique. Broadcasting manure may also damage grass swards and contaminate crops with microorganisms that can impede silage fermentation. Indeed, this technique is banned in Denmark.

Surface-applied manure may also enter watercourses via run-off. Crop response to broadcast application of manures is often inconsistent, largely due to ammonia volatilisation. This probably discourages farmers from using them as a primary nutrient source. Ammonia volatilisation may be reduced by minimising exposure of the manure surface to air and improving contact with the soil. Ammonia losses are greater from broadcasting slurry on stubble than on bare soil, particularly if the manure has a high dry matter content, because of an increased exposure to the air and a reduced infiltration rate. Ammonia volatilisation is negatively correlated with the rate of infiltration of manure into the soil.

With injection or incorporation, manure is placed within the soil, effectively bypassing infiltration. However, despite conserving NH_3, injection of manure may reduce the yield of perennial grasses caused by cutting of roots during injection, drying of the soil, and anaerobic and toxic conditions due to concentrated manure in slots. Manure injection may not be practical on rocky or sloping land or on farms lacking access to powerful tractors.

A technique rarely used is the direct ground injection system; this forces finely separated slurry ~~manure~~ under pressure into the soil with little soil disturbance.

The surface-banding of slurry manure with a trailing shoe or trailing hose is a compromise between injection and broadcasting. Band spreading applies manure more uniformly than splash plates, and trailing shoe machines place the manure beneath grass canopies, so that little adheres to and contaminates foliage.

Slurry application in bands enables greater yields than with broadcasting and also less contamination of the grass regrowth is obtained by delivering manure under the grass canopy. Surface banding and broadcasting are usually less expensive than injection.
[254, Webb J.M. et al. 2009]

However, landspreading is environmentally important because of its potential for odour and ammonia emission during spreading and for emissions of nitrogen and phosphate to soil, groundwater and surface water. Energy consumption and soil compactation related to of the spreading equipment could can also be considered. Application techniques and equipment, which are detailed in the following sections, vary depending on:

- type of manure (slurry or dry manure)
- land use
- structure of the soil.

For spreading solid manure, all types of mechanical spreaders are in use with little difference in the environmental impact. The field application of slurry is also done by all types of techniques: band spreading, trailing hoses/shoes, irrigation, injection, but especially splash plate. Irrigation systems are only commonly in use in Italy. **MOVED TO IRRIGATION** [264, Loyon et al. 2010]

2.8.1 Slurry transport systems

There are four main types of slurry transport systems used in Europe and that can be used in combination with different slurry distribution systems. The features of these transport systems are discussed in subsequent sections and are set out in Table 2.21. and listed below:

2.8.1.1 Vacuum tanker

The slurry is sucked into the tanker by using an air pump to evacuate the air from the tank to create a vacuum; the tanker is emptied using the air pump to pressurise the tanker, thereby forcing the slurry out. It can be used for most slurry transport jobs; and has a versatile applicability.

2.8.1.2 Pumped tanker

The slurry is pumped into and from the tanker using a slurry pump, either a centrifugal (e.g. impeller type) or positive displacement pump (PD pump), such as a lobe type pump. The pumped tanker generally has have better spreading precision (m^3 or tonnes/ha) than vacuum tankers. PD pumps require more maintenance.

2.8.1.3 Umbilical hose

The slurry is fed by a drag hose to the distribution system, fitted to the tractor; the hose is supplied with slurry, usually directly from the slurry store by a centrifugal or positive displacement pump. There is possible crop damage as the hose drags across the ground; hose damage and wear can especially be a problem on abrasive or flinty ground.

The umbilical hose tends to be used where high application rates are applicable and on wetter soils where heavier machinery would mark the land (with increased potential for run-off).

2.8.1.4 Irrigation equipment ~~Irrigator~~

This is a self-propelled machine with flexible or reeled-in hoses, usually fed from a network of underground pipes, with a centrifugal or positive displacement pump, situated near the slurry store. It is suitable for semi-automatic operation, but anti-pollution safeguards are needed (e.g. pressure and flow switches).

Irrigators tend to be associated with high application rates. Systems with pressures higher than 2 bar at the tube, are prohibited in some Member States, as they can generate aerosols that are potential sources of microbiological contamination.

Table 2.21: Qualitative comparison of the main characteristics of four slurry-transport systems

Features	Transport system			
	Vacuum tanker	Pumped tanker	Umbilical hose	Irrigation equipment
Range of dry matter	Up to 12 %	Up to 12 %	Up to 8 %	Up to 3 %
Requires separation or chopping	No	No (centrifugal) Yes (PD pump)	No (centrifugal) Yes (PD pump)	Yes
Work rate	●●●	●●	●●	●● (Depends on field size/shape)
Accuracy of application rate	●	●● (Centrifugal) ●●● (PD pump)	●● (Centrifugal) ●●● (PD pump)	●●
Soil compaction	●●●	●●●	●●	●
Capital costs	●	● (centrifugal) ●● (PD pump)	●●●	●●
Labour requirement per m^3	●●●	●●●	●●	●
Number of bullets (●) ~~arrows, ticks etc.~~ indicates input level or value, e.g. irrigator requires low labour input. *Source*: [390, ADAS 2001]				

2.8.2 Slurry application systems

2.8.2.1 Broadcast spreader

A distribution system is used to apply ~~bring~~ the slurry onto the land. Drifting droplets that may occur during the distribution are associated with potential odour emissions and the risk of spreading pathogens.

A widespread technique used to landspread manure is the combination of a tractor with a tank with a spreading device at the rear. The broadcast spreader was previously ~~can be~~ considered as a reference system (see Figure 2.38). The untreated slurry is forced under pressure through a discharge nozzle, often onto an inclined splash plate to increase ~~the~~ sideways spread.

Source: [390, ADAS 2001]

Figure 2.38: Example of a broadcast spreader with a splash plate

With broadcast spreaders, ammonia losses after application are reported to be in the range of 40 – 50 % of the total ~~applied~~ ammoniacal nitrogen (TAN), independent of the dilution of the slurry. [248, ADAS 2001] On the other hand, it is also reported that dilution of (cattle) slurry reduces ammonia losses by approximately 50 %.

The use of broadcast spreading is restricted by the risk of crop quality deterioration or damage caused by slurry contamination.

Figure 2.39 shows a hose-reel irrigator with a 'raingun' attached to a moveable trolley, which is also a broadcast spreader. The trolley is pulled out to about 300 metres with its supply pipe and is wound back to the reel (using the supply hose) where it automatically shuts off. Dilute slurry is pumped to the hose-reel from the slurry lagoon via a main pipe – often buried underground and with valved outlets in a number of places in the field. The applicator in this picture is the 'raingun' that operates at a high connection pressure. [408, UK 2002]

Source:[408, UK 2002]

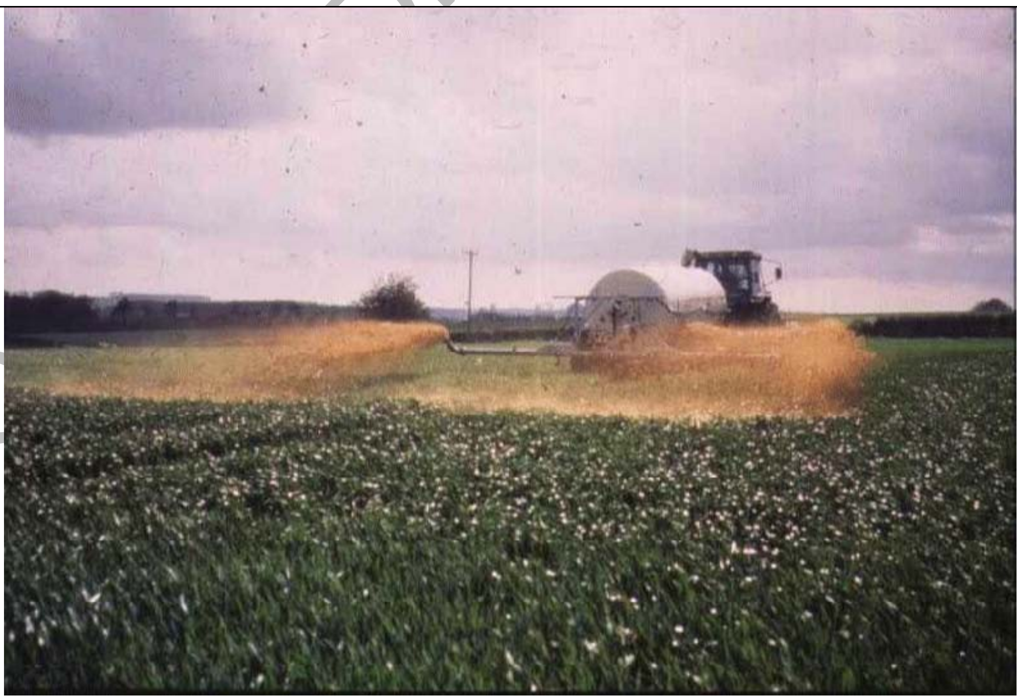
Figure 2.39: Example of a raingun

Broadcasting can also be operated with a low trajectory and at a low pressure to produce large droplets, to avoid atomisation and wind drift. Figure 2.40 shows a tractor applying dilute pig slurry (in April) through a boom with two ~~2~~ splash plates to a crop of winter wheat. The slurry is supplied to the tractor/boom using an umbilical hose from the slurry lagoon. It is possible to apply slurry to winter wheat crops at later dates than April. In Suffolk, England, pig slurry is often very dilute and will run off the crop onto the soil; therefore leaf scorch is not an issue.

Source:[408, UK 2002]

Figure 2.40: Example of a broadcast technique with low trajectory and low pressure

Figure 2.41 shows the same type of boom applicator with 2 splash plates, but this time on the back of a tractor and tanker combination, applying slurry to winter wheat in Hampshire, England. Slurry is supplied from the tanker and is spread, again, with a low trajectory and at low pressure.



Source: [408, UK 2002]

Figure 2.41: Example of a broadcast technique with low trajectory and low pressure

2.8.2.2 Irrigators

Dilute slurry (less than 2 % of dry matter content) can be landspread by irrigation systems, including rainguns, boom-mounted splash plates and rotary boom systems. In Figure 2.42 and Figure 2.43, the rear and side views of an irrigation system, consisting of an horizontal boom with splashplates, are shown.

Source: [247, IGER 2003]

Figure 2.42: Rear view of a horizontal boom with splashplate for slurry application

Source: [247, IGER 2003]

Figure 2.43: Side view of a horizontal boom with splashplate for slurry application

~~Diluted slurry to less than 2 % of dry matter content can be applied via large-scale irrigation systems. the pulse jet irrigator pictured in Figure, delivers a pulse of liquid over some 60 m along the radius of the circle, slowly rotating to give a circular pattern.~~

The pulse jet irrigator pictured in Figure 2.44 can handle undiluted slurry at up to 5 % dry matter content.

~~The ultra-low application rate and high degree of accuracy allow nitrogen to be supplied to crops when needed, with minimal risk of water pollution and virtually no risk of soil compaction. The disadvantage of increased aerial emissions compared to low-level placement techniques is in any case relatively low due to the very large droplet size. The energy use of the technique is also very low at 0.5 – 0.8 kWh/cubic metre. [246, UK 2010]~~

THIS INFORMATION IS NOW REPORTED IN SECTION 4.13.4, WITH SOME AMENDMENTS

Source: [246, UK 2010]

Figure 2.44: Pulse jet irrigator in operation

~~Dilute slurry irrigation systems on pig farms do not represent a significant source of NH_3 pollution. Replacement of raingun or splash plate irrigators with other low emission systems do not seem to be a useful mitigation option, in view of the marginal reductions in emissions.~~

~~Ammonia emitted during irrigation (before reaching the soil) of the dilute pig slurries ranges from 0.1 to 2.6 % of the total available N (TAN) applied. Emissions are expected to be greater from the raingun than boom-mounted splash plate systems. Emissions following irrigation (following irrigation) are estimated of approximately 10 % of applied TAN.~~

~~It is estimated that approximately 20 % of total pig slurry output in the UK is applied to land by irrigation systems, including rainguns, boom-mounted, pulse-jet and rotary boom systems. [247, IGER 2003]~~

THIS INFORMATION IS NOW REPORTED IN SECTION 4.13.4, WITH SOME AMENDMENTS

2.8.2.3 Low-pressure irrigators

The system is based on the use of controlled rates of slurries or clarified fractions of slurry which are mixed with ~~to~~ waters for irrigation, and are distributed at a low pressure by irrigation systems such as pivots and mechanical wings. These systems are widely used. More information is reported in Section 4.13.4.2, including a picture of a typical irrigator. ~~systems~~ (see Figure 4.88). [242, CRPA 2009]

2.8.2.4 Band spreader (or trailing hoses)

Band-spreading is commonly referred to as ‘trailing hose”, but it is also known as ‘drag hose’ and ‘drop hose'.

Band spreaders discharge slurry at or just above the ground level in strips or bands through a series of hanging or trailing pipes attached to a boom. The band spreader is fed with slurry from a single pipe, it thus relies on the pressure at each of the hose outlets to provide an even distribution. ~~Advanced~~ Most systems use rotary distributors to proportion the slurry evenly to each outlet. The width is typically 12 – 28 m with about 30–50 cm between bands (see Figure 2.45).

The technique is applicable to grass and arable land, e.g. for applying slurry between rows of growing crops.

~~Because of the width of the machine, the technique is not suitable for small, irregularly shaped fields or steeply sloping land. The hoses may also become clogged if the straw content of the slurry is too high.~~
THIS INFORMATION IS NOW REPORTED IN SECTION 4.13.4.3, under 'Applicability'

Source: [562, MARM 2011]

Figure 2.45: Example of a band spreader fitted with rotary distributor to improve lateral distribution

2.8.2.5 Trailing shoe spreader

This is a similar configuration to the band spreader with a 'shoe' device added to each hose allowing the slurry to be deposited under the crop canopy onto the soil (see Figure 2.46). It is also known as 'drag shoe' and 'sleighfoot'.

Source: Hi-Spec Engineering Ltd.

Figure 2.46: Example of a trailing shoe spreader

This technique is mainly applicable to grassland. Grass blades ~~leaves~~ and stems are parted by trailing a narrow shoe or foot over the soil surface and slurry is placed in narrow bands on the soil surface at 16 – 35 ~~20 – 30~~ cm spacings. The slurry bands should be covered by the grass canopy so the grass height should be a minimum of 8 cm. The machines are available in a range of widths up to 6 – 16 ~~7 – 8~~ m. [575, UBA 2011]. ~~Applicability is limited by size, shape and slope of the field and by the presence of stones on the soil surface.~~

THIS INFORMATION IS NOW REPORTED IN SECTION 4.13.4.3, under 'Applicability'

2.8.2.6 Injector (open slot)

Slurry is injected under the soil surface. There are various types of injectors but each fits into one of two categories; either open slot shallow injection, up to 50 mm deep; or deep injection over 150 mm deep.

The technique is not applicable on very rocky ~~stony~~ soil nor on very shallow or compacted soils, where it is impossible to achieve uniform penetration of the tools ~~knives or disc coulters~~ to the required working depth.

This technique is mainly for use on grassland. Different shaped knives or disc coulters are used to cut vertical slots in the soil up to 5 – 6 cm deep into which slurry is placed (see Figure 2.47). The spacing between the slots is typically 20 – 30 ~~40~~ cm, with a typical working width of 6 m that can reach 9 – 12 m. The application rate must be adjusted so that excessive amounts of slurry do not spill out of the open slots onto the soil surface.

Source: [563, MARM 2011]

Figure 2.47: Example of an open-slot shallow injector

2.8.2.7 Injector (closed slot)

This technique can be shallow (3 – 5 5 – 10 cm depth) or deep (generally 10 – 15 cm, or up to 20 cm). Slurry is fully covered after injection by closing the slots with press wheels or rollers, possibly fitted behind the injection tines. Shallow closed-slot injection is more efficient than open-slot for decreasing the ammonia emissions. To obtain this added benefit, soil type and conditions must allow for effective closure of the slot. The technique is, therefore, less widely applicable than open-slot injection.

Deep injectors usually comprise a series of tines, potentially fitted with lateral wings or 'goose feet', to aid lateral dispersion of slurry in the soil, so that relatively high application rates can be achieved. Tine spacing is typically 25 – 50 cm, with a working width of 2 – 12 3 m. Although ammonia abatement efficiency is high, the applicability of the technique is severely limited. The use of deep injection is restricted mainly to arable land because mechanical damage may decrease herbage yields on grassland. Other limitations include soil depth and the clay and stone content, the slope, and a high draught force requiring a large tractor. Also in some circumstances there is a greater risk of nitrogen losses as nitrous oxide and nitrates. However, the technique is widely used in some Member States.

2.8.2.8 Incorporation

Incorporation may be done achieved with a plow or other type of equipment such as discs or cultivators, depending on the soil type and soil conditions. Working the manure spread on the surface into the soil can be an efficient means of decreasing ammonia emissions. The manure must be completely buried under the soil to achieve maximum efficiency. Efficiencies depend on the cultivation machinery; ploughing is mainly applicable to solid manures on arable soils. Plows are more efficient but much slower than rotor harrows; therefore, manure remains uncovered on the soil for a longer time, with consequent ammonia emissions. For this reason, the overall effect may be that ploughing is less efficient than other incorporation techniques. Where injection techniques are not possible or unavailable, the technique may also be used for slurries.

As ammonia losses take place quickly after spreading, the manure on the surface, higher reductions in emissions are achieved when incorporation takes place immediately after spreading. At the same time incorporation will reduce the development of odour in the neighbourhood of the manured land. ammonia emissions and odour in the neighbourhood are reduced by limiting the time of exposure of the manure to air. Incorporation can be done by combined equipment in one single handling, or can be done after a few hours (4 – 48) in a separate run.

2.8.2.9 Slurry acidification

Acidification of slurry is a commonly used technique in a few countries (e.g. Denmark, the Netherlands). By adding acid (usually sulphuric acid), the pH of the slurry is lowered to around 5.5, and thereby the ammonia volatilisation is unfavoured. The technique can be applied in manure stores in animal houses (see Section 4.12.9), but it is also possible to acidify the slurry in the tank immediately before landspreading. Another alternative is to continuously acidify in a system directly mounted on the slurry spreader. In this case, the acidified slurry is spread with standard equipment (e.g. trail hoses) and an additional acid tank is placed in front of the tractor.

2.8.3 Solid manure application systems

For spreading solid manure, three main types of solid manure spreaders are commonly used:

- Rotaspreader (see Figure 2.48): a side discharge spreader which features a cylindrical body and a power take-off drive shaft (PTO shaft) fitted with flails running along the centre of the cylinder. As the rotor spins, the flails throw the solid manure out to the side.

Source: [390, ADAS 2001]

Figure 2.48: Example of a rotaspreader

- Rear discharge spreader (see Figure 2.49): a trailer body fitted with a moving floor or other mechanism which delivers solid manure to the rear of the spreader. The spreading mechanism can have either vertical or horizontal beaters, plus in some cases spinning discs.

Source: [390, ADAS 2001]

Figure 2.49: Example of a rear discharge spreader

- Dual-purpose spreader: a side discharge spreader with an open top V-shaped body capable of handling both slurry and solid manure. A fast-spinning impeller or rotor, usually at the front of the spreader, throws the material from the side of the machine. The rotor is fed with material by an auger or other mechanism fitted in the base of the spreader and a sliding gate controls the flowrate of the material onto the rotor (see Figure 2.50).

In Table 2.22, a quality comparison of the characteristic of solid manure spreaders is presented.

Table 2.22: Comparison of the characteristics of solid manure spreading systems

Features	Spreading system		
	Rotaspreader	Rear discharge spreader	Dual-purpose spreader
Suitability for slurry	No	No	Yes
Work rate	●●●	●●●	●●●
Accuracy of application rate	●	●●●	●●
Lateral precision	●	●●●	●●
Soil compaction	●●●	●●●	●●●
Ease of bout matching ([1])	●	●●●	●●
Relative costs	●	●●	●●●

(●) Number of bullets indicates the input level or value, e.g. rotaspreader has a low accuracy in application rate.
(1) Bout matching: to determine overlapping of adjacent runs.
Source: [390, ADAS 2001]

Spreading is successful if three conditions are met:

- the manure to spread is suitable ~~to~~ for the equipment to be used;
- the mass is well homogenised before it is loaded on the spreader;
- the operator knows how to finely adjust the equipment, in order to everly spread the desired amount ~~for a regular spreading~~. [257, France 2010]

Spreaders with a narrow tank-case are most often used, allowing the use of wheels of a large diameter that need limited traction power. Great capacity spreaders are equipped with large tanks, possibly needing a double axle. A regular spreading and a relative low soil compression are possible by the double axle.

Source: [390, ADAS 2001]

Figure 2.50: Example of a dual-purpose spreader

Spreading devices used are currently mainly vertical drums (see Figure 2.51) and the deflector plate, the old spreaders with two horizontal drums ~~being unfavoured~~ are not favoured because of a low spraying width.

Source: [257, France 2010]

Figure 2.51: Vertical drum manure spreader

Vertical drums are suitable ~~to~~ for solid manure (more than 400 kg/m^3). Drums of a large diameter are preferred. The spraying width is 6 – 12 metres. Drums are mechanically simple and require relatively low power.

Deflector plate spreaders with horizontal drums have a more general purpose, being more suited~~able~~ to lower density (poultry solid) manure~~s~~. Spraying widths are wider, from 10 to 12 metres and adjustable shutters optimise the transverse distribution for an achievable load of 4 – 6 tonnes of solid manure per hectare. [257, France 2010] Some models allow discs to be tilted to provide an even spread right up to the spreading boundary, in the same way as fertiliser spreaders do.

An accurate application of nutrients demands an uniform spread pattern. The Coefficient of Variation for a machine's spread pattern is a measure of the uniformity of spread achieved, both laterally and longitudinally. A high number indicates a poor uniformity. Research suggests that manure spreaders should be chosen and operated to give a Coefficient of Variation of less than 25 %. [390, ADAS 2001]

2.9 ~~Transport~~ On-farm transport

The scale of transport operations on farms depends on the farm size, farm layout and the location of fuel storage~~s~~ areas ~~stores~~, feed ~~storages~~ stores and feed processing, livestock buildings, product processing (for example egg packing and grading), manure storage, and fields for applying manure~~s~~ to land.

Feed is usually mechanically or pneumatically handled, and on some pig units wet feed is pumped to feeding troughs.

Typically, tractors are used as the prime mover for manure transport and spreading, although on some pig units, slurry irrigation using pumps and pipelines is practised~~, for example in the UK~~. Many farmers use contractors who typically use larger equipment and occasionally self-propelled vehicles with mounted ‘spreader’ bodies. Tractor-mounted slurry scrapers or loaders/grabs are used for moving manure around buildings and concrete areas, but in some egg-laying systems, manure is moved mechanically by belts and conveyors.

Eggs are usually mechanically handled through to packing, where forklift trucks assist the loading of lorries for road transport. Forklifts ~~trucks~~ are used to transfer crates containing birds from broiler housing to road transport vehicles.

General purpose material~~s~~ handlers (a specialist form of tractor) are used on some sites to undertake a variety of tasks around the farm buildings.

The movement of road transport lorries around the farm site can be extensive on large integrated egg production enterprises dealing with produce output and inputs such as birds, feed, fuel, and packaging~~ and produce output~~. Some sites carry out egg grading and packing for other producers.

2.10 Maintenance and cleaning

Maintenance and cleaning primarily ~~refers~~ relates to equipment and housing. Paved areas of the farmyard can also be cleaned by sweeping or by spraying with water. In UK, farmers are reporting that that modern building materials are easier to clean than older ones, resulting in water and labour savings.

General building maintenance is necessary, including feed handling systems and other conveying equipment. Ventilation systems are checked for the correct operation of fans, sensors, temperature controllers, outlets and back-draught shutters and emergency provisions. Drinking water supply equipment are ~~will be~~ checked regularly. The provision and maintenance of appropriate conditions for keeping livestock is required to meet welfare legislation and to reduce emissions of odour.

Buildings are usually cleaned and disinfected after batches of livestock and manure have been removed. As a minimum, the frequency of cleaning is therefore equal to the number of production cycles per year.

Typically on pig units, wash-down water enters the slurry system, but on poultry units such contaminated water is often collected separately in (underground ~~below-ground~~) storage tanks, before being applied to land or treated. ~~in some way.~~ Good hygiene practices are required in other building areas where product is handled and packed ready for dispatch.

For cleaning, use is often made of high-pressure washers using only water, but surface active agents are sometimes added. For disinfecting, formaline or other agents are used and ~~they~~ when are applied with an atomiser or sprayer. Disinfection ~~This~~ is not a procedure normally applied ~~if, for instance,~~ only in the case of ~~when~~ disease outbreaks (salmonella) has been found, but also as a prevention measure in order to avoid them.. ~~in a flock of broilers~~

Regular maintenance (refurbishing and repairs) and cleaning of vehicles, such as tractors and manure spreaders, can also take place. Regular checks should be made during operational periods, also with appropriate maintenance as described in the manufacturers' instructions. These activities usually involve the use of oil and cleaning agents and can require energy for equipment use.

Many farms have a supply of ~~the~~ faster wearing parts in order to carry out ~~effect~~ repairs and maintenance quickly. Routine maintenance and cleaning is carried out by suitably trained farm staff, but more difficult or specialist maintenance work is carried out with specialist assistance help.

2.11 Use and disposal of residues

The operation of a pig or poultry ~~unit~~ farm gives rise to a number of different residues, some of which are identified in the following list:

- wood
- pesticides
- veterinary products and wastes, whose collection and disposal is subject to special requirements in order to prevent infection
- vehicle and machinery waste, like tires, oils and lubricants
- scrap metals
- ~~tyres~~
- packaging (rigid plastic, film plastic, cardboard, paper, glass, pallets, etc.)
- feed residues
- building residues (cement, asbestos and metal)
- waste from electrical and electronic equipment, WEEE (e.g. fluorescent tubes)
- waste from diagnosis, treatment or prevention of disease (e.g. sharps), whose collection and disposal is subject to special requirements in order to prevent infection.

The processing of manure, carcasses and waste water is subject to special provisions and is dealt with in Section 2.8, Section 2.12 and Section 2.13. ~~other sections of this document.~~

Most of the residues are paper and plastic packaging material. The most common hazardous residues are those from medicines that have been used or that are past their expiry ~~expiration expiring~~ date. Small amounts of residues of cleaning material or of chemicals necessary to operate special processes (e.g. air scrubber) may be found on a farm as well.

~~The way in which residues are dealt with varies widely. Existing European and national legislation on environmental protection and on waste management regulate waste storage and disposal and promote the minimisation of the amount of litter and waste and the use of recyclable materials.~~

In general, on larger enterprises, residues can be more economically disposed of than on small farms. For collection, the residues are stored in containers or in small bins and collected by municipal or special collection services. Where no public waste collection is organised, farms may be obliged to organise collection and transportation themselves and are responsible for associated costs and treatment (Finland). Collection is difficult to organise or non-existent in remote areas.

~~A survey on treatment of residues on farms recently carried out in the UK gives the following picture of techniques that are used if the residues are not collected and transported off-farm [146, ADAS, 2000]:~~
Depending on their nature, wastes are also treated on-farm by:

- stockpiling
- ~~burning in the open~~
- ~~burying~~
- reusing
- using in anaerobic digestion or composting.

Off-farm waste handling ~~disposal~~ includes disposal or treatment routes such as:

- landfilling
- storing in dustbins, including~~ed~~ in household collection
- collecting by suppliers
- transfering to contractor

- recovery or treatment of waste (e.g. composting, anaerobic digestion, oil recovery).

~~Burning of packing material and used oils is still quite common in some MSs, whereas~~ The burning of residues is forbidden ~~of any kind is strictly forbidden in others~~. There are only limited exemptions, restricted to wastes excluded by the Industrial Emission Directive 2010/75/EU, Chapter IV, on the incineration of waste, and that need to be authorised by the competent authorities.

In some MSs, oils are stored in purpose-designed cans/containers and are collected to be treated off-farm. ~~Burning is also the most favoured method of disposal of all kinds of plastic products such as covers and containers.~~ Veterinary residues are stored in special boxes and sometimes collected by the veterinary service or by licensed operators offering waste disposal services. ~~although burning and landfill occur as well~~.

Plant residues, like feed and crop residues, can be mixed with farmyard manure or slurry and applied to land, or are reused in other ways.

Tires are dealt with in different ways, varying between collection by suppliers, ~~and burning on farm and~~ stockpiling, use in construction as tire bales, use in silage as clamps, or use as crash barriers.

In general, waste management (storage, transport, disposal or treatment) needs to be carried out in compliance with the provisions of the Waste Framework Directive 2008/98/EC.

2.12 Storage and disposal of carcasses

The procedures for the collection, storage and disposal of dead animals' carcasses are prescribed by EC Regulation 1069/2009 of 21 October 2009, laying down health rules regarding animal by-products and derived products not intended for human consumption, which repealed Regulation (EC) No 1774/2002 (Animal by-products Regulation). In particular, Regulation 1069/2009 classifies on-farm carcasses of pigs and poultry as Category 2 material, according with Article 9, and specifies all the necessary conditions to ensure that management of animals' carcasses is carried out properly, in authorised dedicated plants, in order to prevent the possible spread of pathogens.

According to Article 13 of Regulation 1069/2009, possible disposal procedures for Category 2 material are:

- disposal as waste by incineration or co-incineration;
- disposal in an authorised landfill, following processing by pressure sterilisation and permanent marking of the resulting material;
- used for the manufacturing of organic fertilisers or soil improvers to be placed on the market in accordance with Article 32 following processing by pressure sterilisation, when applicable, and permanent marking of the resulting material;
- composted or transformed into biogas following processing by pressure sterilisation and permanent marking of the resulting material;
- used as a fuel for combustion with or without prior processing;
- used for the manufacture of derived products referred to in Articles 33, 34 and 36 and placed on the market in accordance with those Articles.

Only animal by-products, including dead animals, originating in remote areas and under specific conditions and circumstances, may be disposed of as waste by burning or burial on site under official supervision, according to Article 19 of Regulation 1069/2009. Several Member States have already granted derogations in regard to the possibility to dispose of animal by-products as waste by burial or burning, in remote areas. [492, DG SANCO 2005]

A remote area is defined as an area where the animal population is so small, and where disposal establishments or plants are so far away that the arrangements necessary for the collection and transport of animal by-products would be unacceptably onerous compared to local disposal.

Burial and burning of animal by-products, may be justified also in disease control situations requiring the emergency disposal of the animals killed as a measure to control an outbreak of a serious transmissible disease. In particular, disposal on site should be allowed under special circumstances, since the available rendering or incinerator capacity within a region or a Member State could otherwise be a limiting factor in the control of a disease.

~~Services to collect carcasses and to process them by contractors are common. In Italy, many farms have equipment to transform carcasses into liquid feed under special pressure and heating conditions. [412, Italy 2001] Also, in other Member States the processing of carcasses into feed is or has been practised, but this is now declining or completely forbidden.~~
~~Burying of carcasses and open burning are still widely practised methods. In some MSs, such as the Netherlands, Germany, Denmark and France burying is strictly forbidden, but in the UK, Italy and Spain authorised burial is allowed.~~

Some farms have an installation for incineration of carcasses. This can be a quite simple burner without any provision for the emitted waste gases. ~~In the UK about 3000~~ Several small scale incinerators (<50 kg/hr) are operated in the UK, mainly on large poultry and pig farms for the incineration of animal carcasses. Strict controls apply to their use, including a periodic inspection and monitoring regime. The ash may be landfilled, ~~or~~ disposed of by other routes, or recycled, as ashes have a high P content. ~~Otherwise carcasses are collected and processed elsewhere.~~ ~~Carcasses can also be composted,~~

2.13 Treatment of waste water

Waste water is the water used by domestic, industrial, agricultural or other usage, and which has undergone changes in its properties as a result and is discharged. Added to this is the water from rainfall, which collects and flows away from built-on or compacted areas (precipitation water).

Waste water, also called dirty water, originates from washing livestock houses ~~water~~, from facilities for personnel, ~~from yard run-off~~ and particularly from run-off from yards and open concrete areas that are contaminated by manure. The amounts depend very much on the amount of rainfall. Cleaning water from livestock farming facilities can contain residues of dung and urine, litter, and feedstuffs, as well as cleaning agents and disinfectant.

Dirty water can be managed in combination with slurry, but can also be treated and handled separately, in which case separate storage will be needed.

Authorisation permits may require (e.g. 'Standard Farming Installation Rules' in the UK) the ~~to~~ appropriate~~ly handle and treat~~ handling and treatments of lightly contaminated run-off from livestock settlements.

Common treatment methods mimic some of the properties of natural wetland systems, and include swales, ponds, wetlands and soakaways. These treatments can reduce the contaminant load by allowing pathogens to die off before they reach the natural surface or groundwaters, trapping sediments containing nutrients and heavy metals, and allowing for controlled plant uptake of some of the nutrients.

Swales are ideal for collecting and transporting run-off but require large spaces. Constructed Wetlands can offer excellent treatment potential but will take up dedicated space. Ponds remove part of the sediment with a partial treatment. Soakaways practically need no care, but must not be used where there is a high level of contaminants.

On poultry farms, the aim is to keep manure dry to reduce ammonia emissions and to allow easier handling. Waste water is stored in special tanks and dealt with separately.

On pig farms, waste water is commonly added to the slurry and treated in combination or applied directly to land. Various treatment systems for slurry exist and they are described in Section 2.7. ~~On some farms in Finland using solid manure systems, waste water is conducted through a sedimentation tank into soil treatment or from production buildings into a ditch.~~

If kept separate, waste water (dirty water) may be applied to land through low-rate irrigators (e.g. UK and FI) or treated in a communal or on-farm waste water treatment plant (e.g. sedimentation treatment as a minimum in Finland).

For discharge into running waters or public sewage system, waste waters from intensive livestock farming must comply with emissions limit stipulated under water regulations. [373, UBA 2009] Due to the large volumes produced and to the high ~~potential~~ biological contamination of waters from livestock facilities, waste waters rarely comply with the required levels of acceptability for direct discharge to ~~in~~ watercourses. [364, Portugal 2010]

2.14 Installations for heat and power production

On-farm solutions exist to use self produced renewable energies that can reduce the need to buy other forms of energy.

~~Some farms have installed~~ Solar or wind-driven generators are more frequently installed with both the intention to cover part of the farm ~~their own~~ power need and for sale on the market. In France, contracts for the purchase of wind power electricity are established ~~with~~ for 15 years ~~length~~, and are not within the scope of this document.

Electricity production from photovoltaic panels is possible in pig and poultry installations ~~because~~ as large roof surfaces are available on pig houses. Roof slopes fall in the useful range of 26 – 45 % that allow a good efficiency of the system.

At the time of drafting (2011), the cost for the purchase of equipment is high~~, ~~and investment returns are long (10 to 20 years), although government incentives, such as 'Feed-In Tariffs' applied in many EU Member States, have reduced payback times to 5-10 years.~~ and on-farm uses of the produced energy are not economically convenient.~~ Costs for ~~P~~photovoltaic panels ~~cost~~ are falling rapidly: costs of about EUR 3 500 per kW, or EUR 450 – 600~~ – 800~~ per m² are reported.~~), and~~ The installation of ~~a~~ small wind turbines ~~mill~~ is also becoming more convenient:~~,~~ for sizes up to 12 m in height, costs are around EUR 500/kWh; while for capacities of 10 – 50 kW and 15 – 30 m in height, costs are reported to be around EUR 3 500 per kW.

Livestock production is a sector where anaerobic gas production might be interesting, due to the availability of organic matter, although manure and slurry have relatively low energy contents and generally need to be supplemented with high-energy feedstocks like silage maize. After a first wave of digesters that were built in the 80s and 90s had little real success, anaerobic treatment is in a new phase of development in Europe, especially due to attractive prices that have been gained by the produced electricity, that is classified as renewable.

~~Solar power supply depends very much on the weather conditions and therefore cannot serve as a main supply, but rather as an additional energy source or a replacement for energy supply aiming at a reduction of costs. Windmills attached to a generator can supply power, particularly in areas with relatively high wind speed. The application is even more economical if excess power can be delivered to the general electricity supply network. More detailed information would be needed to assess its applicability and environmental benefits.~~
~~In some MSs much attention is given to the use of any biogas that develops during the storage and treatment of manure.~~

Strategies of energy savings from heating techniques can be put in place for the use of energy directly on farm, like heat recovery by exchangers or pumps.

2.14.1 Heat recovery by heat exchangers

Several solutions for the recovery of energy from various media are available, that use heat exchangers based on three major principles:

- Air/air heat exchangers;
- Air/water heat exchangers;
- Air/ground heat exchangers.

Air/air exchange. The principle consists of warming-up the air that enters the house by the heat of the waste air that exits the house.

In poultry production, the heat is transferred through plates that separate the flows that enter and exit the house. The heat exchangers are used during the starter period, when only minimum air renewal and humidity abatement (10 %) are necessary.

These exchangers are similar to MCV (mechanical controlled ventilation) double-flow equipment. They allow an economy of 30 – 40 %, and can only complement centralised air heating.

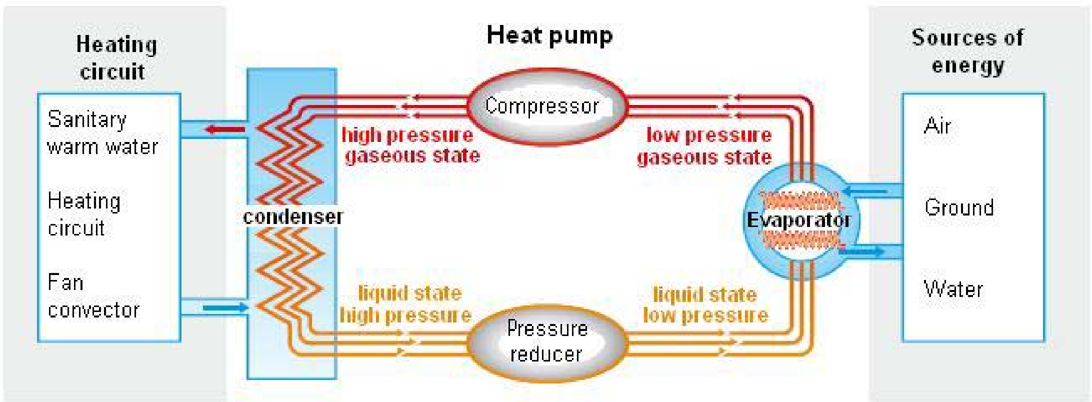
Air/water exchange. Aluminium plates (commonly called fins) are placed in the centralised extraction shaft. The heating water located in line with these fins is heated by the warm extracted air and is closed-circuit circulated to a fan-convector which returns the energy indoors. Electric consumption~~s only refer to~~ is only needed for the pump, which ensures the circulation of the water. The maximum recorded ~~efficiency is the~~ effect is an increase of 12 °C of the incoming air.

Air/ground exchange, (also known under the name 'Canadian well'). The exchangers use the inertia of the ground to smooth the seasonal variations of temperatures and, consequently, to improve the conditions of thermal comfort of the animals. They are used to preheat the air in winter as well as to cool it in summer, and to decrease the variations of temperature. [347, Bartolomeu 2007]

2.14.2 Heat pumps

Heat pumps consist of two thermal exchangers, a compressor and an evaporator, where a coolant liquid allows for drawing energy from a source of heat (ground, slurry, scrubber water, biological reactor, etc.) and for returning it to the building (see Figure 2.52). The recovered heat can be used to produce sanitary warm water, to feed a heating circuit (warm water buckles), or to ensure the heating of the buildings by means of fan convectors.

The thermal ~~thermic~~ fluid flows in a closed circuit as pictured in Figure 2.52. In liquid form, the fluid collects calories to evaporate from sources of energy, such as water, ground or air from a biological engine. A compressor turns the fluid into gas and circulates it to a condenser where the heat is exchanged to the fluid of the heating circuit, while cooling and returning in a liquid state. A pressure reducer (while reducing the pressure), allows the fluid to restart the cycle, collecting heat at the evaporator. ~~then optimises the return of the fluid back to a gaseus state~~.
[348, Bartolomeu 2008]



Source: [348, Bartolomeu 2008]

Figure 2.52: Operating principles of heat pumps

2.14.3 Biogas energy production

Anaerobic digestion is a process of degradation of the organic matter without oxygen that leads to the production of biogas (mainly constituted by methane). Biogas can be used as fuel for a co-generator to produce electricity to sell it to the commercial network and to produce heat. The thermal ~~thermic~~ energy ~~that develops in~~ from the combustion is reused according to the farm's needs, such as for homes, rearing houses, greenhouses and piglet heating. [345, France 2010]. The heat produced by power-heat cogeneration plants can also be transferred to external users by district heating

To improve the performance of the biogas production from pig slurry, a co-digestion of supplementary high-energy feedstocks is necessary. The profitability of the process depends on the production capacity and on the sale price of the electric power. Different grants and incentives are in place in various Member States, which are taken into account in the economic evaluation of these production systems.

An example is reported from Austria (Hirnsdorf) where a farm-scale biogas plant is loaded only with farm pig slurry and waste (laying hen manure or other wastes). The biogas reactor has a volume of 750 m³ and treats around 4 500 m³ of substrate every year in bimonthly batches (the residence time is 50 – 60 days on average). The reactor is a cylindrical concrete container subdivided into two chambers (no stirrer); the lower chamber is the slurry loading section, which is connected with the upper reaction (fermentation) chamber by means of communicating shafts.

The produced gas is directed to the combined heat and power unit and excess gas is stored in a dry gas silo reservoir. Two compressors are installed to operate alternatatively. A torch is installed as a safety measure.

The gas that is produced is desulphurised and fed to a CHP plant made of two engines, with synchronous generators with a maximum electrical power of 2 × 57 kW. The produced electricity supplies the farm's own requirements and the excess power is fed into the public grid (between 2 000 and 6 000 kWh per month). However, for the in-farm peak demands, external power has to be bought. The waste heat from the process is recovered and used in winter to heat the sorting hall and the pig houses, as well as to fully condition the gas reactor itself. From March to September, the heat is also used to feed the maize-drying facility in the continuous flow-dryer system.

The digested slurry is stored in a main store with a capacity of 800 m³, plus a few other slurry pits, before its application to land. No emission reduction measures are provided to these storage systems. [373, UBA 2009]

The manure treatment for producing biogas is described in Section 2.7.4.

2.14.4 Energy production from biomass

Heat production using biomass (or wood) firing requires a whole infrastructure to benefit from the produced heat. These requirements, that normally are not present in existing farms, consist of the network of heating, hot air blowers or, heating floors or fins.

Boilers must be installed close to buildings, because the heat distribution piping network is relatively expensive. However, biomass fuel costs generally offer substantial savings over imported fossil fuels, once the capital has been invested.

This heating system is profitable when heat needs are large and stable, as ~~happens~~ in the case with multiple houses or users. Some examples of heat requirements for different size farms and

animal categories are reported in Section 4.5.1.3.2. Three examples from Brittany, France, are reported in Table 2.of the heat requirements in mixed poultry and dairy farms combined with the farmer's house.
[345, France 2010]

Table 2.23: Examples of mixed farms heating needs that can be supplied by warm water produced by wood boiler

Workshop	Heat needs (Boilers capacity)
3000 m^2 poultry housing + 230 calf places	300 kW
1800 m^2 poultry housing + farmer's house	240 kW
600 m^2 poultry housing + farmer's house + hot water in milking room	100 kW or 60 kW + 8 infrared supplementary heaters
Source: [346, CA Bretagne 2009]	

ABOVE TEXT AND TABLE ARE ALREADY INCLUDED IN SECTION 4.5.1.3.2.

2.15 Monitoring and control of consumption and emission

~~In the IPPC Directive (96/61/EC), article 9.5 gives farmers a special status concerning monitoring. The article says:~~

~~'The permit shall contain suitable release monitoring requirements, specifying measurement methodology and frequency, evaluation procedure and an obligation to supply the competent authority with data required for checking compliance with the permit. For installations under subheading 6.6 in Annex 1, the measures referred to in this paragraph may take account of costs and benefits.'~~

~~This text should be seen as a signal to avoid excessive monitoring obligations on pig and poultry farms.~~

~~This section gives some ideas on common practice in monitoring. However, not enough information was submitted to assess what the suitable level of monitoring at a farm is, taking into account the costs and benefits.~~

~~In some areas, farmers have to keep a register of their phosphate and nitrogen. This is usually where intensive livestock production is responsible for high pressures on the environment. The resulting balance gives a clearer indication of the input and losses of minerals on the farm. The information can be used to optimise the feeding of minerals to the animals and to the application of manure to land.~~

~~Some farmers assess the nutrient status of soils and apply an appropriate amount of organic nutrients and mineral fertiliser according to crop requirements and rotations. The level of precision varies from those who undertake soil and manure analysis and use some form of recognised nutrient management planning to those who estimate requirements using general published information or those just using experience or guesswork. The legislation that applies in some countries is described in Section 2.8, which explains that the extent of record keeping is variable.~~

~~Farmers will have records (receipts) of purchased items, although the extent to which they are kept in an organised way will vary. Such records will usually exist for the main items of feed, fuel (including electricity) and water (not all private abstractions) so the amounts used can be identified. Since feed and water are primary inputs to livestock systems their usage may be monitored by farmers irrespective of whether receipts are kept. Most poultry farmers will have bought in bedding material, whereas pig producers who use straw may produce their own or have an agreement with neighbouring farmers exchanging manure for clean straw.~~

Computerised registration and the administration of costs, inputs and outputs is increasing and is already common on large enterprises. Monitoring provides data, often remotely or instantaneously, that is useful for the farm management. This information allows operators to ensure that systems are operating within their specification and to easily identify failures or areas where further investigation is required. Where measuring is applied, water gauges, electric meters and computers for indoor climate control are used.

There may be requirements to check slurry stores ~~storages stores~~ regularly for any signs of corrosion, ~~or~~ leakage or intactness of the solid or floating cover and to find any faults that need to be put right. Professional help may be required. Checking takes place after completely emptying the stores.

Regular emissions to water occur under specific legislation and within set (discharge) conditions and monitoring requirements (Portugal, Italy).

~~Currently~~, In most cases, farmers do not normally monitor and control emissions (Austria, [373, UBA 2009]) to air unless specifically required to do so as a result of complaints from neighbours. These complaints are usually related to noise and odour emissions.

In Ireland, monitoring of emissions and sampling points for air (odour), noise, surface water, groundwater, soil and waste are required under Integrated Pollution Control Licensing arrangements. In Denmark, where surface crusts are required as an alternative to the slurry stores covers, farmers are required to inspect the crust at least monthly, and to maintain a record of registrations.

3 CONSUMPTION AND EMISSION LEVELS OF INTENSIVE POULTRY AND PIG FARMS

This chapter presents data on consumption and emission levels associated with activities on farms for the intensive rearing of poultry and pigs, based on the information that has been submitted in the framework of the information exchange. It aims to give an overview of the ranges that apply to these sectors in Europe and so to serve as a benchmark for the performance levels associated with the techniques presented in Chapter 4. The factors that account for the variation of data are briefly described when possible, or sometimes only mentioned. The circumstances under which data have been obtained is described in more detail in the evaluation of applied techniques in Chapter 4.

3.1 Introduction

The major production activities and systems or and techniques on an intensive pigs and ~~ans~~ poultry ~~livestock~~ farm have been described in Chapter 2. ~~The consumption and emission levels that were reported were not always clear and easy to comprehend, and major variations occur due to a large number of factors~~. Table 3.1 summarises the key environmental issue of the major on-farm activities.

Table 3.1: Key environmental issue of the major on-farm activities

Major on-farm activity	Key environmental issue	
	Consumption	**Potential emission**
Housing of animals: • the way the animals are stocked (cages, crates, free) • the system to remove and store (internally) the manure produced	Energy, litter, feed, medication	Air emissions: (NH_3), odour, noise, , greenhouse gases (CH_4, N_2O, etc.), dust and fine dust particles (PM_{10}); manure; waste (i.e. carcasses from animal mortality)
Housing of animals: • the equipment to control and maintain the indoor climate and • the equipment to feed and water the animals	Energy, feed, water	Noise, waste water, dust, CO_2
Storage of feed ~~and feed additives~~	Energy	Dust and fine dust particles (PM_{10}), waste
Storage of manure in a separate facility	Energy	Air emissions (NH_3), odour, emissions to soil, greenhouse gases
Storage of residues other than manure		Odour, emissions to soil, groundwater
Storage of carcasses		Odour, energy
Unloading and loading of animals		Noise, dust
Application of manure on land	Energy	Air emissions (NH_3, odour, greenhouse gases), emissions to soil, groundwater and surface water of N, P and K, etc., noise
On-farm treatment of manure	Additives, energy, water	Air emissions, waste water, emission to soil
Milling and grinding of feed	Energy	Dust and fine dust particles (PM_{10}), noise
Treatment of waste water	Additives, energy	Odour, waste water
Carcasses incineration ~~Incineration of residues (e.g. carcasses)~~	Energy	Air emissions, odour

~~**Structure of information:** It is important to understand the links between the on-farm activities, described in Chapter 2, to be able to interpret the emissions from intensive livestock farming. Obviously, there is a direct link between the input levels of the different resources and the emission levels.~~

~~In both sectors, most attention has been given to the emissions related to the metabolism of the animals.~~ The central environmental issue for poultry and pig sector emissions is manure: the amounts produced, ~~the~~ composition, method of removal, storage, treatment and its application on land. This is reflected in the order in which the activities are presented, starting with feed as the major consumption issue and followed by manure production as the most important emission.

~~**Understanding of data:**~~ The levels of consumption and emission depend on many different factors, such as the animal breed, production phase, and management system. Additionally factors such as climate and soil characteristics also have to be taken into account. Hence, averages have very limited value and where possible are avoided. The tables show the widest possible ranges of reported consumption and emissions. In the accompanying text an attempt is made to explain this variation as far as information allowed, but without being too specific.

Consumption of water and energy, and emissions to water, air and soil must be interpreted in relation to the climatic conditions. As an example, the climate in the Mediterranean regions is characterised by two very distinct seasons, spring-summer and autumn-winter, in which consumption and emissions might have distinct values.

~~Within MSs standard units are applied that may not always be comparable with units used elsewhere. If the data is at levels in the same order of magnitude as other levels that have been reported, then they form part of the data range and are not explicitly distinguished. Consumption and emission levels can be measured in different ways and at different moments involving the factors mentioned above. For the sake of comparison and for reference, relevant factors will be mentioned that influence the character and the level of the consumption or emissions level presented.~~

In the assessment of consumption and emission levels, a distinction can be made between single activities and the farm as a whole. Where possible, data are directly associated with a single on-farm activity, so as to enable a clear link to the reduction techniques described in Chapter 4. Some other data are given ~~For some issues it is not possible to identify emissions on an activity-by-activity basis. In this case it is easier to assess the consumption and emission~~ for the farm site as a whole.

In the assessment of consumption and emission levels of pig farming, it is important to know the production system applied. Growing and finishing aim for a slaughter weight of 90 ~~– 95 kg (UK), 100~~ – 110 kg ~~(other)~~ or 150 – 170 kg (Italy) and can be reached within different periods of time. Poultry production systems seem to be quite similar throughout the EU.

~~A remark may be made on the use of animal units to standardise data and to achieve comparability. For this purpose EU countries use the 'animal unit' or 'equivalent animal'. There is a problem with these standardised units, because in different EU countries they are defined in different ways, e.g. in Sweden 1 unit = 3 sows = 10 finishers = 100 hens, whereas in Ireland 1 unit = 1 finisher and 10 units = 1 sow including progeny. In Portugal the 'equivalent animal' for the pig sector has a 45 kg average, whereas for presenting data on heavy pig production in Italy, 85 kg is taken as a representative weight.~~

3.2 Consumption levels

3.2.1 Feed consumption and nutritional levels

The amount and composition of feed given to poultry and pigs is an important factor in determining the amounts of manure produced, its chemical composition and its physiological structure. Thus, feeding is an important factor in the environmental performance of an intensive poultry and pigs ~~livestock~~ enterprise.

Emissions from livestock farms are predominantly related to the metabolic processes of the housed animals. Two processes are considered ~~to be~~ essential:

- enzymatic digestion of feed in the gastrointestinal tract
- absorption of nutrients from the gastrointestinal tract.

~~An increasing~~ The advanced understanding of these processes is responsible for the development of the ~~a~~ wide range of feeds and feed additives adapted to the needs of the animal and to the production aims. Improving the utilisation of nutrients in the feed not only leads to a more efficient production, but ~~could~~ also leads to a reduction of the environmental load.

Consumption levels vary with the energy requirements of the individual animal, which involve maintenance requirements, growth rate and production level. The total amount of feed intake is a result of the duration of the production cycle, the daily intake and the type of production purpose and it is also influenced by a number of factors connected with the animal.

Data on consumption levels are reported in kg per head per production cycle or kg per kg of product (eggs or meat). Comparisons do not take into consideration the ~~are difficult to make with the use of~~ different breeds that are reared, but normally refer to the specific ~~and the application of different~~ production targets (egg weight or animal weight) and production cycles.

The following sections present an overview of the feed intake levels and nutrient requirements reported and show the existing variation where possible together with the factors that account for that variation.

3.2.1.1 Poultry feeding

Indicative feeding levels for different poultry species are presented in Table 3.2.

Table 3.2: Indication of ~~production time,~~ conversion ratio, ~~and~~ feeding level and feed consumption per poultry species

Types of animal production	Feed conversion ratio	Feeding level range (kg/bird/cycle)	Feed amount in kg/birdplace/year
Laying hens	2.1 – 2.8 (3)	5.5 – 6.6	34 – 47
Standard broilers	1.6 – 2.2 (3)	2.4 – 5.72 (4)	16.8 – 33 (3) (4)
Heavy broilers	1.8 – 2.3 (3)	3.96 – 8 (4)	22.6 – 33 (3) (4)
Male turkey	2.6 – 3.1 (3)	50 – 60 (3)	150 (3)
Female turkey	2.3 – 2.8 (3)	24 (3)	65 (3)
Duck Pekin	2.45	5.7 – 9.0 (3)	37 – 58 (3)
Duck Barbary	2.66 – 2.82 (1) (2)	7.6 – 12.9 (1)	37 – 42
Guinea fowl	2.75 – 3.37 (2)	4.5 – 4.7 (1)	17 (2)

Source: (1) [280, France 2010],
(2) [418, ITAVI 2010],
(3) [500, IRPP TWG 2011]
(4) Calculations based on data reported in Table 1.3 and 19 days of sanitation.

~~Poultry species~~	~~Cycle~~	~~FCR (1)~~	~~Feeding level range (kg/bird/cycle)~~	~~Amount in kg/birdplace/year~~
~~Laying hens~~	~~12 – 15 months~~	~~2.15 – 2.5 (2)~~	~~5.5 – 6.6 (up to production)~~	~~34 – 47 (during egg production)~~
~~Chicken broilers~~	~~35 – 55 days (5 – 89 crops/yr)~~	~~1.65 1.70 – 2.58 1.73 – 2.1~~	~~2.5 3.3 – 4.5 8.0~~	~~17 22 – 29 33~~
~~Turkeys~~	~~120 (female) – 150 (male) days~~	~~2.65 – 4.1~~	~~33 – 38 24 – 56~~	~~65 – 150~~
	~~French production~~	~~1.85 – 2.58~~	~~7 – 33~~	~~7 – 65~~
~~Ducks~~	~~Pekin: 48 – 56~~	~~2.45~~	~~5.7 – 9.00 8.00~~	~~37 – 58~~
	~~French production Barbary: 85~~	~~2.45 – 2.78~~	~~7.6 – 12.9~~	~~42 – 44 37 – 42~~
~~Guinea fowl~~	~~56 – 90 days~~	~~2 – 2.85~~	~~4.5 – 4.7~~	~~17~~

~~(1) FCR = feed conversion ratio~~
~~(2) FCR kg feed per kg eggs, higher levels in litter based systems~~
~~*Source*: [24, LNV 1994] [391, Italy 1999] [27, NFU 2001] [413, Portugal 2001] [280, France 2010] [328, CORPEN 2006]~~

The purpose of poultry feeding and the components used in poultry feed mixtures have been described in Section 2.2.5.1. The amino acid composition of feeds has to be as close as possible to the ideal amino acid profile for the relevant animal species. is based on the ideal protein concept for the relevant species. ~~With~~ In this 'ideal protein' concept, the required amino acids levels are expressed relative to lysine levels of the feed. ~~found by indicating the lysine level and relating the other amino acids to the actual lysine level of the feed.~~ Current field practices are (along with their variability) reported in Table 3.3. The recommended amino acid balances are quoted from literature, but the appraisal of current protein and lysine levels results from field observations at a European level.

Table 3.3: Appraisal of current protein and lysine levels and scope for recommended amino acids balance

	Broilers	**Layers**	**Turkeys medium weight**
Current energy level MJ/kg, ME basis			
Phase 1	12.5 – 13.5	11.6 – 12.1	11.0 – 12.5
Phase 2	12.5 – 13.5	11.4	11.0 – 12.5
Phase 3	12.5 – 13.5	11 – ~~12 11.4~~	11.5 – 12.5
Phase 4			11.5 – 13.5
Phase 5			
Current protein level (CP=N*6.25), total content			
% feed, phase 1	24 – 20	15.4 – 20	25 – 30
% feed, phase 2	18 – 22	15.5 – 19	22 – 28
% feed, phase 3	17 – 21	15 – 17 ~~18 – 16~~	19 – 26
% feed, phase 4		15 – 17	18 – 24
% feed, phase 5		13 – 16	15 – 22
Current lysine levels, total content			
% feed, phase 1	1.1 – 1.5 ~~1.30 – 1.10~~		1.80 – 1.50
% feed, phase 2	1.0 – 1.3 ~~1.20 – 1.00~~		1.60 – 1.30
% feed, phase 3	0.9 – 1.2 ~~1.10 – 0.90~~		1.40 – 1.10
% feed, phase 4			1.20 – 0.90
% feed, phase 5			1.00 – 0.80
mg/day		850 – 900	
Recommended amino acid balance, in percentage of lysine level			
Threonine: lysine	63 – 73	66 – 73	55 – 68
Methionine +cystine: lysine	70 – 75	81 – 88	59 – 75
Tryptophan: lysine	14 – 19	19 – 23	15 – 18
Valine: lysine	75 – 81	86 – 102	72 – 80
Isoleucine: lysine	63 – 73	79 – 94	65 – 75
Arginine: lysine	105 – 125	101 – 130	96 – 110

NB: -ME = metabolisable energy.
-CP = crude protein.
Source: [506, TWG ILF BREF 2001], [280, France 2010], [327, Germany 2010], [294, UK 2010] [500, IRPP TWG 2011]

Indications of the applied levels of calcium and phosphate in feed are given in Table 3.4.

Table 3.4: Applied calcium and phosphorus levels in feed for poultry

Element	Layers		Broilers		
	(mg/animal/day)	g/kg feed	(mg/animal/day)		
			0 – 2 wks	2 – 4 wks	4 – 6 wks
Ca (%)	0.9 – 1.5	3.5	1.0	0.8	0.7
P_{av} (%) ([1])	0.4 – 0.45	0.354–0.45	0.50	0.40	0.35

([1]) Available phosphate.
Source: ~~[117, IPC Livestock Barneveld College, 1998] [118, IPC Livestock Barneveld College, 1999]~~ [24, LNV 1994] [41, Netherlands 2001] [280, France 2010]

3.2.1.2 Pig feeding

For pigs, the feeding strategy and feed formulation vary with factors such as live weight and stage of (re)production. A distinction is made between the feeding of young sows (gilts), mating and gestating sows and farrowing sows and between piglets, weaners, growers and finishers. Feed amounts are expressed in kg per day and in required energy content per kg of feed. A large number of tables and data on various feeding strategies are available (see also Section 4.3 ‘Nutritional management’ and Annex 9.2). The following tables in this section merely present the ranges of reported levels applied in Europe, acknowledging that higher or lower nutrient levels may also be applied in certain cases. The final intake depends on the amount consumed and on the nutrient concentration and therefore minimum levels are recommended for the different feeds to meet the pigs’ requirements given its average daily intake. The amount of feed given to a sow in production, including dry periods, and depending on energy intake, amounts to about 1 300 to 1 400 kg per year.

In Table 3.5, average nutritional levels are shown for sows.

Lactating sows generally need ~~slightly~~ higher nutritional levels than gestating sows due to milk production; in particular, the lysine concentration ~~CP and lysine are~~ is required to be ~~in~~ higher ~~concentrations~~ in the dietary crude protein ~~the feed ration~~. The energy requirements increase towards the moment of birth. After farrowing, daily energy requirements increase with increasing size of the litter. Between weaning and first mating, energy levels remain high to help the animal to recover ~~recover~~ and to prevent loss of its condition. After mating, the energy content of the feed can be reduced. During winter, higher energy levels are applied for gestating sows.

The amino acid composition of feeds has to be as close as possible to the ideal amino acid profile. ~~is based on the ‘ideal protein’ concept for the relevant species. In this ‘ideal protein’ concept, the required amino acids levels are found by indicating the lysine level and relating the other amino acids to the actual lysine level of the feed.~~ The sum of the amino acid contribution of each ingredient used to make the feed is compared to the ideal protein profile. Lysine being the first limiting amino acid for pig performance in this 'ideal protein' concept, the required amino acids levels are expressed relative to lysine. Current field practices are (along with their variability) reported in Table 3.5 and Table 3.8. The recommended amino acid balances are quoted from literature, but the appraisal of current protein and lysine levels result from field observations at a European level.

Table 3.5: Appraisal of current protein and lysine levels and scope for recommended amino acids for sows (one phase for every ~~each~~ major stage of growth)

	Lactating sow	Gestating sow
Current energy level (MJ/kg), ME basis		
Phase 1	12.5 – 13.5	
Phase 2		12 – 13
Current protein levels (CP=N*6.25), total content		
% feed, phase 1	18 – 16	
% feed, phase 2		16 – 13
Current lysine levels, total content		
% feed, phase 1	1.15 – 1.00	
% feed, phase 2		1.00 – 0.70
Recommended amino acid balance, in percentage of lysine level		
Threonine: lysine	65 –72	71 – 84
Methionine +cystine: lysine	53 – 60	54 – 67
Tryptophan: lysine	18 – 24 ~~20~~	16 – 21
Valine: lysine	69 – 100	65 – 107
Isoleucine: lysine	53 – 70	47 – 86
Arginine: lysine	67 – 70	NA

NB: ME = metabolisable energy.
CP = crude protein.
Source: [506, TWG ILF BREF 2001], [430, Paulicks et al. 2006]

Indications of the applied levels of calcium and phosphate in feed for sows are given in Table 3.6.

Table 3.6: Applied calcium and phosphorus levels in feed for sows

	Mating and gestating sows	Lactating sows
Feed (kg/sow/day)	2.4 – 5.0	2.4 – 7.2
Calcium (% feed)	0.7 – 1.0	0.75 – 1.0
Total phosphorus (% feed)	0.45 – 0.80	0.55 – 0.80

Source: [44, IKC 1993] [391, Italy 1999] [39, Germany 2001]

Pigs are fed according to their body weight, with feed intake increasing with increasing weight. Towards the end of the finishing period (the last 20 – 30 kg) the amount of feed given is unchanged, while the protein level is generally lowered. An example is presented in Table 3.7 for finishers in Italy, where a distinction is made between heavy and light pigs. In general, the feeding is *ad libitum* for light pigs, that are capable of strong muscular development, but rationed for heavy pigs, that have a considerable propensity towards fat accumulation and towards a higher weight level. This changes the feed composition. For example, whey (5 – 6 % of dry matter) can be used for the heavy pig with 13 – 15 litres of whey substituting for 1 kg of dry feed. The whey can be used in increasing quantities, from 3 – 4 litres per head per day at 30 kg of weight up to a maximum of 10 – 12 litres for more than 130 kg (quantities beyond these levels may have negative effects on the utilisation (i.e. FCR) of the total daily ration).

Table 3.7: Example of rationing used for light and heavy finishers in Italy

Heavy pig							
Live weight (kg)	Up to 25	30	50	75	100	125	150+
Feed (88 % dm) (kg/day)	Ad lib.	1.2 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	2.7 – 3.2	3.0 – 3.4
Feed (% of live weight)		4 – 5	3 – 4	2.7 – 3.3	2.5 – 3.0	2.2 – 2.5	2.0 – 2.2
Feed (% of metabolism mass ~~weight~~) ($w^{0.75}$)		10 – 12	8 – 10	8 – 10	8 – 10	7 – 9	7 – 8
Light pig							
Feed (88 % dm) (kg/day)	*Ad lib.*	1.5	2.2	2.8	3.1		
Digestible energy (MJ/kg)	13.8	13.4	13.4	13.4	13.4		
Lysine (%)	1.20	0.95	0.90	0.85	0.80		
Source: [391, Italy 1999]							

The total amount of feed consumed during growing and finishing depends on the breed, FCR, daily growth, length of the finishing period and final live weight. For pigs growing from 25 kg up to 110 kg of live weight, about 260 kg of feed is consumed. Obviously, the nutrient levels of the feed are most important. Nutritional levels have to meet the requirements of daily growth or production. For each weight category average requirements can be distinguished, as reported by various sources and summarised in Table 3.8. Increasingly, finishing periods range between 30 kg and final weight and are divided into 2 or 3 feeding phases. In these phases, the nutrient content in the feed varies to meet the varying demand of the pig. The end of the first growing phase ranges between 45 and 60 kg live weight and the second phase between 80 and 110 kg. Where one feed is given between 30 and 110 kg, the content of the feed is equal to the average of the level of the two-phase feeds.

Table 3.8: Appraisal of current protein and lysine levels and scope for recommended amino acids for pigs (1 phase for each major stage of growth)

	Pig
Current energy level (MJ/kg), ME basis	
Phase 1 (piglet)	12.5 – 13.5
Phase 2 (growing pig)	12.5 – 13.5
Phase 3 (finishing pig)	12.5 – 13.5
Current protein levels (CP=N*6.25), total content	
% feed, phase 1	21 – 17
% feed, phase 2	18 – 14
% feed, phase 3	17 – 13
Current lysine levels, total content	
% feed, phase 1	1.30 – 1.10
% feed, phase 2	1.10 – 1.00
% feed, phase 3	1.00 – 0.90
Recommended amino acid balance, in percentage of lysine level	
Threonine: lysine	60 – 72
Methionine +cystine: lysine	50 – 64
Tryptophan: lysine	18 – 20
Valine: lysine	68 – 75
Isoleucine: lysine	50 – 60
Arginine: lysine	18 – 45
ME = metabolisable energy CP = crude protein *Source:* [506, TWG ILF BREF 2001]	

Indications of the applied levels of calcium and phosphate in feed for growers/finishers are given in Table 3.9.

Table 3.9: Calcium and phosphorus levels applied to feed for growers/finishers

Nutritional parameters	Pig live weight range			
	30 – 55 kg	**55 – 90 kg**	**90 – 140 kg**	**140 – 160 kg**
Calcium (% feed)	0.70 – 0.90	0.65 – 0.90	0.65 – 0.90	0.65 – 0.80
Total phosphorus (% feed)	0.44 – 0.70	0.45 – 0.70	0.50 – 0.70	0.48 – 0.50
Source: [44, IKC 1993], [39, Germany 2001], [391, Italy 1999]				

In finishing the heavy weight pig in Italy, different weight ranges are distinguished with their associated nutrient levels (Table 3.10).

Table 3.10: Average nutritional levels applied in Italy for heavyweight pigs for different live weight intervals (as % of raw feed)

Nutritional parameters	Pigs 35 – 90 kg	Pigs 90 – 140 kg	Pigs 140 – 160 kg
Crude protein (CP, %)	15 – 17	14 – 16	13
Crude fats	4 – 5	<5	<4
Crude fibre	<4.5 – 6	<4.5	<4
Total lysine	0.75 – 0.90	0.65 – 0.75	0.60 – 0.70
Total methionine + cystine	0.45 – 0.58	0.42 – 0.50	0.36 – 0.40
Total threonine	0.42 – 0.63	0.50	0.40
Total tryptophan	0.15	0.15	0.10 – 0.12
Calcium	0.75 – 0.90	0.75 – 0.90	0.65 – 0.80
Total phosphorus	0.62 – 0.70	0.50 – 0.70	0.48 – 0.50
Digestible energy MJ/kg	>13	>13	>13
Source: [391, Italy 1999]			

3.2.2 Water consumption

The total amount of water used includes not only consumption by the animals, but also the water used to clean ~~for the cleaning of~~ housing, equipment and the farmyard and the water used for cooling purposes. Cleaning water ~~use~~ particularly affects the volume of waste water produced on farms.

3.2.2.1 Water requirements of poultry farms

3.2.2.1.1 Animal consumption

In the poultry sector, water is required for satisfying the physiological needs of the birds ~~animals~~. Water intake depends on a number of factors, such as:

- animal species and age
- animal condition (health)
- water temperature
- ambient temperature
- feed composition and
- the drinking system used.

With increasing ambient temperatures the minimum water intake of broilers increases geometrically (x^n). A higher laying percentage also raises daily consumption of layers ~~[89, Spain, 2000]~~. With respect to drinking systems, nipple drinkers show lower consumption than round drinker systems, due to lower spillages.

Average water consumption levels are shown in Table 3.11. Water/feed ratios were reported for broilers and laying hens only.

Table 3.11: Water consumption of different poultry species per cycle and per year

Poultry species	Average ratio water/feed (l/kg)	Water consumption per cycle (l/head per cycle)	Annual water consumption (l/bird place per year)
Laying hens	1.8 – 2.0	10 (up to production)	73 ~~– 83 –~~ 120 (egg production)
Chicken broilers	1.7 – 1.9	4.5 – 11	30 ~~– 40 –~~ 70
Turkeys	1.8 – 2.2	45 – 100 ~~70~~	117 ~~– 130 –~~ 150
Ducks	3.5 – 6	30 – 46	195 – 300
Source: [44, IKC 1993] [391, Italy 1999] [24, LNV 1994] [358, France 2010] [500, IRPP TWG 2011]			

3.2.2.1.2 Use of cleaning water

Waste water primarily results from the cleaning of the animal houses. All water spills from drinking are usually removed as part of the manure. Farms that produce wet manure (no drying in the poultry house) can store this water in the manure storage facility. On farms where dry manure is produced, waste water is stored separately ~~differently~~ (e.g. in tanks). Table 3.12 shows the estimated cleaning water use for different poultry housing types.

The volume of water used for cleaning purposes is variable and depends on the applied technique and the water pressure of the high-pressure cleaner. Also, using hot water or steam instead of cold water will reduce the volume of cleaning water used.

For laying hens, water use for cleaning varies with the housing system. Cleaning is done after each round of 12 – 15 months. For layers kept in enriched cages, less cleaning water is needed than for layers in a deep litter system. The cleaning of housing systems where layers are kept on deep litter, varies with the area covered with slats. The larger the surface with slats the higher the volume. With a fully solid floor the average water use is estimated to be at least 0.025 m^3 per m^2.

Cleaning water use for broiler houses varies widely, e.g. between Finland and the Netherlands, where 10 times more water is used. The application of warm water can reduce the water use by 50 %.

Table 3.12: Estimated water use for cleaning of poultry housing

Poultry species	Use in m^3 per m^2 per cleaning	Cycles per year	Use in m^3 per m^2 per year
Layers – cages	0.01	~~0.67~~ 1	0.01
Layers – deep litter	0.030 – 0.060 ([1]) ~~>0.025~~	~~0.67~~ 1	~~>0.025~~ 0.03 – 0.06 ([1])
Broilers	0.005 – 0.008 ([1]) ~~0.002 – 0.020~~	6	0.03 – 0.048 ([1]) 0.085 – 0.105 ([2]) ~~0.012 – 0.120~~
Turkeys	0.009 – 0.010 ([1]) 0.02 ([2]) ~~0.025~~	2 – 3	0.018 – 0.03 ([1]) 0.04 – 0.06 ([2]) ~~0.050 – 0.075~~
Ducks	0.005 – 0.050 ([2])	8.6	0.040 – 0.430 ([2])

([1]) Data related to French poultry farms.
([2]) Data related to UK poultry farms.
Source: [392, LNV 1992], [500, IRPP TWG 2011]

3.2.2.1.3 Use of cooling water

Water consumption related to cooling of bird houses by fogging or spraying systems depends on climatic conditions, and only occurs for limited periods during the year. One litre of water that evaporates at 25 °C absorbs from the environment 678 Wh.

To cool by fogging a house of 1 000 m^2, during 30 days for 10 hours a day, 100 m^3 of water are needed. With a spraying system operating in the same conditions, the water requirement would be of 190 m^3. [354, ITAVI 2004]

3.2.2.2 Water requirements of pig farms

3.2.2.2.1 Animal consumption

Four types of water consumption can be identified:

1. the water necessary for maintaining homeostasis and meeting the growth requirements;
2. the water ingested by the animals in excess of what is strictly necessary;
3. the water which is wasted at the moment of drinking due to an incorrect structuring of the distribution system;
4. the water used by the animals for satisfying behavioural needs, such as the water spillage during the typical behaviours generated by the lack of ‘play’ objects other than the drinking system.

Animal consumption of water is expressed in litres per kg of feed and depends on:

- animal age and live weight
- animal health
- stage of production
- climatic conditions
- feed and feed structure.

~~Water consumption of finishers per kg of feed ingested decreases with age but, as the animals have a higher feed intake with increasing live weight towards the end of the finishing period, the absolute daily water intake is higher. In Italy, where finishing of much heavier pigs is common, feed is administered predominantly in liquid form, with a water/feed ratio of 4:1 and, when whey derived from cheese production is used, the ratio can reach 6:1. With respect to feed~~

content, reduced CP levels reduce water intake. With a 6 point decrease a 30 % reduction was observed in water intake [134, Spain, 2001].

Two major nutritional factors are known to increase water consumption: protein ingestion and mineral concentration, in particular that of potassium and sodium. [359, MASSABIE 2001]

For sows, water consumption is important for maintaining homeostasis and for the production of piglets or milk. Such high levels of water ingestion also have positive effects on the animal's ingestion capacity during the suckling phase and on maintaining the health of the urogenital organs during pregnancy (see Table 3.13).

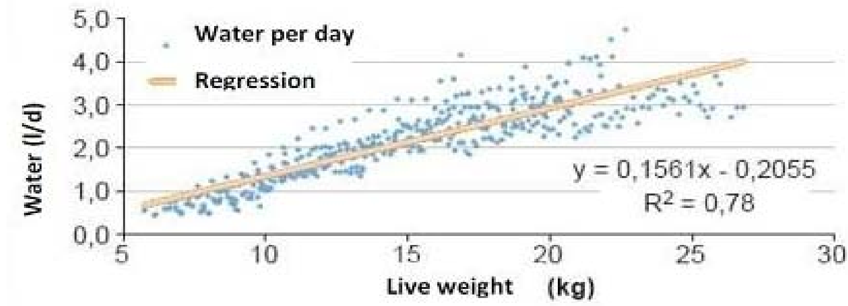
Table 3.13: Average water requirements of pigs finishers and sows in l/head/day with respect to age and stage of production

Pig production type	Water consumption (l/ animal place per day)
Gestating sows (in a farrow-to-finish farm)	60 – 73
Farrowing sows with piglets up to 6 kg	14 – 17
Farrowing sows with piglets until 20 kg	21 – 26
Gilts	10 – 13
Piglets 6 to 20 kg	2.7 – 3.3
Growers from 20 to 50 kg	5.4 – 6.6
Fatteners from 50 to 100 kg	11 – 14
Fatteners from 20 to 100 kg	7 – 9
Boars	15 – 18
Source: [431, MARM 2010]	

Pig production type	Weight or production period	Ratio water/feed (l/kg)	Water consumption (l/day/head)
Finishers	25 – 40 kg 40 – 70 kg 70 – finish	2.5 2.25 2.0 – 6.0	4 4 – 8 4 – 10
Gilts	100 – mating	2.5	
Sows	Dry to 85 days gestating		5 – 10
	From 85 days gestating to farrowing	10 – 12	10 – 22
	Lactating	15 – 20	25 – 40 (no limit)
Source: (Derived from [27, IKC Veehouderij, 1993] [391, Italy 1999] [26, Finland 2001] and [8, Portugal 1999])			

In Denmark, typically around 800 kg of dry feed are used per pig place per year. To that amount, the pigs are drinking 2.5 – 3.0 litres of water per kg. In total, 2 000 – 2 400 litres of drinking water are needed per pig place per year.

The water consumption increases linearly with body weight after weaning, as represented in Figure 3.1. At the entry (7 kg of live weight) animals consume 0.8 litres per day, reaching 4 – 5 litres per day at the end of the weaning phase (27 kg of live weight). The water consumption would then increase linearly at a rate of about 0.16 litres of water per kg of live weight. when animals growing from 7 to 27 kg drink from 0.5 to 4 – 5 litres per day.



Source: [358, France 2010]

Figure 3.1: Evolution of water consumption with the live weight of post-weaning piglets

In the next growing phase, the water intake increases by 0.06 litres per kg of live weight at a temperature of 20 – 24 °C, or by 0.10 l/kg at 28 °C. [359, MASSABIE 2001]

Water (or fluid) intake is important for the growth of finishers and has a clear influence on manure production and manure quality.

~~For 25 to 60 kg of live weight, the water intake is about 4 to 8 litres per head per day, increasing to 6 to 10 litres per head per day with increasing live weight.~~

In general, manure production increases, but with a simultaneous decrease of its dry matter percentage, due to an increased water intake (Table 3.14). This pattern is similar for pigs, lactating sows (including litter) and dry sows with water including other fluids such as whey, skimmed milk and silage effluent. ~~[91, Dodd, 1996]~~

Table 3.14: Example of the effect of water/feed ratio on the production and dry matter content of manure of growers/finishers

Water/feed-ratio	Ration (kg/pig per day)	Manure production (m^3/pig place per year)	Dry matter content (%)
1.9: 1	2.03	0.88	13.5
2.0: 1	2.03	0.95	12.2
2.2: 1	2.03	1.09	10.3
2.4: 1	2.03	1.23	8.9
2.6: 1	2.03	1.38	7.8

Source: [44, IKC 1993], with reference to Mestbank Overijssel en Midden, the Netherlands, 1991

Water spillage and slurry production are both influenced by the type of drinking system and the speed of water delivery. In Table 3.15 it can be seen that an increase in the speed of the water delivery of the drinking nipples by a factor 2 leads to an increase in the volume of the slurry produced by a factor 1.5, and at the same time a decrease in the DM content of the slurry.

Table 3.15: Effect of water delivery of drinking nipples on the production and dry matter content of manure of growers/finishers

Water delivery (l/pig per min)	Manure production (m^3/pig place per year)	Dry matter content (%)
0.4	1.31	9.3
0.5	1.45	8.1
0.6	1.60	7.2
0.7	1.81	6.1
0.8	2.01	5.2
Source: [44, IKC 1993], with reference to Mestbank Overijssel en Midden the Netherlands, 1991		

A higher speed of water delivery leads to higher wastes, that are even more accentuated at high temperatures, by the efforts that animals make to cool themselves. [359, MASSABIE 2001]

3.2.2.2.2 Use of cleaning water

The volume of waste water produced on pig farms is directly related to the amount of cleaning water used. Water consumption on pig farms is affected not only by the applied cleaning technique, but also by the housing system, as a lot of water is used if washing the floors is required for the purpose of slurry removal. For example, the larger the slatted floor surface, the lower the cleaning water use. ~~Not many data are available on cleaning water use.~~ In Table 3.16, ~~some~~ data are reported that have been measured in different farm types or floor systems, but large variations are observed depending on the use of high pressure cleaning and the application of detergents to soak the surface. Variation in use between floor systems can therefore not explain the level and variation between different farm types.

Table 3.16: Estimated water use for the cleaning of pig housing

Reared animal	Housing type (slurry management)	Consumption litres/animal
Farrowing sows	Crates, fully-slatted floor	340
	Crates, partly-slatted floor	340
Piglets (7 – 30 kg)	Fully-slatted floor	15
	Draining floor with slits	20
	Fully-slatted floor	20
Fattening pigs (30–100)	Partly-slatted floor (50 – 75 % of solid floor)	25
	Partly-slatted floor (25 – 50 % of solid floor)	25
	Solid floor	30
	Draining floor with slits (33 % / 67 %)	25
Source: [437, Agrsci 2008]		

~~System/farm type~~	~~Consumption~~
~~Solid floors~~	~~0.015 m^3/head/day~~
~~Partly-slatted floor~~	~~0.005 m^3/head/day~~
~~Slatted floors~~	~~0~~
~~Breeding farm~~	~~0.7 m^3/head/year~~
~~Finishing farm~~	~~0.07 – 0.3 m^3/head/year~~
~~*Source*: [391, Italy 1999] [392, LNV 1992]~~	

Differences in the ease of cleaning have been reported but not measured, in relation to wall and hard surface material; although, a reduced water consumption has been reported for the cleaning of hard-packed floor in broilers housing, in comparison with a concrete floors. This aspect might represent a potential for a reduced water use.

~~3.2.2.2.3 Cooling water~~

This section referred to poultry and was moved to Section 3.2.2.1.3

~~Water consumptions related to cooling houses by fogging or spraying systems depend on climatic conditions, and only occur for limited periods during the year. One litre of water that evaporates at 25 °C absorbs from the environment 678 Wh watts.~~
~~To cool by fogging a house of 1000 m^2 during 30 days for 10 hours a day, 100 m^3 of water are needed. The water requirement with a spraying system in the same condition, would be 190 m^3. [354, ITAVI 2004]~~

3.2.2.2.3 Use of water for air cleaning systems

Air cleaning systems like biofilters, water scrubbers, chemical scrubbers and multiple-stage systems consume significant volumes of water. The treated air leaves these systems at a humidity of more than 95 %. Water consumption is a function of the air flowrate, humidity and ambient temperature. This means that more water is provided to these systems in summer than in winter. On average over the year, fresh water consumption from 5 to 7 litres per 1 000 m^3 of treated exhaust air are reported with the application of any of these air cleaning systems. Typical air volumes required for type of animal are reported in Section 2.2.4.1. Additional information concerning air cleaning techniques is available in Section 4.9.

3.2.3 Energy consumption

~~Quantification of the energy consumption of livestock farms is a complex undertaking for all the production systems, as their organisation and systems are not homogeneous. Moreover, the technologies applied to the production system, on which the amount of energy consumption depends to a large extent, vary substantially depending on the structural and production characteristics of the farms.~~

The energy consumption of livestock farms varies substantially depending on the production system, as their organisation and ~~and~~ production characteristics are not homogeneous. Another important factor that influences the energy consumption is the climatic conditions [506, TWG ILF BREF 2001] ~~[188, Finland, 2001]~~.

~~The collection of data on energy consumption is also difficult, as energy consumption is usually variable and generally poorly or not clearly monitored. Units will differ depending on the type of energy carrier and will thus need converting into kWh or Wh per day to allow comparisons to be made. Data can be expressed per day per head, but if calculated over a year the seasonal effects of weather on ventilation and heat inputs can be averaged out.~~

The main measures applied in poultry and pig housing systems for reducing energy consumption consist of the insulation of buildings, control of ventilation and artificial lighting systems. [264, Loyon et al. 2010]

~~Italy, U.K. and Finland~~ The reported energy use on poultry and pig farms and their main findings are presented in the following sections.

3.2.3.1 Poultry farms

As regards **layer farms,** artificial heating of the housing is not commonly applied, due to the low temperature needs of the birds and the relatively ~~(still)~~ high stocking density. ~~Application of the minimum standards for the protection of laying hens [74, EC, 1999] may increase the energy consumption on laying farms, but also depends on the saving techniques applied.~~ Activities requiring energy are:

- heating the water in winter;
- feed distribution;
- housing ventilation;
- lighting, this requires high consumption levels in order to artificially maintain a constant period of high light levels illumination during the year, so as to at increase egg production during the periods of the shortest days;
- egg collection and sorting: consumption is about 1 kWh per 50 – 60 m of conveyor belt;
- operating the sorting and packaging facilities.

Estimates of energy consumption in layer houses (pullets and laying hens) are shown in Table 3.17.

Table 3.17: Estimate of energy consumption (kWh/animal) for pullets and laying hens

Animal	Gas		Electricity	
	Cage	Non cage	Cage	Non cage
Pullets	1.42	1.42	0.45	0.45
Laying hens	Not used	Not used 3.15	3.15 Not used	2.45
Source: [340, ADEME 2007]				

On **broiler poultry meat farms,** the main energy consumption is related to the following areas:

- local or ambience heating in the initial phase of the cycle, this is effected with hot air heaters, and accounts for around 80 % of the consumptions;
- housing ventilation, which varies between the winter and summer periods from 2 000 to 12 000 m^3/h per 1 000 heads, or 5 m^3/h per kg of LW in France and moderate climates;
- lighting, which is critical for both animal welfare and performance;
- watering, energy used for water distribution and sometimes preparation of feed.

In poultry farms, the main sources of energy are propane gas and electricity. In addition to electricity and propane gas, the fuel oil is used to run tractor engines and generators. gas. propane gas is an important source of energy.

Propane gas is widely mostly used for heating poultry meat houses, and, for instance, in France it accounts for approximately 2 % of the production costs in poultry meat broliers production. In poultry meat housing, gas heating is very important not only to provide the high ambient temperatures required allows quick raise of temperature at the birds arrival (32 ºC for chicks and 34 ºC for turkeys on the first breeding day) and during the first days of rearing, but also because of the large big volumes of air flowing in the large poultry houses, which induce high energy requirements for heating. produce The required installed heating power requirements is equivalent to of about 85 to 100 W/m². Gas consumptions depend on the type of ventilation and the reared animal, and generally range from EUR 3.5 to 5.0 per m^2 per year for poultry meat species (broiler, turkey and duck). [341, Amand et al. 2008].

Data concerning the average gas consumption for poultry meat houses, observed in France, are reported in Table 3.18.

Table 3.18: Annual average gas consumption reported for poultry production in France

Type of animal production	Annual average gas consumption ([1])		
	kg gas/m^2	kWh/m^2	kWh/kg of meat produced
Standard broilers	6.8 (4.7 – 8.2)	93.8 (64.9 – 113.2)	0.38 (0.34 – 0.48)
Heavy broilers	6.7 (4.2 – 8)	92.5 (58 – 110.4)	0.35 (0.30 – 0.43)
Female turkey	6.9 (5.9 – 8.2)	95.2 (81.4 – 113.2)	0.56 (0.50 – 0.58)
Duck Barbary	7.3 (6.0 – 8)	100.7 (82.8 – 110.4)	0.57 (0.47 – 0.58)
Guinea fowl	7.5 (7.1 – 8)	103.5 (98.1 – 110)	1.12 (1.06 – 1.19)
Broiler breeders	0.08	1.1	-

([1]) The range reported for each poultry species includes different housing, heating and ventilation systems
Source: [342, ADEME 2008]

The average consumption of propane gas that is reported from the UK is approximately 15 kg/m^2 for broilers, corresponding to a share of the total production costs of around 6.5 – 8 %. For the rearing of turkeys, average energy consumption is reported to be 77.2 kWh/m^2, which corresponds to around 3.4 % of the total production costs.

As for gas, electricity consumption varies according to the type of production ~~(see Table 3.19)~~ due to the differences in type of buildings, ventilation and heating needs.
~~For turkey and broiler production, the average consumptions for the whole of the closed buildings are around 108 kWh/m² per year, that is to say 0.52 kWh/kg per live weight.~~

Data concerning the average electricity consumption for poultry meat houses, observed in France, are reported in Table 3.19.

Table 3.19: Annual average electricity consumption for poultry production in France

Type of animal production	Annual average electricity consumption		
	kWh/m^2	25 % of the lower reported values (kWh/m^2)	25 % of the higher reported values (kWh/m^2)
Standard broilers	15.2	9.4	20.3
Female turkey	11.7	7.2	13.1
Broiler breeders	18.8	-	-

Source: [342, ADEME 2008]

In the UK, electricity consumption for the rearing of turkey is reported equivalent to 2.64 kWh/m^2.

Examples of breakdown values for electricity consumption are reported in Table 3.20, for two different poultry farms located in France, with a surface of 1 000 m^2 each.

Table 3.20: Distribution of electricity consumption for two poultry farms in France

Type of animal production	Ventilation (%)	Lighting (%)	Feeding (%)	Watering (%)	Others (%)	Annual consumption (kWh)
Broilers – High consumption farm (mechanical ventilation, artificial lighting, water pumping from borehole)	48.1	32.5	4.7	8.7	6	21 000
Turkeys (broilers) – Low consumption farm (no fans, natural lighting, connected to water supply network)	18.4	41.4	16	10.9	13.3	5 440

Source: [342, ADEME 2008]

Approximately 50 – 70 % of the heat losses from animal houses occur from roofs that hence need to be well insulated isolated. Figure shows The amounts of losses from roofs that occur in a building of 1200 m^2 of area. Losses are dependent on For the different levels of insulation and of outdoor temperature (see example in Table 4.30).the energy that is lost and the amount of propane needed to replace the losses are displayed.

The existing Table 3.18 has been moved to Section 4.5.1.1.

The following text and energy data were moved above (with amendments)

Electricity consumptions vary according to productions (see Table 3.19) due to the differences in type of buildings, ventilation and heat needs. For turkey and broiler production, the average consumptions for the whole of the closed buildings are around 108 kWh/m² per year, that is to say 0.52 kWh/kg per live weight. [339, ITAVI 1997] [340, ADEME 2007] [341, Amand et al. 2008].

Table 3.19 Average annual consumption of propane gas and electricity in meat poultry houses

Animal	Gas propane		Electricity
	kg/m^2	kWh/m^2	kWh/m^2
Duck	9.3	128.1	39.5
Turkey	7.2	99.2	11.7
Chicken	6.6	90.9	15.2
Source: [340, ADEME 2007]			

Energy consumption in an Italian layer farms, related to the preparation of feed, housing ventilation and water heating during the winter months (where necessary), can be 30 – 35 % higher than that of the broiler farms; see Table 3.21. The

Seasonal variability of energy consumption during the year is primarily related to the type of farm and the type of systems used. On broiler farms, in which the consumption attributable to climate control is prevalent, seasonal variations can be substantial, i.e. the energy consumption for heat production in winter is higher than that used for ventilation in summer. On broiler farms, electrical energy consumption is at a maximum in the summer (ventilation) and thermal consumption is at a maximum in winter (ambient heating). At laying hen farms, where winter heating is not used, the peak of (electrical) energy consumption is in summer, due to the increase in ventilation rate. [391, Italy 1999].

Table 3.21 shows the energy requirements of some essential activities on broiler and layer farms in Italy.
, from which it would be possible to calculate their total energy consumption. The daily consumption will be quite variable depending on the size and the equipment used, on energy saving measures, as well as on losses caused by lack of insulation.

Table 3.21: Indicative levels of daily energy consumption of activities on poultry farms in Italy

Activity	Estimated energy consumption (Wh/bird/day)	
	Broilers	Laying hens
Local heating	13 – 20	
Feeding	0.4 – 0.6	0.5 – 0.8
Ventilation	0.10 – 0.14	0.13 – 0.45
Lighting	-	0.15 – 0.40
Egg preservation (Wh/egg per day)		0.30 – 0.35
Source: [391, Italy 1999]		

The overall energy ~~consumed~~ consumption based on these (Italian) ~~consumption~~ data was reported as ranging between 3.5 and 4.5 Wh per bird per day depending on the type of farm. Data from the UK confirm the ~~data~~ pattern except for the energy consumption associated with feeding of broilers, where a range of between 0.4 and 0.7 Wh/bird/day has been reported.

Indicative levels of energy use in poultry farms in the UK ~~and~~ are shown in Table 3.22. [500, IRPP TWG 2011]

~~This range does not correspond with data on the consumption of poultry farms in the UK, where much higher energy consumptions have been reported for both layer and broiler farms. It was pointed out that the underlying data in the UK study include energy used in other parts of the poultry enterprise as well and may thus overestimate the actual energy use of a poultry unit. For example, where poultry farms may also have an on-site feed production plant, the energy input would be markedly higher than on those farms where feedstock is delivered (for example, the total energy use for a hammer mill with pneumatic meal transfer: 15 – 22 kWh).~~

Table 3.22: Indicative levels of energy use of poultry farms in the UK (kWh/bird per year or dozen eggs)

Type of animal	Live weight (kg) at marketing	Electricity	Non-electric static equipment	Mobile machinery (fuel)
Chickens	2.2	0.66	1.10	Trace
Turkeys	14	4.20	7.00	Trace
Ducks	3.5	2.6 ~~1.05~~	1.75	Trace
Geese	NA	Trace	Trace	Trace
Dozen eggs	–	0.54	0.09	Trace
NA: Not available *Source*: [355, Warwick 2007] [500, IRPP TWG 2011]				

The exiting Table 3.18, referring to 1999 data, has been deleted.

Apart from annual trends, daily trends in electrical energy consumption are also quite variable and relate~~d~~ to the type of technical systems used on the farm. Often, there are two daily peaks corresponding to feed distribution.

In France, the annual electricity consumption is reported in the range from 0.6 to 0.8 kWh/bird/year for broilers, and 17 kWh/bird/year for turkeys. [500, IRPP TWG 2011]

~~As far as the energy use for other poultry species is concerned concerns, total energy use for turkeys was reported be about 1.4 to 1.5 kWh per bird per year [39, Germany 2001] and [26, Finland 2001].~~

3.2.3.2 Pig farms

TEXT IN THIS SECTION HAS BEEN REARRANGED ON THE BASIS OF THE DISCUSSED TOPIC: TOTAL ENERGY CONSUMPTION, ELECTRIC ENERGY, ETC.

Energy use on pig farms is related to lighting ~~illumination~~, heating ~~and~~ ventilation and feed preparation.

Electricity is the main form of energy used as it responds to both needs for heating (e.g radiant electric heaters) and power (e.g. ventilation, feed distribution, lighting).

Fuel oil is the second source ~~most consumed type~~ of energy, and it is mainly used to power ~~in particular for powering~~ generators but also for heating water in boilers (in more than 60 % of French farms). and heating water in boilers. [343, ADEME 2008] ~~that are used in more than 60 % of the French farms, and for running warm water boilers.~~

Gas, such as propane, is exclusively used for heating. In colder climates in northern Europe like in Finland, consumption of fuels is significant because of the need for supplementary heating.

Energy sources are used in variable ~~ways~~ shares across Europe. In Italy, about 70 % of energy used in pig rearing comes farming supplies are from fuel oil, whilst in the UK more than 57 % of the energy used is electricity. In moderate climates, such as France, electricity is the form of energy that is consumed the most.

In Table 3.23, the share of each energy source and the total average energy consumption, observed in France for different types of pig farms, are reported. The variability between farms in total energy consumption is substantial, i.e. the standard deviation of the average energy consumption is equivalent to 328 kWh per sow per year for the integrated farrow-to-finish farm.

Table 3.23: Share of energy sources and total average energy consumption for different types of pig farms in France

Type of farm	Electricity	Fuel Oil	Gas	Total average energy consumption	
	%	%	%	kWh/pig produced/year	kWh/sow/year
Farrow-to-finish	76	21	3	48	983
Rearing (weaners-to-fatteners)	86	14	-	25	-
Breeding	70	30	-	19 ([1])	403
([1]) Value expressed in kWh/weaner produced. *Source:* [343, France 2010] [344, France 2010]					

The distribution of total energy consumption, reported from France for each physiological stage present in an integrated pig farm (where rearing from farrowing to finish is performed), is presented in Table 3.24. The shares of energy used for each process (heating, ventilation, lighting, feeding) are shown in Table 3.25.

Table 3.24: Distribution of energy consumption in integrated farms in France, for each physiological stage (average values from 15 farms)

Physiological stage	Weaners	Farrowing	Fattening	Gestating sows	Other stages
Energy consumption (%)	36	22	27	8	7
Source: [343, ADEME 2008]					

Table 3.25: Shares of energy consumption for each consuming process, in integrated farms in France

	Heating (%)	Ventilation (%)	Lighting (%)	Feeding (%)
Weaners	79	15	6	1
Fattening	2	90	3	5
Farrowing	81	10	8	1
Source: [344, ADEME 2008]				

Average daily consumption per head was calculated in Italy on different types of farms of the same size with at least 10 heads/farm (Table 3.26). A very wide variation was observed. On average, the finishing farms have lower energy use than breeding farms and integrated farms. In particular a lower consumption of diesel fuel and electricity accounts for this.

Table 3.26: Average daily energy consumption per type of pig farm and by type of energy source used in Italy

Energy source	**Energy consumption per farm type (kWh/head per day)**		
	Integrated farms	**Breeding**	**Finishing**
Electrical energy consumption	0.117	0.108	0.062
Diesel fuel	0.178	0.177	0.035
Natural gas	0.013	0.017	0
Fuel oil	0.027	0.011	0.077
Liquid gas	0.026	0.065	0.001
Total thermal consumption	0.243	0.270	0.113
Total energy consumption	**0.360**	**0.378**	**0.175**
Source: [391, Italy 1999]			

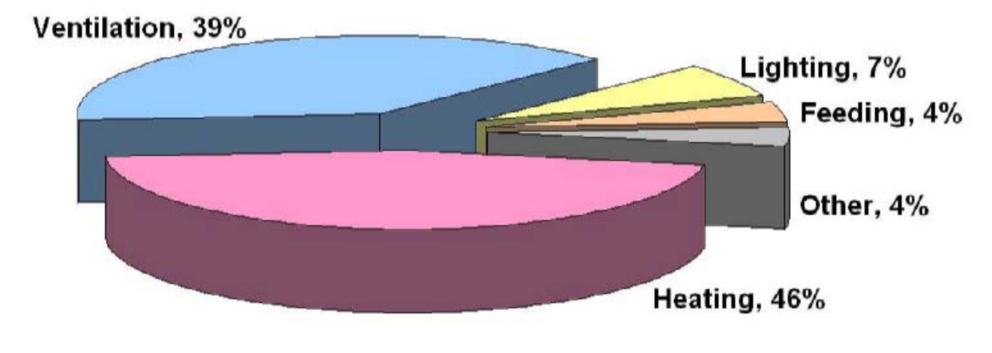
The effect of farm size is also illustrated for farms in Italy (Table 3.27). Here, the larger the farm, the higher the energy consumption. This was explained by the use of higher technology on larger enterprises, with an associated higher consumption of power (factor 2.5). Interestingly, this is in contrast with the experiences in the UK, where large herds have lower energy inputs per head than small herds. [395, ADAS 1999]

Table 3.27: Average daily energy consumption for farms in Italy by ~~farm size~~ animal capacity and energy source

Energy source	**Estimated energy consumption per ~~farm size~~ animal capacity (kWh/head per day)**			
	Up to 500 pigs	**501 to 1 000 pigs**	**1001 to 3 000 pigs**	**Over 3 000 pigs**
Electrical energy consumption	0.061	0.098	0.093	0.150
Diesel fuel	0.084	0.107	0.169	0.208
Natural gas	0.002	0.012	0.023	0.010
Fuel oil	0.048	0.029	0.011	0.049
Liquid gas	0.042	0.048	0.018	0.026
Total thermal energy consumption	0.176	0.196	0.221	0.293
Total energy consumption	**0.237**	**0.294**	**0.314**	**0.443**
Source: [391, Italy 1999]				

~~It satisfies the needs for ventilation, feed distribution, pumps supply, etc. and for other equipment such as computers, lighting and refrigeration. Electricity is also largely used for heating. Fuel oil is the second most consumed type of energy, in particular for powering generators that are used in more than 60 % of the French farms, and for running warm water boilers. [343, ADEME 2008]~~

Heating and ventilation are the main consumers of electricity in pig farms. In Figure 3.2, ~~represents~~ the average electricity consumption is presented for the different uses in the farm; ~~where the proportion of~~ the share for ventilation might be highly variable, depending on the characteristics of fans and management, and on the animals' physiological stages. [344, ADEME 2008]



Source: [344, ADEME 2008]

Figure 3.2: Breakdown of electric consumption on pig farms in France.

A study concerning electricity consumption on pig farms adopting different techniques, was conducted in the UK over around 2 years. The observed results are reported in Table 3.28. A major conclusion reached by this study was that the choice of the system to be adopted has less influence on electrical consumption than the way the system is operated on a daily basis. [432, BPEX 2010]

The main factors affecting the electricity use for ventilation are the stocking density (pig heat needs to be removed), and the differential between the outside temperature and the indoor target temperature. Whilst outside temperature is beyond the control of users, the indoor target temperature is indeed a variable that can be managed.

THE FOLLOWING TEXT HAS BEEN MOVED TO SECTION 4.5

~~From Table 3.22 it can be deduced that increasing the ventilation flow from the minimum recommended (in France) of 3 m^3/h per animal to 5 m^3/h per animal can result in a double energy consumption for heating up the mass of air. [344, ADEME 2008].~~

~~**Table 3.22: Heat consumption according to ventilation flows**~~

~~Ventilation~~	~~Heat consumption~~	~~Heat consumption with 1 cm of insulation added~~
~~m^3/h per animal~~	~~kWh per produced pig~~	~~kWh per produced pig~~
~~3~~	~~6.68~~	~~6.00~~
~~4~~	~~9.02~~	~~8.22~~
~~5~~	~~12.29~~	~~11.00~~
~~6~~	~~14.82~~	~~12.79~~
~~7~~	~~17.40~~	~~14.35~~
~~*Source*: [344, ADEME 2008]~~		

THE EXISTING TABLE 3.23 (REFERENCE YEAR 1999) HAS BEEN DELETED. UPDATED VALUES REPORTED FROM UK ARE REPORTED IN THE FOLLOWING TABLE

Table 3.28: Electric energy consumption for different rearing stages in pig farms in the UK (data from 11 farms)

Animal category	Electric energy consumption			
	Total (kWh/pig)	Heating (kWh/pig)	Ventilation (kWh/pig)	Lighting (kWh/pig)
Farrowing sows	6.3 – 11.3	3.9 – 12.6	0.04 – 1.43	0.6 – 0.9
Weaners	1.7 – 10.6	0.1 – 4.1	0.34 – 5.39	0.3 – 0.7
Growers	3.2 – 11.7	-	3.59 – 14.7	0.9 – 2.6
Source: [432, BPEX 2010]				

Lighting generally represents the third most relevant share of the total electric consumption of a pig farm. Daylight is considered to be desirable, but artificial light is used in its place instead in areas where natural light intensity can be highly variable. Minimum lighting requirements are set by the welfare legislation. Energy requirements for the lighting illumination of pig housing can therefore be quite different for different areas in Europe.

Energy use for heating depends on the type of animal, the climate in the different areas of the EU, and the housing system Examples are presented in [72, ADAS, 1999] and show a considerable range in energy input. as well as and the management of air turnover in rooms, especially for what concerns the minimum ventilation. Creep heating in farrowing houses represents a large proportion of total electricity use.

For feed preparation, the total energy use is considered to be between 15 and 22 kWh/tonne of meal produced where a hammer mill with pneumatic transfer is used to mill cereals. Pelletisation or cubing of the feed on-farm will double the input, requiring about 20 kWh per tonne. Electrical consumption due to feed distribution is quite low in the case of dry feeding but can be significant in the case of wet feed. [432, BPEX 2010]

With these data the total energy use on both farm types was calculated for different herd sizes (table 3.24).

Table 3.24: Total annual energy use per head on different farm types of different size in the UK

Weaner/breeder herd farm size	Energy use (kWh/sow per year)	Breeder/finisher herd farm size	Energy use (kWh/pig sold per year)
< 265 sows	457 – 1038	< 1200 pigs	385 – 780
265 – 450 sows	498 – 914	1200 – 2100 pigs	51 – 134
> 450 sows	83 – 124	> 2100 pigs	41 – 147
Source: [395, ADAS 1999]			

Another difference between the surveys was that electrical energy in Italy was considered as the basic energy source, but the survey revealed that the energy requirements of pig farms are predominantly met by fossil fuels, which supply up to 70 % of their total energy requirements. In the UK the majority of the energy supply is consumed as electricity (>57 %).

Pig rearing on litter is associated to little energy use because dynamic ventilation and heating are only provided to farrowing stages, and fuel oil energy is only used for the operations of litter spreading and cleaning out. Hence, as reported from France, average consumptions are 206 kWh/sow per year (10.8 kWh per produced pig) for integrated farms, and of 11.1 kWh/produced pig for rearing farms with the post-weaning and fattening stages only.
[344, ADEME 2008]

3.2.4 Other inputs

3.2.4.1 Bedding (litter)

The amount of litter used depends on the animal species, the housing system and the farmers' preferences. Use of litter (bedding material) is normally expressed ~~expressed in m^3 per 1000 birds, or~~ in kg per animal (per year). Examples of typical amounts of bedding material, for different animal categories, housing systems and operating conditions, are reported in Table 3.29 and Table 3.30. Amounts used may increase for both layers and pigs, where legislation on animal welfare and market demands will require more litter-based housing techniques.

THE EXISTING TABLE 3.27 HAS BEEN AMENDED WITH NEW DATA AND SPLIT INTO TWO SEPARATE TABLES

Table 3.29 Typical amounts of bedding materials applied in France in pig housing systems

Animal species	Litter used	Typical amounts used
		kg/animal
Finishers	Accumulated straw	50 – 80
	Scraped straw	30 – 50
	Deep straw bedding	50 – 60
	Thin sawdust bedding	20 – 40
Sows	Accumulated straw	900
	Scraped straw	637
Weaners	Accumulated straw	10 – 15
Source: [263, France 2010]		

Table 3.30: Typical amounts of bedding material used by poultry and pigs in housing systems

Animal species	Housing system	Litter used	Typical amounts used kg/animal per yr
Poultry			
Layers	Deep litter on total or part of the area, with or without veranda and outdoors	Chopped straw, wood shavings	0.16 – 0.5
		Sand	0.075
	Deep litter with forced air drying system with vertical tubes	Wood shavings	2.5
Pullets	Deep litter	Chopped straw, wood shavings	2.3
Broilers	Deep litter, with or without veranda and outdoor run	Chopped straw	0.3 – 0.59
		Peat	0.096 (free range) 6.5 (closed housing)
		Wood shavings	0.066 – 0.067
Ducks	Deep litter	Chopped straw	7 – 28
Turkeys	Deep litter	Chopped straw	5.8
Pigs			
Sows	Individual pen for farrowing	Straw	180
	Deep litter for mating/gestating		640
	Plane floor with yard		300 – 450 (average 420)
	Individual pen with partly-slatted floors and vacuum removal, for mating/gestating		4
Weaners	Deep litter on solid floor	Straw	40 – 60 (average 53)
	Kennel housing with partly-slatted floor		26
	Plane floor with yard		35
Fatteners	Deep litter on solid floor	Straw	275 – 400 (average 350)
	Plane floor with yard		250 – 300 (average 275)
	Partly-slatted floor with vacuum removal		8.7

Source: [87, Germany 2010] [144, Finland 2010] [145, Finland 2010] [97, UK 2010] [96, UK 2010] [116, Germany 2010] [117, Germany 2010] [193, Germany 2010] [191, Germany 2010] [181, Germany 2010] [183, Germany 2010] [185, Germany 2010] [276, Finland 2010] [60, Germany 2010] [61, Germany 2010] [62, Germany 2010] [64, Germany 2010] [65, Germany 2010] [66, Germany 2010] [71, Netherlands 2010] [72, Netherlands 2010] [109, Netherlands 2010] [49, Germany 2010] [81, Germany 2010] [172, Germany 2010] [161, Germany 2010] [157, Germany 2010] [229, Finland 2010] [119, Germany 2010]

3.2.4.2 Cleaning material

Cleaning material (detergents) are used with water and will end up in waste water treatment facilities or in the slurry.

A variety of detergents are used for cleaning the housing. Very little information is available on the amounts used. For poultry, a concentration of 1 litre of disinfectant per m^3 was reported, but for pigs, quantification is considered to be very difficult and no representative data have been reported.

3.3 Emission levels

THE ORIGINAL TEXT (IRPP BREF 2003), ALREADY DELETED IN DRAFT 1, HAS BEEN ELIMINATED

The majority of emissions from the main activities on any poultry or pig farm can be attributed to the amount, structure and composition of manure. From an environmental point of view, manure is the most important residue to be managed on-farm. This section therefore starts by presenting an overview of the characteristics of poultry and pig manure before presenting the emission levels of the on-farm activities which involve manure management.

~~Total ammonia-N losses from the whole farming operations, housing, storage and landspreading, are reported from UK in range between 2.1 and 3.6 kg NH_3-N/LU (1 LU= 500 kg of live weight of any animal species). From the different experiences, it appears clear that ammonia losses following landspreading and during housing are the biggest. most important, representing a mean of 57 and 28 % of total system ammonia-N losses, respectively. The losses during storage, including handling and the heap break-out, account for 15 % of total system losses. [146, DEFRA 2002] In France, nitrogen emissions in all stages of production have been calculated both for poultry (Table 3.28) and pigs (Table 3.29)~~

~~Table 3.28 Nitrogen cumulative losses from poultry production systems in France by type of produced manure~~

SEE SECTION 3.3.6 FOR NEW TEXT AND TABLES

~~Type of produced manure~~	~~Housing losses Building (% of excreted N)~~	~~Storage losses (% of the initially stored N)~~	~~Losses at landspreading (% of the applied N)~~	~~Available to plants Usable N (% of the excreted N)~~
~~Solid manure, indoor rearing confinement~~	~~30~~	~~15~~	~~10~~	~~54~~
~~Solid manure, indoor rearing, confinement composting~~	~~30~~	~~30~~	~~0~~	~~49~~
~~Solid manure, broiler, with range~~	~~40~~	~~15~~	~~NA~~	~~46~~
~~Solid manure, force-fed ducks and geese, with free range~~	~~50~~	~~15~~	~~NA~~	~~38~~
~~Solid manure, breeding~~	~~55~~	~~15~~	~~NA~~	~~34~~
~~Slurry~~	~~50~~	~~20~~	~~20~~	~~32~~
~~Dropping, pre-dried, storage under shed~~	~~30~~	~~30~~	~~10~~	~~44~~
~~Dropping, dried~~	~~25~~	~~25~~	~~NA~~	~~51~~
~~Dropping, deep pit~~	~~60~~	~~15~~	~~NA~~	~~29~~
~~*Source*: [258, France 2010]~~				

~~Table 3.29 Nitrogen cumulative losses from pig production systems in France by type of flooring system~~

~~Type of flooring~~	~~Housing losses Building (% of excreted N)~~	~~Storage losses (% of the initially stored N)~~	~~Losses for composting (% of the initially stored N)~~	~~Losses at landspreading (% of the applied N)~~	~~Available to plants Usable N (% of the excreted N)~~
~~Slatted floor~~	~~25~~	~~5~~	-	~~20~~	~~43~~
~~Straw litter~~	~~24~~	~~NA~~	~~27~~	~~10~~	~~29.1~~
~~Straw litter composted~~	~~24~~	~~NA~~	~~27~~	~~0~~	~~37.8~~
~~Sawdust litter~~	~~20~~	~~NA~~	~~9~~	~~10~~	~~23~~
~~Sawdust litter composted~~	~~20~~	~~NA~~	~~9~~	~~0~~	~~22.7~~
~~*Source*: [258, France 2010]~~					

3.3.1 Excretion of manure

The characteristics of manure are, in the first place, affected by the quality of feed, expressed in dry matter (DM) % and the concentration of nutrients (N, P, etc.), and by the efficiency with which the animal can convert it into product (FCR). The efficiency of protein utilisation depends on the dietary composition and the physiological status or the growth stage of the animals. As feed characteristics vary largely, the concentrations in fresh manure will show similar variations. Measures applied to reduce emissions associated with collection (housing), storage and treatment of manure will affect the structure and composition of manure and in the end will influence the emissions associated with application to land.

Emissions are presented as ranges rather than as single averages (mean values), which would not allow the existing variation to be acknowledged or the lower levels achieved to be identified.

~~The lowest and the highest levels that were reported are presented to form the overall European emission range and the factors responsible for this variation are explained. On a national basis, emissions will vary within different ranges, but it is assumed that similar factors apply. Differences have been explained where the data were supported in a way that made this possible.~~
~~This section reports on the excretion levels of manure and nutrient contents that have been submitted. A lot of research has been conducted to understand how~~

Models and tables are available in various Member States to estimate manure production and nutrient content depending on ~~vary with~~ the production stage and the composition of the diet.

An example of model used to estimate animal excretion, reported by Belgium, is presented in Table 3.31. With a known composition of the feed, the ~~Belgian~~ model allows for the identification of the potential mineral gross production of N and P_2O_5. ~~The average losses of N during storage, treatment and spreading are estimated to be 15 % of the gross production~~ [506, TWG ILF BREF 2001] ~~[174, Belgium, 2001]~~. Based on continuous improvement in feed quality and feed conversion, updates of the calculation parameters can be derived.

Table 3.31: Models used in Belgium for the calculation of mineral gross excretion in pig and poultry manure

Animal category	P_2O_5 excretion (kg/animal/year)	N excretion (kg/animal/year)
Piglets (7 – 20 kg)	1.65 (P-uptake) – 0.819	0.10 (N-uptake) – 1.322
Pigs (20 – 110 kg)	1.94 (P-uptake) – 1.698	0.13 (N-uptake) – 3.046
Pigs (>110 kg)	1.8503 (P-uptake) + 0.344	0.133 (N-uptake) – 0.2208
Sows including offspring (<7 kg)	1.8503 (P-uptake) + 0.344	0.133 (N-uptake) – 0.2208
Boars	1.8503 (P-uptake) + 0.344	0.133 (N-uptake) – 0.2208
Layers	2.2254 (P-uptake) – 0.0606	0.1496(N-uptake) – 0.2455
Layers breeders	2.2606 (P-uptake) – 0.0587	0.1548 (N-uptake) – 0.2305
Layer pullets	2.2277 (P-uptake) –0.0512	0.1492 (N-uptake) – 0.1149
Broilers	2.334 (P-uptake) – 0.196	0.1541 (N-uptake) – 0.5283
Broiler breeders	2.2606 (P-uptake) – 0.0587	0.1517 (N-uptake) – 0.1918
Broiler breeders pullets	2.2152 (P-uptake) – 0.0770	0.1571 (N-uptake) – 0.1705

NB: -P: uptake in kg P/animal per year.
-N: uptake in kg crude ~~raw~~ protein/animal per year.
Source: [500, IRPP TWG 2011]

Several mathematical models have been developed to predict pig excretion. As an example, one calculation tool for fattening pigs is based on the following simple approach [610, FEFANA 2012]:

Nutrient Ingested (NI) – Nutrient Retained (NR) = Nutrient Excreted (NE)

The calculation of nitrogen retention in the animal body tissues is based on the following equation [611, C.Rigolet et al. 2010]:

$$N_{body} = [\exp(-0.9892-0.0145*\text{Lean }\%)*\text{EBW}\hat{}(0.7518+0.0044*\text{Lean }\%)]/6.25$$

Where:

Lean % = percentage of lean meat at slaughter weight
EBW = Empty Body Weight (0.96 × body weight)

The tool can also calculate the excreted phosphorus, copper and zinc content taking into account specific conditions of each farm (observed or calculated feed intake, dietary content of feed, weight gain, production cycles, initial and final weight of animals, one phase or bi-phase feeding).

A methodology has been developed within an EC-funded study, to assist individual producers in calculating manure coefficients for different animal categories, taking into account the animal type, diet and management practices [558 , EC , 1999]. The methodology is flexible enough to accommodate the variations in environmental conditions and farming practices within the EU. Table 3.32 summarises the ranges of calculated coefficients for animal excretion, adapted to different animal categories.

Table 3.32: Nitrogen excretion standards calculated for different animal categories

Animal category	Sows with piglets (till 25 kg)	Fattening pigs (25-105 kg)	Laying hens	Broilers (1.8 kg)	Ducks (3.3 kg)	Turkeys (13 kg)
Nitrogen excretion (kg/ap/yr)	21 – 32	7.5 – 13.1	0.35–0.82	0.23 – 0.52	0.41 – 0.97	0.9 – 1.68

Source: [558 , EC , 1999]

3.3.1.1 Levels of excretion and characteristics of poultry manure

Depending on the housing system and the way of collecting manure, different types of poultry manure are produced:

- wet manure from laying hens with a dry matter (DM) content of 25 – 28 %
- wet manure from ducks with a dry matter content of 0 – 20 %
- dry manure (>45 % DM) from layers in ~~battery~~ housing where drying is applied
- deep litter manure (50 – 80 % DM) from laying hens, broilers, turkeys and ducks
- DM contents lower than 20 % obtained by adding water to handle the manure as slurry.

Manure with a dry matter percentage ~~dm %~~ between 20 and 45 % is difficult to handle and in practice water ~~is~~ may be added to enable pumping of the slurry.

Deep litter manure is manure mixed with the bedding over which ~~litter and typically a residue of housing when~~ animals are kept ~~over which is~~ on concrete or slatted floors ~~on litter~~.

The DM content is important, as with increasing DM content, emission of NH_3 will decrease. Calculations showed that with quick drying to a DM content of > 50 %, the emissions of NH_3 (g/hr) were reduced to less than half the emissions as from manure with a DM content of < 40 %.

Feed type, housing system (application of manure drying and the use of litter) and poultry breeds are factors that account for ~~this~~ the variation of the manure composition. With respect to feeding, it is clear that the higher the protein level in feed, the higher the N levels in manure. For the different poultry species, N concentration levels vary within a similar range also as a consequence ~~of housing, feeding and~~ manure management (see Table 3.31 and Table 3.37).

In the next tables, examples of emissions factors for excreted nitrogen, phosphorus and metals are reported for different EU Member States. In Table 3.33 the quantities of various elements (nutrients and metals) excreted with the manure, for different poultry species, reported from France, are presented.

Table 3.33: Excretion levels of different elements in poultry manure, in France

Poultry category	Production cycles per year	Excretion level (g/bird place/year) (1)					
		Nitrogen	P_2O_5	K_2O	CaO	Cu	Zn
Standard broiler	6.15	314	154	203	92	338	1 470
Laying hens	1	713	307	337	1 021	374	2 616
Turkey female	2.6	991	619	577	372	949	4 173
Turkey male	2.04	1 169	785	667	457	1 271	5 004
Barbarie duck	3.4	721	432	367	320	524	3 254
Pekin duck	4.9	858	451	417	353	666	4 077

(1) Values are derived from original data expressed as g/bird, using the given production cycles.
Source: [328 , CORPEN , 2010]

Examples of excretion levels concerning total nitrogen and phosphorus, reported from Ireland and Italy, are presented in Table 3.34.

Table 3.34: Examples of excretion levels for total N and P, from Italy and Ireland

Poultry type	Total Nitrogen (kg/bird place per year)		Total Phosphorus (kg/bird place per year)
	Ireland	Italy	Ireland
Laying hen	0.56	0.66	0.12
Broiler	0.24	0.36	0.09
Turkey	1	NA	0.4

Source: [612, TWG comments 2012]

Calculated excretion levels for different poultry species in the Netherlands, based on standard data from 1999 – 2008, are presented in Table 3.35, together with the relevant parameters used in the calculation.

Table 3.35: Calculated excretion levels for different poultry categories, in the Netherlands (reference year 2008)

Poultry categories	Production cycle	Initial and final weight	Feed conversion	Total feed use	N excreted	P_2O_5 excreted	K_2O excreted
	days	kg + egg production	kg feed/kg growth	kg/yr	kg/ap/yr	kg/ap/yr	kg/ap/yr
Broiler	41.8	0.42 – 2.23	1.8	34.5	0.53	0.19	0.26
Broiler breeders (<18 weeks)	126	0.42 – 2(hens) 2.75 (cocks)	NA	20.7	0.33	0.2	0.16
Broiler breeders (>18 weeks)	298	2 – 7.75(hens) 3.7 – 4.8 (cocks) + 11.9 kg eggs	NA	57.3	1.12	0.55	0.44
Laying hen (<18 weeks)	119	0.35 – 1.47	NA	17.3	0.34	0.17	0.14
Laying hen (>18 weeks)	409	1.47 – 1.76 + 17.3 kg eggs	NA	41.9	0.75	0.39	0.33
Turkey	129.5	0.57 – 15	2.65	112	1.71	0.87	0.9
Duck	46	0.56 – 3.21	2.22	56.6	0.76	0.36	0.48

NA: Not available.
Source: [613, Wageningen 2012]

Data concerning the quantity of manure and total nitrogen produced by different poultry categories, reported from UK, are presented in Table 3.36.

Table 3.36: Nitrogen and excreta production by poultry places, in UK

Poultry	Total N produced (kg/year) (1)	Manure quantity (tonnes/month)
1 000 replacement layer pullet places, up to 17 weeks	210	1.1
1 000 laying hens in cages, 17 weeks and over	400	3.5
1 000 laying hen places, free range, 17 weeks and over	530	3.5 (2)
1 000 broiler places	330	1.5
1 000 replacement broiler breeder pullet places, up to 25 weeks	290	1.1
1 000 broiler breeder places, 25 weeks and over	700	3.4
1 000 turkeys (male)	1230	4.3
1 000 turkeys (female)	910	3.2
1 000 duck places	750	2.5

(1) N produced in excreta is per 1 000 poultry places and includes an allowance for N losses from livestock housing and manure storage.
(2) The time that birds are not housed is not considered. Commonly, free range laying hens are housed for 80 % – 90 % of the cycle.
Source: [614, UK 2012]

~~Emissions from housing and storages,~~ The quantity of manure produced, as well as the nutrients content in manure after housing and before landspreading (after storage) are reported from France and presented in Table 3.37.

Table 3.37: Nutrient composition of manure from different poultry species and management in France

Animal production	Type of manure	Manure produced			Cycles	Animal density (initial)	Nutrient content in the manure (kg/tonne)				
		(kg/bird place per year) (1)	kg/m^2 per year	DM (%)	No	animal per m^2	N	P_2O_5	K_2O	CaO	MgO
Laying hens	Wet droppings			25	1		15	14	12	40.5	3
	Pre-dried droppings on belt	30 – 40		40	1		22	20	12	50	4.8
	Dried droppings in deep pit	15 – 17		80	1		30	40	28	60	8
	Dried droppings under shed	15 – 17		80	1		40	40	28	60	8
	Slurry	70		10	1		6.8	9.5	5.5	16.2	1.2
	Aviary			33 – 44			15 – 28	10 – 12	7 – 8		2 – 3
Ducks	Slurry	82		10 – 15	4.9	14.5	5.9	5.9	4.1	6	1
Standard Broilers	Solid manure out of housing	5	120	75	6.15	22	29	25	20	14.5	3.7
	Solid manure after storage	5	120	75	6.15	22	22	23	18	11	2.8
Heavy Broilers	Solid manure out of housing	12 – 14	130 – 150	70	3.25	11	20	18	15	10	2.5
	Solid manure after storage	12 – 14	130 – 150	70	3.25	11	15	17	14	7.5	1.9
Turkeys	Solid manure out of housing	19 – 22	150 – 170	65	2.6	7.8	27	27	20	23.5	3.7
	Solid manure after storage	19 – 22	150 – 170	65	2.6	7.8	21	25	18	18.2	2.8
Guinea fowl	Solid manure out of housing	7 – 8	110 – 130	70	3.63	16.3	32	25	20	18	2

(1) Values calculated on the basis of the reported data.
Source: [258, France 2010], [328, CORPEN 2006], [434, ITAVI 2001]

3.3.1.2 Levels of excretion and characteristics of pig manure

The annual amount of pig manure, urine and slurry that is produced varies by with pig production category, nutrient content of feed and the drinking system applied, as well as by different production stages with their typical metabolism. During the post-weaning period, feed conversion and live weight gain primarily affect the outputs per animal, whereas growth rate and muscle percentage are less important. For sows, outputs are not influenced by performance when expressed per animal, but can vary a lot when expressed per piglet. The length of the production period and the feed/water ratio are important factors that further account for the observed variation in amounts of slurry per year (Table 3.38). With higher slaughter weights, higher levels of slurry production are found (UK, 4.5 – 7.2 kg per head per day for baconers pigs between 83 and 101 kg).

Table 3.38: Range of levels reported on daily and annual production of manure, urine and slurry by different pig categories

Pig category	Production (kg/head/day)			Production in m^3/head	
	Manure	Urine	Slurry	Per month	Per year
Gestating sow	2.4	2.8 – 6.6	5.2 – 9	0.16 – 0.28	1.9 – 3.3
Farrowing sow ([1])	5.7	10.2	10.9 – 15.9	0.43	5.1 – 5.8
Weaner ([2])	1	0.4 – 0.6	1.4 – 2.3	0.04 – 0.05	0.5 – 0.9
Finisher ([3])	2 – 4.1	1 – 2.1	3 – 7.7	0.09 – 0.26	1.1 – 3.1
Finisher (160 kg)	No data	No data	10 – 13	No data	No data
Gilt	2	1.6	3.6	0.11	1.3

([1]) Water intake varies by with drinking system.
([2]) Feeding and drinking system account for variation.
([3]) Finishing weight 85 – 120 kg.
Source: [44, IKC 1993], [394, Smith et al. 2000] [411, Ireland 2001] [289, MLC 2005]

The following remarks can be made on the variation of nutrient composition of manure. Feed composition and the level of feed utilisation (feed conversion rate, FCR) determine the nutrient levels of pig manure. Utilisation may vary, but advances in the understanding of pig metabolism make it possible to manipulate the composition of manure by adapting the nutrient content of the feed and using ingredients which improve feed utilisation by the animals. changing the nutrient content of pig. FCRs vary between the different stages of production, e.g. finishing pigs have FCR levels ranging between 2.5 and 3.1.

Important factors for the level of excretion of N and P are:

- N and P concentration in the feed
- animal production type
- stage of the rearing cycle level of animal production.

The relationship between the intake of N and P through feed and their excretion in manure has been analysed to allow estimations of N and P outputs through land application. Models have been developed that attempt to give an indication of the excretion levels in pig slurry. A review of excretion by pigs and poultry revealed that these models are in line with data where excreta outputs from pigs have been measured alongside information on feed inputs. At the same time, it was concluded that the information can be used as general guidance, but that at the individual farm level some variation in levels will be observed and different figures for manure output and N excretion will be appropriate. [394, Smith et al. 2000]

Many reports clearly show that lower N levels in manure result from lower crude protein levels (CP levels) in feed. With a lower consumption and an unchanged retention, N losses are considerably reduced (Table 3.39).

Table 3.39: Example of effect of reduced CP-levels in feed for growers and finishers on daily consumption, retention and losses of nitrogen

Species	Level of nitrogen (g/d)					
	Consumption		Retention		Losses	
	Low CP	High CP	Low CP	High CP	Low CP	High CP
Grower	48.0	55.6	30.4	32.0	17.5	23.7
Finisher	57.1	64.2	36.1	35.3	21.0	28.9
Total	105.1	119.8	66.5	67.3	38.5	52.6
Relative (%)	88	100	99	100	73	100
Source: [28, FORUM 2001]						

The annual excretion of N and P by farrowing sows is the result of the excretion of both sow and piglets up to weaning, but varying litter size has a minor influence as illustrated with an example from the Netherlands (see Table 3.40). The data show clearly that excretion is influenced by the content of N in the feed, rather than by differences in technical performance (number of pigs). Efficiency in N utilisation is considered to be highest by farrowing sows and piglets just after weaning.

Table 3.40: Average excretion of nitrogen (kg per year) in a housing with a breeding sow (205 kg) and different numbers of piglets (up to 25 kg) at weaning

	Average number of weaned piglets					
	17.1		21.7		25.1	
	N1([1])	N2([2])	N1([1])	N2([2])	N1([1])	N2([2])
N excretion factor						
Piglet feed	29.0	27.4	29.0	27.4	29.0	27.5
Sow feed – pregnant	22.0	20.4	22.0	20.4	22.0	20.4
Sow feed – lactation	25.5	23.9	25.5	23.9	25.5	23.9
N excretion						
N excretion (kg/yr)	28.7	26.2	29.5	26.7	29.5	26.6

([1]) N1: Higher nitrogen content in feeds.
([2]) N2: Lower nitrogen content in feeds.
Source: [399, ID Lelystad 2000]

Compared to the gestation-farrowing phases, the ~~and~~ growing-finishing ~~fattening~~ stages ~~areas~~ are ~~comparatively~~ biologically inefficient. In addition, the protein efficiency is lower for heavier live weights, as can be seen for the Italian heavy pig that is reared up to an average final weight of 160 kg (see Table 3.41). Since the growing and finishing phases (together, fattening) ~~alone~~ account ~~makes up~~ for the major contribution ~~(77 - 78 %)~~ of excreted nitrogen in a closed cycle farm (77 – 78 %), the most efficient measures for abating the nitrogen emissions are those that are taken in these productions. ~~to the elimination of nitrogen in excretions, measures taken with the diet aimed at improving the balance of this element must be concentrated on this category. The ratio of nitrogen excreted/nitrogen ingested for growers/finishers is generally high, e.g. around 65 % on a closed cycle farm.~~

Table 3.41: Nitrogen retention in different growing phases of fattening pigs finishers (Italian data)

Nitrogen balance (g/head per day)	Growing Fattening phase (kg)		
	40 – 80	**80 – 120**	**120 – 160**
Nitrogen ingested	40.9	69.3	61.3
Nitrogen excreted	25.3	45.7	40.7
Nitrogen retention (%) (N ingested – N excreted)/N ingested)	38.1 61.9	34.1 65.9	33.6 66.4
Source: [391, Italy 1999]			

The applied finishing method is very important. Whereas in Italy 1.5 finishing cycle are possible over one year periods apply, in other European Member States it is common to have between 2.5 and 3 rounds of finishing with different farming systems, leading to weights between 90 and 120 kg. The associated annual levels of N excretion are summarised in Table 3.42. reportedly between 10.9 and 14.6 kg N per animal place. [399, ID Lelystad 2000]

Table 3.42: Annual excretion of nitrogen for different categories of finishers

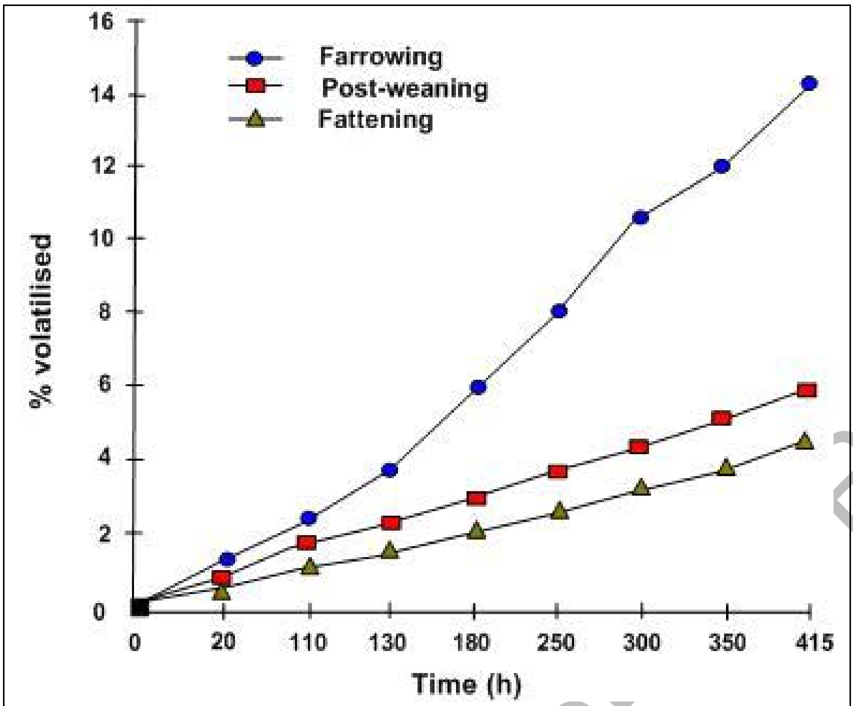
Finishing pigs	Member States			
	France	**Denmark**	**Netherlands**	**Italy**
Finishing period (kg)	28 – 108	32 – 107	25 – 114	40 – 160
Excretion (kg/animal)	4.12	2.94	4.32	NA
Annual excretion (kg/place)	10.3 – 12.36	11.79	10.8 – 12.96	15.4
Source: [399, ID Lelystad 2000] [391, Italy 1999] [500, IRPP TWG 2011]				

In France, where it is common to have 3 rotations of fatteners cycles for fattening pigs per year and 6 rotations cycles for of piglets, the levels of nitrogen excretion that are possible with standard and two-phase feeding are those shown in Table 3.43.

Table 3.43: Standard level of nitrogen excretion in French pig productions

Excretion	Standard feeding	Two-phase feeding
Sow (1), kg/year	24.6	20.4
Piglets (2) (8 – 30 kg), kg/pig	0.62	0.56
Growers/finishers (3) (30 – 112 kg), kg/pig per additional kg live weight (4)	4.56 0.067	3.79 0.060
(1) The discharges are calculated by sow and year (for 1 200 kg of feed/sow per year). (2) The discharges are calculated by produced piglet between 8 and 30 kg of live weights for a feed conversion of 1.74 kg/kg. (3) The discharges are calculated by produced pig between 30 and 112 kg of live weights for a feed conversion in fattening of 2.86 kg/kg. (4) Correction to be brought to the discharge when the weight of slaughter is higher than 112 kg (kg/additional kg at slaughter). *Source*: [258, France 2010]		

The evolution level of ammonia volatilisation in relation to the total nitrogen excreted is ultimately different depending on the animal category stage, as it is represented in Figure 3.3.



Source: [258, France 2010] [436, Guingand N. 2002]

Figure 3.3: Evolution over time of ammonia volatilisation (percentage of total nitrogen excreted) for different pigs in production

Similarly to N excretion levels, P excretion varies by with the total phosphorus content in the diet, the genetic type of the animal and the weight class of the animal (see Table 3.44). Availability of phosphorus in the diet is an important factor. In fact, and measures to improve phosphorus availability this (phytase) show reduced P emissions in manure. Comparing the different pig groups, Retention of P is highest in weaners.

Table 3.44: Example of consumption, retention and excretion of phosphorus in pigs (kg per pig)

	Days	Consumption	Retention	Excretion			
				Faeces	Urine	Total	%
Sow							
Lactation	27	0.78	0.35	0.34	0.09	0.43	55
Dry + gestating	133	1.58	0.24	0.79	0.55	1.34	85
Total/cycle	160	2.36	0.59	1.13	0.64	1.77	75
Total/year	365	5.38	1.35	2.58	1.46	4.04	75
Pig							
Piglet (1.5 – 7.5 kg) (1)	27	0.25	0.06	0.12	0.07	0.19	75
Weaner (7.5 – 26 kg)	48	0.157	0.097	0.053	0.007	0.06	38
Finisher (26 – 113 kg)	119	1.16 (2)	0.43	0.65 (3)	0.08	0.73	63

(1) Based on 21.6 piglets/sow per year.
(2) Feed intake 2.03 kg/day and 4.8 g P/kg feed.
(3) Feed intake 2.03 kg/day and 2.1 g P/kg feed.
Source: [538, Netherlands 1999] [138, the Netherlands, 1999]

Next to the nitrogen and phosphorus content, the excretion of potassium, magnesium oxide and sodium oxide are also relevant for application, see Table 3.45.

Table 3.45: Average composition of different pig manure and standard deviation (in brackets) in kg per 1 000 kg of manure

	DM	OM	N_{total}	N_m	N_{org}	P_20_5	K_20	MgO	Na_20	CaO	Density
	kg per 1 000 kg of manure										kg/m^3
Slurry											
Finishers	90	60	7.2	4.2	3.0	4.2	7.2	1.8	0.9		1 040
	(32)		(1.8)	(1.1)	(1.3)	(1.5)	(1.9)	(0.7)	(0.3)		
Sows	55	35	4.2	2.5	1.7	3.0	4.3	1.1	0.6		
	(28)		(1.4)	(0.8)	(1.0)	(1.7)	(1.4)	(0.7)	(0.2)		
Average slurry			9.6			4.8	5.9	1.7		5.2	
Diluted slurry			4.3			3.8	2.6	1.2		3.6	
Liquid fraction of solid manure											
Finishers	20 – 40	5	4.0 – 6.5	6.1	0.4	0.9 – 2.0	2.5 – 4.5	0.2 – 0.4	1.0		1 010
Sows	10	10	2.0	1.9	0.1	0.9	2.5	0.2	0.2		
Solid manure											
Pigs (straw)	230 – 250	160	7.0 – 7.5	1.5	6.0	7.0 – 9.0	3.5 – 5.0	0.7 – 2.5	1.0		
Solid manure of accumulated straw litter			7.2			7.0	10.2	2.5		6	
Solid manure of scraped straw litter			9.1			10.9	11.2	3.1		7.5	
Solid manure of sawdust litter	336	278	6.4			8.2	11.1				
Solid manure of dried shavings	398	335	6.5			8.8	12.9				
Compost of accumulated litter			7.6			10.2	14.7	3.0		8	
Compost of scraped straw litter			11.0			18.3	20.8	4.0			
Compost of scraped litter and straw			7.7			14.9	10.5	2.0		5	
Compost of sieved residue of slurry			7.2			43.4	2.6	3.0			

NB: OM Organic matter
N_m metabolic nitrogen
N_{org} organic nitrogen
Source: [44, IKC 1993], [389, ADAS 2001][258, France 2010] [429, Texier et al. 2004] [433, CORPEN 2006]

In Table 3.46, the quantities of nitrogen and excreta produced by different pig categories in the UK are presented.

Table 3.46: Pig excreta and nitrogen produced in relation to different pig categories and nutritional measures, in UK

Pig category	Total N produced (kg/year) (1)	Volume of excreta (m^3/month)
1 weaner place, 7 to 13 kg	1.0	0.03
1 weaner place, 13 to 31 kg	4.2	0.05
1 grower place, 31 to 66 kg (dry fed)	7.7	0.10
1 grower place, 31 to 66 kg (liquid fed)	7.7	0.18
1 finisher place, 66 kg and over (dry fed)	10.6	0.13
1 finisher place, 66 kg and over (liquid fed)	10.6	0.26
1 maiden gilt place, 66 kg and over	11.1	0.13
1 sow place, 66 kg and over, with litter up to 7 kg, fed on a lower protein diet but supplemented with synthetic amino acids	16.0	0.33
1 sow place, 66 kg and over, with litter up to 7 kg, fed on a diet without synthetic amino acids	18.0	0.33
1 breeding boar place, from 66 kg to 150 kg	12.0	0.15
1 breeding boar place, 150 kg and over	17.5	0.26

(1) N produced in excreta is per pig place and includes an allowance for N losses from livestock housing and manure storage.
Source: [614, UK 2012]

From the Netherlands, calculated excretion rates per pig category and information on the physiological data associated with the calculations are presented in Table 3.47.

Table 3.47: Calculated annual excretion of nutrients per pig category, in the Netherlands (reference year 2008)

Pig category	Production cycle	Initial weight – Final weight	Growth rate	Total feed use	N excreted	P_2O_5 excreted	K_2O excreted
	Days	kg	kg/day	kg/yr	kg/ap/yr	kg/ap/yr	kg/ap/yr
Fattening pigs	117	25.3 – 116.6	0.778	781	12.9	5	8.1
Gilt - young boar	163	25.3 – 140	0.704	804	13.5	5.9	8.1
Breeding sows (mixed)		140 – 230 (1)	(2)	1941	30.8	14.7	19.4

(1) 25.3 kg finishing weight per piglet.
(2) 26.5 reared piglets per sow.
Source: [613, Wageningen 2012]

In Table 3.48, excretion rates per pig category in terms of Total Nitrogen (kg/year) and Total Phosphorus (kg/year) are presented, as reported by Ireland.

Table 3.48: Annual excretion rates and slurry production for pig rearing units and different pig categories, in Ireland

Pig category	Slurry production	Annual Excretion Rate	
	m^3/ap/yr	kg N/ap/yr	kg P/ap/yr
Breeding unit (sow)	NA	35	8
Integrated unit (per sow place)	NA	87	17
Finishing unit (per pig place)	NA	9.2	1.7
Gilts in pig	2.48	20	NA
Gilts not yet served	1.77	9.2	NA
Sows in pig	5.93	20	NA
Other breeding sows	2.48	20	NA
Boars	2.48	16	NA
Fatteners >20 kg	1.77	9.2	NA
Fatteners <20 kg	0.67	3	NA

NA: Not available
Source: [615, IE EPA 2012]

3.3.2 Emissions from housing systems

~~After The manure that is produced in livestock houses is not lost in the environment but it produces emissions to air that are the major emissions from animal housing.~~ Key emissions to air that are produced in animal housing systems are ammonia (NH_3), odour, ~~and~~ dust, ~~but~~ methane (CH_4) and nitrous oxide (N_2O)~~ emissions can have an impact as well~~.

The main source of **ammonia** is the rapid hydrolysis of urea contained in urine by the urease leading to ammonium (NH_4^+). Another source of NH_3 is the degradation of undigested proteins, but this pathway is not as fast as the previous. The urease is an enzyme largely present in faecal bacteria and it can be found in abundance on fouled surfaces like floors, pits and walls inside livestock buildings. Urease activity is affected by temperature; it is low at temperatures below 5 – 10 °C and above 60 °C. Under practical conditions, models show an exponential increase of urease activity related to temperature. Urease activity is also affected by pH with optimum ranging from 6 to 9; while, animal manure pH is usually buffered to between 7.0 and 8.4. Therefore, optimal conditions for complete urea hydrolysis are largely met in animal husbandry, making the urea availability the limiting factor. The NH_4^+ production depends also on manure moisture content because water is necessary for bacterial activity. Thus, NH_4^+ production is optimal between 40 % and 60 % moisture content; emissions decrease at values above and below this range. Ammonia production stops below 5 – 10 % moisture content. [590 , BATFARM, 2013]

Ammonia release from manures is also associated with the difference in NH_3 concentration between the manure and the air above. On the one hand, NH_3 concentration in the manure is affected by pH and temperature, as described above; on the other hand, NH_3 removal from the surface air is governed by the convective mass transportation due to the house ventilation. [277, Ji-Qin et al. 2000]

Due to its very low olfactory threshold, NH_3 has a ~~strict~~ relationship with nuisance odour, at higher than neutral pH conditions. [277, Ji-Qin et al. 2000] [500, IRPP TWG 2011]

Nitrous oxide formation occurs during incomplete nitrification/denitrification processes that normally convert NH_3 into N_2. Thus, N_2O synthesis requires a close combination of aerobic and anaerobic areas; in general, these heterogeneous conditions are not met with slurry but with litter. However, N_2O emissions can occur from slurry when a dry crust is formed on the surface, generating anaerobic and aerobic micro-sites. Because of these numerous sources and different conditions that affect N_2O emissions formation, N_2O production from manure has a highly random nature, especially with litter systems. [590 , BATFARM, 2013]

Methane production originates from the anaerobic degradation of organic matter performed by mesophilic/thermophilic bacteria with an optimal pH close to neutrality. In pig houses, the sources of CH_4 emissions are the animal digestive tract and the releases from the manure. The level of enteric CH_4 is function of the fermentative capacity of the digestive tract in the animal, and the content, source and solubility of dietary fibre. In indoor slurry/manure storage, CH_4 release is promoted by high temperature, high organic matter content and availability of oxygen. On the contrary, the production is inhibited under aerobic conditions or high concentration of ammonium and sulphides. If a surface crust is formed on slurry, CH_4 releases are less since the CH_4 produced can be oxidised into CO_2 during passage through the crust. [590, Batfarm 2013]

A long term investigation carried out in fattening pig houses, found a clear influence of the average daily outside temperature (above 25 ºC) on the level of the CH_4 emissions. In the same study, it was also demonstrated that CH_4 emissions were reduced significantly when a complete slurry removal at the end of each fattening cycle and subsequent cleaning of the slurry pits were performed. [444, Haeussermann et al. 2006]

Dust emissions originate from the feed, bedding material and from the animal activities. The amount of airborne dust may vary significantly depending on the type of animal, but also in the course of a day. The concentration of dust in animal housing, in particular the PM_{10} fraction,can have a direct negative effect on the animals and humans, due to the compounds that the dust particles may carry (bacteria, toxins). Dust also plays an important role as a carrier of odorous compounds.

The airborne particles that can be generated in livestock buildings range from non organic substances (e.g. soil material) to organic particles from plants and animals, including dead and living microorganisms that are usually named 'bioaerosols'.

Between the factors that affect dust emissions there are:

i ventilation
ii activity of the animals
iii type and quantity of bedding
iv the type and the consistency of feedstuff
v humidity in the animal house.

More dust is raised from bedded pens than from non-bedded ones. The kind and quality of litter influence the emissions. Finely structured material (e.g. chopped straw) emits more particles than coarse material (long straw, wood shavings).

The indoor dust concentration depends very much on the animal activity. Housing techniques which offer the animals only little freedom of motion (e.g. small group housing of laying hens) emit less dust than those which provide more freedom of motion (e.g. large group housing, aviary housing, floor husbandry).

In pig housing, airborne particulate matter also depends on the feeding technique and human presence. Each time feed and when the animals are disturbed (e.g. during inspection rounds), higher concentrations are measured than at night and in resting phases.

The formation of dust can also be reduced, by serving liquid, moistened or pelleted feed and by using corn and grass feedstuffs in place than roughage (hay, straw) or by adding dietary fat or oil to dry feed.

The level and variation of air emissions are determined by many factors that ~~these~~ can be linked and can also affect one another ~~each other~~. Major factors that influence air emissions from housing are:

- design of the animal housing and manure collection system

- ventilation system and ventilation rate
- applied heating and indoor temperature
- the type of reared animal hence its age, the type of production and final weight
- the amount and quality of manure, which in turn ~~also~~ depends on:
  - feeding strategy
  - feed formulation (protein level)
  - application of litter
  - watering and watering system
  - moisture content of manure
  - ~~number of~~ animal~~s~~ load (number and weight)
  - the seasonal and climatic conditions
  - animal's health state.

The following sections will present the levels of emissions of different substances to air from poultry and pig housing systems. The lowest levels are generally achieved with additional air cleaning techniques (end-of-pipe)~~, such as a chemical scrubber~~.

3.3.2.1 Emissions from poultry housing

Ammonia

In accordance with Council Directive 2007/43/EC, concentrations of ammonia must not exceed 20 ppm in the house, measured at the level of the birds' head. According to a study carried out in UK in 2002, ~~and~~ ammonia concentrations in commercial broiler houses appear to be consistently below 15 ppm. [149, Robertson et al. 2002] In case of reduced ventilation or high humidity, extremely high concentrations of ammonia are possible (50 – 200 ppm) [433, CORPEN 2006]. In general, peaks in ammonia concentrations are related to poor litter management.

~~Quantification of the concentrations and emission rates of NH_3, CO_2 and dust have been reported for layers in, respectively, a perchery and a deep pit house, and for broilers in a typical broiler house [400, Silsoe Inst. 1997] [129, Silsoe Research Institute, 1997]. This highlighted that The ammonia concentration can rise to peaks (for more than an hour) of 40 ppm (g/m^3) in broiler houses, which was considered to be due to poor litter management.~~

Daily values of poultry emissions have been measured in the UK, for conditions without diet manipulation to reduce emissions, and are expressed as grams of emission per kilogram of live weight. Average ammonia emissions were measured for different bird categories:

- ~~0.38~~ 0.34 kg/bird/day for broilers, with significant site variability ranging from 0.15 kg/bird/day to a peak measured value of around 1.3 kg/bird/day; higher emission rates coincided with higher moisture contents;
- values in the range of ~~0.8~~ 0.2 – 1.8 kg/bird/day for laying hens, depending on manure storage, removal and/or crop age;
- 0.14 kg/bird/day for turkeys, ranging from 0.05 kg/bird/day during winter to 0.4 kg/bird/day in summer;
- 1 kg/bird/day for ducks, associated with higher moisture levels in the straw litter [151, Link CR 2005].

In Table 3.49, the range of ammonia emission factors reported by various Member States, for housings of different poultry categories, is presented.

Table 3.49: Range of reported national ammonia emission factors for poultry housing

Bird categories	Ammonia emission (kg NH_3/ap/yr)	Source
Broilers	0.034 – 0.10 ([1])	[614, UK 2012] [500, IRPP TWG 2011]
Hens in cages (with belts)	0.085 – 0.168	[462, VITO 2005] [616, Spain 2012]
Hens on floor, with manure pit	0.29 – 0.45	[614, UK 2012] [500, IRPP TWG 2011]
Hens on floor, with manure belts	0.091 – 0.15	[571, Eurich-Menden et al. 2011] [500, IRPP TWG 2011]
Turkeys (male)	0.436 ([1]) – 0.68	[500, IRPP TWG 2011] [571, Eurich-Menden et al. 2011]
Turkeys (female)	0.23 – 0.387	[614, UK 2012] [571, Eurich-Menden et al. 2011]
Ducks	0.11 – 0.146	[614, UK 2012] [571, Eurich-Menden et al. 2011]

([1]) Values from Denmark have been calculated from reported data given in Table 3.50

Two indicative, more detailed, examples of national ammonia emission factors for poultry houses applied in Denmark and UK, are presented in Table 3.50 and Table 3.51, respectively.

Table 3.50: Ammonia emission factors for different poultry types and systems, in Denmark

Type of production	Ammonia emission	
	kg/1 000 birds produced	kg/ap/year ([1])
Broilers, 35 days at slaughter	9.74	0.10 – 0.124
Broilers, 40 days at slaughter	13.1	0.12
Turkeys, females, 112 days at slaughter	96.2	0.31
Turkeys, males, 147 days at slaughter	175.6	0.435
Ducks, 52 days at slaughter	34.6	0.24
Layers in cages with manure belt, 365 feeding days	69.5	0.069
Layers, barn eggs, deep litter and manure pit	302.9	0.30
Layers, aviary (multi tier and manure belt), 365 feeding days	99.2	0.099

([1]) The production cycles have been derived by dividing the breeding time by 365 days.
Source: [500, IRPP TWG 2011]

Table 3.51: Ammonia emission factors for different poultry types, in UK

Housing/Type of production	Average live weight	NH_3 emission factor	
	kg	g N/LU/d	kg NH_3/ap/yr
Layers – Aviary	2.2	149	0.29
Layers – Cages (belt)	2.2	60	0.12
Broilers ([1])	0.9	64	0.034
Turkeys (male)	8	64	0.45
Turkeys (female)	4	64	0.23
Ducks	2	64	0.11
Pullets	1	64	0.06

([1]) The calculation for the emission factor includes also the period for delittering the empty poultry sheds, during which emissions occur.
Source: [614, UK 2012]

As for stocking density, ammonia emissions from broiler houses can be expressed as a factor for LU in the range of 16.6 kg of ammonia in the 290 days a year that the house is used. [147, Demmers et al 1999]

Drinking water spillages increase the litter moisture content; therefore, the system's operation planning and type of equipment affect ammonia emissions. In particular, ammonia losses from broiler houses using traditional bell drinkers have been found to be three times greater (3.3 g NH_3-N/h on average per LU) than those using nipple drinkers, although differences seem not to be statistically confirmed. [146, DEFRA 2002]

Calculation of emission factors for broilers that are made in the UK consider occupation periods of 278 days per cycle. Emissions occurring during delittering should be added to sum a full-cycle factor. [148, BPC 2009] Studies in the UK [147, Demmers et al 1999] [149, Robertson et al. 2002] measured as 1.4 g NH_3/animal place per year, the emissions due to 7 days of delittering after each cycle. The cleaning out period is also pointed out as when the 22 % of the total ammonia emissions are lost. [146, DEFRA 2002]

A cost-benefit analysis In the UK, it has been shown that for broilers a 1 °C reduction in temperature leads to a reduction in emissions of ammonia by 0.04 g per kg of live bird per day. The cost per bird of abating ammonia emissions through a reduction in temperature by 1 °C is EUR 0.27 – 0.28 per bird. However, there are concerns that temperature reduction may reduce the productivity and that there may be a related increase in greenhouse gas emissions, partly as more energy is used in ventilation. [151, Link CR 2005] **Moved to Section 4.6.4.1**

NO_2, Nitrous oxide, methane and other gaseous emissions
The development of nitrous oxide (N_2O), methane (CH_4) and non-methane volatile organic compounds (NMVOC) is associated with the internal storage of manure; in general, their levels in housing can be considered very low when the manure is frequently removed.

Hydrogen sulphide (H_2S) is generally present at very low quantities, i.e. about 1 ppm [391, Italy 1999].

Dust
In general, dust levels are higher in litter-based systems than in cage systems. As Dust may functions as a carrier for part of the air emissions, higher levels for gaseous compounds such as CH_4 and NO_2 are associated with litter-based systems but its correlation with odours is less clear than for pig housing. [438, Lacey et al. 2004]

Studies carried out in France in laying hens housings, showed a much higher dust concentration in aviaries than in cage systems. In one particular study, average dust emissions (<100 µ) are were measured, for a period of 5 hours resulting in 1.8 mg/m^3 in cage housing and 15.3 mg/m^3 in aviaries. [367, Michel et al. 2005]. Another study showed that the daily (24 hours) average concentration of fine dust (<4 µ) in deep litter houses was is equivalent to 0.36 mg/m^3, which is significantly higher than the average emission in cages system, around 0.12 mg/m^3. In addition, the measured values had a high variability in the case of litter systems (from 0.30 to.42 mg/m^3); whereas, values from cage systems were more homogeneous (from 0.10 to 0.14 mg/m^3).

Under UK conditions, reported daily average dust emissions (with higher concentrations during the day and lower overnight) do not show significant differences are similar for all between non-caged poultry houses (with the exception of a few broiler houses), with values generally below 0.4 g per kg of bird per day [151, Link CR 2005]. Dust emission increases with the birds' growth and activity. During the first three weeks of rearing, young chicks little animals are not very active and little dust is raised, but in the following stages, the older birds heavier animals occupy most of the available space, walk more actively and lose feathers. As a consequence, more dust is raised. Punctual Point source concentrations of inhalable dust at broilers houses (at day 30) are about 5 – 7 mg/m^3 [149, Robertson et al. 2002] but average values are between 1 and 3.5 mg/m^3. [366, Renault et al 1997] In Austria, an emission factor of

0.1 kg of dust per animal place per year is considered for laying hen reared on aviaries. [373, UBA 2009]

In ducks rearing, ~~it can be~~ an increase in dust emissions with the animals age/live weight is clearly observed, as it is reported in Table 3.52.

Table 3.52: Estimated emissions from fan ventilated duck housings in the UK

Duck age (days)	NH_3 emission (g/bird per day)	Dust emission (g/bird per day)
20	0.33	0.02
27	0.55	0.08
34	0.82	0.12
41	1.15	0.22
47	1.57	0.28
Source: [152, Link CR 2006]		

The highest concentrations are found in guinea fowl houses, where indoor dust concentrations are on average 35.7 mg/m^3. [366, Renault et al 1997]

Odour
In UK commercial-scale studies have been carried out on four broiler houses, by measuring odour concentration from flocks of approximately 34 000 birds, fed with different protein level diets. In particular, male broilers received *ad libitum* diets with target protein levels (based on lysine content) of 85, 90, 100 or 110 % of the normal commercial level. Odour concentrations were fairly consistent between houses, falling in the range of 600–800 ou_E/s per m^3 around day 16, and 1 300 – 2 300 ou_E/s per m^3 around day 30, corresponding to odour emissions in the range of 20 000 – 33 000 ou_E/s. [149, Robertson et al. 2002]

An overview of the reported emission values (given as ranges) for NH_3, CH_4, N_2O, dust and odour , methane, for the different types of poultry, is given in Table 3.53.

Table 3.53: Range of reported air emission levels for different types of poultry

Type of poultry	NH_3	CH_4	N_2O	PM_{10}	Odour (1)	Source
	kg per animal place per year				ou_E/s per animal place	
Laying hens – Enriched cage systems	0.02 – 0.15		0.0017 – 0.0024	0.01 – 0.04	0.102 – 0.37	[57, Denmark 2010] [63, Germany 2010] [68, Spain 2010] [69, Spain 2010] [84, UK 2010] [56, Denmark 2010]
Laying hens – Non-cage systems	0.019 – 0.352	0.078	0.002 – 0.006	0.02 – 0.12	0.143 – 0.61	[71, Netherlands 2010] [66, Germany 2010] [85, UK 2010][60, Germany 2010] [64, Germany 2010][85, UK 2010] [65, Germany 2010]
Pullets	0.014 – 0.21			0.023 – 0.12	0.042 – 0.227	[76, Netherlands 2010][49, Germany 2010] [77, Netherlands 2010][49, Germany 2010] [81, Germany 2010][74, Netherlands 2010]
Broilers	0.015 – 0.18	0.078	0.009 – 0.024	0.015 – 0.025	0.032 – 0.24	[94,Netherlands 2010][50, Austria 2010] [98, UK 2010][2003 IRPP BREF] [87, Germany 2010] [96, UK 2010] [586 , The Netherlands, 2011]
Broiler breeders	0.08 – 0.435		0.01 – 0.084	0.028 – 0.049	0.18 – 0.93	[108, BE Flanders 2010][109, Netherlands 2010][117, Germany 2010][115, Netherlands 2010][114, Netherlands 2010] [109, Netherlands 2010][114, Netherlands 2010][112, Netherlands 2010]
Turkeys (female)	0. 045 – 0.387		0.015	0.09 – 0.5	0.4	[500, IRPP TWG 2011][118, Germany 2010][2003 IRPP BREF][500, IRPP TWG 2011]
Turkeys (male)	0.138 – 0.68			0.24 – 0.9	0.71	[500, IRPP TWG 2011][118, Germany 2010]
Ducks	0.05 – 0.21		0.015		0.29 – 0.49	[117, Germany 2010] [115, Netherlands 2010] [2003 IRPP BREF][116, Germany 2010] [115, Netherlands 2010]
Guinea fowls	0.80		0.015			[2003 IRPP BREF]

(1) Odour emissions have been elaborated from original data expressed in ou_E/s per LU.

3.3.2.2 Emissions from pig housing

Many factors determine the level of emissions from pig housing, such as nutrient content of the feed, indoor climate conditions and the level of maintenance of the housing facilities, influencing the aerial losses from the manure that is excreted by animals.

Ammonia

A major factor influencing NH_3 emission from housings is the increase in feed intake during the growing period, in particular with fattening pigs, which results in an increased excretion of total ammoniacal nitrogen (TAN) leading to a greater emission of ammonia. [439, Sommer et al. 2006]

Increasing the number of animals per pen/room reduces the relative loss of NH_3 per unit area. However, animal welfare considerations would limit this reduction measure. [439, Sommer et al. 2006]

In **slurry-based** pig housing systems ammonia emissions may vary significantly because of differences in surface area of the slurry channels, ratio of solid floor and slatted area, slurry pH, TAN concentration in the slurry, temperature and ventilation rate. It is generally assumed that in buildings with partly- slatted floors the majority of the emission arises from the slurry channels and that floor emissions account for between 11 and 40 % of the emission from the pens. The variation depends on the cleanliness of the solid floor and the size of the slatted area. The magnitude of soiled area is related to the animal behaviour, which can be controlled partly through the design of the pens, position of feeders and drinkers, and indoor climate. [439, Sommer et al. 2006]

It has been observed that pigs prefer to defecate/urinate with their back end to a wall, and particularly to the back wall of the pen furthest away from the lying area. The pigs seek seclusion for excretory behaviour because of their unstable position during this activity. [439, Sommer et al. 2006].

Normally, in ventilated buildings, pigs prefer to lie on a warm floor that is solid, which contribute to a tendency for dunging in the slatted floor area. Thus, fattening pigs (30– 110 kg) spend 87 % of their time lying, mostly on the solid concrete floor in buildings with a partially slatted floor. However, at high ambient temperatures, pigs prefer to lie on a cool surface, which will be the slatted floor and, consequently, dung on the warmer (previously lying) surface. This fouling causes an increase in the emitting area, not only from the floor but also, to some extent, from the fouled animals themselves. [439, Sommer et al. 2006] From France, it is reported that the temperature threshold for this behavioural change is around 24 °C, and ammonia emissions are increased by around 30 %. In this way, the temperature counter-effects the benefits of the emission reduction that is expected by the partly-slatted floor rearing technique. [261, France 2010].

The number of pigs lying on the slatted area and the number of urination and defecation events taking place on the solid concrete floor increase toward the end of the fattening period due to lack of space and increased heat generated by the pigs themselves as they grow bigger. However, variations in NH_3 emissions can be accounted for in terms of the degree of soiling of the solid concrete floor rather than the quantity of slurry stored beneath the slats in partly-slatted floors. [439, Sommer et al. 2006].

Studies showed that planning the position of drinking and feeding areas, social behaviour in a group and reactions to changes in climate all influence the defecating ~~manure manuring~~ behaviour of the animals and hence can change the emission levels. ~~For example, in designs with solid or partly-slatted floors, temperature increases stimulate animals to find cooling by lying in their manure on the non-slatted part of the floor, thus spreading the manure and enhancing emissions.~~ ~~The indoor temperature also affects emissions.~~

The indoor ammonia concentration is inversely proportional to the ventilation rate (by a dilution effect) and is proportional to the total weight of reared pigs. Hence, the emission rate from the buildings is directly proportional to the live weight and ammonia concentration times the ventilation rate. ~~and liveweight~~.

EXISTING TABLE 3.43 AND TABLE 3.44 HAVE BEEN DELETED AND SUBSTITUTED WITH NEW TABLES, ON THE BASIS OF THE COMMENTS RECEIVED FROM TWG

~~Table 3.43 shows the emissions recorded in conditions of relatively warm weather (21.8 °C as outdoors average during 3 months) and the conditions at which measurements were taken.~~

~~In Table 3.44, some reported emission factors levels have been summarised for animal category. Odour and dust emissions are described in section 3.3.6 and section **Error! Reference source not found.**. The levels apply to different housing techniques and different areas. Data on CH_4 and N_2O are the result of an inventory that concluded that data for pig housing are indicative. Only a few data are available and they can be used to a limited extent. Observed ranges vary and in the table only the lowest and highest observed levels are reported.~~

In a reported ~~another~~ example, in pens for group-housed sows designed with functional areas, it was observed that care must be taken to guarantee the accessibility of these areas, as the social order in the group prevented younger sows from free and easy access, when older sows blocked small passageways to the feeding and defecating ~~dunging~~ area. The young sows then started to defecate ~~manure~~ outside the designed slatted area causing an increase in ammonia emissions. The use of periodical water shower drizzles has been reported as an effective measure to reduce this type of behaviour in the rearing of fattening pigs and sows. [500, IRPP TWG, 2011]

In **litter-based systems**, urine infiltrates the litter (sawdust or straw), thus, reducing the surface area in contact with the air. Straw also has the effect of reducing the airflow over the emitting surface. At the same time, dung can be absorbed by the straw and transformed into organic-N by microorganisms. This would suggest that the potential for N losses via volatilisation of NH_3 from deep litter systems might be smaller compared to slurry systems. However, the O_2 that diffuses into the porous surface layer, is utilised by aerobic microbial activity in the litter, resulting in a temperature increase to about 40 – 50 ºC, with consequent NH_3 losses. [439, Sommer et al. 2006]

Ammonia emissions may be ~~are~~ higher from straw litter floors than from slatted floors where the straw is accumulated or removed at longer intervals, i.e. once per month. [375, Philippe et al. 2007] or if composting starts in the straw-based systems. If soiled bedding material is regularly removed and replaced (weekly or daily), no significant difference of ammonia and dust emissions should arise from straw bedded housings compared to slatted floor systems. [289, MLC 2005] [439, Sommer et al. 2006]

In insulated buildings ~~rearing~~ where pigs are reared on deep litter straw beddings (more straw is added up at intervals and the manure is removed at the end of the cycle), ammonia emissions can vary from 15 – 25 % of the excreted nitrogen to 5 – 15 %, ~~if~~ in the case bedding exceeds 50 – 80 kg/animal, if the duration of breeding decreases or if rearing densities decrease from 1 – 1.4 m^2/pig to 2 and more m^2/pigs. [378, Robin et al. 2004]. Nevertheless the variation in the reported emissions of comparative studies, demonstrate that there is no consistent difference between slurry-based and deep litter systems. [439, Sommer et al. 2006]

An example of detailed reference emission factors used in pig housing in UK is presented in Table 3.54.

Table 3.54: Ammonia emission factors for pig rearing, used in UK

Housing/Type of production	Average live weight	NH_3 emission factor	
	kg	g N/LU/d	kg NH_3/ap/yr
Sows – straw	200	25.8	4.57
Sows – slats	200	17	3.01
Farrowing sows – straw	225	44.5	8.88
Farrowing sows – slats	225	29.3	5.84
Weaners – straw	12	19.9	0.21
Weaners – slats	12	27.7	0.29
Growers – straw	25	51.6	1.14
Growers – slats	25	71.9	1.59
Fatteners – straw	65	51.6	2.97
Fatteners – slats	65	71.9	4.14
Boars – straw	250	25.8	5.72

Source: [614, UK 2012]

In Table 3.55, ranges of reported national ammonia emission factors for pig housing are presented. The differences reflect the specific characteristics of the livestock and manure management systems, as well as different climatic conditions.

Table 3.55: Ranges of ammonia emission factors for pig housing, reported by Member States

Type of production	Ammonia emission factors	
	kg NH_3-N/N ex-animal	kg NH_3/ap/yr
Fattening pigs (Growers – Finishers from 20 to 100 kg)	0.15 – 0.332 (1)	1.57 – 3.00
Growers (20 – 50 kg)	0.20	1.59 – 1.92 (2)
Finishers (50 – 100 kg)	0.20	2.58 (2) – 4.14
Sows	0.14 – 0.17	
Sows (mating/gestating/gilts in pigs, etc.)	0.15 – 0.25 (1)	3.01 – 5.5
Gilts	0.15	2.53 (2) – 2.58
Farrowing sows	0.19 (1)	5.02 (2) – 8.9
Weaners	0.148 (2) – 0.20 0.15 (1)	0.21 – 0.51 (2)

(1) Values expressed as % of TAN.
(2) Values calculated from reported emissions given in kg NH_3-N/ap/yr.
Source: [612, TWG comments 2012]

Nitrogen oxide and methane

In pig houses where no bedding is used, the slurry produced remains in a predominantly anaerobic state with little opportunity for the NH_4^+ to be nitrified. As a result, little or no N_2O emissions are likely to occur from such buildings. [443, Chadwick et al. 2011]. Emissions ranging between 0.66 to 3.62 g N_2O/LU per day have been measured from slurry-based pig houses with fully-slatted floors. Much higher emissions may occur in deep litter systems with fattening pigs, where values between 4.8 and 7.2 g N_2O/LU per day have been reported. [443, Chadwick et al. 2011]. From other literature sources, in housings for fattening pigs in the Netherlands, Germany and Belgium, the measured average value for N_2O emissions is 2.7 g N_2O-N/day per animal place [441, Webb et al. 2011].

Investigations on methane release from a pig house with indoor slurry storage showed an emission rate of 3.8 kg CH_4/ap/yr when slurry pits were emptied at the end of the cycle but not cleaned afterwards. In particular, average daily CH_4 emissions ranged from 0.8 to 124 g/day/LU or 0.1 to 22.5 g/day/pig. CH_4 emission rates were very low until day 16–19 of the fattening period. The average CH_4 emission per animal per year was reduced by 40 %, if the slurry removal was combined with a complete cleaning of the slurry pit. [444, Haeussermann et al. 2006]

Dust and odour

See also Section 3.3.2.1 for general information concerning these emissions.

In Table 3.56, Table 3.57 and Table 3.58, the ~~some~~ reported emission factors associated with different housing techniques ~~levels~~ have been summarised per animal category (sows, weaned piglets and fattening pigs).

Table 3.56: Range of air emissions from sow (mating/gestating, farrowing) housing systems

Housing system	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	kg/ap/yr				ou_E/s/ap	
PSF – Group housing Mating/Gestating	1.85 – 2.77	NA	1 – 2.3	0.16– 0.22	18.7	IRPP BREF 2003 [263, France 2010] [156, Germany 2010]. [166, Netherlands 2010]
PSF – Individual housing Mating/Gestating	1.23 – 2.4	1.5 – 55.5	NA	0.16 – 0.22	18.7	IRPP BREF 2003 [164, Spain 2010] [165, Netherlands 2010]
FSF – Group housing Mating/Gestating	2.77 – 5	NA	NA	NA	NA	IRPP BREF 2003 [156, Germany 2010].
FSF – Individual housing Mating/Gestating	4.2 – 8.6	NA	NA	NA	NA	IRPP BREF 2003 [159, Austria 2010]
Solid litter floor Mating/Gestating	2.5 – 5.6	NA	NA	0.8	22	[261, France 2010]
Slatted floors Farrowing sows	2.4 – 9.0	0 – 232	NA	0.16	8	IRPP BREF 2003 [261, France 2010]. [171, Germany 2010] [170 Spain 2010]
Littered floor Farrowing sows	8.3	NA	NA	0.16	8	[172, Germany 2010]
NA= Not available						

Table 3.57: Range of air emissions from weaned piglets housing systems

Housing system	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	kg/ap/yr				ou_E/s/ap	
Partly-slatted/Fully-slatted floor	0.029 – 0.78	NA	NA	0.132	5.4	[179, Spain 2010] [261, France 2010]. [177, Netherlands 2010]
Littered floor	0.2 – 0.7	NA	NA	0.08	3	[181, Germany 2010]
NA= Not available						

Table 3.58: Range of air emission from fattening pig housing systems

Housing system	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	kg/ap/yr				ou_E/s/ap	
Fully-slatted floor	0.54 – 7	0.42 – 6	0.02 - 0.15	0.24	3.8 – 7	[187, Spain 2010] [261, France 2010] [189, Germany 2010]
Partly-slatted floor	0.89 – 3.6	0.9 – 30	0.02 – 0.15	0.11 – 0.275	5.9 – 17.9	[196, Spain 2010] [192, Germany 2010].
Solid and litter	2.39 – 5	0.58 – 18.0	0.06 – 3.7	0.32	3.9 – 6.9	[191, Germany 2010] [193, Germany 2010] [519, Amon et al. 2007

3.3.3 Emissions from external manure storage facilities

The storage of solid manure and slurry is a source of ~~airborne~~ gaseous emissions of ammonia, methane, nitrous oxide and other odorous components. The liquid draining from solid manure (e.g. stacks in field) can also be considered ~~as~~ an emission. Emissions of manure storage depend on a number of factors.

Solid manure

- Chemical composition of manure
- Composting potential (water content, density and C content)
- Application of covers.

Slurry

- Chemical composition of ~~manure/~~slurry/~~compost~~
- Physical characteristics (~~DM~~ Dry Matter %, pH, ~~temperature~~)
- Emitting surface (size, crusts, ~~covers~~)
- Climatic conditions (ambient temperature, rain, wind)
- Application of covers.

Of ~~all~~ the previously mentioned factors, the most important factors ~~are dm %,~~ are the dry matter and nitrogen ~~(N) nutrient~~ contents (in particular TAN). Dry matter essentially depends on the management, whilst nitrogen ~~which~~ depends on the feeding practice. In addition, housing techniques that aim for a reduction of emissions from in-house collection ~~and~~ they affect the manure nitrogen content and, consequently, emissions during storage ~~of manure and slurry may affect the manure content as well~~.

~~As~~ Quantification of ammonia emissions, although not easy, can be done through measurements by means of direct methods, such as the dynamic chamber technique for slurry or by enclosing the manure heap in a large 'polytunnel' where emissions can be captured. [258, France 2010] [500, IRPP TWG 2011] ~~is difficult, few emission data have been reported. In general, reference is made to emission factors (kg/head/yr) or percentages of N lost from manure during an average storage period. a specific method of semi-continuous measurement of emissions is needed has been developed in France, consisting of a floating tunnel that captures emissions from the whole windrow for all types of solid manures and slurry.~~

3.3.3.1 Emissions from solid manure storage

Measured ammonia and nitrous oxide emissions from solid manure heaps are presented in Table 3.59 and Table 3.60. Data represent a literature review derived from official reports and peer-reviewed articles. A limited number of studies concerned N_2O emission from manure heaps.

Table 3.59: Ammonia and nitrous oxide emissions during storage of pig solid manure, as reported from literature reviews of reports and publications

Type of manure	Emissions	Average	SD	No	Max	Min	Source
FYM ([1])	NH_3-N (% of total N)	30.8	37.8	13	123.4	0.1	[441, Webb et al. 2011]
FYM		23.5	0.7	NA	NA	NA	[439, Sommer et al. 2006]
Deep litter		4.8	2	4	7	2.4	[441, Webb et al. 2011]
Deep litter		30.2	7.7	NA	NA	NA	[439, Sommer et al. 2006]
FYM	N_2O-N (% of total N)	0.5 – 2.63	NA	2	NA	NA	[443, Chadwick et al. 2011]
Deep litter		4.6	3.5	4	9.8	2.5	[441, Webb et al. 2011]
FYM	N_2O-N (g N/m^2/day)	1.9	1.1	4	2.9	0.7	[441, Webb et al. 2011]

NB: No= Number of reports and publications from which the values were derived.
SD= Standard deviation.
FYM= Farmyard manure.
NA= Not available.
([1]) Emission factors vary from being negligible to being very high, and may even account for more than the initial TAN ($NH_3 + NH_4^+$), because NH_3 emissions origin from mineralised organic N, due to the effect of treatment and/or storage conditions of manure, i.e. storage time, aeration, temperature. [441, Webb et al. 2011]

Table 3.60: Ammonia and nitrous oxide emissions during storage of poultry solid manure as reported from literature reviews of reports and publications

Type of manure	Emissions	Average	SD	No	Max	Min	Source
Litter	NH_3-N (% of total N)	8.3	5.9	13	18.4	0.3	[441, Webb et al. 2011]
Daily removed manure with belt		2.1	1.8	4	4.5	0	[441, Webb et al. 2011]
Litter	N_2O-N (% of total N)	0.17 – 0.81		1	NA	NA	[443, Chadwick et al. 2011]

NB: No= Number of reports and publications from which the values were derived.
SD= Standard deviation.
NA= Not available.

In Table 3.61, a range for national emission factors as they were reported by several Member States is presented.

Table 3.61: Range of reported ammonia emission factors for poultry solid manure storage used by Member States

Type of poultry	Ammonia emission factor (kg NH_3-N/animal place/year)	Source
Broilers	0.024 – 0.04	[615, IE EPA 2012] [612, TWG comments 2012]
Laying hens	0.027 – 0.067	[500, IRPP TWG 2011] [614, UK 2012]
Turkeys	0.092 – 0.14	[500, IRPP TWG 2011] [615, IE EPA 2012]
Broiler Breeder	0.022	[615, IE EPA 2012]

An example of emission factors used by a Member State (UK) for calculating overall ammonia emissions from solid manure stores is presented in Table 3.62.

Table 3.62: Emission factors reported by UK for solid manure storage

Production	Manure type	N emission factors	
Pig manure	Manure heap	1 224 g N/tonne	1.49 kg NH_3/tonne
Poultry manure	Manure belts	1 956 g N/tonne	2.38 kg NH_3/tonne
Poultry manure	Manure deep pit	1 956 g N/tonne	2.38 kg NH_3/m^2
Poultry manure	Litter	1 435 g N/tonne	1.74 kg NH_3/m^2
Source: [612, TWG comments 2012]			

~~During the storage of solid pig manure, up to 2.6 % of the total nitrogen was found to be is lost as N_2O emission, whilst emissions from broiler litter range between 0.2 % and 0.8 % of the total N.~~

~~Sheet covers for pig manure and broiler litter heaps reduce ammonia emissions but do not effect N_2O emissions.~~ [250, IGER 2004] [443, Chadwick et al. 2011] **Moved to Section 4.11.1**

The total N content of pig manure heaps reduces during storage by a mean of 40 %, and broiler manure by 24 %. In conventionally stored manure heaps, ammonia emissions range from 7 % to 16 % of the total initial N content in the case of pig manure and 10 – 13 % in the case of broiler litter.

Ammonia emissions can be reduced (75 – 80 % by sheeting) or increased (80 – 150 % by turning the heap), depending on the applied management strategy. ~~treatmeant that can be applied.~~ Nitrogen losses in leachate from the heaps range between 2.3 % and 5.3 % of the total initially stored N for pig manure and range between 0.8 and 8.2 % for broiler litter. [207, ADAS 2004]

It has been reported that within the first 30 days of storage, ammonia losses ~~occur with~~ are over 80 % of the total emissions for pig manure and ~~with~~ 25 – 45 % for broiler litter, whereas losses from slurry storage continues at a relatively steady pace throughout the storage period [253, ADAS 2002]. Because the time course of NH_3 emissions is basically determined by the tendency for self-heating (composting) which occurs in most heaps of porous manure, ammonia emissions can be reduced by covering the heap in order to limit internal air transfer interior or by a deliberate compaction of the manure. [441, Webb et al. 2011]

A literature review concluded that **N_2O emissions** from manure heaps are very variable and a single major condition affecting the emission could not be established. The production of N_2O that takes place during storage is significant due to nitrification and subsequent denitrification. Emissions of N_2O from poultry manure tend to be smaller. [441, Webb et al. 2011]

CH_4 emissions occur only under locally-anaerobic condition. Aerobic decomposition in straw-rich porous heaps of solid manure leads to both high temperatures and anaerobic hotspots, causing CH_4 emissions. On the other hand, if an air-tight cover is used on the heap, inhibiting the activity of aerobic microorganisms and the associated temperature increase, CH_4 emissions will be reduced. Another strategy that can be used to reduce methane emissions from stored solid manure is frequent turning, which reduces anaerobic zones in the heap. [441, Webb et al. 2011] [443, Chadwick et al. 2011].

3.3.3.2 Emissions from slurry storage

~~The physical characteristics of pig slurry generally cause low N emission. No crust is formed on pig slurry, as most of the dry matter of manure sinks to the bottom of the slurry tank.~~ ~~In the beginning~~ ~~While~~ When initially storing slurry, some NH_3 is emitted from the surface layer~~,~~ but later, the impoverished surface layer blocks evaporation. The formation of a floating crust may depend on the dry matter content of the slurry as well as the climatic conditions: heavy rains soak the crust that will tend to weigh it down, dilute the slurry at the surface; whereas, warm and sunny climate conditions allow a quick formation of a crust. An intact crust is an effective barrier against NH_3 losses.

~~Relatively little N is emitted and several sources reported about 5 – 15 % (average 10 %) evaporation from the deeper layers~~. Low evaporation ~~is probably~~ may also be caused by the neutral pH value. Stirring will obviously raise the dry matter to the surface and increase the evaporation of NH_3, thereby causing peaks in air emissions.

Ammonia emission factors from uncovered stored pig slurry, as reported in a literature review, are presented in Table 3.63.

Table 3.63: Ammonia emissions from uncovered stored pig slurry

Parameter	Ammonia emission (kg NH_3-N/m^2/yr)		
	Concrete Store Untreated slurry	Lagoon Untreated slurry	Concrete Store Slurry fermented in biogas plant ([1])
Average value	2.18	0.78	2.33
Standard deviation	2.1	1.07	0.68

([1]) Cattle and pig slurry.
Source [439, Sommer et al. 2006]

NH_3-N emissions from slurry in open tanks and lagoons correspond to between 6 and 30 % of the total N in stored slurry, assuming there is an emitting surface over the whole year.

In Table 3.64, emission factors reported by Denmark for slurry storage, showing the effect of slurry covers are presented.

Table 3.64: Ammonia emission factors for covered and uncovered slurry storage in Denmark

Type of cover	Raw Slurry		Digested slurry	
	NH_4-N as % of NH_4-N ex house	NH_4-N as % of total N-ex house	NH_4-N as % of NH_4-N ex house	NH_4-N as % of total N ex-house
No cover	11.4	9	27.3	21
Covered (natural crust, straw cover)	2.5	2	5.2	4
Tent or concrete cover	1.3	1	2.6	2

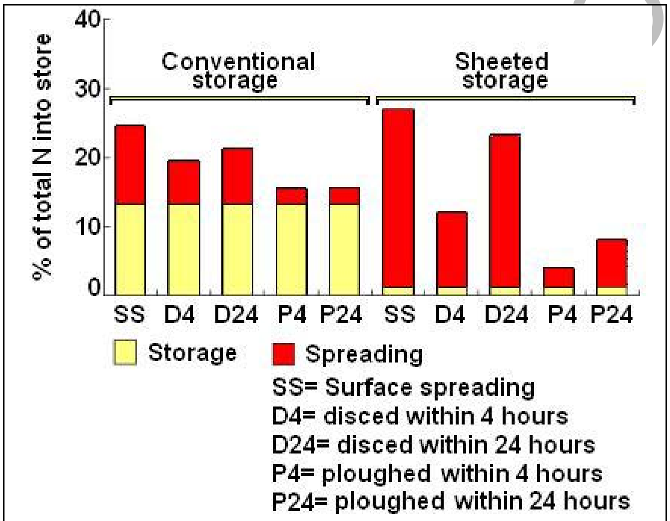
Source: [442, Hansen et al. 2008]

Ranges of reported national ammonia emission factors for storage of pig slurry are presented in Table 3.65. The ammoniacal nitrogen loss from pig slurry storage, expressed as a percentage of total nitrogen contained in the stored slurry, is estimated between 6 and 30 % [439, Sommer et al. 2006].

Table 3.65: Range of ammonia emission factors for pig slurry storage as reported by Member Stated

Production	kg NH_3-N/animal place/year
Growers-Finishers (20-100 kg)	0.6 –2.62
Weaners (6-20 kg)	0.15 – 1.07
Farrowing sows	2.05 – 6.82
Sows in full cycle	14.4
Source: [412, Italy 2001] [258, France 2010] [439, Sommer et al. 2006] [616, Spain 2012] [615, IE EPA 2012]	

An example is presented in Figure 3.4, to illustrate the relationship between emissions at storage and at landspreading of broiler litter. It can be seen that an effective storage (sheeting), that preserves the content of available nitrogen in the manure, can lead to increased overall emission if it is followed by poor spreading techniques (surface spreading without incorporation). [536, Sagoo et al. 2007]



Source: [536, Sagoo et al. 2007]

Figure 3.4: Cumulative ammonia volatilisation losses during storage and following landspreading of broiler litter

Nitrous oxide emission from slurry or liquid manure with no surface cover is negligible, as slurry stores remain principally anaerobic unless O_2 is introduced as a consequence of a treatment process, or windy conditions prevail. In contrast, a straw or natural crust on the surface layer of stored slurry can control N2O emissions, e.g. at reduced water content of the surface layer N2O emissions increase and may be as high as 25 mg N_2O-N/h per m^2 of surface. Emissions are reduced or stopped at low temperatures and with high water content of the surface crust or surface straw layer [443, Chadwick et al. 2011]. A synthetic permeable cover can enhanced or delay N_2O emissions, depending on whether a natural crust will form in the absence of a synthetic cover [517, Petersen et al. 2011].

The Intergovernmental Panel on Climate Change (IPCC) currently assumes a N_2O emission factor of 0.005 kg N_2O-N/N ex-animal for slurry stores with a crust (IPCC, 2006); however, there is little knowledge about the extent and control of N_2O emissions from slurry crusts. Actual emissions will probably vary seasonally, according to local climatic conditions, but also depending on the potential for nitrification, which may vary considerably. [517, Petersen et al. 2011]

Slurry stores are sources of **methane** as the anaerobic environment favours methanogenesis. Covers were found to have contrasting effects, in particular:

- the formation of a slurry crust can reduce CH_4 emissions as a result of methane oxidation;
- amending slurry with straw may enhance the methanogenic formation of CH_4;
- covering slurry stores with porous surfaces, e.g. straw, expanded clay pebbles or recycled polyethylene, may reduce CH_4 emission due to oxidation to CO_2;
- high concentration of cellulose and lignin may limit the rate of CH_4 production due to the reduced hydrolysis of the lignified structures in the biomass.

Methane emissions are also influenced by the following parameters:

- mild agitation of the slurry has been to shown to increase CH_4 emissions;
- frequent removal of slurry from the store or channel reduces the pool of methanogenic bacteria within this environment. Thus in pig houses where slurry was removed from channels after each fattening period, emissions were 40 % lower then in houses where channels were not cleared as frequently;
- a positive correlation between CH_4 emissions during storage and the temperature of manure or slurry has been observed. Methane production is low at temperatures below 15 ºC, but increases exponentially as temperature rises above 15 ºC; [443, Chadwick et al. 2011]
- Reducing the organic matter content of slurry through separation or fermentation in a biogas digester may prove to be the most efficient way of reducing CH_4 emissions during outdoor storage. However, it is shown that digested slurry should be cooled to ambient temperatures in post-treatment storage tanks to reduce CH_4 emissions. Also, acidification of slurry for the purpose of reducing NH_3 emissions from storage has been observed to reduce CH_4 emissions.

3.3.4 Emissions from manure treatment

For various reasons manure is treated on farm and several techniques are described in Chapter 4, together with a report on their environmental and technical characteristics. As far as data were reported, consumption and emission levels were indicative and specific for the situation in which they were obtained.

Input levels of manure and slurry vary by ~~with~~ the number of animals on the farm. Various additives are used to enhance chemical reaction(s) or to react with unwanted elements in the reaction substrate. These may affect emissions to water or air.

During the treatment processes, e.g. lagoon systems, liquid fractions may be produced that have to be discharged to (surface) water. Odour may arise due to sub-optimal process conditions, although a number of techniques aim to reduce odorous components. Incineration emits dust and other flue gases. Techniques such as the biogas reactors deliberately form gaseous compounds, which can be used in heaters and engines but from which exhaust gases are then emitted.

Intensive aeration to remove excess N from livestock slurries has been shown to increase N_2O emissions up to 19 % of total N in pig slurry. From slurry separation a nutrient rich solid fraction and a liquid fraction are obtained. The solid fraction is similar to untreated solid manure and may results in N_2O emissions of up to 4.8 % of the initial total N over a 4 month period of storage.

In anaerobic digesters there is little opportunity for nitrification of NH_4^+ to NO_3^-, and N_2O emissions from the stored digestate are not altered. [443, Chadwick et al. 2011]

3.3.5 Emissions from landspreading

The level of emissions from landspreading depends mainly on the chemical composition of slurries and manures, the prevailing climatic conditions and, mostly, the way they are handled. The composition varies and depends on the diet as well as on the method and duration of storage and the treatment, if any, applied before application. Values of N and K_2O will be lower for farmyard manure (FYM) stored for long periods in the open. Slurries may become diluted by drainage and wash water thus increasing in volume, albeit with a decreasing dry matter content.

The nitrogen content of livestock manure is present in two main forms:

- Readily available nitrogen (RAN), or mineral nitrogen (ammonium, nitrate and uric acid), which is potentially available for rapid crop uptake
- Organic nitrogen, which is slowly released to become available for crop uptake over a time period of months to years. Organic N contributes only to a small extent to N-fertilisation in the year of application. In this way, around 10 % of the total nitrogen content may become available for the second crop following application.

Two major processes regulate the loss of nitrogen from landspreading:

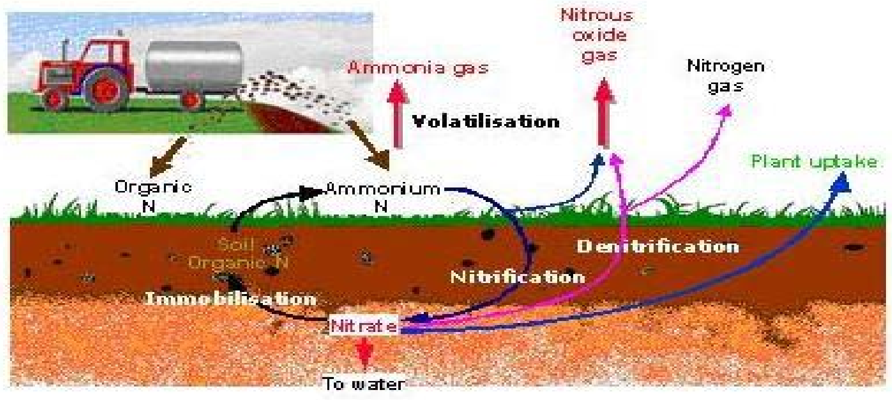
- Ammonia volatilisation is the most important source of emissions. Ammonia emissions following slurry or manure landspreading at this stage are strongly influenced by the readily available N content of the manure which is the ammonium-N in pig (26 – 38 % of total N) and NH_4-N plus uric acid-N in broiler litter. Slurries and poultry manures are ‘high’ in readily available N (typical 40 – 60 % of total N), compared with farmyard manure which is ‘low’ in readily available N (typical 10 – 25 % of total N)
- Nitrate leaching. Livestock manures are the greatest source of avoidable nitrate leaching losses. The NH_4-N content of manure is rapidly converted to nitrate-N and can then be used by plants or, otherwise, lost by leaching or by denitrification. The amount of N leached is mainly related to the manure application rate, readily available N content and timing of applications.

Ammonia volatilisation is the most important source of emissions, and, following conversion of ammonium to nitrate N in the soil, further losses may also occur through nitrate leaching and denitrification. [389, MAFF 1999]

It is now clear that the Manure management practices
There are various manure management practices that minimise nitrogen losses via ammonia volatilisation, such as rapid soil incorporation on arable land for solid manures and band spreading (trailing hose/shoe) or shallow injection for slurries.

In order to reduce and nitrate leaching losses, it is important to apply manure in late winter/spring when there is a crop demand for N, rather than in the autumn/winter period when the demand is low and nitrate in the soil is likely to be leached into the groundwater or surface waters. Changing manure application timings from autumn to spring compared with autumn application timings) is likely to increase the pool of soil mineral nitrogen, hence increasing the potential for nitrous oxide and di-nitrogen losses following land application, which is of concern, since it is a greenhouse gas. [245, ADAS 2002] which is available for the crop uptake but also for nitrification/denitrification microbial processes in the soil, leading to production of NO_3^-, N_2 and a potential increase of ‘direct’ N_2O emissions. If needed, additional applications of mineral N to the soil should be adapted properly.

A schematic representation of the process regulating the utilisation and losses of nitrogen from manure landspreading is presented in Figure 3.5



Source: [244, ADAS 2006]

Figure 3.5 Nitrogen losses from landspreading of manure

3.3.5.1 Emissions to air

~~Many factors influence ammonia emissions into the air during landspreading.~~
Ammonia emissions during and following slurry application are influenced by a wide range of interacting variables which are shown in Table 3.66.

Table 3.66 Factors influencing the emission levels of ammonia into air from landspreading

Factor	Characteristic	Influence
Soil	pH	Low pH gives lower emission
	Cation exchange capacity of soil (CEC)	High CEC leads to lower emissions
	Moisture level of soil and porosity	Ambiguous
Climate factor	Temperature	Higher temperature gives higher emissions
	Precipitation	Causes dilution and better infiltration and therefore lower emissions to air, but increased emissions to soil
	Wind speed	Higher speed means higher emissions
	Humidity of air	Low levels give higher emissions
Management	Application method	Low emission techniques
	Manure type	DM content, ph and ammonium concentration affect emission level
	Time and dose of application	Warm, dry, sunny and windy weather should be avoided; too high doses increase infiltration periods
Crop conditions	Crop height	Limited ammonia losses when slurry is spread in crops compared to bare land
Source: [37, Bodemkundige Dienst, 1999] [442, Hansen et al. 2008]		

~~Studies indicate that~~ Any ammonia conserved during storage is subsequently subjected to losses following surface ~~land~~spreading. To achieve an overall (storage plus application) reduction in ammonia losses, ~~the~~ manures need to be incorporated ~~ploughed~~ into the soil. This happens because the readily available nitrogen that is retained ~~not lost~~ in covered stores ~~storages~~ is lost in a large proportion after landspreading.

~~Without ploughing, losses from landspreading are around 25 – 30 % of the total initially stored nitrogen in any type of solid manure. If the litter is ploughed incorporated after 4 hours of application, overall ammonia losses represent only 4 – 9 % of the total N into the store for the covered litter, and 37 – 60 % from the conventionally stored manure. [207, ADAS 2004]~~

Results of field trials carried out in UK, illustrating the effect of different storage conditions, incorporation technique and manure composition on emissions after landspreading of solid manure, are presented in Table 3.67.

Table 3.67: Emissions from solid manure application, with or without incorporation, reported from UK

Type of manure	Storage before application	Incorporation	Manure composition	Ammonia emissions	Emission reduction after incorporation, compared with surface application
			NH_4-N as % total N content	NH_4-N as % total N applied	(%)
Fresh pig manure	No	No	26 – 38	13 - 41	-
Fresh broiler litter	No	No	46– 52	16 - 28	-
Pig manure	Conventionally stored (open air) for 6 months	No	NA	8	-
Broiler litter	Conventionally stored (open air) for 6 months	No	20 – 32	16	-
Pig manure	Sheet covered for 6 months	No	NA	22	-
Broiler litter,	Sheet covered for 6 months	No	40 – 50	29	-
Pig manure	Conventionally stored (open air) for 12 months	No	<5	<3	-
Fresh pig manure	No	by plough after 4 hours	26 – 38	-	84
Fresh broiler litter	No	by plough after 4 hours	46 – 52	-	90
Fresh pig manure	No	by plough after 24 hours	26 – 38	-	64
Fresh broiler litter	No	by plough after 24 hours	46 – 52	-	78

NA= Not available.
Source: [207, ADAS 2004]

A range of NH_3 emissions after landspreading of solid pig and poultry manure, as derived from a survey of published results, is presented in Table 3.68. Data mainly relate to experimental results obtained under different climatic conditions in central and northern Europe.

Table 3.68: Range and average values of ammonia emissions measured after field application of solid manure without incorporation

Type of manure	Emissions (NH_3-N as % of TAN)	No
Pigs	63 (average) 41– 76	19
Poultry	40 (average) 36 – 73	6
No= Number of data-sets used. *Source*: [441, Webb et al. 2011]		

In general, poultry manure is expected to emit less than pig manure as the hydrolysis of uric acid to urea may take several months and it is often incomplete even after application. [441, Webb et al. 2011]

In Table 3.69, the ranges of reported national ammonia emission factors for field application of slurry are presented for the two main pig categories: fattening pigs and sows.

Table 3.69: Range of national ammonia emission factors for slurry application, as reported by Member States

Production	Ammonia emissions (kg NH_3-N/animal place/year)
Fattening pigs	0.56 – 1.47
Sows	1.45 – 3.65
Source: [612, TWG comments 2012] [615, IE EPA 2012] [615, IE EPA 2012]	

The average emissions of ammoniacal nitrogen from landspreading of slurry, in relation to different application methods, expressed as percentage of total NH_4-N applied, are presented in Table 3.70. Data refer to 199 measurements on grassland and 58 measurements on arable land carried out in the Netherlands.

Table 3.70: Average NH_4-N emission factors and range of measured values, expressed as percentage of total ammoniacal nitrogen applied

Type of land	Application technique	Emissions (NH_4-N as % of TAN applied)	
		Average	Range
Grassland	surface spreading	74	28 – 100
	narrow band	26	9 – 52
	shallow injection	16	1 – 63
Arable land	surface spreading	69	30 – 100
	surface incorporation	22	3 – 45
	deep placement	2	1 – 3
Source: [232, Huijsmans et al. 2009]			

Emissions of N_2O-N during field application of pig slurry have been estimated by the the Intergovernmental Panel on Climate Change (IPCC 2006) equivalent to 0.01 kg N_2O-N/N ex-animal, with a minimum and a maximum value of 0.003 kg N_2O-N/N and 0.03 kg N_2O-N/N respectively.

In Table 3.71, results of a study reporting N_2O losses (average and range) after landspreading and incorporation of solid manure, under different storage conditions, are presented.

Table 3.71: Emissions of N_2O-N from landspreading of solid manures

Manure management	Emissions (N_2O-N as % of total N)
Surface applied manures, conventionally stored	1.04 (average) 0.07 – 3.09
Stored manure, incorporated into the soil after 4 hours	0.38 (0.08-1.08)
Fresh manure, applied on surface.	0.7 (average) 0.05 – 2.17
Fresh manure, incorporated into the soil after 4 hours	1.02 (average) 0.4 – 3.27
Source [250, IGER 2004]	

A summary of field-test results from a literature review, concerning landspreading of pig slurry or solid manure under different soil texture, crop, season, application method and amount of nitrogen per ha, is presented in Table 3.72.[443, Chadwick et al. 2011]

Table 3.72: Reported N_2O-N emissions from pig manure (solid or slurry) field application

Type of manure	Nitrous oxide emissions		
	N_2O-N (% of total N)	N_2O-N (% of TAN)	Total N_2O-N (kg/ha)
Slurry (No=15)	0.12 – 2.95	0.26 – 9.55	0.4 – 2.51
Solid (No=12)	0 – 3.27	0 – 5.3	0.03 – 3.27
No= Number of experiments inventoried. *Source*: [443, Chadwick et al. 2011]			

~~Denitrification losses following land application are approximately 4.2 % of the applied readily available N from pig slurry and 2.7 % for layer manure. [245, ADAS 2002]~~

Emissions of CH_4 generally occur only immediately after manure application to land as methanogenesis is inhibited by the presence of O_2. In total, the amount of methane emitted from surface application was shown to be negligible, whereas when slurry is applied via shallow injection, the anaerobic nature of the slot environment results in higher CH_4 emissions. [443, Chadwick et al. 2011]

3.3.5.2 Emissions to soil, surface water and groundwater

A large amount of the nitrogen (N), phosphorus (P) and potassium (K) in livestock diets is excreted in manure and urine. Manures contain useful amounts of these plant-available nutrients, as well as other major nutrients such as sulphur (S), magnesium (Mg) and trace elements. For a number of reasons not all of these elements can be used and some may cause ~~a~~ pollution onto ~~of~~ the environment.

Two types of pollution can be distinguished: ‘point source’ and ‘diffuse’ pollution. Point source water pollution can occur through direct contamination of a watercourse from a burst or overflowing slurry store ~~storage store~~, yard run-off or immediately after landspreading and during heavy rain. Such incidents can have catastrophic effects on fish and other aquatic life, mainly because of the high biochemical oxygen demand (BOD) and dissolved ammonia contained in manures. BOD measures the amount of oxygen consumed by micro-organisms in breaking down organic matter and typically ranges between 10 000 and 30 000 mg/l for slurries, compared with 300 to 400 mg/l for raw domestic sewage [389, ADAS 2001].

'Diffuse' pollution can affect soil, water and air and, unlike point source pollution, is not easily seen. The resulting contamination is associated with farming practices over a wide area and over extended time periods, rather than a particular action or event, and may have long-term effects on the environment. An example is volatised ammonia deposition which can contribute to soil acidification problems, particularly in woodland soils. It can raise N levels in soils poor of nutrients, causing a change in the type of plants that grow in the affected area, e.g. botanically-rich habitats in old meadows and heathlands [389, ADAS 2001]. Deposited ammonia can also contribute to nitrate leaching losses.

Of the agricultural emissions to soil and groundwater, the most important are the residual emissions of N and P. The processes involved in the distribution of N and P are:

- for N – leaching (NO_3^-), denitrification (NO_2, NO, N_2) and run-off
- for P – leaching and run-off.

Nitrogen (N) leaching from livestock manure occurs mainly by percolation through soil layers when manure is applied on fields improperly, without taking into account existing regulations and fertiliser planning. Similarly, phosphorus (P) is lost to the environment via run-off and leaching; although, P leaching is closely connected to soil erosion mechanisms.[218, Baltic Sea 2020 2010]

On the contrary, parts ~~the also accumulation~~ of N and P are also stored ~~occurs~~ in the soil for medium or long term release.

N and P have completely different turnover in the agricultural environment. Excess fertilisation with P is not necessarily leached like in the case of nitrogen; phosphorus can accumulate in the soil layers, where it can be slowly converted into other forms. Agricultural soils can bind varying amounts of P, but accumulation increases the amount of labile-P and the risk for P leaching. [218, Baltic Sea 2020 2010]

Potassium can also be lost by leaching and surface runoff, causing a decrease in the fertiliser value of manure; however, without posing an environmental risk.

European concerns on the environmental impacts of nitrates leaching led to the adoption of the Nitrate Directive (Council Directive 91/676/EEC). The directive introduced voluntary Codes of Good Agricultural Practices, the designation of Nitrate Vulnerable Zones (NVZ's) for areas with high nitrate levels (or a risk for this) in the waters, and a mandatory Action Programme for farms within the NVZ's. The Action Programme require farms to fertilise according the needs of the crops and not to spread livestock manure in periods where lands are water saturated or frozen; indirectly, this is a requirement for sufficient manure storage capacity.

However, the nitrogen that is saved by measures to reduce ammonia emissions from landspreading may increase the potential for nitrate leaching, especially if application of mineral N is not reduced. In comparison with slurry, solid manures, ~~contain smaller, more readily-available N fractions than slurries and a proportionately greater loss of nitrogen due to NH_3 volatilisation. As a consequence FYM~~ having inherently a lower ammoniacal nitrogen content, are considered to leave less readily-available nitrogen for nitrification and subsequent nitrates leaching. [249, Webb et al. 2001]. However, the loss of N during storage of solid manures would depend on the potential for composting.

Emissions to the surface water are due to leaching and run-off. N leaching is highest in winter and on sandy soils. This is more evident where landspreading of manure occurs in autumn and with empty fields in winter, as rainfall is likely to wash nitrate out of the soil before crops can use it. P loss in surface run-off following manure application occurs when the soils infiltration capacity is exceeded, or when P attached to soil particles is eroded. It is most likely to occur if heavy rain follows application, or when the soil is already saturated [506, TWG ILF BREF 2001]. On soils with low organic matter content, this will rarely occur.

Where practically possible, applications during the autumn-early winter period should be avoided, as over winter. Delaying applications, particularly of high available N manures, until the late winter or spring will increase the utilisation of manure N and reduce nitrate pollution

3.3.5.3 Emissions of ~~heavy~~ metals

There are several sources responsible for the input of heavy metals into agricultural ecosystems, such as:

- indigenous sources, e.g. the weathering of rock
- atmospheric deposition
- manure application, pesticides and irrigation
- artificial fertiliser
- secondary material, such as waste water sludge, compost
- crumbling away of riverbanks
- feed import
- feed additives and animal medication.

Livestock manures, and pig slurry in particular, contain significant amounts of certain metals, specifically Cu and Zn, mainly because they are used as feed additives. Continuous application of manures to crop land can lead to the accumulation of these metals and undesirably high levels in the soil, which may pose a medium or long-term toxicity risk to plants and micro-organisms. Concentration in soil should be maintained below the level that assures the non-transference to the food chain. [253, ADAS 2002] [590, BATFARM, 2013]

In situations where pig and poultry manures have been applied to land for a number of years, and will continue to be applied, it is advisable to have these soils analysed to determine their current metal status and to monitor build-up periodically [389, ADAS 2001]. A proportion of metal inputs from surface-applied manures is recycled through the agricultural system in animal feeds grown and fed on farms [253, ADAS 2002].

Cu and Zn are involved in many metabolic functions, and their provision in sufficient amount in feeding is indispensable to ensure good performance and animal health. However, because they are used as growth promoters at pharmacological levels, or because large safety margins are applied, Cu and Zn may be oversupplied in pig diets. Consequently, these elements are highly concentrated in manure, especially in pig manure. Moreover, when a treatment is applied to the slurry, Cu and Zn will follow the solid fraction where their concentration often exceeds the maximal values allowed for the utilisation of these products as organic fertilisers. The only way to decrease the concentration of trace element in manure is to restrict their incorporation in the diet.

The incorporation of 150 to 250 ppm (mg/kg) Cu in pig diets has been employed for a long time because of its growth promoting effect. This practice is currently authorized in EU allowing diets containing a maximum of 170 ppm Cu for piglets up to 12 weeks. After 12 weeks of age, the use of Cu as a growth factor is no more allowed within the EU, and the maximum level of incorporation is 25 ppm. Nevertheless, the practical supply remains high compared with the theoretical requirements (<10 ppm according with published data), and the average retention efficiency is still less than 1 %.

In 2003, the maximum allowed Zn incorporation in pig diets was reduced to 150 ppm, from a previous concentration of 250 ppm, (Regulation 1334/2003/EC). These levels are closer to the theoretical requirement found in published literature, which vary between 50 and 100 ppm, depending on the growing stage, and according to the different authors. However, in some EU Member States supplementation with 2 500 ppm Zn is still allowed as medication, resulting in an increased excretion of metal. [590, BATFARM , 2013]

With the present EU regulation, reported Cu and Zn contents in the manure dry matter (about 350 and 1 250 mg/kg DM, respectively) are below the maximum concentration allowed in sewage sludge in France (1 000 and 3 000 mg/kg DM, respectively), but they exceed the concentration allowed for organic fertilisers (300 and 600 mg/kg DM, respectively for Cu and Zn). Assuming that 170 kg N/ha are spread each year, it will take 160 – 170 years for the soil to reach 50 mg Cu or 150 mg Zn per kg of soil dry matter. This timeframe is much longer than with the previous regulation (50 to 100 years). Although the situation has been drastically improved by the new regulations, Cu and Zn inputs to soil with a manure application rate of 170 kg N/ha still exceed the exported metals by crops. [590, BATFARM , 2013]

In Table 3.73, emissions of metals (Cu, Zn) associated with the landspreading of poultry manure, as reported by France are presented.

Table 3.73: Emissions of metals (Cu, Zn) associated with the landspreading of poultry manure

Type of poultry	Cu (mg/bird place/year)	Zn (mg/bird place/year)
Broilers ([1])	342	1 410
Laying hens	708	3 380
([1]) Calculation based on 6.15 cycles per year. *Source*: [617, ITAVI 2012]		

~~Heavy metals are, according to the common definition, metals that have a density larger than 5 g/cm^3. Elements that belong to this group are the essential nutrients Cu, Cr, Fe, Mn, Ni and Zn, but also Cd, Hg and Pb, which are not essential. Beyond a certain concentration, which is species-specific, these elements become toxic for microorganisms, animals and plants, but shortage can lead to deficiencies as well.~~

~~In a German study on heavy metals in agriculture, the most important sources of heavy metals appeared to be atmospheric deposition (Cd, Pb, Zn), and organic fertilisers (Cr and Cd) and so-called ‘diffuse’ emissions by manure (Cu, Zn and Ni).~~

~~Quantification is difficult and data are scarce.~~

The following levels in pig and poultry manure were reported from a number of sources and are shown in Table 3.74 and Table 3.75. The number of analyses varied or was not ~~wasn’t~~ reported. In some cases only two averages were reported. It is interesting that, particularly in pig manure, very high levels of copper and zinc were found; these were attributed to feed additives (Cu and Zn salts).

Table 3.74: Heavy metal concentrations in slurry and dry manure

Type of manure	Heavy metals (mg/kg dry matter)					
	Cd	Cr	Cu	Ni	Pb	Zn
Pig slurry	0.50 – 1.8	2.2 – 14.0	250 – 759	11 – 32.5	7.0 – 18.0	691 – 1 187
Pig solid manure	0.43	11.0	740	13	NA	1 220
Layer manure (wet)	0.2 – 0.3	<0.1 – 7.7	48 – 78	7.1 and 9.0	6.0 and 8.4	330 – 456
Layer manure (dry)	NA	NA	32 and 50	NA	NA	192 – 300
NA: Not available *Source*: [398, KTBL 1995]						

Table 3.75: Heavy metal concentrations in slurry and dry matter

<table>
<tr><th rowspan="2">Type of manure</th><th rowspan="2">pH</th><th rowspan="2">kg/1 000 kg dm</th><th colspan="6">mg/kg dm</th></tr>
<tr><th>Cd</th><th>Cr</th><th>Cu</th><th>Ni</th><th>Pb</th><th>Zn</th></tr>
<tr><td rowspan="10">Pig slurry</td><td>8.5</td><td>94.2</td><td>0.60</td><td>12.1</td><td>603.0</td><td>23.4</td><td rowspan="15"><5</td><td>1 285.0</td></tr>
<tr><td>7.9</td><td>107.9</td><td>0.60</td><td>11.3</td><td>580.8</td><td>22.3</td><td>1 164.0</td></tr>
<tr><td>8.9</td><td>99.6</td><td>0.63</td><td>7.6</td><td>292.0</td><td>21.9</td><td>861.6</td></tr>
<tr><td>7.5</td><td>68.5</td><td><0.5</td><td>8.3</td><td>210.4</td><td>29.2</td><td>747.8</td></tr>
<tr><td>6.9</td><td>95.3</td><td><0.5</td><td>19.8</td><td>203.8</td><td>24.9</td><td>1 447.0</td></tr>
<tr><td>7.9</td><td>45.4</td><td><0.5</td><td>8.3</td><td>290.0</td><td>22.0</td><td>955.3</td></tr>
<tr><td>7.9</td><td>35.4</td><td><0.5</td><td>14.3</td><td>720.5</td><td>26.7</td><td>2 017.0</td></tr>
<tr><td>8.4</td><td>40.5</td><td>0.86</td><td>12.3</td><td>1 226.0</td><td>25.4</td><td>1 666.0</td></tr>
<tr><td>8.4</td><td>39.3</td><td>0.51</td><td>11.3</td><td>398.1</td><td>26.6</td><td>1 159.0</td></tr>
<tr><td>8.0</td><td>86.9</td><td><0.5</td><td>12.4</td><td>258.1</td><td>22.9</td><td>1 171.0</td></tr>
<tr><td rowspan="2">Layer manure</td><td>7.2</td><td>722.4</td><td rowspan="5"><0.5</td><td><0.5</td><td>99.3</td><td>14.5</td><td>543.3</td></tr>
<tr><td>6.5</td><td>473.1</td><td>6.3</td><td>48.4</td><td>14.5</td><td>536.0</td></tr>
<tr><td rowspan="3">Broiler</td><td>6.4</td><td>540.1</td><td rowspan="3"><0.5</td><td>147.1</td><td>7.7</td><td>465.9</td></tr>
<tr><td>6.0</td><td>518.0</td><td>132.4</td><td>16.5</td><td>454.2</td></tr>
<tr><td>6.3</td><td>816.6</td><td>53.8</td><td>16.9</td><td>279.9</td></tr>
<tr><td colspan="9">Source: [506, TWG ILF BREF 2001]</td></tr>
</table>

These levels are considered ~~to be~~ the potential emission to land during land application. The relative contribution depends on the contribution of the other factors mentioned above. For the German situation, the heavy metal load as a result of the application of pig and poultry manure was estimated, see Table 3.76.

Table 3.76: Estimated average yearly contribution to heavy metal input through pig and poultry manure in Germany

<table>
<tr><th rowspan="2">Type of manure</th><th colspan="7">Heavy metals
(g/ha per yr)</th></tr>
<tr><th>Output
(10^6 tonnes dm)</th><th>Cd</th><th>Cr</th><th>Cu</th><th>Ni</th><th>Pb</th><th>Zn</th></tr>
<tr><td>Pig slurry</td><td>1.6</td><td>0.09</td><td>0.9</td><td>38.15</td><td>1.76</td><td>1.01</td><td>88.33</td></tr>
<tr><td>Pig solid manure</td><td>2.0</td><td>0.05</td><td>1.3</td><td>87.32</td><td>1.53</td><td>0.00</td><td>143.95</td></tr>
<tr><td>Layer manure (wet)</td><td>0.3</td><td>0.00</td><td>0.14</td><td>1.07</td><td>0.14</td><td>0.13</td><td>7.01</td></tr>
<tr><td colspan="8">Source: [398, KTBL 1995]</td></tr>
</table>

3.3.6 Emissions from the whole farm (approach)

In general, nitrogen emission reductions achieved in one production step influence the nitrogen quantity in the following steps and, therefore, also the quantity of potential NH_3 emissions from each step. A reduction of ammonia emissions in the pig house would normally lead to more ammonium reaching the slurry store; this will increase the risk of ammonia emissions from the store. As a result, part of the reduction effect in the animal house may be lost. At the same time, an emission reduction measure applied for manure storage can result more cost-effective than measures taken for other production steps. In principle, emissions that might be avoided in one step of the production may increase in the following step, i.e. due to a higher nitrogen content in the manure. In order to address this important interrelationship, animal husbandry has also to be considered as entire process chain. For this purpose, nitrogen emissions in the individual process steps: feeding, housing, as well as slurry storage and field application, are combined into an entire chain. [575, UBA 2011]

3.3.6.1 Emissions from the whole-farm process chain for the rearing of poultry

Reported examples of general emissions factors used by some Member States to define the nitrogen flow at each stage of manure management are presented in Table 3.77 and Table 3.78 for broilers and laying hens.

Table 3.77: Examples of the nitrogen flow through the whole farm chain for broiler manure

Parameter	France		Denmark		Spain	
	N losses (%)	N content (%)	N losses (%)	N content (%)	N losses (%)	N Content (%)
N excreted in housing		100		100		100
In-house losses (% N excreted)	30	30	20	20	19.6	19.6
N available in outside storage		70		80		80.4
Storage losses (% N ex-house)	15	10.5	7	14.4	11	8.8
N available for landspreading		59.5		65.6		71.5
Spreading losses (% N ex-storage)	10	5.9	31.4 ([1])	20.6	38	27.2
Usable N for crop		53.5		45		44.3
N losses of whole farm		46.5		55		55.7

([1]) Elaborated from a reported value of 45 % as usable N when applied to the fields. N, expressed as proportion of N-excreted.
Source: [328, CORPEN 2006] [616, Spain 2012] [500, IRPP TWG 2011] [618, DAFC, DK 2013]

Table 3.78: Examples of the nitrogen flow through the whole farm chain for laying hens manure

Parameter	Denmark Hens in cages		Denmark Hens in barn		Spain Hens	
	N losses (%)	N content (%)	N losses (%)	N content (%)	N losses (%)	N Content (%)
N excreted in housing		100		100		100
In-house losses (% N-excreted)	10	10	14	14	28.7	28.7
N available in outside storage		90		86		71.3
Storage losses (% N ex-house)	5	4.5	5	4.3	8	5.7
N available for landspreading		88.5		81.7		65.6
Spreading losses (% N ex-storage)		NA		NA	37	24.3
Usable N for crop		NA		NA		41.3
N losses of whole farm		NA		NA		58.7

NA: Not available (Danish data on application losses not available).
Source: [616, Spain 2012] [618, DAFC, DK 2013]

Data concerning nitrogen losses for each step of the poultry production system, reported by France for different types of poultry manure, are presented in Table 3.79

Table 3.79: Examples of nitrogen cumulative losses in poultry production systems in France, by type of produced manure

Type of produced manure	Housing losses Building (% of excreted N)	Storage losses (% of the initially stored N)	Losses at landspreading (% of the applied N)	Available to crops (Usable N as % of excreted N)
Littered solid manure, indoor rearing	30	15	10	54
Solid manure, indoor rearing, composting	30	30	0	49
Solid manure, broiler, with free range	40	15	10	46
Solid manure, force-fed ducks and geese, with free range	50	15	10	38
Solid manure, broiler breeders	55	15	10	34
Slurry	50	20	20	32
Droppings, pre-dried, storage in shed	30	30	10	44
Droppings, dried	25	25	NA	51
Droppings, deep pit	60	15	NA	29

NA= Not available
Source: [433, CORPEN 2006]

3.3.6.2 Emissions from the whole-farm process chain for the rearing of pigs

Reported examples of general emissions factors used by France at each stage of pig production for slurry management are presented in Table 3.80.

Table 3.80: Nitrogen losses through all stages of pig slurry management, considered in France

Parameter	% N losses ([1])	N content (g)
N excreted in housing		1000
In-house losses (% N-excreted)	25 (15 – 30)	250
N available in outside storage		750
Storage losses (% N ex-house)	5 (5 – 15)	38
N available for landspreading		712
Spreading losses (% N ex-storage)	20 (10 – 50)	142
Usable N for crop ([2])		570
N losses of whole farm		430

([1]) N losses as due to N_2O formation are considered low.
([2]) Average nutrient composition of slurry applied to land: N-P_2O_5-K_2O = 1.00 – 0.67 – 0.89. 70 % of nitrogen is considered to be ammoniacal.
Source: [329, CORPEN 2003]

Disaggregated emissions factors for ammonia emissions, for each stage in the production chain have been reported by Spain for different pig categories; data are presented in Table 3.81.

Table 3.81: Example of ammonia emission factors used as a reference for housing, storage and field application of slurry in Spain

Type of pig	Housing stage	Storage stage	Field application stage	TOTAL
	kg NH_3-N/place/year	kg NH_3-N/place/year	kg NH_3-N/place/year	kg NH_3-N/place/year
Weaner	0.417	0.150	0.369	0.936
Grower 20-49 kg	1.584	0.570	1.401	3.556
Finisher 50-79 kg	1.904	0.685	1.684	4.274
Finisher 80-109 kg	2.128	0.766	1.882	4.776
Finisher > 110 kg	1.988	0.716	1.758	4.462
Gestating sow	3.421	1.698	3.025	8.144
Farrowing sow	4.132	2.051	3.653	9.836
Gilt	2.088	1.036	1.846	4.971
Boar	2.763	1.371	2.443	6.577
Grower-finisher 20-100 kg	1.665	0.599	1.472	3.736
Source: [616, Spain 2012]				

3.3.7 Noise

Noise originating from intensive farming units is a local environmental issue and has to be considered particularly in those situations where units are located close to residential areas. On the farm, high noise levels can also affect the animals' condition and the production performance, as well as being able to damage ~~damaging~~ the hearing capacity of farm personnel.

Equivalent continuous noise (L_{aeq}) is the measure used to asses the noise levels of farms, since it makes it possible to compare noise sources of variable intensity or sources that are intermittent.

Typical site levels have not been reported. The equivalent noise level that arises from the site is a combination of the levels of the different activities listed in Table 3.82 and Table 3.83, together with a correction for the time duration. A different combination of activities will obviously lead to a different equivalent noise level. Background noise is noise which may be experienced in the environment, for example, around a poultry unit. It consists of road traffic, birdsong, aircraft, etc. and may also include existing noises in the poultry unit.

In order to account for all the variable intermittent noises, the background noise level (L_{a90}) is taken to be the noise level which is exceeded ~~for~~ 90 % of the time over a period of measurement. Background noise varies over a 24-hour period as a result of changes in activities. In rural areas typical daytime background noise is 42 dB, but may fall below 30 dB in the early hours of the morning.

The final impact at sensitive objects in the neighbourhood depends on many factors. For instance, land surface, reflecting or absorbing objects, construction of the receiving object and the number of noise sources determine the sound pressure level that is measured. In tables in the following sections, ~~tables~~ sound pressure levels have been given for only a few sources at the source or very close to it. The noise level at a sensitive object is normally lower further from the farm site.

The data must be seen as reported examples of what has been measured. Total noise levels will vary depending on farm management, the number and species of animals and the equipment used.

3.3.7.1 Sources and emissions on poultry farms

Sources of noise from poultry units are associated with:

- livestock
- housing
- feed production and handling
- manure management.

Typical sources of noise for a number of specific activities are shown in Table 3.82. Sound pressure levels are reported next to the source or at a short distance.

Table 3.82: Typical sources of noise and example of noise levels on poultry units

Noise source	Duration	Frequency	Day/night activity	Sound pressure levels dB(A)	Equivalent continuous L_{aeq} dB(A)
House ventilation fans	Continuous/ intermittent	All year	Day and night	43	
Feed delivery	1 hour	2 – 3 times every week	Day	92 (at 5 metres)	
Mill mix unit 1. inside building 2. outside building				 90 63	
Gas fuel delivery	2 hours	6 – 7 times per year	Day		
Emergency generator	2 hours	Every week	Day		
Catching chickens (broilers)	6 hours up to 56 hours	6 – 7 times per year	Morning/ night		57 – 60
Cleaning out (broilers)					
3. Manure handling	1 to 3 days	6 – 7 times per year	Day		
4. Power washing etc.	1 to 3 days	6 – 7 times per year ~~year~~	Day	88 (at 5 metres)	
Cleaning out (laying hens)					
5. Manure handling	Up to 6 days	Annually	Day		
6. Power washing etc.	1 to 3 days			88 (at 5 metres)	

NB: L_{aeq} equivalent continuous noise - unit for noise of variable intensity
Source: [393, ADAS 1999] and [24, LNV 1994]

3.3.7.2 Sources and emissions on pig farms

Sources of noise from pig units are associated with:

- livestock
- housing
- feed production and handling
- equipment
- manure management.

Typical sources of noise for a number of specific activities are shown in Table 3.83. Sound pressure levels are reported next to the source or at a short distance.

Table 3.83: Typical sources of noise and examples of noise levels on pig units

Description	Duration	Frequency	Day/Night Activity	Sound pressure levels dB(A)	Equivalent continuous L_{aeq} dB(A)
Normal housing levels	Continuous	Continuous	Day	67	
Feeding animals • pigs • sows	1 hour	Daily	Day	93 99	87 91
Feed preparation	3 hours	Daily	Day/night	90 (inside) 63 (outside)	85
Stock movement	2 hours	Daily	Day	90 – 110	
Feed delivery	2 hours	Weekly	Day	92	
Cleaning and manure handling	2 hours	Daily	Day	88 (85 – 100)	
Manure spreading	8 hours/day for 2 – 4 days	Seasonal/weekly	Day	95	
Ventilation fans	Continuous	Continuous	Day/night	43	
Fuel delivery	2 hours	Fortnightly	Day	82	
Source: [559, ADAS 1999] and [24, LNV 1994]					

3.3.8 Solid waste from poultry and pig farms

The amounts and composition of waste that arise from poultry and pig farms vary considerably. No representative data of the categories identified in Section 2.11 have been reported. Data estimated on a national scale have been reported by the UK and are shown in Table 3.84. Data refer to all types of farms, with arable land, with livestock, mixed, etc.

A waste stream of about 44 000 tonnes per year of packaging waste is generated by farms, of which 32 000 tonnes is plastic (polyethylene and polypropylene). The waste water emission is difficult and expensive to measure, as it is often part of the slurry fraction. The amounts of dirty water vary with rainfall and cleaning water used. The BOD levels are reported to be 1 000–5000 mg/l. [386, DEFRA 2009]

Table 3.84: UK estimates of agricultural waste arising (tonne/year), for year 1998

Waste stream	Type of waste	Tonnes
Plastic packaging	Agrochemical packaging, Fertiliser bags, Seed bags, Animal feed bags, Animal health packaging, Oil containers, Miscellaneous packaging	32 219
Cardboard and Paper packaging	Agrochemical packaging, Animal health packaging, Animal feed bags, Seed bags, Silage wrap boxes	9 985
Metal, Wood, Glass and Rubber Packaging	Animal health metal and rubber (incl. sheep dip containers), Animal health glass, Oil drums, Wooden pallets Low	1 951
Non-Packaging Films	Silage plastic, Greenhouse and tunnel film, Mulch film and crop cover	30 000
Non-Packaging Plastics	Cores for silage wrap, Other horticultural plastics, Bale twine and net wrap, Tree guards	60 506
Animal Health Products	Used syringes	46
Machinery Waste	Oils, Batteries, Tyres, Redundant vehicles and machinery	79 193
Source: [510, UK EA 2003]		

In summary, emission data for intensive poultry and pigs ~~livestock~~ enterprises under natural farming conditions are either scarce or were not available to incorporate in this document. Most data concern ammonia emissions to air or potential emissions from manure to soil and groundwater. Measuring emissions from intensive poultry and pigs ~~livestock~~ enterprises is difficult and requires clear protocols to be able to compare data collected in different Member States and under different production circumstances.

4 TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT

PLEASE NOTE THAT THE STANDARD TEXT ATTACHED BELOW IS THE CURRENTLY ADOPTED VERSION FOR ALL BREF DOCUMENTS UNDER REVIEW.

This chapter describes techniques (or combinations thereof), and associated monitoring, considered to have the potential for achieving a high level of environmental protection in the activities within the scope of this document. The techniques described will include both the technology used and the way in which the installations (farms) are designed, built, maintained, operated and decommissioned.

It covers environmental management systems, process-integrated techniques and end-of-pipe measures. Waste prevention and management, including waste minimisation and recycling procedures are also considered, as well as techniques that reduce the consumption of raw materials, water and energy by optimising use and reuse. The techniques described also cover measures used to prevent or to limit the environmental consequences of accidents and incidents, as well as site remediation measures. They also cover measures taken to prevent or reduce emissions under other than normal operating conditions (such as start-up and shutdown operations, leaks, malfunctions, momentary stoppages and the definitive cessation of operations).

Annex III to the Directive lists a number of criteria for determining BAT, and the information within this chapter will address these considerations. As far as possible, the standard structure in Table 4.1 is used to outline the information on each technique, to enable a comparison of techniques and the assessment against the definition of BAT in the Directive.

This chapter does not necessarily provide an exhaustive list of techniques which could be applied in the sector. Other techniques may exist, or may be developed, which could be considered in the determination of BAT for an individual installation.

Table 4.1: Information for each technique

Heading within the sections	**Type of information**
Description	A concise brief technical description using, as appropriate, chemical or other equations, pictures, diagrams and flow charts ~~sheets~~
Achieved environmental benefits	The main potential environmental benefits to be gained through implementing the technique (including reduced emissions to air, soil and water, reduced demand of resources (energy, water), improved animal health and welfare, as well as production yield increases, energy efficiency, etc.)
Cross-media effects	Relevant negative effects on the environment due to implementing the technique, allowing comparison between techniques, in order to assess the impact on the environment as a whole. This may include issues such as: • emissions to air (ammonia, odour, particulate matter, GHG) • consumption and nature of raw materials and water • energy consumption and contribution to climate change • stratospheric ozone depletion potential • photochemical ozone creation potential • acidification resulting from emissions to air ~~• particulate matter in ambient air (including micro particles and metals)~~

Heading within the sections	Type of information
	• eutrophication of land and waters resulting from emissions to air or water (leaching of nutrients) • oxygen depletion potential in water • persistent/toxic/bioaccumulable components in water or to land (including metals) • generation of residues/waste • limitation of the ability to re-use or recycle residues/waste residues • generation of noise ~~and/or odour~~ • adverse effects on animal health and welfare • increased risk of accidents. The Reference Document on Economics and Cross-media Effects (ECM) should be taken into account.
Operational data	Actual and plant-specific performance data (including emission levels, consumption levels – of raw materials, water, energy – and amounts of residues/wastes generated) from well performing farms/plants (with respect to the environment taken as a whole) applying the technique accompanied by the relevant contextual information. Any other useful information on the following items: • how to design, operate, maintain, control and decommission the technique • emission monitoring issues related to the use of the technique • sensitivity and durability of the technique • issues regarding accident prevention. Links between inputs (e.g. nature and quantity of raw material and fuel, energy, water) and outputs (emissions, residues/wastes, products) are highlighted, in particular where relevant to enhancing an understanding of different environmental impacts and their interaction, for example where trade-offs have been made between different outputs such that certain environmental performance levels cannot be achieved at the same time. Emission and consumption data are qualified as far as possible with details of relevant operating conditions (e.g. percentage of full capacity, fuel composition, bypassing of the (abatement) technique, inclusion or exclusion of other than normal operating conditions, reference conditions), sampling and analytical methods, and statistical presentation (e.g. short and long-term averages, maxima, ranges and distributions). Information on conditions/circumstances hampering the use of the (abatement) technique at full capacity and/or necessitating full or partial bypassing of the (abatement) technique and measures taken to restore full (abatement) capacity.

Applicability	It is indicated whether the technique can be applied throughout the sector. Otherwise, the main general technical restrictions on the use of the technique within the sector are indicated. These may be:
	• an indication of the type of plants or processes within the sector to which the technique cannot be applied;
	• constraints to implementation in certain generic cases, considering, e.g.:
	  • whether it concerns a new or an existing plant, taking into account factors involved in retrofitting (e.g. space availability) and interactions with techniques already installed
	  • plant size, capacity or load factor

Heading within the sections	Type of information
	• quantity, type or quality of product manufactured • type of fuel or raw material used • animal welfare • climatic conditions. These restrictions are indicated together with the reasons for them. These restrictions are not meant to be a list of the possible local conditions that could affect the applicability of the technique for an individual plant.
Economics	Information on the costs (capital/investment, operating and maintenance including details on how these costs have been calculated/estimated) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, reduced payback time compared to other techniques), or revenues or other benefits including details on how these have been calculated/estimated. Cost data are preferably given in euro (EUR). If a conversion is made from another currency, the data in the original currency and the year when the data were collected is indicated. The price/cost of the equipment or service is accompanied by the year it was purchased. Information on the market for the sector in order to put costs of techniques into context. Information relevant to both newly built, retrofitted and existing plants. This should allow assessment, where possible, of the economic viability of the technique for the sector concerned. Information on the cost-effectiveness of the technique (e.g. in EUR per mass of pollutant abated) and related assumptions for their calculation can be reported. The Reference Document on Economics and Cross-media Effects (ECM) and the Reference Document on the General Principles of Monitoring (MON) are taken into account with regard to economic aspects and monitoring costs, respectively.
Driving force for implementation	Where applicable, specific local conditions, requirements (e.g. legislation, safety measures) or non-environmental triggers (e.g. increased yield, improved product quality economic incentives – e.g. subsidies, tax breaks) which have driven or stimulated the implementation of the technique to date. This subsection should be very short using bullet point lists.
Example plants	Reference to (a) plant(s) where the technique has been implemented and from which information has been collected and used in writing the section. An indication of the degree to which the technique is in use in the EU or worldwide
Reference literature	Literature or other reference material (e.g. books, reports, studies) that was used in writing the section and that contains more detailed information on the technique. When the reference material consists of a large number of pages, reference will be made to the relevant page(s) or section(s).

In this chapter, the characteristics listed in the previous table are described to provide all elements that are used for the evaluation of techniques, that is carried out to conclude if the techniques presented here are BAT or not.

As described in Chapters 1 - 3, the main emphasis in the application of environmental measures in intensive farming is on the reduction of emissions associated with manure production. Techniques that can be applied at different stages of the process are linked. It is clear that the application of reduction measures in the early steps of the animal production chain can influence the effect (and efficiency) of any reduction measures applied in later steps. For example, the nutritional composition of the feed and the feeding strategy are important for the animals' performance, but at the same time they affect the manure composition, and therefore influence emissions to air, soil and water from housing, storage and landspreading. The IPPC approach ~~Directive~~ puts the emphasis on prevention; hence this chapter discusses the effects of nutritional management first, followed by integrated or end-of-pipe techniques.

It has been reported that IPPC permits to pig farms issued by Member States vary in their level of detail, few of them containing emission limit values. Member States have reported a number of difficulties in applying emission limit values in agriculture. It is technically difficult and potentially very costly to monitor emission levels and therefore it seems not always appropriate to apply associated emission levels (BAT-AELs). At present, most permits set a range of structural, operational and management conditions for various aspects of the farm. [204, IMPEL 2009] Attention has been paid in writing this document to include all possible data, in order to allow authorities issuing ~~setting~~ permits to have ~~hae~~ the necessary information ~~prescriptions~~ and conditions, including those to conduct ~~run~~ inspections. ~~Care has been taken~~ Consideration has been given to emission levels that have been reported in the exchange of information and from scientific literature.

It is important to note that the performance of a reduction technique is closely linked with the way in which it is operated, and simply applying a reduction measure may not ~~achieve~~ accomplish the highest achievable reduction. This chapter therefore begins with a description of the elements of good practice for environmental management, before paying more specific attention to technical measures for emissions reduction. ~~Aspects of good agricultural practice have been summarised in [105, UK, 1999] and [107, Germany, 2001] and are presented in Section 1.1.~~

~~Whenever possible,~~ This chapter provides information from techniques that can be, or are already being implemented on farms, including information on associated costs and the context in which the techniques can be used effectively.

4.1 Good agricultural practice for environmental management

Agriculture, food production and the use of the countryside are of interest and importance to everyone. Organisations of all kinds are increasingly concerned with achieving to achieve and demonstrating demonstrate sound environmental performance. All organisational activities, products and services interact with and affect the environment and are linked to the health, welfare and safety of both the farmer and the animals, and to all the farm operational and quality management systems. In short, good farming management means aiming for a sound environmental performance, which has been shown to be closely linked to increased animal productivity.

The key to good practice is to consider how activities on pig and poultry farms can affect the environment and then to take steps to avoid or minimise emissions or impacts by selecting the best mix of techniques and opportunities for each site. The aim is to put environmental considerations firmly into the decision-making process. A business that demonstrates good practice will take into account issues such as education and training, proper planning of activities, monitoring, repairs and maintenance, emergency planning and management and protection and restoring of biodiversity. Managers should be able to provide evidence that a system is in place to take account of these issues, many of which are referred to in (so-called) 'Codes of Good Practice' developed by many (some) Member States. [386, MAFF 1999] [387, MAFF 1999] [388, MAFF 1999] [106, Portugal, 2000] and [109, VDI, 2000]. Such action is consistent with many of the steps taken by some businesses aiming for formal accreditation under a recognised Environmental Management System.

Each of the various activities that make up farm management can potentially contribute to the overall achievement of good environmental performance. It is therefore important that someone be identified and given the responsibility to manage and oversee these activities. In larger enterprises in particular, that someone may not necessarily be the owner, but a farm manager, who has to make sure that:

- site selection and spatial aspects are considered;
- education and training exercises are identified and implemented;
- activities are properly planned;
- inputs and waste are monitored;
- emergency procedures are in place, and;
- a repair and maintenance programme is implemented.

The manager and staff should regularly review and evaluate these activities, so that any further development and improvements can be identified and implemented. An appraisal of alternative, new or emerging techniques would be beneficial at this stage.

4.1.1 Site selection and spatial aspects

Often the environmental impact of farms is partly due to an unfavourable spatial arrangement of activities on the farm site. This can lead to unnecessary transport and additional activities, and to emissions close to sensitive areas. Good farming management can compensate for this to a limited extent, but is made easier if attention is paid to spatial planning of farm activities ensures assures a good farm management.

The evaluation and selection of a location for a new livestock farming facility, or the planning of a new installation on an existing site, can be considered as part of good farming practice, if:

- unnecessary transport and additional activities are minimised or eliminated;

- adequate distances are maintained from in respect of sensitive sites requiring protection, e.g. maintaining adequate distances from neighbours to avoid conflicts arising from odour and noise nuisance, and from waters to protect them from the emission of nutrients;
- prevailing climate conditions are considered, (e.g. wind);
- the potential future development capability of the farm is taken into consideration;
- any requirements of outline construction planning or village development planning are satisfied.

Apart from the technical appraisal, the evaluation would also consider, local meteorological conditions as well as any specific topographical features, such as hills, ridges and rivers. [107, Germany, 2001].

For example, for mixed livestock or pig breeding facilities, the low emission production areas could be located closer to critical, sensitive, sites whilst housings producing higher emissions may be are located further away from those same locations.

Ambient air pollution can be avoided at sensitive sites by effectively arranging, relocating, or grouping emission sources, such as in the case with the main air ducts that collect all the waste air from all sub-divisions of sheds in central waste air shafts. For example, it may be possible to increase the distances of the emission source to any critical sensitive sites, or to relocate the sources so that they lie in a subsidiary wind direction, or to discharge waste air through ducting pipelines appropriate distances away [159, Germany, 2001].

4.1.2 Education and training

Farm staff should be familiar with production systems and should be properly trained to carry out the tasks for which they are responsible have responsibility. They should be able to relate these tasks and responsibilities to the work and responsibilities of other staff. This can lead to a greater understanding of the impacts on the environment and the consequences of any equipment malfunction or failure. However, staff may require extra training to monitor these consequences. Regular training and updating may be required, particularly when new or revised working practices or equipment are introduced. The development of a training record could provide the a basis for a regular review and evaluation of each person's skills and competencies.

Special training may be required for operating and maintaining techniques applied for reducing emissions, in particular the more sophisticated ones such as end-of-pipe techniques for the reduction of air emissions and techniques for the on-farm processing of manure.

Awareness of regulations and good practices concerning manure management, planning for manure application fertilisation, emergency planning, repair and maintenance, etc. should be part of the training of people persons responsible for transport and/or the spreading of livestock manure in order to prevent emissions to air and water.

Machinery with large capacities is used to handle the large amounts of slurry produced at intensive pig production installations. There are several aspects of the livestock manure transportation and spreading that are of environmental concern and that should be ordinarily treated as described below.

- The rate of application must should follow a well documented manure management fertiliser plan, and be done evenly on the field. The driver should be familiar with the adjustment of speed, dosing and the capacity of the machinery.
- Slurry can vary widely in chemical composition in different parts of the manure store storage. The driver should be familiar with possibilities for homogenising the manure before loading and how to use quick test methods for assessing the amount of plant nutrients in the manure.

- Accidental spills happen, mainly in connection to loading, transport or the spreading of slurry or other liquid manure. The driver should be able to take precautions, be familiar with alarm systems and safety procedures to avoid spills, as well as be prepared to take the right actions in case of spills.
- The spreading and transport of livestock manure can be ~~is~~ regulated according to the time of year and week, temperature/climate, field slope, buffer zones, etc. The driver should be aware of these regulations.
- Any legal requirements regarding spreading technology, e.g. when injections must be used rather than broad spreading or band laying, should be familiar to the driver.

4.1.3 Planning activities

Many activities can benefit from planning ~~being planned~~, to ensure that they run smoothly and carry reduced risks of unnecessary emissions. An example would be the application of slurry to land. This involves a number of tasks or actions that need to be coordinated, including:

- assessing the land receiving the slurry, in order to identify the risk of causing water pollution and transfer of pathogens to water ~~run-off to watercourses~~ and then deciding whether or not to spread. In Nitrate Vulnerable Zones (NVZ), this aspect is essential;
- avoiding weather conditions in which the soil could be seriously damaged~~, as this could have significant knock-on environmental effects,~~ or when the risk for run-off and the leaching of nutrients could be significant;
- keeping ~~agreeing~~ safe distances from watercourses, boreholes, hedges and neighbouring properties;
- identifying an appropriate application rate, taking into account a risk assessment plan, when it is required (e.g. in NVZ in the UK), the specific nitrogen and phosphorus content ~~concentrations~~ of the manure, ~~and~~ the nutrient uptake of the cultivated plants, and the characteristics of the soil;
- checking that machinery is in good working order and properly set at the correct application rate;
- setting ~~agreeing~~ travel routes to avoid bottlenecks;
- ensuring that there is adequate access to the slurry store ~~storage~~ and that loading can be done effectively and without spillage, i.e. by checking the operation of pumps, mixers and sluice gates or valves;
- assessing the spread areas at regular intervals to check for any sign of run-off;
- ensuring that all staff are trained and educated for their responsibilities so that they can prevent accidents and take the right ~~know what~~ action ~~to take~~ if something goes wrong.

In some regions, tools exist that help or oblige farmers to calculate balanced doses of nutrients for field fertilisation. Manure can then ~~hence~~ be applied correctly, ~~to lands~~ satisfying the needs of soils and crops, limiting ~~without causing~~ overdosing and helping reduce the ~~emissions to water~~ loss of nutrients to water and emissions to air. These tools or obligations are the nitrogen and phosphorus fertiliser norms and the phosphorus index (see Chapter 6).

Other activities that will benefit from a planned approach include the delivery of fuel, feed, fertiliser and other materials to site (inputs), production processes, and the removal of pigs, poultry, eggs, other products and waste materials from the site (outputs). Subcontractors and suppliers also need to be properly briefed.

4.1.4 Monitoring

Monitoring is an important aspect for all livestock farms, in order to assess their operational conditions and environmental performance. It is essential to understand the level of use of inputs (i.e. feed, energy, water) and the creation of waste (i.e. solid or liquid manure) in order to consider whether and how changes may be made to improve profitability and to benefit the environment. Regular monitoring of water usage, energy usage (gas, electricity, fuel), amounts of livestock feed, waste arising and field applications of inorganic fertiliser and manure will form the basis for review and evaluation. Where possible, the monitoring, review and evaluation by comparation comparison should be related to groups of livestock, seasons, buildings, specific operations or done on a field-by-field basis, as appropriate, to give the best chance of identifying areas for improvement. Also, monitoring should help in identifying abnormal situations and enable the appropriate actions to be taken.

~~The mineral bookkeeping system, applied in the Netherlands, is an example of how monitoring the input and output flows of minerals at the a farm level can help to reduce mineral surpluses and ammonia losses. This allows Dutch agriculture to comply with the objectives and obligations of the Nitrates Directive (Council Directive 91/676/EEC). [396, LEI 1999]~~

In general, a range of monitoring obligations is required on poultry and pig farms, which may include:

- Animal numbers
- Manure management procedures
- Integrity of manure stores
- Emissions to air (e.g. ammonia, odour and dust)
- Emissions to water (groundwater quality)
- Spreading activities.

An assessment of the environmental performance of techniques applied at the different stages of the manure management chain is based on monitoring of emissions. The complex interaction between the production stages is generally monitored by determining the nitrogen (N) flow from housing to storage and manure application.

Description

Monitoring of emissions to air

As emissions to air are recognised as a serious environmental impact for the livestock sector, monitoring of the main pollutants, in particular ammonia and odour, is increasing in importance.

Ammonia emissions

Emission calculations based on a nitrogen balance are the most commonly applied monitoring method for ammonia emissions. Nitrogen excretion is estimated on the basis of the crude protein content in the diet and the growth performance of the animal. For a uniform growth performance value, the differences in nitrogen excreted depend solely on the crude protein intake and its digestibility. Loss rates of ammonia between the moment of N excretion and the moment of removing the manure from the housing system and/or spreading manure onto land are estimated. These losses depend on the housing system and manure storage techniques:

$N_{manure} = N_{diet} - N_{products} - N_{gaseous\ losses\ from\ buildings\ and\ manure\ storage}$

N_{diet} = amount of N contained in the diet consumed (kg N/animal/year)

$N_{products}$ = amount of N retained by the animal (live weight × N content) and related products (i.e. piglets for sows, eggs for laying hens)

$N_{excretion} = N_{diet} - N_{products}$

$N_{gaseous\ losses} = N_{excretion} \times$ Loss factor

Nitrogen loss factors depend on the type of housing, animal and manure management, and, to some extent, on climatic conditions.

Ammonia emission factors for different livestock categories and housing systems are generally available at Member State level. Loss factors for the type of housing and manure management have been developed through several field studies carried out in different geographical areas throughout the European Union.

Data concerning the protein intake of animals, conversion rate and growth performance are well known and commonly used to determine production costs.

In general, a nitrogen balance can perform an easy efficiency check. More specific monitoring techniques are dependent upon a cost/benefit analysis and their application strongly depends on local conditions (see also Section 2.15).

Direct ammonia emission measurements may be performed were a (centralised) forced ventilation system is applied on the animal housing system. Determination of the ventilation rate is required, in combination with the measurement of ammonia concentration in the outlet air. Several measuring methods are available: photo-acoustic monitoring: Non Dispersive Infrared spectroscopy (NDIR), Fourier Transform Infrared spectroscopy (FTIR); absorption by impinger system; Open-Path Tuneable Diode Laser (TDL).

All techniques for direct monitoring of ammonia emissions require the employment of skilled technical operators, generally from independent and certified laboratories, able to perform the sampling and analysis of ammonia, together with the measurement of other accessory parameters (i.e. air flow, temperature, humidity), necessary to determine the concentration and mass load of the pollutant, and calculate the related emission factor.

Indirect ammonia emission measurements may be performed in natural ventilated houses, by measuring the concentration of ammonia in different points inside the house and the ventilation rate, in order to determine the emission mass flow. The concentration of ammonia can be determined by (air quality measurements) absorption flasks, passive flux-samplers, acid-impregnated filters.

An alternative method consists of measurements of ammonia concentrations downwind from the emission source (housing system), combined with the use of a mathematical model of the dispersion of tracing gases, such as SF_6 or He, to determine the emission rate (inversed-dispersion technique).

<u>Dust emissions</u>
As for ammonia emissions, dust emissions can be measured by means of direct or indirect measurements. Direct measurements are possible when forced ventilation is applied to the housing system. Indirect measurements are generally based on dust concentration monitoring in different points inside the house and determination of the ventilation rate. Collection of dust on a suitable filter and gravimetric determination of its concentration are performed for thispurpose. European Standard EN 13284-1:2003 is the method normally used for direct dust emissions measurements.

<u>Odour emissions</u>
In general, European Standard EN 13725:2003 (Air quality determination of odour concentrations by dynamic olfactometry) is the method used for monitoring of odour emissions. The method is based on odour detection by trained human assessors by using a specific apparatus (olfactometer) of diluted gas samples at progressive degree of concentration, until the same threshold response is elicited as from the reference odour (n-butanol). The odour concentration is expressed in European odour units ou_E/m^3.

<u>Use of surrogate parameters for monitoring of emissions</u>
When air cleaning systems are applied for controlling emissions from the housing systems (ammonia, dust, odour), the measurement of operational parameters (surrogate parameters) directly related to the good functioning of the air cleaning system and the emission removal

performance, may be considered as a suitable monitoring technique. A control of a combination of the following parameters may be performed:

- Pressure loss in the exhaust air cleaning system
- Air flowrate
- Pump running time
- Water consumption of the wet scrubbers
- Acid consumption of the wet acid scrubbers
- pH and/or conductivity of scrubbing waters.

Monitoring of emissions to water
Water contamination from livestock farms may derive from leakage of manure stores, poor management of run-off waters and inappropriate management of landspreading of manure. Monitoring of groundwater is an important mean to detect leakages, in particular where earth-banked lagoons are used for slurry storage. The typical parameters to be measured are the following:

- Nutrients: nitrogen compounds and phosphorus
- Pathogens, such as coliforms, Escherichia coli
- Metals, such as Zn, Cu.

Achieved environmental benefits
Regular monitoring of air and water emissions ensure a control of the environmental performance of techniques applied for a reduction of emissions from housing, storage and field application of manure.

Cross-media effects
No negative effects are associated with monitoring of emissions.

Operational data
The monitoring regime (direct or indirect measurements) and frequency may vary significantly across the European Union. Nitrogen and phosphorus balances are normally performed for the different animal categories. Direct monitoring of emissions to air is rare; however, it may occur where abatement techniques are in place. Ambient air monitoring for ammonia and/or odour may also be performed, in particular at farms close to sensitive receptors.

The application of end-of-pipe techniques is generally associated with the monitoring of air emissions for the verification of the abatement performance; test protocols exist at national and international level for validating environmental technologies. After installation and verification of a given technique, monitoring of surrogate parameters are commonly implemented in order to ensure a good functioning of the system applied.

Concerning water monitoring, the risk of nutrients, such as nitrogen and phosphorus, reaching groundwater depends on the nutrient and the type of soil. Phosphorus is not very soluble in water and rarely reaches groundwater except in areas with sandy, clay-free soil. Nitrogen is water soluble and rapidly converts into nitrate.

The frequency of monitoring depends on the type of storage adopted for the manure, in particular for slurry stored in earth-banked lagoons, the type of soil and the vicinity to sensitive receptors (i.e. Natura 2 000 zones). In some Member States (e.g. Italy) a monitoring frequency of once per year, up to every six months, is reported. In a significant number of Member States, the burden of sampling and monitoring groundwater may still be left to the competent authorities.

Applicability
Monitoring of emissions is applicable to all farms. However, to due the high costs associated with some monitoring techniques, direct and indirect monitoring of emissions to air are

generally applied in specific circumstances, in particular when the farm is located close to sensitive receptors, its dimension is big, or when specific complaints from neighbours are an issue.

Monitoring of groundwater is considered generally applicable; although, the frequency and the number of parameters to be monitored may vary significantly, depending on the location of the farm and special local requirements.

Economics
The costs of direct and indirect measurements of emissions to air are generally considered quite high, therefore, not viable for the majority of farms. For this reason, control of surrogate parameters is much in use as an alternative to emission measurement.

Monitoring of groundwater is generally limited in frequency and number of monitored parameters, in order to contain costs.

No specific cost data are available.

Driving force for implementation
National legislation or local requirements are the main reasons for monitoring of air and water emissions.

A mass balance of nutrients (nitrogen and phosphorus) allows determining the fertiliser value of the manure to be landspread.

Example plants
Several Member States require the farms to produce a mass balance of nutrients. In some geographical areas where animal density is high (e.g. the Netherlands), end-of pipe techniques are more often applied; consequently, direct or indirect measurements of emissions are also performed.

Reference literature
[445, VERA 2009] [558, EC 1999] [204, IMPEL 2009]

4.1.5 Emergency planning

An emergency plan can help the farmer to deal with unplanned emissions and incidents such as the pollution of water, if they occur. In the UK, an emergency plan is required under the Code of Good Agricultural Practice for farmers, growers and land managers (the 'CoGAP'). This may also cover any fire risks and the possibility of vandalism. The emergency plan should include:

- a plan of the farm showing the drainage systems and water sources;
- details of equipment available on the farm, or available at short notice, which can be used to deal with a pollution problem (e.g. for plugging land drains, damming ditches, or scum boards for holding oil spillages);
- telephone numbers of the emergency services and regulator(s) and others, such as downstream landowners and water abstractors;
- plans of action for certain potential events, such as fires, leaking slurry stores, collapsing slurry stores, uncontrolled run-off from manure heaps, and oil spillages;
- installation of stand-by electricity generators for emergency power to supply the ventilation during power surge.

It is important to review procedures after any incident to see what lessons can be learnt and what improvements can be implemented.

4.1.6 Repair and maintenance

It is necessary to check structures and equipment to ensure that they are in good working order. Identifying and implementing a structured programme for this work will reduce the likelihood of problems arising. Instruction books and manuals should be made available and staff should receive appropriate training.

All measures that contribute to the cleanliness of the facility help to achieve a reduction of emissions. These include drying and cleaning the feed store, ~~storage store, the defecation dunging, exercise and lying areas, the general and defecating dunging passages~~ the dunging areas, the exercise and lying areas and the dunging passages, the housing facilities and equipment, and the outlying areas around the housing. Drinking water losses can be avoided by employing low-loss drinking techniques (e.g. nipple drinkers with drip cups, in poultry keeping).

Livestock buildings may have insulation, ~~fans, cowls, back-draught shutters, temperature sensors, electronic controls, fail-safe arrangements, water supply and feed supply arrangements, and other~~ and mechanical or electrical mechanisms which require regular cleaning, checking, filling and maintenance, for example of fans, cowls, back-draught shutters, manure belts, filters temperature sensors, electronic controls, fail-safe arrangements, water supply and feed supply arrangements, apparatuses under pressure, and acid supplies.

Slurry stores ~~storages stores~~ could be checked regularly for any signs of corrosion or leakage, and any faults need to be corrected, with professional help if necessary.

Stores ~~Storages stores~~ should preferably be emptied at least once a year, or as frequently as justifiable, depending on the quality of the construction and the sensitivity of the soil and groundwater, so that both internal and external surfaces can be checked and any structural problems, damage or degradation put right. In some situations where visual inspection of such constructions is limited, it is advisable to monitor the groundwater, as an indicator of leakages.

The operation of ~~Operating~~ manure spreaders (for both solid and liquid manures) can be improved if they are cleaned and checked after periods of use and any repairs or refurbishment are carried out. Regular checks should be made during operational periods and appropriate maintenance carried out as described in the manufacturers' instructions.

Slurry pumps, mixers, separators, irrigators and control equipment will require regular attention and manufacturers' instructions should be followed.

It is sensible to have a supply of the faster wearing parts available on-farm, in order to carry out repairs and maintenance quickly. Usually, routine maintenance can be carried out by suitably trained farm staff, but more difficult or specialist work will be carried out more accurately by professional help.

4.1.7 Feed storage

No particular techniques have been reported for a reduction of air emissions from feed storage. In general, dry matter storage facilities can ~~might~~ cause dust emissions, but regular inspection and maintenance of the silos and the transport facilities, such as valves and tubes, can prevent this. Blowing dry feed into closed silos minimises dust problems.

Every few months, silos should be fully emptied to allow inspection and to prevent any biological activity building up in feed. This is particularly important in summer, to prevent deterioration of the feed quality and to prevent a development of odorous compounds.

4.2 Environmental management systems

PLEASE NOTE THAT THE STANDARD TEXT ATTACHED BELOW IS THE CURRENTLY ADOPTED VERSION FOR ALL BREF DOCUMENTS UNDER REVIEW, WITH SOME MINOR ADAPTATIONS FOR THE SPECIFIC IRPP SECTOR.

Description
A formal system to demonstrate compliance with environmental objectives.

Technical description
The Directive defines 'techniques' (under the definition of 'best available techniques') as **'**both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned**'**.

In this respect, an environmental management system (EMS) is a technique allowing operators of installations to address environmental issues in a systematic and demonstrable way. EMSs are most effective and efficient where they form an inherent part of the overall management and operation of an installation.

An EMS focuses the attention of the operator on the environmental performance of the installation; in particular through the application of clear operating procedures for both normal and other than normal operating conditions, and by setting out the associated lines of responsibility.

All effective EMSs incorporate the concept of continuous improvement, meaning that environmental management is an ongoing process, not a project which eventually comes to an end. There are various process designs, but most EMSs are based on the plan-do-check-act cycle (which is widely used in other company management contexts). The cycle is an iterative dynamic model, where the completion of one cycle flows into the beginning of the next (see Figure:4.1)

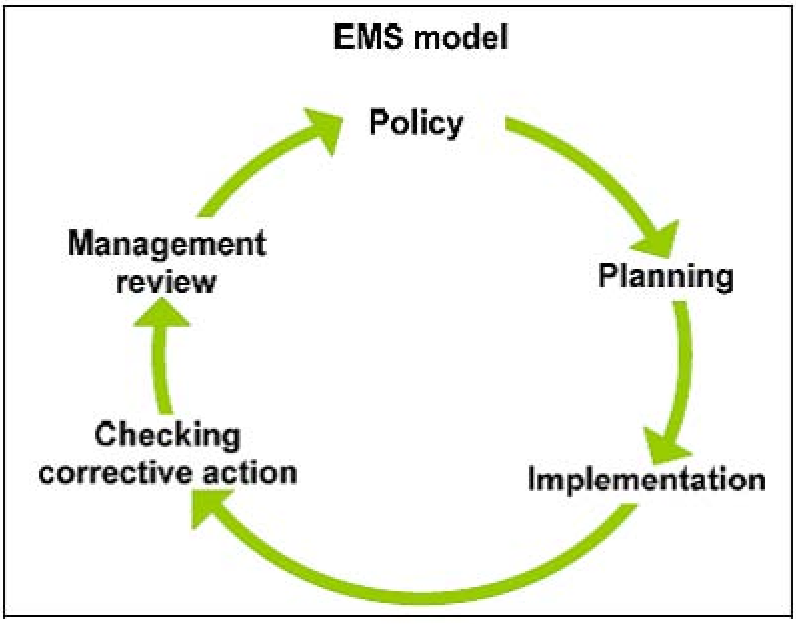


Figure:4.1 Continuous improvement in an EMS model

An EMS can take the form of a standardised or non-standardised ('customised') system. Implementation and adherence to an internationally accepted standardised system, such as EN ISO 14001:2004, can give higher credibility to the EMS especially when subjected to a properly performed external verification. EMAS provides additional credibility due to the interaction with the publc throughi the environmental statement and the mechanism to ensure compliance with the applicable environmental legislation. However, non-standardised systems can, in principle, be equally effective provided that they are properly designed and implemented.

While both standardised systems (EN ISO 14001:2004 or EMAS) and non-standardised systems apply in principle to **organisations**, this document takes a narrower approach, not including all activities of an organisation, e.g. with regard to their products and services, due to the fact that the Directive only regulates **installations/plants**.

An EMS can contain the following components:

a. commitment of management, including senior management;
b. definition of an environmental policy that includes the continuous improvement of the installation by the management;
c. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;
d. implementation of procedures paying particular attention to:

    1. structure and responsibility
    2. training, awareness and competence
    3. communication
    4. employee involvement
    5. documentation
    6. efficient process control
    7. maintenance programmes
    8. emergency preparedness and response
    9. safeguarding compliance with environmental legislation;

e. checking performance and taking corrective action paying particular attention to:

    - monitoring and measurement (see also the Reference Document on the General Principles of Monitoring) [576, EC 2003]
    - corrective and preventive action
    - maintenance of records
    - independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

f. review of the EMS and its continuing suitability, adequacy and effectiveness by senior management;
g. preparation of a regular environmental statement;
h. validation by a certification body or an external EMS verifier;
i. following the development of cleaner technologies;
j. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;
k. application of sectoral benchmarking on a regular basis.

Achieved environmental benefits
An EMS promotes and supports the continuous improvement of the environmental performance of the installation. If the installation already has a good overall environmental performance, an EMS helps the operator to maintain the high performance level.

Environmental performance and operational data
Farms can vary in scale and complexity, from a single building performing on task only (e.g. rearing broilers or finishing pigs) where all materials, such as feed, are purchased ready from the

manufacturer and employing one person, to large farms with multiple activities and several employees.

Depending on the level of complexity of the farm, the implementation of an environmental management system may vary significantly, from the basic control of the rearing process and the performance of the farm in terms of consumption (i.e. feed, energy, water) and production (e.g. live weight of animals, quantity of manure, other waste), to a full implementation with recording of several operating parameters, monitoring of emissions, validation by an external EMS verifier.

Cross-media effects
None reported. The systematic analysis of the initial environmental impacts and scope for improvements in the context of the EMS sets the basis for assessing the best solutions for all environmental media.

Technical considerations relevant to applicability
The components described above can be applied in full or in part to all installations within the scope of this document. The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will be related to the nature, scale and complexity of the farm, and the range of environmental impacts it may have.

Economics
It is difficult to determine accurately the costs and economic benefits of introducing and maintaining a good EMS. There are also economic benefits that are the result of using an EMS and these vary widely from sector to sector.

External costs relating to verification of the system can be estimated from guidance issued by the International Accreditation Forum [577, IAF 2010]

Driving forces for implementation
The driving forces for the implementation of an EMS include:

- improved environmental performance
- improved insight into the environmental aspects of the company which can be used to fulfil the environmental requirements of customers, regulatory authorities, banks, insurance companies or other stakeholders (e.g. people living or working in the vicinity of the installation)
- improved basis for decision-making
- improved motivation of personnel (e.g. managers can have confidence that environmental impacts are controlled and employees can feel that they are working for an environmentally responsible company)
- additional opportunities for operational cost reduction and product quality improvement
- improved company image
- reduced liability, insurance and non-compliance costs.

Example plants
At the time of writing (2013), no example plants applying EMS have been reported for the intensive rearing of poultry or pigs.

Reference literature
EMAS Regulation (EC) No 1221/2009. [579, Reg. 1221/2009]
DG Environment EMAS website. [578, DG Environment 2010]
EN ISO 14001: 2004:
ISO 14000 family of standards website. [580, ISO 2004]
ISO 14000 technical committee. [581, ISO 2010]

4.3 Nutritional management

Reducing the excretion of nutrients (N, P) in manure can reduce emissions. Nutritional management covers all techniques to achieve this reduction. The aim is to meet the animals' nutritional needs without causing a negative impact on animal welfare and taking into account the economics of the production. This is achieved by improving the digestibility of the nutrients and by balancing the concentration of the different essential components with the undifferentiated N-components, in order to improve the efficiency of the body's protein synthesis.

Animals can express their growth potential only if the correct amount of nutritional factors is satisfied and if the minimum level of limiting factors, such as the essential amino acids and the digestible phosphate, is satisfied as well. Diets that are not properly balanced provide the necessary amount of those limiting nutrients only for overdosed amounts of feed, hence ~~with~~ also a waste of excreted nutrients that turns into economic and environmental losses. The protein N in excess is mainly excreted in the form of urea and uric acid, ~~in poultry~~ which are the major source of NH_3 emissions from livestock excreta. Moreover, reduced nitrogen content in the excreta ~~will~~ reduces nitrogen emissions at all stages of manure management.

Animals' requirements change over the growing/production periods. For this reason, matching their needs by using appropriate diets during the cycle (phase feeding) is a way to optimise nutrition and to reduce emissions. ~~Reduction can also be achieved by using different diets during growing/production periods matching the animals' changing requirements (phase feeding).~~

The goal of nutritional ~~The~~ techniques is ~~try~~ to feed animals with an exact ~~aim for a practical minimum~~ level of required nutrients (in particular N and P), ~~in feed~~ ~~to~~ with the aim ~~for the~~ to minimise ~~minimum~~ excretion level that can not be avoided due to the metabolic activity. ~~Ideally, the excretion levels obtained would then be as low as the natural excretion levels from metabolic processes in the animal which cannot be avoided. In other words, nutritional measures aim to reduce the amount of nitrogen waste from undigested or catabolised nitrogen, which is subsequently eliminated through urine. Two types of techniques can be distinguished and these are:~~

Technical improvements have been produced during the years in feed digestibility, and ~~Most attention has been given to increasing the digestion of feed, and consequently~~ large quantities of enzymes (xylanase, protease, glucanase, etc.) are used nowadays in the animal feed industry.

~~The combination of both types of techniques is, in practice, the most efficient way to reduce the pollution load. Some of the above-mentioned options have already been successfully implemented, such as phase feeding, but others still need further investigation. Many published studies have illustrated the effects of feed measures and reduced N intake on the amount of excreted N and their ability to reduce NH_3 emissions. The information exchange focused on nutritional management for both pigs and poultry, although more data were reported for pigs than for poultry.~~

Progress in genetics and nutrition has already shown a considerable improvement in the efficient use of feed. The selection for improved utilisation of feed increases the possibilities for reducing feed nitrogen input and reducing N excretion even further.

~~For example, in a summary of experimental results, it was reported that low-protein rations (17 %) fed to broilers compared to current use of feed (21 %) showed a considerable reduction of N excretion, but that this needed compensation with synthetic amino acids due to the increased N retention (32 %). At the same time, a higher fat level and a reduced N level was observed in the manure.~~

4.3.1 Nutritional Measures ~~General approach~~

Description

The ~~main~~ strategies that are applied in diet formulations to reduce N and P excretion are:

1. Improving the feed characteristics, e.g. through the:

- application of low crude protein (CP) levels~~, use~~ and use of amino acids and related compounds;
- application of low phosphorus levels, and use of phytase and/or digestible inorganic phosphate;
- use of other authorised feed additives, ~~sensible application of~~ including growth-promoting substances
- advanced ~~increased~~ use of highly digestible raw materials.

2. Formulating a balanced diet ~~feed with~~ to achieve an optimum feed conversion ratio based on net energy (for pigs, since commercial net energy systems have not yet been developed for poultry), ~~digestible phosphorus and~~ digestible amino acids (following the ideal protein concept) and digestible phosphorus. [506, TWG ILF BREF 2001] ~~[172, Denmark, 2001]~~ [30, Spain 2001] [281, France 2010]

Among the strategies presented above, the most important are the phase feeding and the use of diet formulations with reduced CP and P contents, as described in Section 4.3.2 and Section 4.3.3. Techniques to reduce the phosphate levels in the manure by increasing phosphorus digestibility are described in Section 4.3.4 and in Section 4.3.5. ~~Low phosphorus levels in feed can reduce the phosphate levels in the manure. In order to increase digestibility, phytase is added to the feeds (see Section 4.3.4). Also highly digestible inorganic feed phosphates are available and their effects are described in Section 4.3.5.~~

Additional strategies [448, Aarnink et al. 2007] that can be put in place to reduce emissions are:

3. Reducing ~~to reduce~~ heavy metals excretions from pigs by:

- ~~finding alternative, natural, growth promoters that could replace Cu and Zn in the diet~~ applying alternative techniques that reduce the use of Cu and Zn in high dosage for performance reasons, such as the use of authorised natural zootechnical feed additives;
- using feedstuffs for diet less contaminated with Cadmium.

4. Reducing ~~to reduce~~ nitrogen emissions by:

- shifting nitrogen excretion from urine to faeces, by including fermentable carbohydrates in the diet;
- lowering the pH of urine by adding relevant and authorised feed additives (e.g. ~~acidifying salts~~ benzoic acid) to the diet.

5. Reducing ~~to reduce~~ odour emission by:

- reducing protein fermentation, by balancing available protein and fermentable carbohydrates in the large intestine
- minimising the breakdown of absorbed sulphur amino acids. [324, Netherlands 2010]

~~Another relatively new practice is the 'sequential feeding' that consists of alternately feeding two diets over cycles of 24 – 48 hours. One diet has a high protein/low energy content and the other has a high energy/low protein content. The nutritional balance that is provided during the growth cycle is no different than in standard feeding, so sequential feeding gives the possibility~~

to use a wide spectrum of raw feed, including those which are difficult to incorporate into traditional feed formulae. [281, France 2010]

Achieved environmental benefits

In general, experience so far shows that considerable reductions in N and P can be achieved. The minimum levels of N- or P- output will vary among different European agricultural regions, due to differences in farm practices, species used and nutritional management.

Across the European agricultural regions, there are many differences in farm practices, species used and nutritional management exist; hence standard production conditions are different. In Table 4.2, examples of reported standard levels of excretion of nitrogen (N) and diphosphorus pentoxide (P_2O_5) and potassium oxide (K_2O) are displayed. These values refer to a baseline situation when no nutritional measures are applied.

Table 4.2: Standard levels of excretion of nitrogen (N) and diphosphorus pentoxide (P_2O_5) excretion in Belgium, Germany, Finland and France

	N (kg/animal place/year)				P_2O_5 (kg/animal place/year)			
Animal categories	**BE**	**DE**	**FI**	**FR (1) (2)**	**BE**	**DE**	**FI**	**FR (1) (2)**
Pigs								
Piglets	2.18	4.3	2.73	4.03	1.53	2.3	1.42	2.02
Growers Finishers	13	13.0	9.8	13.7	5.33	6.3	5.05	6.30
Boars and sows	24	27 – 36	29.3 – 20.3	24.6	14.5	14 – 19	16.7	14
Poultry								
Laying hens	0.81	0.74	0.61	0.71	0.45	0.41	0.37	0.31
Broilers	0.62	0.29	0.31	0.31	0.26	0.16	0.21	0.15
Turkeys	1.70	1.64	1.19	0.99	1.05	0.52	0.62	0.62

(1) Annual data were calculated for the typical number of production cycles per year, equivalent to 6.5 for piglets and 3 for finishers.
(2) Annual data were calculated for the typical number of production cycles per year, equivalent to 6.15 for standard broilers and 2.6 for medium size turkeys.
Source: [414, FEFANA 2001] [323, Finland 2010] [328, CORPEN 2006] [329, CORPEN 2003] [447, BE 2011]

Text and data (Tables 4.2, 4.3, 4.4) reported in the existing IRPP BREF under 'Achieved environmental benefits' have been deleted and substituted with data reported in Table 4.2 (see above).

In comparison with the standard levels reported in Table 4.2, reduced levels of excreted nitrogen and/or phosphorus achieved by applying nutritional measures are reported, from a minimum of 4 % to >30 %, depending on the type of technique applied and the animal category. Examples of reduction levels of excretion associated with specific nutritional techniques are given in other parts of Section 4.3 (see Section 4.3.2, Section 4.3.4).

Former Table 4.3 and introductory text have been deleted and the results reallocated in the relevant sections (e.g. see Section 4.3.2.2)

As an example, a comparison of excreted nitrogen, phosphorus and potassium levels for a standard diet and a bi-phase diet applied to the rearing of pigs is given in Table 4.3.

Table 4.3: Examples of the influence of nutrition measures on excreted nitrogen, phosphorus and potassium for the rearing of pigs

Animal	Diet/parameters	N ([1]) (kg/ap/yr)		P ([1]) (kg/ap/yr)		K ([1]) (kg/ap/yr)	
		Standard	**Bi-phase**	**Standard**	**Bi-phase**	**Standard**	**Bi-phase**
Sow	Two-phases: CP 14 % gestating; 16.5 % farrowing 1 200 kg feed/ap/yr	24.60	20.40	6.11	4.80	9.08	8.00
Post-weaning (8 – 30 kg)	Two-phases: CP 20 % (1st phase); 18 % (2nd phase) FCR: 1.74 kg/kg	4.03 ~~0.62~~	3.64 ~~0.56~~	0.91 ~~0.14~~	0.72 ~~0.11~~	2.02 ~~0.31~~	1.89 ~~0.29~~
Fattening (30 – 112 kg)	Two-phases: CP 16.5 % (growers); 15 % (finishers) FCR: 2.86 kg/kg during fattening (+0.006 per extra kg over 112 kg)	13.68 ~~4.56~~	11.37 ~~3.79~~	2.76 ~~0.92~~	1.89 ~~0.63~~	5.52 ~~1.84~~	4.82 ~~1.61~~
Per each further kg ([2])		0.20 ~~0.067~~	0.18 ~~0.060~~	0.05 ~~0.016~~	0.03 ~~0.011~~	0.08 ~~0.027~~	0.08 ~~0.026~~

([1]) Levels are calculated for the typical number of production cycles per year, of 6.5 for piglets and 3 for finishers, as reported in the reference
([2]) Correction to apply when the slaughtering weight is over 112 kg LW.
Source: [329, CORPEN 2003] ~~[328, CORPEN 2006]~~

The effects of nutritional strategies are independent from each other but ~~and~~ may be synergetic. By combining four different strategies, a 70 % total reduction of ammonia emissions could be achieved ~~reached~~ in the rearing of growing/finishing pigs. [324, Netherlands 2010] [448, Aarnink et al. 2007].
The reduction was achieved by applying the following measures:

1. lowering the crude protein intake in combination with addition of amino acids;
2. shifting nitrogen excretion from urine to faeces by adding fermentable carbohydrates to the diet;
3. lowering the urine pH, by adding acidifying salts to the diet;
4. lowering the pH of faeces, by adding fermentable carbohydrates to the diet.

Reductions in excretion allow reductions in emissions, that eventually rebound to all ~~hence the application of techniques of reduction in~~ further steps of the production chain, ~~may result unnecessary~~ resulting in environmental advantages in all downstream operations. **MOVED from Cross-media effects**

Cross-media effects
Nutritional management is the most important preventive measure to reduce the pollution load. No direct environmental counter effect is seen.

~~either by limiting excess nutrient intake and/or improving the nutrient utilisation efficiency of the animal. Reduced mineral output and changes in the structure and characteristics of the manure (pH, dry matter content) affect the N-emission levels from housing, storage, and application and reduce the polluting load for soil, water, and air, including odours.~~

However it should be mentioned that genetic selection towards better feed conversion is also linked with an increasing growth rate. High growth rate may lead to increase lameness in broiler chickens as to systematic underfeed parent breeds (ad libitum feeding of parents create reproductive difficulties). As a consequence a balance need to be obtained between better growth rate and potential welfare problems.

Reductions in excretion allow reductions in emissions hence the application of techniques of reduction in further steps of the production chain, may result unnecessary.

Operational data

Practically in every country, programmes exist for advising farmers in about nutrition management exist. Nutritional standards are produced to provide farmers with nutrient requirements for efficient production, taking into account the animal welfare and the need for environmental protection.

For each of the three countries (Belgium, France, Germany), the reductions were obtained whilst applying a set of predefined and standardised nutritional specifications. In Belgium, 3 types of feeds were defined:

1. low-nitrogen feed
2. low-phosphorus feed
3. low-nitrogen-and-phosphorus feed.

In Belgium, low-nitrogen, low-phosphorus feed, or a combination of both, are legally recognised through a contract between feed manufacturers and the government [506, TWG ILF BREF 2001] [174, Belgium, 2001].

In Germany, the RAM-feeding programmes of low-nitrogen-and-phosphorus feeds were developed by farmers and feed manufacturers. They also rely on contracts that are controlled by the regional agricultural chambers.

In France, CORPEN recommends a two-phase feeding programme for each physiological stage (e.g. creep/piglet, lactating/gestating sows, grower/finisher pigs) based on low-protein and/or low-phosphorus diets.

Feeding recommendations are prepared for Finland by MTT and for the UK by the British Society of Animal Science (BSAS). [323, Finland 2010]

In Denmark, information on the protein feed level must integrate the fertilisation accounting management plan for crop production. The protein levels provided into feed are registered for 5 years in a log book on pig production, along together with the records of actual consumption of each feed mix. [330, Denmark 2010]

Mandatory nutritional management systems are mandatory already in place in some Member States and are backed up by practical experience. They are mainly run in two ways that are described below.

Monitoring the nutrient input and output

In those areas where intensive livestock production is responsible for high environmental pressure, farmers have to keep a register of their nitrogen and/or phosphate applications. The ‘mineral bookkeeping systems’ monitor the input and output flows at the farm level. Examples of regulatory tools are: the Act on Classified Installations for Environmental Protection (ICPE) in France, the Manure Action Plan (MAP) in Belgium, the mineral bookkeeping system MINeral Accounting System (MINAS) in the Netherlands, and the Düngerverordnung in Germany.

Estimation of mineral output from the slurry on the basis of the feed characteristics
~~The~~ As mineral output is highly correlated with mineral intake, it should be calculated based on the characteristics of the feeds ~~by~~ in terms of the correlation with the mineral content in diets. Indeed, this is done in those Member States where nutritional management systems are already ~~being~~ implemented. Indications of the systems used in France (CORPEN), Belgium (MAP) and Germany (RAM) are given in this section and in the following sections under 'Achieved environmental benefits'.

If the feeding system is different from and/or more efficient than the nutritional specifications used, 'Regression systems' allow for determining the actual level of excretion to be calculated as a function of the feed characteristics (protein and/or phosphorus contents). ~~By~~ As an example, the set of equations used in Belgium is reported in Table 4.4.

Table 4.4: Regressions used in Belgium to calculate the actual level of excretion

Animal species	Nitrogen (N) excretion (kg/animal/year)	Diphosphorus pentoxide (P_2O_5) excretion (kg/animal/year)
Piglets weighing from 7 – 20 kg	Y = 0.10X – 1.322 ~~0.13X – 2.293~~	Y = 1.65X – 0.819 ~~2.03X – 1.114~~
Other pigs weighing from 20 – 110 kg	Y = 0.13X – 3.046 ~~0.13X – 3.018~~	Y = 1.94X – 1.698 ~~1.92X – 1.204~~
Other pigs weighing more than 110 kg	Y = 0.13X + 0.161	Y = 1.86X + 0.949
Sows, including piglets with a weight <7 kg	Y = 0.13X – 0.221 ~~0.13X + 0.161~~	Y = 1.85X + 0.344 ~~1.86X + 0.949~~
Boars Laying hens (including breeders-laying hens) Growing pullets, laying hens Broilers Broiler breeders Growing pullets of broiler breeders	Y = 0.13X + 0.161 Y = 0.16X – 0.434 Y = 0.16X – 0.107 Y = 0.15X – 0.455 Y = 0.16X – 0.352 Y = 0.16X – 0.173	Y = 1.86X + 0.949 Y = 2.30X – 0.115 Y = 2.33X – 0.064 Y = 2.25X – 0.221 Y = 2.30X – 0.107 Y = 2.27X – 0.098

Y = Production (kg) of N and P_2O_5 per animal and per year
X = Consumption (kg) of crude protein (CP) and phosphorus (P) per animal per year
Source: [414, FEFANA 2001] [449, BEMEFA/APFACA 2006]

In France, the amounts of nutrients that are excreted, those that are lost in the environment, and those that are available for spreading are estimated taking into account the main factors involved in production. For poultry, tables are used for each of the many types of animals produced. For pigs, the 'simplified accounting balance' ~~takes into account the main factors involved in pig excretion, i.e. feeding technique and level of performance. It~~ has been published as a calculation sheet and as a computer model. All compound flows are taken into consideration. Nutrients that are provided to animals are estimated based on pigs live weight. Elements associated with manure and bedding are determined by the initial feed composition and quantity. Nitrogen emission flows are calculated as a function of the excreted quantity, depending on the rearing system. Emissions from houses are then estimated as the difference between input (animal + feed + bedding) and output (animal + gas losses) flows. [328, CORPEN 2006] [329, CORPEN 2003]

Examples of diet formulations applied in different Member States are reported in Section 9.2.

Table 4.7 has been deleted and the information on different nutritional management systems applied in Belgium, France, and Germany reported in the most relevant sections, on the basis of the technique described.

Applicability

Nutritional measures are considered generally applicable and their use is widespread across the EU.

~~The technique might require additional investments for stores storages, mixing and supplying devices, metering equipment, conveying technology etc., that might not be convenient for smaller farms. Hence in Denmark, farms with a size under 1300 animal places comply with lower ammonia emission requirements and are not specifically requested of phase feeding. [330, Denmark 2010]~~ **MOVED to Section 4.3.2 (Phase feeding)**

Economics

~~Assessing the costs and benefits of nutritional measures aimed at reducing emissions from intensive livestock farming is complex. The potential economic and environmental benefits of such management measures in reducing nitrogen pollution have been evaluated in a recent report by the Dutch Agricultural Economics Research Institute [77, LEI, 1999]. It evaluates the effect of current and future European policy changes on nitrogen pollution levels at national, regional and farm level using different predictive models and comparing similar approaches.~~

~~It draws attention to the fact that, where dietary protein levels decrease with increasing cereal use in feed, then the changes in cereal price are important for the sustainability of the nutritional management measures. In that respect much is expected of the effects of the CAP reforms. However, the EU-determined Cereal prices are related to is not independent, but has a price relationship with the price of soya, the price of which is set on the world market. These cost levels affect the economic viability of the nutritional management measures, such that low soya prices can lead to high dietary protein levels.~~

~~With successive CAP-reforms, the inclusion of higher levels of cereals has been favoured and the cost of implementing reduced protein diets compared with current norms has decreased accordingly (Table 4.8)~~

~~Table 4.8:Index of costs for compound feed and nitrogen content according to feeding management. [396, LEI 1999]~~

	~~Pigs~~		~~Poultry~~	
	~~Current diet~~	~~Reduced protein diet~~	~~Current diet~~	~~Reduced protein diet~~
~~**Index of costs**~~				
~~CAP 1988~~	~~100~~	~~103~~	~~100~~	~~101~~
~~CAP 1994~~	~~89~~	~~92~~	~~88~~	~~88~~
~~CAP 2000~~	~~73~~	~~74~~	~~74~~	~~74~~
~~**Index of N content in feed (kg N/tonne feed)**~~				
~~CAP 1988~~	~~100~~	~~85~~	~~100~~	~~96~~
~~CAP 1994~~	~~97~~	~~83~~	~~99~~	~~95~~
~~CAP 2000~~	~~88~~	~~83~~	~~96~~	~~93~~

~~It can be concluded that 'applying preventive nutritional management as a means of reducing nitrogen output at the farm level is economically competitive with the downstream processing of excess manure.' The report considers that rules for manure application are expected to become stricter and treatment of excess manure will become more costly.~~

~~In some areas, except for Flanders and the Netherlands, increasing cereal use may be sufficient to reduce the dietary protein to levels that are manageable at a regional level. Additional nutritional management measures will remain beneficial to those intensive livestock holdings that have insufficient land to utilise their manure.~~

~~Also the European Federation of Animal Feed Additive Manufacturers, FEFANA, has the opinion that~~

The cost and affordability of the feeding measure depends on the local commodity supply (such as cereals' affordability), the local land availability for spreading manure (limited availability will enhance the value of the feeding measure), and the world market price for protein-rich feedstuffs. High prices for protein-rich feedstuffs increase the affordability of the feeding measures, as the same happens for an increasing availability of industrial amino acids.

~~(a High prices for protein-rich feedstuffs increases the affordability of the feeding measure, as the same happens for). Expected world market and EU market trends towards lower prices of~~

cereals, higher prices for protein feedstuffs such as soybean meal, and the availability of increasing amounts of industrial amino acids., all tend to reduce the cost of the feeding measure to control nitrogen emissions from animal production. However, it is not feasible to calculate a single cost figure for evaluating the
The costs that are associated with the feeding measures imply depend on vary with, because the market fluctuations in feedstuff prices. These price fluctuations that are too large to derive a universal estimate (see Table 4.5). However, as a general rule one can assume that the extra feed cost in pigs and poultry will range from 0 to 3 % of the total feed cost (FEFAC estimates an increase by 2 – 3 % for poultry and 1 – 1.5 % for fattening pigs [11, FEFAC 2001]). In periods of extremely low prices of soybean meal, the extra feed cost may increase by up to about 5 %. [506, TWG ILF BREF 2001] [171, FEFANA, 2001]

Examples of contract prices for raw materials used in the feed formulation for pigs are given in Table 4.5.

Table 4.5: Contract price for raw materials and estimates of raw material costs for balanced feed formulations for pigs

Feedstuff	February 2010 EUR/tonne	March 2010 EUR/tonne	November 2010 EUR/tonne	September 2011 EUR/tonne
Wheat	116	114	215	202
Barley	99	97	195	203
Maize	125	126	214	226
Wheat bran	84	71	163	131
Corn gluten-feed	144	130	200	-
Peas	170	171	242	256
Soybean meal 48	329	328	350	318
Rapeseed meal	199	194	236	204
Sunflower meal in the husk	143	145	191	149
Plant oil	741	789	978	953
Molasses of sugar cane	168	168	178	-
L-lysine HCl	2 100	2100	1 750	1 950
DL-methionine	3 650	3650	3 800	3 650
L-threonine	2 200	2500	1 900	1 880
L-tryptophan	21 000	21 000	16 000	10 000
Carbonate of calcium	50	50	50	50
Phosphate bicalcique	330	330	380	560
3-Phytase	9 500	9500	9 500	9 500
Balanced growers formula	146.9	144.6	228.5	212.6
Balanced finishers formula	135.1	133.2	219.6	207.6
Source: [281, France 2010] [450, IFIP 2011]				

An example of cost data for nutrition for in the rearing of fattening pigs is reported in Table 4.6. This shows It is shown how raw feed cost fluctuations might produce final feed costs that range from savings (EUR -1.92) to economic losses (EUR 1.61). The price fluctuations to which the example refers are illustrated in Figure 4.3 for the two amino acids used in the process and in Figure 4.4 for the overall cost difference (extra cost) between the low-protein diet and the conventional diet. Extra costs were calculated with using the methodology proposed for the BREF revision by the Spanish delegation. [338, Piñeiro et al. 2009]

The existing Table 4.6 has been reorganised and amended in the following table:

Table 4.6: Example of extra costs calculation for fattening pig feed

Parameters	Values
Animal weight	
(beginning)	20 kg
(end)	100 kg
Average feed consumption	
(animal weight 20 – 60 kg)	1.4 kg/pig/day
(animal weight 60 – 100 kg)	2.2 kg/pig/day
Feed efficiency	2.93 (from 2.76 to 3.13) kg LW/kg feed
Average daily gain	822 (from 766 to 893) g/day
Breeding time	100 days
Extra costs	
New system	From -1.92 to 1.61 EUR/animal place/year ([1])
Existing system	From -0.0064 to 0.0053 EUR/kg product/year
([1]) Cost data are based on raw material costs only. The effect of hardware, manipulation, etc. are not included. *Source*: [335, Spain 2010] [500, IRPP TWG 2011]	

Driving force for implementation
The necessity to comply with nitrogen loads in nitrate vulnerable zones or with basin management plans, according to European legislation protecting waters, is a major force for farmers to reduce and control animal nutrition and excreta. The application of nutritional measures can also be driven by animal performance, and the competitiveness and financial viability of the business that become the major forces for the implementation of techniques when the animal population is within the carrying capacity of land, and where local land banks have the capability to recover nutrients from produced manures and slurries.

~~The application of nutritional measures is largely influenced by the market prices of grain and soya. A driving force could be the potential cost savings, where nutritional measures may reduce the need to apply later techniques that are aimed at emissions reductions from animal housing, manure storage and application.~~
Market prices (grains and soya above all) can produce extra savings for the application of nutritional measures.

Example plants
Many farms located in nitrate vulnerable zones (according to the Nitrate Directive 91/676/EEC), such as those in Brittany (France), the Netherlands, Belgium and Germany, already comply with some nutritional constraints in order to control their pollution load. [506, TWG ILF BREF 2001] ~~[171, FEFANA, 2001]~~

In France, since the publication of CORPEN recommendations for pigs in 1996, two-phase feeding with low protein feeds has been much developed, especially for sows. It is reported that by the end of 1997 nearly one-third of fattening pigs and nearly 60 % of all sows were fed this way. [11, FEFAC 2001]

Moved from "Driving force for implementation"
In Germany, N-adapted feeding has been mandatory for intensive livestock installations, since 2002.

In Denmark, the implementation of the Danish BAT system in the framework of the ammonia emissions legislation sets a requirement starting in 2011 that the feed management in farms produce a reduction of ammonia emissions of 30 % compared to standard feeding for all new houses. [330, Denmark 2010]

Reference literature
[328, CORPEN 2006] [329, CORPEN 2003] ~~[28, CORPEN, 1996; 29, CORPEN, 1996; 30, CORPEN, 1997]~~, [22, Bodemkundige Dienst 1999], [396, LEI 1999] ~~[81, Adams/Röser, 1998]~~ [414, FEFANA 2001]

4.3.2 Phase feeding

General description
Phase feeding is a nutritional measure in which the nutrient content of the diet is adjusted to the different requirements, ~~optimise~~ as well as to the different feed intake of the animals in the different growth phases. ~~nutrition adapting the diet formulation to the requirements that are specific to the production period~~.

4.3.2.1 Poultry

Description
~~For poultry~~, Different feeding strategies have been developed which aim at meeting the right balance between energy and amino acid requirements or which aim to influence the nutrient uptake through an improved passage of the feed through the birds' digestive channel.

Phase feeding for layers is a method of feeding which involves adjustment of the levels of Ca and P in the different production stages. A uniform group of animals and a gradual transition from one feed to the next is required.

Achieved environmental benefits
The primary effect of phase feeding is a reduction in the excretion of nutrients (N and P).

The typical achieved environmental benefits for the implementation of phase feeding in the poultry production are reported as a range of 4 - 10 % reduction of N excreted. [281, France 2010] [414, FEFANA 2001]. Values as high as 15 - 35 % reduction of N excreted are reported for broilers.

- ~~Broilers: The application of phase feeding to broilers has been reported as giving a 15 - 35 % reduction in N excreted.~~

Cross-media effects
~~The primary effect of phase feeding is a reduction in the excretion of nutrients (N and P). Reduced levels further contribute to a reduction in emissions from housing and external manure storage. At the same time, water usage and slurry volume can be reduced.~~
Moved to "Achieved environmental benefits"

A lower nutrient content of the manure leads to lower nutrient emissions from field application, but also to a higher use of mineral fertilisers, in the case where crop nutritional needs cannot be met by manure application alone.

Operational data
For broilers, phase feeding is currently applied in some EU countries. This involves dividing their requirements into three to five phases in which the broilers show a considerable change in their nutritional requirements. In each phase, the aim is to optimise the feed conversion ratio (FCR). Applying a slightly restricted feeding regime in the first phase results in a more efficient growth at a later stage. Proteins and amino acids must be fed at a high level and balanced. In Phase 2 the digestive capacity of the bird will have improved, so that more feed with ~~a~~ higher energy content can be fed. In Phase 3, the protein and amino acid content decreases again~~, but~~ at the same or reduced amount of energy~~ remains the same~~. In all phases, the Ca-P balance remains the same, but the total concentration in the feed decreases. [281, France 2010]

Compared with broilers, turkeys require large amounts of feed. Their requirements in the different phases vary in the same way as those of broilers. The required concentration of proteins and amino acids decreases with increasing age, but the required feed energy increases. Depending on the type of turkey produced, the number of phases applied can vary, with 4 to 5 being normal practice. For instance, in the Netherlands, a 5-phase feeding is applied, which means five different feeds, although more phases can be distinguished and rations are adapted accordingly. For turkeys, the shape in which the feed is offered influences the FCR and the growth. Tests have shown that pellets show better FCR and growth than meal.

In Table 4.7 examples of diet formulation for multi-phase feeding regimes (reduced crude protein and supplement of amino acids) are reported, together with the associated performance results, in terms of total nitrogen and ammonia in the excreta. Data refer to installations operated in Germany.

Table 4.7: Examples of phase feeding regimes and associated emissions in the poultry sector

Phases ([1])	Broilers	Pullets	Laying hens	Ducks	Turkey Male	Turkey Female
	3	4	3	2	4	3
Phase 1 weeks (days)	(1 – 10)	1 – 3	NA	1 – 3	5 – 8	5/6 – 8/9
Crude Protein (%)	22	20.5	18	22	24	24.4
Amino acids (%)	0.55	0.48	0.40	0.44	1.4	1.45
Phase 2 weeks (days)	(11 – 27/32)	4 – 8	NA	4 – 7	9 – 12	9/10–12/13
Crude Protein (%)	21	18.5	17	18	20	20
Amino acids (%)	0.55	0.40	0.35	0.43	1.25	1.25
Phase 3 weeks (days)	(28/33 – 35/42)	9–15/16	NA	-	13 – 16	13/14–16/17
Crude Protein (%)	19.5	14.5	16.5	-	18	18
Amino acids (%)	0.50	0.33	0.35	-	1	1.05
Phase 4 weeks (days)	-	16/17	-	-	>17	-
Crude Protein (%)	-	17.5	-	-	16	-
Amino acids (%)	-	0.36	-	-	0.85	-
Feed efficiency (kg feed/kg wgt gain)	1.75	(0.2) ([2])	2.05 ([3])	2.3	2.67	2.58
Quantity of manure (kg/kg live weight)	0.6	2.73	1.4 ([4])	3.2	1.45	1.21
Dry matter content (%)	60	52	55.2	20.46	52	50
N total (g/kg live weight)	18.2	66	40	26.5	39	39
NH_4-N (g/kg live weight)	12.8	NA	NA	10.38	15.8	NA
P_2O_5 (g/kg live weight)	3.79	53.18	20	13.7	30.6	7

NA: not available.
([1]) The exact feeding programme is presented in Section 9.2.2.
([2]) Value expressed in kg weight gain/kg feed.
([3]) Value expressed in kg weight gain/kg egg.
([4]) Value expressed in kg manure/kg egg.
Source: [327, Germany 2010]

Applicability

Phase feeding is considered generally applicable in the poultry sector. The number of phases and the potential for reducing nitrogen excretion depend on the animal species, and might need adaptation to local conditions. [508, TFRN 2011]

The availability of animal feedstuffs with low protein content and synthetic amino acids may cause some limitations to the applicability of the technique, in particular in terms of achievable reduction levels.

A computerised system ~~makes it possible to~~ automatically delivers the proper mix of high nutrient feed and low nutrient feed at the requested intervals. Applying such a system requires qualified personnel that might not be available to smaller farms. [30, Spain 2001].

Economics
Changing from conventional diets to low protein diets may lead to ~~is expected to have~~ a slight increase in feed costs, particularly when protein rich feedstuffs are inexpensive.

The implementation of the technique might require high additional investment for storing ~~storages~~, mixing and supplying devices, metering equipment, conveying technology etc., that might not be affordable ~~convenient~~ for small~~er~~ farms.

Driving force for implementation
Optimisation of animal growth performances and of expenses for feedstuff.

Example plants
The use of phase feeding for the rearing of poultry is reported to be commonly applied in several Member States.

Reference literature
[24, LNV 1994] [396, LEI 1999] [508, TFRN 2011]

4.3.2.2 Pigs

Description
Phase feeding for pigs consists in successively giving 2 to 5 ~~4~~ feeds for pigs with weights of 25 kg, up to 100 – 110 kg (slaughter weight). Feeding programmes vary among countries. The two-phase feeding programme (25 – 60 kg and 60 – 110 kg) is rather well developed but could be further developed~~,~~ to include environment concerns, as well as the economic~~al~~ value. Italian feeding programmes differ substantially from those of other EU countries, because they work with much higher slaughter weights (140 – 150 kg).

Multi-phase feeding for pigs consists of ~~in~~ providing pigs with a mix of preparations that match the animal requirements of amino acids, minerals and energy. This is achieved by mixing a high nutrient feed with a low nutrient feed, on a regular basis (from daily to weekly), as the ideal animal feed needs change continuously with the increase in live weight. Multi-phase feeding allows adjusting nutrient supply closer to the needs of the animal.

~~Further developments in multiphase feeding are pending relating to farm equipment for silos and distribution lines. [171, FEFANA, 2001].~~
~~Trials with 5-phase low CP/DE (Crude Protein/Digestible Energy) diets for growers/finishers have been done in the UK, which showed in a consistent trend that total nitrogen and ammonium-N in slurry from pigs were reduced compared to levels resulting from the commercial two-diet feeding strategy [110, MAFF, 1999] [111, MAFF, 1999].~~

Achieved environmental benefits
The primary effect of phase feeding is a reduction in the excretion of nutrients (N and P).

The achieved environmental benefits for the implementation of phase feeding to the production of pigs are reported as a range of 10 - 30 % reduction of N excreted. [281, France 2010] [414, FEFANA 2001]

A three-phase feeding program for growers can reduce N excretion by 16 % compared to a one-phase feeding program. [448, Aarnink et al. 2007]

It is reported that a two-phase feeding program for pigs from 25 to 110 kg live weight theoretically reduces nitrogen output by up to 20 %, in comparison with a single phase. Nitrogen excretion can be further reduced by 9 % through a multi-phase versus a two-phase system [396, LEI, 1999].

- Finishers: Three-phase feeding to finishers reduced nitrogen (3 %) and phosphate (5 %) excretion. Multiphase feeding leads to an extra reduction in excretion of N (5 – 6 %) and of P_2O_5 (7 – 8 %).
- Sows: For sows, the application of two-phase feeding can lead to a reduction of N excretion (7 %) and of P_2O_5 excretion (2 %), compared to no phase feeding.

Cross-media effects

A lower nutrient content of the manure leads to lower nutrient emissions from field application, but also to a higher use of mineral fertilisers in the case where crop nutritional needs cannot be met by manure application alone.

Operational data

For pigs, a different diet formulation for piglets (>30 kg live weight), growers (from 30 to 60 kg live weight) and for finishers (from 60 to 112 kg live weight) is generally applied. In some cases, a different diet formulation is used for young piglets (creep) and for older piglets.

For sows, phase feeding consists of in giving at least two different feeds: one for lactation and one for gestation. This differentiation Feeding the sow differently in gestation and in lactation is rather well developed across Europe. In some cases, a specific feed might be given before farrowing. [506, TWG ILF BREF 2001] [171, FEFANA, 2001]

Examples of detailed phase feeding programmes have been reported from the UK and Germany and are described in Annexes 9.2.1 and 9.2.2.

In Table 4.8 a summary of the reduction potential for ammonia emissions associated with phase feeding in fattening pig production is shown for different feeding strategies and diet formulations.

Table 4.8 Reduction potential for ammonia emissions in fattening pig production with different crude protein adjusted feeding

Feeding strategy	Reduction potential ([1]) (%)	Remarks
Phase feeding (2 phases)	Up to 10	Adjustment between preliminary feeding and main feeding periods (from 18 to 15 % crude protein)
Phase feeding (3-4 phases)	Up to 20	Adjustment every few weeks; from 18 to 13 % crude protein balancing of essential amino acids (lysine, methionine)
Multiphase feeding plus amino acid balancing	Up to 40	Daily adjustment; from 18 to 13 % CP; balancing essential amino acids (lysine, methionine)

([1]) Reference feeding regime: No phase feeding, 18 % crude protein (CP).
Source: [571, Eurich-Menden et al. 2011]

Examples of excreted nitrogen reductions associated with the use of two-phase feeding programmes applied in France and Germany are reported In Table 4.9, together with the indication of the diet formulation applied.

Table 4.9: Examples of excreted nitrogen reductions for two-phase feeding programmes in the pig sector

Animal	Source	Diet/parameters	Nitrogen reduction ([1]) (%)
Piglets	France CORPEN 1	Two-phases: CP 20 % (1st phase); 18 % (2nd phase)	9
	France CORPEN 2	Two-phases: CP 20 % (1st phase); 17 % (2nd phase)	18
Fattening pigs	France CORPEN 1	Two-phases: CP 16.5 % (growers); 15 % (finishers)	17
	France CORPEN 2	Two-phases: CP 15.5 % (growers); 13.0 % (finishers)	30
	Germany RAM	Two-phases: CP 17.0 % (<60 kg LW); 14.0 % (>60 kg LW)	19
Sows	France CORPEN 1	Two-phases: CP 16.5 % (lactation); 14.0 % (gestation)	17
	France CORPEN 2	Two-phases: CP 16.0 % (lactation); 12.0 % (gestation)	27
	Germany RAM	Two-phases: CP 16.5 % (lactation); 14.0 % (gestation)	19 – 22
Source: [414, FEFANA 2001] [329, CORPEN 2003]			

An example of the performance variation observed by applying a two-phase feeding and a five-phase feeding regime on fattening pigs is presented in Table 4.10. The detailed composition of the different diets used for both feeding strategies is reported in Annex 9.2.2.

Table 4.10 Example of the influence of phase feeding on excreted nitrogen an phosphorus for fattening pigs

	Operating and performance data	
Feeding strategy ([1])	2 phases	5 phases
Parameters		
Total Nitrogen ([2]) (kg/animal place/year)	7.8	7.35
Nitrogen excreted (kg N/m^3 manure)	~ 5.2	4.9
Total P_2O_5 (kg/animal place/year)	4.8	4.5
P_2O_5 excreted (kg/m^3 manure)	~ 3.2	~ 3.0
Operating conditions		
Phases	Phase 1: from 25 to 60 kg Phase 2: from 60 to 110 kg	Phase 1: from 30 to 40 kg Phase 2: from 40 to 60 kg Phase 3: from 60 to 80 kg Phase 4: from 80 to 100 kg Phase 5: from 100 to 110 kg
Feed consumption	2.15 kg/d	
Average daily gain	720 g/d	
Feed efficiency	0.34 kg weight gain/kg feed	
Quantity of manure	1.5 m^3/ap/yr, with 7.5 % DM	

([1]) The exact feeding programmes are presented in Section 9.2.2.
([2]) Housing and stock losses deduced.
Source: [326, Germany 2010]

Applicability

It has been reported that multiphase feeding for pigs requires sophisticated and expensive equipment for dry feeding and so is best employed in large scale production enterprises. In practical terms, three-phase feeding may be the most feasible option for growers/finishers. [396, LEI 1999]

Multiphase feeding is also possible with liquid feeding systems, and indeed liquid feeding systems are increasingly becoming more popular. However, multiphase feeding can be ~~rather~~ complicated to implement in a continuous flow system, such as that normally used in small farms. [30, Spain 2001]

A computerised system ~~makes it possible to~~ automatically delivers the proper mix of high nutrient feed and low nutrient feed at the requested intervals. Applying such a system requires qualified personnel that might not be available to smaller farms. [30, Spain 2001].

For new fattening pigs installations, both dry and wet feeding systems can be employed; though, wet systems are considered more flexible for phase feeding. [541, MLC 1998]

Economics

~~No cost data have been reported. However, the costs associated with multiphase feeding are expected to be higher than those for phase-feeding, as, for example, additional costs may need to be included for additional storage facilities for the different feeds and for mixing facilities. [173, Spain, 2001] [171, FEFANA, 2001]~~

It has been estimated that changing pig nutrition from one ~~feed~~ phase to two and three ~~feeds~~ phases not only improves the growth performances but can reduce both the feed costs and the nitrogen excretion, as reported in Table 4.11.

Table 4.11: Modelled results of pig performances (30 to 95 kg), costs and nitrogen excretions for the substitution of a single feed regimen with a two and a three phases nutrition management

Performance	Unit	Single phase	Two phases	Three phases
Feed cost	EUR/t (1)	138.1	125.8 - 110.45	125.8; 110.45; 103.4
Feed intake	kg/day	1.88	1.89	1.92
Daily gain	g/day	698	703	709
Feed conversion rate	-	2.69	2.69	2.70
Feed cost	EUR/pig (1)	24.39	23.13	22.07
Backfat thickness	mm at P2 (2)	10.9	11.2	11.5
Nitrogen excretion	kg/pig	3.24	2.94	2.28
Slurry nitrogen	kg/ produced pig per year	6.91	6.26	4.86

(1) Values in EUR as per exchange GBP/EUR = 0.88.
(2) Reference position for taking backfat thickness measurement.
Source: [290, Univ. of Newcastle 2002]

Changing from conventional diets to low protein diets may lead to ~~is expected to have~~ a slight increase in feed costs, particularly when protein rich feedstuffs are inexpensive. ~~that is~~ This can be totally or partially offset by reductions in water and slurry handling costs. The net result should be an increase of EUR 0.22 per kg carcass production cost (0.2 UK pence). [290, Univ. of Newcastle 2002]

The implementation of the technique might require high additional investment for storing storages, mixing and supplying devices, metering equipment, conveying technology etc., that might not be affordable convenient for smaller farms. Hence in Denmark, the technique is not considered applicable to farms with a size of less than approximately under 1 300 animal places. comply with lower ammonia emission requirements and are not specifically requested of phase feeding. [330, Denmark 2010]

Driving force for implementation
Optimisation of animal growth performance and of expenses for feedstuff costs.

Example plants
Phase feeding is a consolidated technique commonly applied across the European Union. commonly applied.

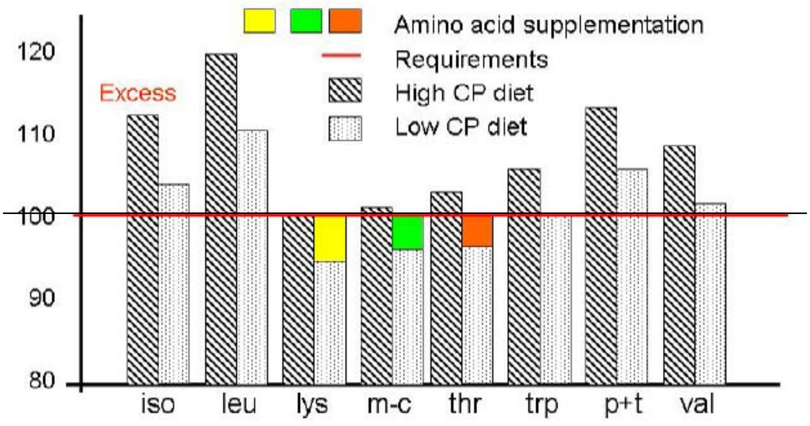
Reference literature
[24, LNV 1994] [44, IKC 1993] [396, LEI 1999] [539, MAFF 1999] [540, MAFF 1999] [110, MAFF, 1999] [111, MAFF, 1999] [290, Univ. of Newcastle 2002]

4.3.3 Addition of amino acids to make low-protein, amino acid-supplemented diets for poultry and pigs

Description
This technique is most often referred to in the literature. The principle is to feed animals with the appropriate level of essential amino acids (AA) for optimal performance to whilst limiting the ingestion of excess of ingested protein ingested (Figure 4.2).

Reducing the crude protein in the feed to reduce the amount of nitrogen excreted, also has an impact on both amino acids and the energy content of the diet. The reduction should not be done at the expense of the animal growth. For this, an adequate nutritional system is required with digestible amino acids and net energy. The digestible amino acid profile has to meet animal requirements by using industrial amino acids supplementation in appropriate quantities and proportion.

The formulation of low-protein diets requires reducing the incorporation of
In this way, a certain amount of crude protein (CP) coming from protein-rich feedstuffs (like soybean soya bean meal) whilst balancing the diets is substituted with amino acids from industrial production. supplements. Some Commercially available and registered Amino acids like are lysine (L-lysine), methionine (DL-methionine and analogues), threonine (L-threonine), and tryptophan (L-tryptophan) and valine (L-valine) are registered as feed additives and are commercially available and registered.
Other essential amino acids are likely to be developed in the future, which might facilitate a further decrease in dietary protein content. [108, FEFANA, 2001]



NB: lys = Lysine m-c=Methyonine+Cysteine
thr = Threonine

Source: [396, LEI 1999]

Figure 4.2: Amino acid supplementation allows a decrease in the amount of protein intake by animals, while maintaining an adequate amino acid supply

Achieved environmental benefits

Reduction of dietary protein ingested (input) leads to a significative reduction of the N excreted (output), hence emissions will be reduced at all stages of the manure management (housing, storage and land application)

When the crude protein and each amino acid ~~is~~ are provided in the diet at levels as close as possible to the effective animal requirements ~~needs~~, the growth performances are optimised, alongside ~~and the most~~ the reduction of nitrogen excretion ~~is allowed~~.

A series of examples are reported in Table 4.12, showing the environmental and economic effects of a possible reduction in the given amounts of crude protein (CP), together with the corresponding amino acid supplement.

Table 4.12: Environmental and economic benefits of the substitution of crude protein with controlled amounts of essential amino acids.

Feed components	Type of animal				
	Laying hen ([1])	Broiler ([2])	Turkey ([3])	Fattening pig ([4])	Fattening pig ([5])
Phase 1					
Initial CP level (%)	19	22	27.7	17.5	17.5
Initial AA supplementation (%)	0.21	0.35	0.32	0.202	0.066
Reduction of CP level (%)	-2.9	-2	-1.9	-3	-1.5
Final CP level in diet (%)	16.1	20	25.8	14.5	16
Additional AA supplementation (%)	+0.38	+0.25	+0.32	+0.426	+0.242
Total AA supplementation in the reduced CP diet (% of diet)					
L-Lysine HCl (%)	0.24	0.20	0.29	0.49	0.156
DL-Methionine (%)	0.28	0.31	0.27	-	0.088
L-Threonine (%)	0.07	0.07	0.08	0.124	0.064
L-Tryptophane (%)	-	0.02	-	0.014	-
Phase 2					
Initial CP level (%)	-	20.6	23.3	-	15.5
Initial AA supplementation (%)	-	0.22	0.37	-	0.116
Reduction of CP level (%)	-	-2.4	-1.7	-	-2.0
Final CP level in diet (%)	-	18.2	21.6	-	13.5
Additional AA supplementation (%)	-	+0.19	+0.31	-	+0.325
Total AA supplementation in the reduced CP diet (% of diet)					
L-Lysine HCl (%)	-	0.17	0.38	-	0.255
DL-Methionine (%)	-	0.24	0.22	-	0.090
L-Threonine (%)	-	0.07	0.08	-	0.096
L-Tryptophane (%)	-	0.01	-	-	-
Overall results					
Reduction of total-N excreted (%)	22.9	19.9	8.3	29.2	16.2
Annual savings per animal place (EUR)	0.32	0.116	0.41	8.006	5.21
Annual savings per production in EUR/kg ([6]) or (EUR/egg)	(0.0164)	0.018	0.025	0.0391	0.0307

([1]) [316, Fefana 2010].
([2]) [312, Fefana 2010].
([3]) [313, Fefana 2010]. Two more phases of the test have not been displayed.
([4]) [314, Fefana 2010].
([5]) [315, Fefana 2010].
([6]) Price calculations are based on AA and feed raw materials prices of December 2009.

The effects of two different low-protein diets for fattening pigs (finishers), with partial or total substitution of soybean by essential amino acids, have been tested during two field trials; the results are presented in Table 4.13.

Table 4.13: Effects of two low-protein diets with partial or total substitution of soybean by essential amino acids to fattening pigs (finishers)

Parameters		**Diet description and performance data**	
Diet		Low Protein diet – 1 Soybean is reduced and partially substituted by essential amino acids	Low Protein diet – 2 Without soybean which is fully substituted by essential amino acids
Time of application		Summer	Winter
Animal weight		From 98.6 to 163.8 kg	From 102.8 to 160.2 kg
Crude protein (%)		11 – 12	9
Average reduction in nitrogen, compared to standard diet ([1]) (%)		21.9	37.9
Average reduction of ammonia emissions to air, compared to standard diet ([1]) (%)	Estimated (Nitrogen balance)	26.2	50.3
	Measured	26.2	54.6
Average reduction of nitrogen to field, after air losses, compared to standard diet ([1]) (%)		18	30

([1]) Standard diet with 13 – 14 % CP, in three phases.
Source: [325, Italy 2009]

A summary of the most important environmental effects associated with the use of a low-protein diet and partial substitution with essential amino acids are listed below.

Poultry

- A reduction in dietary protein content of 1 percentage point results in a reduction in nitrogen excretion of 10 % for poultry. ~~layers and 5 – 10 % for broilers, turkeys and other meat birds~~ [414, FEFANA 2001]
- Low-protein diets contribute to a reduction of ammonia emission from poultry houses. In an experiment on growing broilers, a reduction in crude protein of two points resulted in a reduction in ammonia emission of 24 %.
- A reduction in water consumption of 8 % ~~was found~~ is possible when the protein level in grower feed is ~~was~~ decreased by 3 points. [414, FEFANA 2001]
- According to the Dutch model realised for the European Commission (ERM/ABDLO, 1999), for a reduction of 10 % of the protein content in feed, reductions of nitrogen in litters are expected for laying hens, ducks, turkeys and broilers of 14 %, 15 %, 15 % and 19 %, respectively. [281, France 2010]
- The litter quality is enhanced by a reduced nitrogen content, that results in reductions of the incidence of illness conditions, such as hock burn, sternal bursitis, focal ulcerative, dermatitis and foot pad dermatitis (also important for improving working conditions for farm personnel).

Pigs

- It is possible to reduce the nitrogen excretion by up to 20 %, by reducing up to 2 % ~~with a reduced~~ the initial protein level ~~in~~ feeds of 14 – 22 % CP ~~of by up to 2 percentage points~~ in ~~for~~ all categories of pigs ~~resulting in a decrease in nitrogen excretion of up to 20 %~~ and without requiring any specific technical skills. [34, Ajinomoto 2000] However, it is necessary to add the four essential amino acids (lysine, methionine, threonine and tryptophan) and to formulate diets respecting net energy requirements to prevent ~~growth~~ reductions in growth and carcass quality.

- Protein content is gradually reduced according to the need for amino acids and, in this way, a high surplus of nitrogen is avoided. The lower excretion of nitrogen through kidneys and faeces reduces the intestinal problems and physiological "stress" of the excretion process [330, Denmark 2010]

- In general, reduced crude protein levels have a tendency to lower odour emissions (see Section 4.10) and the emission of odorous components like H_2S [414, FEFANA 2001]. This effect is reported minimal or negligible, when a relatively low protein diet is already used [330, Denmark 2010] [326, Germany 2010].

  ~~low protein diets also reduce the emission of odorous components like H_2S [414, FEFANA 2001] (with reference to Hobbs et al., 1996).~~

- A reduction in water consumption of about 6 – 9 % was reported when the protein level in the diet for fattening pigs was decreased by 3 points. [414, FEFANA 2001]. The saving of water results in a decreased volume of manure to be handled. With higher DM contents, the slurry may also gain in value in terms of its fertilising quality.

~~Protein intake reduction leads to a reduced Such diets also reduce the animals' water intake. This results in a saving of water and a decreased volume of manure to be handled. With higher DM contents, the slurry may also gain in value in terms of its fertilising quality.~~

~~The contribution of feeding measures to the actual reduction of emissions from animal housing systems varies with a number of factors, such as air temperature inside the housing, air velocity (ventilation rate) and manure surface area.~~

Cross-media effects

~~Low-protein amino acid fortified diets as supplied in the reviewed trials discussed above did not affect~~ Only an excessive reduction of protein level without balancing the amino acid profile will have a negative effect on growth, feed conversion or the nitrogen retention in ~~animals~~ pigs ~~the pig~~. Although, it has not been demonstrated whether there is a biological limit to reducing the crude protein content after all the essential amino acids are supplemented.

~~In fact, trials (Portejoie et al., 2002) showed that ammonia emissions can be reduced by 63 % when dietary protein is decreased from 20 to 12 %, but at the same time, pig performances and carcass quality are affected. [281, France 2010]~~

Operational data

~~Operational data of the trials on pigs have not been reported. The weight range of the pigs was generally between 25 and 110 kg of live weight and the feeding varied between 2-phase and multiphase feeding.~~

Amino acid (AA) integration (and CP reduction) in a Standard feeding

The dietary crude protein content can be lowered if at the same time the energy content of the diet is increased and nutritional amino acids are supplemented to meet the animal requirements.

In a literature review reported by Ajinomoto Animal Nutrition, data from reported trials on the effects of low protein diets (and ~~but~~ supplemented with industrial amino acids) on nitrogen and slurry output from pigs, were selected from a large variety of sources within and outside Europe ~~(see reference [99, Ajinomoto Animal Nutrition, 2000]). In the trials it was found~~ The conclusion that could be reached was that the excretion of nitrogen drops ~~dropped~~ by 10 % per 1 percentage point reduction in dietary protein for pigs between 25 and 110 kg, with a linear trend in the range of 12 to 20 % of CP level.

~~The reported trials showed remarkably similar results. They are summarised in Table 4.14.~~

Table 4.14 summarises the effects of a reduction in dietary crude protein levels and the use of low-protein diets.

Table 4.14: Summary of the effect of a reduction of dietary protein and the use of low-protein diets on nitrogen excretion and ammonia emission

Parameters	Effect of 1 point reduction of dietary protein (%)	Using low-protein diets	
		Frequent cumulative effect (%)	Best cumulative effect (%)
Total nitrogen excreted	- 10	- 25	- 50
Ammonia content in slurry	- 10	- 30	- 50
Slurry pH	-	- 0.5 points	- 1 point
Ammonia emission to air	- 10	- 40	- 60
Water consumption (ad libitum)	- 2 to - 3	- 10	- 28
Slurry volume	- 3 to - 5	- 20	- 30
Source: IRPP BREF 2003.			

Results of a trial carried out in a fattening pigs farm (30-115 kg in straw housing system), applying a one-phase feeding strategy in which the dietary crude protein level was reduced by 3 points (% in the diet) with the addition of supplementary crystalline amino acids (L-lysine, L-threonine and L-tryptophane), are presented in Table 4.15. The experimental results are in line with those reported in Table 4.14.

Table 4.15: Effects of reduced crude protein levels with amino acid supplementation in one-phase feeding of fattening pigs

Parameters	Standard One-phase feeding	Modified One-phase feeding
Crude protein in diet (%)	17.5	14.5
Amino acids in diet (%)	0.2019	0.6274
Total Nitrogen excreted (g/kg live weight)	15.37	10.88
NH_3 + N_2O (N gaseous emissions) reduction (%)	-	30
Savings for feed cost ([1])		
EUR/animal place/year	-	8.006
EUR/kg produced/year		0.0391
([1]) Cost calculations based on amino acids and feed raw materials prices of December 2009. *Source*: [572, FEFANA 2010]		

Amino acid (AA) integration on a Two-phase feeding

~~With the aim of adapting the feeding strategy to the pig requirements to reduce the excreted nitrogen, the strategy of transitioning from one phase feeding to two phases feeding strategy might be successful for converting the feeding scheme to a scheme that better fits the pig requirements during growth.~~

The conversion from a one-phase to a two-phase feeding system, with the aim of adapting the feed to the pig requirements and, at the same time reducing the excreted nitrogen, may better fulfil the animal requirements during growth. Similarly, in an already applied phase feeding strategy, based on the needs of the animal at various life stages, the protein intake can be firther reduced by adding industrial amino acids to the feed.

The substitution of a single feeding scheme with 17.5 % of crude protein (CP) with a ~~scheme of~~ two-phase scheme where the CP level is reduced by 1 point in the first phase and by 2 points in the second phase, ~~and~~ while integrating the two diets with proper doses of AA (for around a total of 0.4 %) provides a reduction in nitrogen excretion of around 18.5 % (see Table 4.16). [317, Fefana 2010] [318, Fefana 2010]

The ~~mere~~ introduction of a second phase with 2 points reduction of the dietary crude protein level leads to ~~such reduction in raw protein after a first phase with unreduced feed provides~~ a reduction of the nitrogen excreted of around 8 % ~~in excreted nitrogen~~. [319, Fefana 2010]

The substitution of expensive protein meals with small doses of industrial amino acids still allows for reductions in the cost of feed preparation, as ~~that are~~ shown in Table 4.16 for two different formulations of two-phase feeding in comparison with a single phase previously applied.

Table 4.16: Examples of emissions and costs reductions for two-phase feeding schemes ~~compared to a~~ after transition from a ~~standard~~ single-phase feeding scheme for fattening pigs

Feeding scheme	CP (%)		~~Emission~~ Reduction of total excreted N (%)	Feed cost reduction ([1]) (% /ap per year)	Feed cost savings	
	Phase 1 (growing period)	Phase 2 (finishing period)			EUR/ap per year	EUR/kg of produced meat
Standard single-phase feed	17.5		NA	NA	NA	NA
Switch from single phase to two-phase feeding – Reduction of CP level in the finishing period ~~Only second phase, reduced CP~~	17.5	15.5	7.8 %	5.76 %	5.675	0.0334
Switch from single-phase to two-phase feeding – Reduction of CP level in both growing and finishing periods ~~Two low CP phases~~	16.5	15.0	18.5 %	5.47 %	5.25	0.0256

NA: Not available.
([1]) Feed costs calculated on December 2009 prices.
Source: [317, Fefana 2010] [318, Fefana 2010] [319, Fefana 2010]

Amino acid (AA) integration in a Three-phase feeding

A further step in the feeding strategy might be the transition from a two-phase feeding to a three-phases feeding strategy. Results that were obtained in commercial farms, concerning three different situations corresponding to a minimal, medium and strong reduction of CP in the diet, and related compensation by amino acids supplementation, are summarised in Table 4.17 (note that negative savings are, in effect, increased costs).

Table 4.17: Effectiveness of transition from two-phase feeding to three-phase feeding for fattening pigs and different crude protein reduction

Parameters		Crude protein reduction		
		Minimal ~~CP reduction~~	**Medium ~~CP reduction~~**	**Strong ~~CP reduction~~**
2 phases ~~test~~ feeding				
Phase 1 (30 – 45 kg)	Crude protein content (%)	17.5	17.5	17.5
	Supplemented AA (%)	0.43 (Lys, Thr, Met)	0.43 (Lys, Thr, Met)	0.43 (Lys, Thr, Met)
Phase 2 (45 –110 kg)	Crude protein content (%)	15.5	15.5	15.5
	Supplemented AA (%)	0.38 (Lys, Thr, Met)	0.38 (Lys, Thr, Met)	0.38 (Lys, Thr, Met)
3 phases feeding				
Phase 1 (30 – 45 kg)	Crude protein content (%)	17.5 ~~15.5~~	16.5 ~~17.5~~	15.5 ~~16.5~~
	Supplemented AA (%)	0.43 (Lys, Thr, Met)	0.61 (Lys, Thr, Met, Trp)	0.79 (Lys, Trp, ~~Thr~~, Met)
Phase 2 (45 – 75 kg)	Crude protein content (%)	16.5	15.5	14.5
	Supplemented AA (%)	0.36 (Lys, Thr, Met)	0.52 (Lys, Thr, Met)	0.69 (Lys, Thr, Met, Trp)
Phase 3 (75 – 110 kg)	Crude protein content (%)	14	13	12
	Supplemented AA (%)	0.48 (Lys, Thr, Met)	0.60 (Lys, Thr, Met)	0.73 (Lys, Thr, Met, Trp)
Growth (g/day)		607	629	631
Weight gain produced/animal place/year		215.25	222.77	224.81
Nitrogen excretion Performances				
~~Difference in Average Daily Growth (g)~~		~~-13~~	~~9~~	~~11~~
Reduction of excreted nitrogen (%)		8.7 ~~8.66 %~~	12.4 ~~12.41 %~~	21.1 ~~21.05 %~~
Economics ([1])				
Savings/animal place per year (EUR)		2.33	7.15	7.57
Savings/animal place per year (%)		2.24 ~~-0.42~~	6.87 ~~7.64~~	7.27 ~~8.92~~
Savings per kg of produced meat per year (EUR)		-0.002	0.037	0.042
Savings per kg of produced meat/year (%)		-0.42	7.85	8.92

NB: Lys = Lysine
Met = Methionine ~~Methyonine~~
Thr = Threonine
Trp = Tryptophane
([1]) Feed cost savings calculated on October 2009 prices.
Source: [320, Fefana 2010] [321, Fefana 2010] [322, Fefana 2010].

Applicability

This technique is already implemented throughout Europe. No specific technical requirements are necessary for the application of low-protein feed diets. However, the applied levels of crude protein might differ from country to country.

The feeding of low-protein diets can reduce the animals' heat production caused by the growing process. This is considered to be an advantage, particularly in Mediterranean Member States during hot summers. This effect is even more pronounced with lactating sows.

In general, pigs are not sensitive to dietary CP levels as long as they receive the essential amino acids in appropriate quantities and proportions to meet their requirements.

In the case of an excessive reduction of protein level and after all the essential amino acids are supplemented, a negative effect on growth may occur; this type of event has been observed in some test trials of Portejoie et al. [451, Portejoie et al. 2002], where ammonia emissions reductions of up to 63 % were observed over the whole process, when dietary protein was decreased from 20 to 12 %, but at the expense of pig performance and carcass quality[281, France 2010]. On the other hand, it might be argued that there is no biological limit to reducing the CP content as long as the amino acid profile is balanced and the net energy content is adapted. The reason for the aforementioned performance deterioration should be the deficiency of the amino acid valine, that was not supplemented and was found in the diet to be in a very low ratio to the amino acid lysine. ~~(58 %)~~ Recalculation of the amino acid profile based on the INRA tables (2004) showed that the valine to lysine ratio in the 12 % CP diet was too low (58 %) compared to the recommended ratio of at least 65 %.

Commercial broiler lines can become quite sensitive to reductions in protein levels. In many commercial diets that are already well optimised to protein content, further crude protein reductions could compromise certain amino acid levels, which are difficult to balance with industrial amino acids that are not available at commercial prices. The resulting amino acid deficiency would have a negative effect on the animal growth rates. It has been reported that any further crude protein reductions in current UK diets are most likely to compromise valine levels and, therefore, affect animal growth.

For UK conditions, poultry nutritionists advise that also for laying hens aged 18 to 40 weeks, tryptophan, which currently is not added in the feed, is a limiting amino acid. Therefore a crude protein level of 15.5 – 16.5 (% in feed) ~~(see Table 5.5)~~ is not technically available and under UK conditions a higher crude protein level will be needed for this class of poultry.

~~For UK pigs, which are kept entire, slaughtered at relatively low weights and have a genotype developed to maximise lean deposition in these circumstances, it is likely that even the higher end of the ranges as reported in Table 5.1 is not technically available. Under UK conditions higher levels of CP can be used and still result in a lower total N input over the life of the pig.~~

This nutrient management approach to reducing nitrogen pollution can be implemented very readily on a large scale since:

- little investment is needed and no structural alterations are required on the farm, and
- one feed mill generally covers a large number of farms, therefore reducing individual farm formulation costs.

The optimum crude protein level will depend on local raw materials and will vary from region to region e.g. where higher protein cereals are predominant, higher protein levels will be needed to optimise diets.

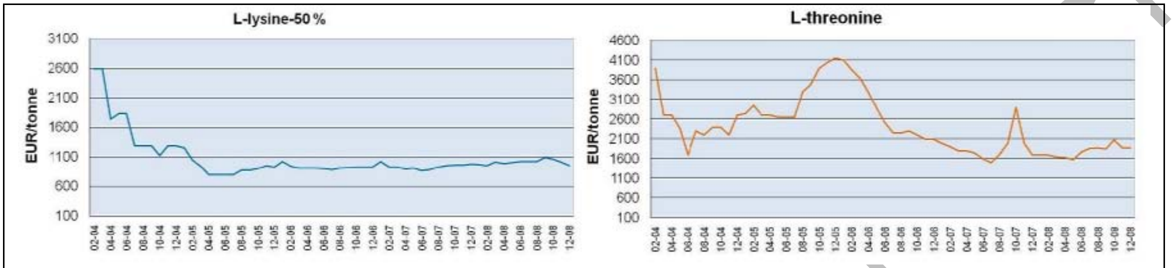
Economics
A general description on cost assessment of nutritional management is given in Section 4.3.1. For feeding low-protein diets, no special equipment has to be applied and no new investment needs to be made. Although, there may be a cost for feed formulation and, when going from one-phase feeding to two-phase feeding, there may be an additional cost ~~and~~ for ~~additional~~ supplemental storage. Cost estimates of nutritional measures take into account the following factors:

1. additional feed costs;
2. additional costs for increased storage needs when adding a new phase feeding;
3. savings in water costs;
4. savings in slurry transport and treatment or spreading costs;
5. savings in capital investment, e.g. less storage capacity required for rough feedstuffs.

~~To illustrate the effects of reduced CP diets, calculations have been made, but results depend on the assumptions made for the cost factors. Where one publication assumes an increase of feed costs varying between 1 and 3 % [116, MAFF, 1999], another report mentions cost savings with reduced feed costs of about 3 % [115, Rademacher, 2000]. Portugal has reported an increase of feed costs between 5.5 and 8 % for weaners and finishers when lowering the level of crude~~

~~protein between 2.0 to 2.5 % and balancing the feed with amino acids. For sows this increase was 2.9 and 4.9 % for gestation and lactation respectively. These calculations were made based on the prices for the raw materials in May 2001. Regarding the variations in costs of raw materials, mainly protein rich ingredients, and the factors involved in the calculation of feed costs, more information from Member State on costs could be helpful. [201, Portugal, 2001]~~

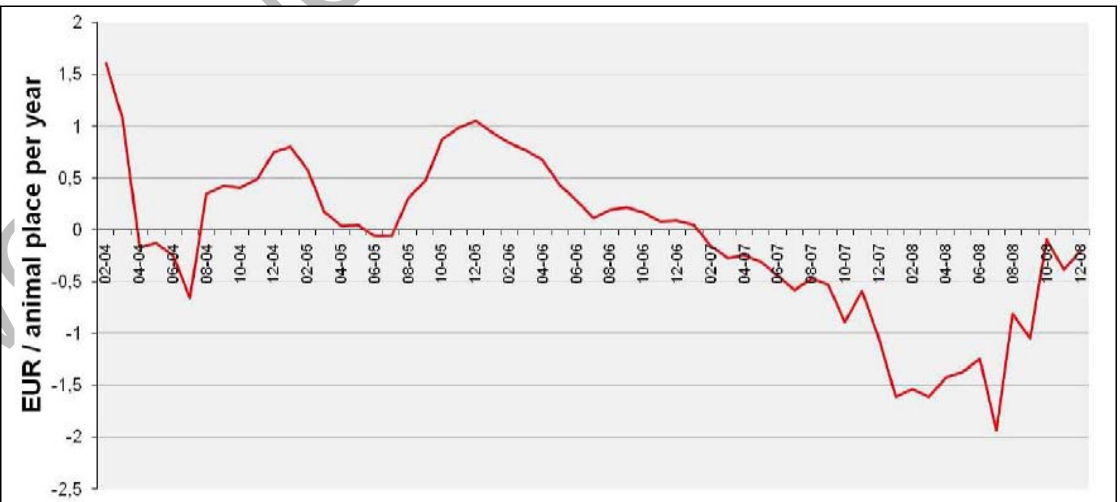
Fluctuations of prices for raw feed, namely soya and protein feed and cereals, condition the fluctuations of final feed costs. Amino acid prices are also subjected to fluctuations (see Figure 4.3). A reduction of protein intake can be achieved at ~~moderate~~ lower or moderate costs, depending on the relative prices of cereals and protein-rich feedstuffs, or with the use of the ~~two~~ three amino acids lysine, threonine and methionine; therefore, the use of other ~~synthetic~~ industrial amino acids such as tryptophan and valine can give greater reductions but can lead to an ~~considerable~~ increase in feed costs. [337, Webb et al. 2005]



Source: Spanish Ministry of the Environment and Rural and Marine Affairs

Figure 4.3: Fluctuation of industrial amino acids prices in Spain ~~over time~~

Figure 4.4 ~~describes the evolution of~~ shows the price fluctuation in Spain from 2004 and 2009 for the difference in cost between a common diet and a low protein diet with the supplementation of ~~synthetic~~ industrial amino acids. The example refers to the same data reported in Table 4.6, where two programmes of two-phase diets for pigs of 26 to 60 and of 60 to 100 kg LW were compared for the crude protein level and the supplementation of amino acids. The crude protein levels in the standard diet ~~and the low protein diet respectively~~ were 19 % in Phase 1 and 16 % in Phase 2, and in the low protein diet were ~~and~~ 16.5 % in Phase 1 and 13.5 % in Phase 2. The difference, that is the bare extra cost, oscillated between EUR -1.92/place per year (savings) and EUR 1.61 (extra costs), or in other units, between EUR -6.5/tonne and EUR 5.5/tonne of pigs produced. [338, Piñeiro et al. 2009]



Source: Spanish Ministry of the Environment and Rural and Marine Affairs

Figure 4.4: Example of the cost difference between a low protein diet and a conventional diet ~~Industrial amino acids prices in Spain over the time~~

Driving force for implementation

Along with the aim of reducing emissions, this technique is put in place for a parallel optimisation of growth performance, the health status of the animals, and feed costs. Formulating with a constraint on each amino acid allows optimising nutrients to the animal requirement. The reduction of protein excess in animal's stomach also decreases the occurrence of diarrhea. At an EU scale, reducing the utilisation of proteic raw materials allows reducing the soybean meal imports from non-EU countries.

Example plants

Low-protein, amino acid-supplemented diets are already used throughout Europe~~ to a certain extent in some intensive poultry and pigs livestock production areas~~.

Reference literature

[396, LEI 1999] ~~[82, Gill, 1999]~~ [541, MLC 1998] ~~[100, MLC, 1998]~~ [414, FEFANA 2001] ~~[115, Rademacher, 2000] and [116, MAFF, 1999]~~ [281, France 2010] [451, Portejoie et al. 2002] [34, Ajinomoto 2000] [330, Denmark 2010]

4.3.4 Addition of phytase to make ~~low phosphorus, phytase supplemented~~ phosphorus balanced diets for poultry and pigs

Description

~~This technique has been often published in scientific as well as practical documents. Phytate-Phosphorus that is combined in phytates is not normally available to pigs and poultry as they lack the appropriate enzyme activity in their digestive tract. Therefore, the principle of the technique is to feed animals with the appropriate level of digestible phosphorus necessary to ensure optimum performance and maintenance, whilst limiting the excretion of non-digestible phytate phosphorus normally present in plants (Table 4.12).~~

Phosphorus that is contained within phytate, the principal storage form of phosphorus in feed ingredients of plant origin (see Table 4.18), cannot be readily digested by monogastric animals like poultry and pigs, as they lack the appropriate enzyme activity in their digestive tract. Traditionally, inorganic phosphorus is supplemented to feed in order to meet the animal nutritional needs. The addition of phytase in the diet allows the phosphorus release from phytate, so it becomes available for digestion, thus reducing the level of supplementation of inorganic phosphorus. The reduction of phosphorus excretion ~~formulation of a low phosphorus diet~~ ~~can be~~ is thus achieved by:

- adding phytase;
- increasing the availability (digestibility) of phosphorus in plant feed materials;
- reducing the use of inorganic phosphate in feeds.

~~Currently four phytase preparations are authorised as feed additives in the European Union (Directive 70/524/EEC category N). Authorisation of new phytase products depends on an evaluation of the product, which should guarantee their efficiency in the declared animal categories.~~

New approaches are currently being developed by some plant-breeding companies and which involve developing plant varieties with high phytase activity and/or low-phytic acid content.
[30, Spain 2001] [453, DEFRA 2011]

Table 4.18: Total phosphorus, phytate-phosphorus and phytase activity in selected plant feedstuff

Feedstuffs	Total P (%)	Phytate-P (%)	Phytase activity (U/kg)
Maize	0.28	0.19	15
Wheat	0.33	0.22	1 193
Barley	0.37	0.22	582
Triticale	0.37	0.25	1 688
Rye	0.36	0.22	5 130
Sorghum	0.27	0.19	24
Wheat bran	1.16	0.97	2 957
Rice bran	1.71	1.1	122
Soybean meal	0.61	0.32	8
Peanut meal	0.68	0.32	3
Rapeseed meal	1.12	0.4	16
Sunflower meal	1	0.44	62
Peas	0.38	0.17	116
Source: [452, FEFANA 2002] ~~[170, FEFANA, 2002] with reference to J. Broz, 1998~~			

Achieved environmental benefits

The data reported below for pigs and poultry can be found in many publications on the use of phytase in feedstuffs. They provide a summary of the results obtained with different feeds and in different situations, with possible reductions presented in relative terms:

Benefits for pigs include:

- the inclusion of phytase in feed improves the plant phosphorus digestibility by 20 to 30 percentage points in piglets, 15 to 20 % for growers and finishers, as well as for sows;
- as a general rule, a reduction of phosphorus of 0.1 % in feed, by using phytase, results in a reduction in phosphorus excretion of 35 to 40 % for piglets, 25 to 35 % for growers and finishers, and 20 to 30 % for sows.

Benefits for poultry include:

- The inclusion of phytase in feed improves the plant phosphorus digestibility by 20 to 30 percentage points in broilers, layers and turkeys. Variations in the results are linked with the level of phytate-phosphorus contained in the plant materials used in the diet formulation.
- As a general rule, a reduction of 0.1 % total phosphorus in feed by using phytase results in a reduction in phosphorus excretion of more than 20 % for layers and broilers.

Low phosphorus-phytase supplemented diets, as supplied in the trials, did not affect growth, feed conversion ratios or egg production when compared with reference diets containing a higher phosphorus concentration.

TEXT MOVED FROM CROSS-MEDIA EFFECTS

It has been shown ~~quite recently,~~ that phytase improves not only phosphorus digestibility, but also protein digestibility. [170, FEFANA, 2002] with reference to (Kies et al., 2001). Moreover, as less mineral phosphorus needs to be added to the diets, it allows reducing the use of scarce and non-renewable resources from P mineral reserves.

A reduction of phosphorus with the addition of phytase should be applied with a general view of the feed formulation, in order to avoid an uncontrolled modification of the phosphorus-calcium ratio. At the farm level, no specific technical skills are needed to use low phosphorus-phytase supplemented feed.

Cross-media effects

The substitution of mineral phosphorus with phytase needs to be followed by a parallel reduction of calcium, in order to maintain growth and bone mineralisation at a proper level. Conversely, calcium reduction cannot be excessive in order not to limit in turn the growth performances. [281, France 2010, with reference to Narcy A. et al 2009]

~~It has been shown quite recently, that phytase improves not only phosphorus digestibility, but also protein digestibility. [170, FEFANA, 2002] with reference to (Kies et al., 2001)~~

Operational data

~~Operational data of the trials have not yet been reported. However phytases are feed additives and their efficiency with regards to phosphorus digestibility has been favourably assessed by SCAN (Scientific Committee on Animal Nutrition).~~

Since phytases are feed additives, they are evaluated for their efficacy before authorisation for use in animal nutrition. The evaluation of the scientific information supporting the efficacy of phytase is carried out by the European Food Safety Authority's Panel on Additives and Substances used in animal nutrition (FEEDAP). Different phytases have been evaluated by the FEEDAP and their evaluation led systematically to the authorisation of the products, based on their safety and efficacy.

Phytase can be incorporated in feedstuffs in powder, granulated coated or liquid form. Powder and granulated forms are used in production processes, only where the temperature does not exceed 75 – 80 °C. Commercial coated forms exist that have demonstrated stability at temperatures higher than 80 °C, and up to 90 °C. At higher conditioning temperature, the use of the liquid form (post pelleting) is advised. ~~is not too high (up to 80 – 85 °C)~~. ~~Note the stability performance may vary from one product to another; information on stability is usually supplied or requested from the supplier.~~

~~Liquid phytase is applicable when processes lead to high temperature in the dye. In this case, specific liquid equipment is necessary to supply the liquid product post-pelleting. Some feed mills are already equipped with such systems for enzyme application.~~

Examples of reduction in excreted diphosporus pentoxide (P_2O_5) associated with the use of low phosphorus diets, with or without the addition of phytase, are reported in Table 4.9 for pig production, together with an indication of the diet formulation applied.

Table 4.19: Examples of excreted phosphorus reduction for different feeding programmes in the pig sector, applying a low phosphorus diet with or without addition of phytase

Animal	Source	Diet/parameters	P_2O_5 reduction ([1]) (%)
Piglets	France CORPEN 1	Two-phases: CP 20 %; P 0.85 % (1st phase) CP 18 %; P 0.70 % (2nd phase)	11
	France CORPEN 2	Two-phases: CP 20 %; P 0.77 % (1st phase) CP 17 %; P 0.60 % (2nd phase)	29
	Germany RAM	One phase CP 18 %; P 0.55 % (<30 animal weight	22
	Belgium	One phase: P 0.60 % (7 – 20 kg animal weight)	31
Fattening pigs	France CORPEN 1	Two-phases: CP 16.5 %; P 0.52 % (growers) CP 15.0 %; P 0.45 % (finishers)	31
	France CORPEN 2	Two-phases: CP 15.5 %; P 0.47 % + phytase (growers) CP 13.0 %; P 0.40 % + phytase (finishers)	44
	Germany RAM	Two-phases: CP 17.0 %; P 0.55 % (<60 kg LW) CP 14.0 %; P 0.45 % (>60 kg LW)	29
	Belgium	Two-phases: P 0.55 % (20 – 40 kg animal weight) P 0.50 % (40 – 110 kg animal weight)	19
Sows	France CORPEN 1	Two-phases: CP 16.5 %; P 0.65 % (lactation) CP 14.0 %; P 0.50 %(gestation)	21
	France CORPEN 2	Two-phases: CP 16.0 %; P 0.57 % + phytase (lactation) CP 12.0 %; P 0.42 % + phytase (gestation)	35
	Germany RAM	Two-phases: CP 16.5 %; P 0.55 % (lactation) CP 14.0 %; P 0.45 % (gestation)	21
	Belgium	Two-phases: P 0.55 % (20 – 40 kg animal weight) P 0.50 % (40 – 110 kg animal weight)	19

Source: [414, FEFANA 2001] [329, CORPEN 2003]

Applicability

On farm, no specific additional requirements are needed for the application of low phosphorus-phytase supplemented diets compared to a high phosphorus diet, when applied under the same conditions (single~~one-~~phase or multiphase feeding programmes).

This approach to reducing phosphorus pollution can be implemented very readily on a large basis ~~-scale~~ as:

- no investment is needed for powder and granulated phytase, although some investment is needed in feed mills using liquid phytase;
- no structural alterations are required on the farm;
- one feed mill generally covers a large number of farms. [452, FEFANA 2002] ~~[170, FEFANA, 2002]~~

Economics

~~A general description on the cost assessment of nutritional management is given in Section 4.3.1. For feeding low phosphorus phytase supplemented diets, there is no need for any special~~

~~equipment at the farm level or any additional investment. Furthermore, adaptation of the feed, by adding phytase and adaptation of the nutrient levels, can lead to a reduction of the feed costs. [170, FEFANA, 2002]~~

Phytase is cost-effective for a reduction of total phosphorus in the feed of about 15 – 20 % of its content (0.1 % in the raw feed), with savings up to EUR 0.88 per tonne feed (exchange rate EUR 0.88 = 1 GBP). [290, Univ. of Newcastle 2002]

Driving force for implementation
The reduction of phosphorus in diets reduces not only the feed costs, but ultimately also reduces the land surface requirements for manure spreading, since the phosphorus load in the excreta is smaller. Limitations to phosphorus application on the fields are in place in some MS.

Example plants
~~Since the introduction of the first phytase product on the market over ten years ago, the feed industry has been producing low phosphorus phytase supplemented diets, especially (but not only) in areas with intensive livestock production. Since the prohibition of the use of meat and bone meal, this kind of diet for pigs and poultry has been developing at a high rate both in the EU and in third world countries. [170, FEFANA, 2002]~~
The addition of phytase is a well established technique and is generally ~~applicable~~ applied.

Reference literature
[30, Spain 2001] [281, France 2010] [290, Univ. of Newcastle 2002]

- ~~FEFANA, 2000 – WP 'Enzymes and Micro-organisms' contribution to BREF document~~
- ~~Broz J. 1998 - Feeding strategies to reduce phosphorus excretion in poultry – in: 5. Tagung Schweine und Geflügelernährung – 01-03-12-1998 – pp. 136-141~~
- ~~Kies, A.K., K.H.F. van Hemert and W.C. Sauer, 2001 - Effect of phytase on protein and amino acid digestibility and energy utilisation. World's Poultry Science Journal, 57, 109-126.~~

4.3.5 Highly digestible inorganic feed phosphates

Description
Inorganic feed phosphates are classified as mineral feed ingredients. They are listed in the catalogue of feed materials published in accordance with EC Regulation 767/2009 on the marketing of feed. ~~In Directive 96/25/EC, part B, Chapter 11 several types of feed phosphates are included.~~ These feed phosphates differ with ~~in~~ respect to ~~of~~ their mineral content and their chemical composition and as a result they have different phosphorus digestibilities. ~~The use of the more digestible inorganic feed phosphates will have a favourable impact on nutrient excretion, and thus the environment.~~ [542, CEFIC 2002] ~~[198, CEFIC, 2002]~~

~~The inclusion of~~ Highly digestible ~~feed~~ phosphates are used to replace conventional sources of phosphorus, and hence are included in ~~animal~~ the feed at ~~in animal feed will result in~~ lower ~~phosphorus~~ levels ~~and thus a reduction of nutrient excretion into the environment~~.

Achieved environmental benefits
The reduction in phosphorus ingestion results in a reduction of P excretion and ~~a~~ subsequent losses ~~in~~ to the environment. An example is given in Table 4.20.

Table 4.20: Calculated reduction of phosphorus excretion based on digestibility, for the poultry sector

Feed phosphate	Digestibility (%)	Inclusion rate (%)	Inclusion rate (gram P)	Absorbed P ([1]) (gram)	Excreted P([1]) (gram)
Defluorinated phosphate	59	1.56	28.0	16.5	11.5
Monocalcium phosphate	84	0.87	19.6	16.5	3.1
(1) Originating from the inorganic feed phosphate. *Source*: [542, CEFIC 2002] [					

From the calculation it is obvious that there is a huge environmental benefit in using highly digestible feed phosphates instead of lower quality feed phosphates.
The same type of calculation can be applied for pigs, resulting in the same reduction in phosphorus excretion.

Cross-media effects
There are no cross-media effects of the use of highly digestible phosphorus, as the reduction of excretion is a direct consequence of the phosphorus digestibility. There is no impact on phytate-bound phosphorus excretion, which transits unabsorbed and is then kept in the manure.

However, it should be considered that, probably, supplies of the highest digestibility feedstuffs might become insufficient to cover the overall market need for animal feed, particularly, as is currently the case, when phosphorus supplies are tight.

Operational data
Feed phosphates are incorporated into animal feed either in the powder or in granulated form, depending on the physical properties of the end product. Inorganic feed phosphates are predictable in chemical composition and in their digestible phosphorus content, partly because they are not susceptible to process conditions (such as heat or moisture).

Applicability
The use of highly digestible feed phosphates can be implemented very easily.
Since phosphates need to be used either in complete feed or mineral feed used on the farm, highly digestible feed phosphates are available.
No investments are needed, either at the farm level or at the feed compounder. [542, CEFIC 2002] [198, CEFIC, 2002]

Economics
A general description on cost assessment of nutritional management is given in Section 4.3.1. No cost increases for the farmer are involved for the change to the use of highly digestible inorganic feed phosphates. Feed phosphates are normally sold based on the total phosphorus content. Highly digestible inorganic feed phosphates are in fact, calculated on digestible phosphorus content, and economy of use over other feed phosphates.

Lower inclusion rates will lead to savings both at the farm level and with the feed compounder.
Less phosphorus is excreted, resulting in lower manure processing costs for the farmer. [542, CEFIC 2002] [198, CEFIC, 2002]

Depending on the inorganic phosphorus availability, the price of these sources of phosphate is highly volatile and can lead to an increase of feed prices, and for inorganic phosphorus to become expensive.

Driving force for implementation
Phosphorus is a pollutant that locally raises particular concerns and is subject to strict compliance.

Example plants
Some feed producers and farms in regions which have environmental problems because of the high level of intensive animal breeding, have already started to use more digestible inorganic feed phosphates. Notably, this has taken place in the Netherlands, where there was no negative impact on animal performance, but there was a positive effect on phosphorus excretion. [542, CEFIC 2002] [198, CEFIC, 2002]

Reference literature
- Phosphorus Nutrition of Poultry. In: Recent Advances in Animal Nutrition, Nottingham University Press. Pages 309-320 by van der Klis, J.D., and Versteegh, H. A. J. (1996)
- A guide to feed phosphates by Sector Group Inorganic Feed Phosphates of CEFIC
- Feed phosphates in animal nutrition and the environment by Sector Group Inorganic Feed Phosphates of CEFIC

4.3.6 Other feed additives

Description
Enzymes and other feed additives growth stimulators are added in small amounts to the feed in order to enhance the animal performance by improving the digestion of nutrients and the utilisation of feed. As a consequence, animals achieve higher growth rates and a reduced amount of nutrients is excreted.
used to reduce the feed ingestion whilst still achieving the same rate of growth.

Other Feed additives that are added in small amounts to the feed of poultry and pigs are:

- Enzymes (xylanases, glucanases, proteases, etc.)
- growth promoters stimulators
- microorganisms
- organic acids.

The use and drawbacks of antimicrobials are described in Section 2.3.3.1.

Several groups of feed additives used in animal nutrition are authorised and regulated at the European Union level. (e.g. animal species, withdrawal period, minimum and maximum dosage in feeds). The EC Regulation 1831/2003 of September 2003, Annex I, reports a list of feed additive groups, many of them not included in this section since their use is not associated with specific environmental benefits. This is particularly the case for many 'technological additives' and 'sensory additives'.

Achieved environmental benefits
As a consequence of the reduced ingestion of the improved feed conversion rate, a reduction of total nutrient excreted by pigs (as a general approximation) of 3 % can be achieved; for poultry this can be approximately 5 %. These reductions are expected at an improvement in the feed conversion rate (FCR) of 0.1 units. [543, FEFANA 2002] [199, FEFANA, 2002]

Certain additives, such as enzymes, may also allow the use of feed materials of lower energy content and high non-starch polysaccharides content in the feed, with a positive influence on gut health in pigs.

Cross-media effects
No specific cross-media effects have been reported for the use of this type of additive.

Operational data
Information and data concerning the use of different feed additives are reported in the specific sections (see Sections 4.3.6.1, 4.3.6.2, 4.3.6.3, 4.3.6.4).

Applicability
Feed additives are incorporated in feedstuffs in powder, granulated, coated or liquid form. Powder and granulated forms are to be used in production processes, only where the temperature is not too high (up to 80 – 85 °C). Coated forms can be used at higher temperatures, up to 90 – 95 ºC.

Stability performance may vary from one product to another; hence information on the stability may be ~~supplied or~~ requested from the supplier.

Liquid feed additives are applicable when processes lead to high temperatures in the dye by means of~~. In this case,~~ specific ~~liquid~~ equipment ~~is necessary to~~ that supply the ~~liquid~~ product after pelletisation ~~post-pelleting~~. Some feed mills are already equipped with such systems.

There are no specific additional requirements for the application of feed additives on the farm.

This approach to reducing nutrient excretion can be implemented very readily on a large scale as:

- no investment is needed for powder and granulated feed additives, although some investment is needed in feed mills using liquid additives;
- no structural alterations are required on-farm;
- one feed mill generally covers a large number of farms. [543, FEFANA 2002] ~~[199, FEFANA, 2002]~~

Economics
A general description of the cost assessment of nutritional management is given in Section 4.3.1. The introductory cost is generally covered by better animal performance. [543, FEFANA 2002] ~~[199, FEFANA, 2002]~~

Driving force for implementation
The optimisation of animal growth, together with a potential positive effect on animal health and a reduction of the excreted proteins, are the main driving forces for the use of these additives.

Example plants
Feed additives are generally used in intensive animal production and show good results in performance and reductions in nutrient excretion. [543, FEFANA 2002] ~~[199, FEFANA, 2002]~~

Reference literature

- FEFANA, 2000 – WP ‘Enzymes and Micro-organisms’ contribution to BREF document
- Geraert P.R., Uzu G., Julia T., 1997 – Les Enzymes NSP: un progrès dans l’alimentation des volailles – in 2° Journées de la Recherche Avicole 08-09-10-04-1997 – pp.59-66
- Eric van Heugten and Theo van Kempen – Understanding and applying Nutrition concepts to reduce nutrient excretion in swine – NC State University College of Agriculture and Life Sciences – 15 pages document published by North Carolina Co-operative Extension Service
- A.J. Moeser and T. van Kempen – Dietary fibre level and xylanase affect nutrient digestibility and excreta characteristics in grower pigs – NC State University Annual Swine report 2002.

4.3.6.1 Benzoic Acid

Description
Benzoic acid (C_6H_5-COOH) is possibly the most known feed additive having an environmental effect. Its use in pig feeding is regulated by Commission Regulations 1730/2006 and 1138/2007,

in particular ~~It is used~~ for the rearing of weaned piglets and fattening pigs in doses of 0.5 % and between 0.5 % and 1.0 %, respectively.

Benzoic acid is mainly added to feed to lower the urine pH, hence to shift the equilibrium in urine and manure from the volatile ammonia to the ionised and non-volatile ammonium. The housing system does not produce any modification to this effect. The active principle has been extensively tested in farms equipped with the most used and most modern housing integrated system for fattening pigs. [288, Fefana 2007]

Moreover, the addition of 0.5 % benzoic acid to the feed for growing/finishing pigs is reported to ~~also increases~~ increase the average daily gain (ADG) and r~~educes~~ reduce feed conversion rate (FCR) ~~(0.14 point)~~ through a mechanism of improving amino acid digestibility. [281, France 2010]

Achieved environmental benefits

Ammonia is maintained in the ammonium form in the urine and consequently is less volatilised. Because more nitrogen is retained in the manure, it may lead to a reduced consumption of chemical fertilisers and lower indirect emissions (associated with the production of the fertilisers).

Since a lower pH reduces the activity of bacteria responsible for methanogenesis, it can be expected that direct CH_4 emissions from the manure will be reduced as well.

An addition of 0.5 % benzoic acid to the feed in fattening pigs production, has been reported as having an influence on the digestion of nutrients and the utilisation of feed, with a consequent reduction of the amount of nutrients excreted (0.14 points) [281, France 2010].

Cross-media effects

~~Addition of benzoic acid might reduce the nutritional value of the diet. This has to be compensated for by shifting nutritional ingredients.~~

As the addition of benzoic acid is relatively high (from 0.5 to 1.0 %), this has to be taken into account when formulating the feed, to avoid the nutritional value of the feed being reduced.

Benzoic acid has no direct effect on odour or greenhouse gas emissions. [288, Fefana 2007] Though, an increase of sulphur-based odour emissions has been reported for higher doses (2 %) of benzoic acid for diets supplemented with methianine.[454, Eriksen et al. 2010]

Since a relatively higher quantity of nitrogen is retained in the manure, the subsequent changes in the manure composition in the proceeding operations must be taken into consideration, from higher nutrient supply to increased potential in NH_3 and GHG emissions from landspreading.

Operational data

Many research studies have been carried out on this substance, and results are variable. Nevertheless, all studies evaluate positively the environmental effects which are summarised in Table 4.21. Data reported show that ~~The~~ an addition of benzoic acid is consistently associated with lower urine pH. The reduction of ammonia emissions ~~abatement~~ expressed ~~in term of~~ compared with the identical situation without the addition of benzoic acid shows significant variations depending on the different diet formulations. [288, Fefana 2007] ~~The table is completed with~~ Additional information concerning ~~on~~ other important characteristics and the results of the trials, in particular the average dietary protein content or the difference in cost compared to the untreated feed, are reported in the table. Effects on the average daily gain performance ~~ADG~~, the feed conversion rate performance, ~~FCR~~ and on the carcass quality have been reported as not significant or having a positive effect. Only in one case, with 1 % benzoic acid addition, has a negative effect on the carcass quality been reported.

~~judgement (CQ) are expressed, as '+', and '-' to mean an improvement or a worsening. while 'ns'(not significant) means that the effect is negligible (empty cells just mean that no data was reported).~~

The following table is a redrafting of the previous Table 4.14; some information has been deleted and summarised in the text introducing the table.

Table 4.21: Measured results of Benzoic acid effects by the rate of addition and the characteristics of the tests in growing and finishing pigs

Benzoic acid in feed 0.5 % (0.5 % in 1st phase; 0.5 % in 2nd phase)		
Source	**Diet**	**Test results (1) (2)**
[283, Fefana 2005]	Two-phase feeding: CP 16.6 – 15.1 %	NH_3 reduction: 5 % Δ pH urine: 0.45 Additional costs: EUR 7.7 per animal place
[284, Fefana 2005]	Two-phase feeding: CP 16.6 – 15.5 %	NH_3 reduction: 3.6 % Δ pH urine: 0.3 Additional costs: EUR 7.93 per animal place
[285, Fefana 2004]	Three-phase feeding: CP 18.0 – 16.4 – 15.0 %	NH_3 reduction: 40 % Δ pH urine: Not available Additional costs: EUR –2 per animal place (3)
Benzoic acid in feed 1 % (0.5 % 1st phase; 1 % 2nd phase)		
[284, Fefana 2005]	Two-phase feeding: CP 16.6 – 15.5 %	NH_3 reduction: 24 % Δ pH urine: 0.9 Additional costs: EUR 11.74 per animal place
[288, Fefana 2007]	Two-phase feeding: CP 17.0 – 16.0 %	NH_3 reduction: 21 % Δ pH urine: 0.96 Additional costs: EUR 6.94 per animal place
	Two-phase feeding: CP 18.1 – 15.5 %	NH_3 reduction: 13 % Δ pH urine: 1.30 Additional costs: EUR 8.1 per animal place
	Two-phase feeding: CP 18.1 – 15.0 %	NH_3 reduction: 6.4 % Δ pH urine: 1.72 Additional costs: EUR 7.3 per animal place
	Two-phase feeding: CP 18.1 – 16.2 %	NH_3 reduction: 6.4 % Δ pH urine: 1.39 Additional costs: EUR 9.36 per animal place
[281, France 2010] [282, Netherlands 2010]	Not available	NH_3 reduction: 15.8 – 25.0 %

(1) Feed costs calculated on March 2010 prices and for pig places at farms from 2.8 to 3.5 pigs/year.
(2) Δ pH urine refers to the difference between untreated and treated urine.
(3) The figure referes to a reduction of feed cost of EUR 2.00/animal place.

The table above shows that the addition of benzoic acid at a concentration of 1.0 % significantly reduces the ammonia emission from the housing system. The reduction varies from 6 to 25 %, depending on the operating conditions.

~~Benzoic acid has no effect on odour and greenhouse gas emissions. [288, Fefana 2007]~~

Applicability

At the time of writing, benzoic acid is used in pig farming; its effectiveness in the poultry sector is unproven.

In the pig sector, this feeding strategy is already applied for the production of fattening pigs (growers and finishers). ~~in pig production and can be used under any pig production process~~. This technique does not lead to additional investment costs. The addition of benzoic acid in feed is normally done by the feed millers and does not require any specific equipment for the farmers.

Economics

In Table 4.21, ~~calculations~~ data are reported for the cost variations of feed with the addition of the related percentage of benzoic acid, expressed per pig place. ~~meaning that~~ Depending on the tested farm, the number of production cycles that have been considered were from 2.8 to 3.5 cycles/year.

Driving force for implementation
In comparison with others techniques for ammonia reduction, the addition of benzoic acid to pig feed appears to be easier and less expensive. [281, France 2010]

The technique is considered a best available technique for the reduction of ammonia emissions in the Netherlands.

Example plants
Industrial organisations report that benzoic acid use for pig feeding is increasing.

Reference literature
[281, France 2010] [282, Netherlands 2010] [283, Fefana 2005] [284, Fefana 2005] [285, Fefana 2004] [288, Fefana 2007]

4.3.6.2 Probiotics

Description
Probiotics are living microbial feed additives that have a positive effect on animal performance.

Bacillus organisms are specifically selected to improve growth performance and manure decomposition. *Bacillus* species produce extracellular degrading enzymes (amylases, cellulases, lipases, proteases, etc.). The addition of these microbes in pig feed provides a source of enzymes to animals, improving the nutrient digestion and the utilisation of feed, and thereby improving growth efficiency. These enzymatic activities are a likely explanation of the ~~effect of~~ faster dispersion of manure in pens where pigs are fed with *Bacillus*. In fact, spores survive through the digestive process and germinate within the digestive tract, so that mature microbes are excreted with faecal matter and can produce an enzymatic effect also in the external environment.

Lactobacillus and *Enterococcus faecium* rapidly install into animal intestines and improve the sanitary state and the growth performance.

Achieved environmental benefits
The enhanced animal performance in feed conversion reduces the excretion of nitrogen and phosphorus, since more nutrients are retained in the animal bodies. However, the scientific evidence is not all conclusively positive on the consistent effectiveness of probiotics. Some test results showed that growth performance, feed conversion ratios and mortality were not significantly different after the use of probiotics on broilers. [477, O'Dea et al. 2006]

The improved manure degradability induced by *Bacillus* improves pen cleaning, as it reduces the time to disperse the manure mat.

Cross-media effects
No ~~counter~~ negative effects are reported.

Operational data
Bacillus subtilis and *Bacillus licheniformis* strains are added in the feed at rates of around 0.05 % of dietary supplement that contains some 10^{e+8} – 10^{e+9} cfu per gram of product.

Enterococcus faecium NCIMB 10 415 is provided in doses of $7.0\times10^{e+8}$ cfu/kg of feed for sows and starter diet, and in doses of $3.5\times10^{e+08}$ cfu/kg of feed for grower and finisher diets.

For both *Bacillus* and *Enterococcus*, improvements of the feed conversion rates are reported in the range of 0.37 – 0.38.

The effect of these probiotics is a reduced excretion of nitrogen and phosphorus, due to the increased efficiency of the feed conversion. Estimated effects in pigs are displayed in Table 4.22.

Table 4.22: Reductions in excretion with the direct-fed microbial strains of microbes in pigs

Microbial species	Excreted Nitrogen			Excreted Phosphorus (P_2O_5)		
	g of N per kg LW	kg of N per sow per year	kg of N per pig	g of P_2O_5 per kg LW	kg of P_2O_5 per sow per year	kg of P_2O_5 per pig
Lactobacillus([1])	-1.15	-2.29	-0.12	-0.65	-2.02	-0.068
Enterococcus([2])		-2.86	-0.147		-2.52	-0.085
NB:-Comparisons are made with the same diets without nutritional additives. *Source*: ([1]) [301, Fefana 2010], type of data = measured data, based on statistical analysis. ([2]) [302, Fefana 2010], type of data = measured data, based on statistical analysis.						

The effect of *Lactobacillus* in broilers may vary depending on the combination of the dose and the protein content in the diet. An example is reported in Table 4.23, where the effects are displayed ~~of~~ for different doses ~~that are crossed~~ mixed with different levels of dietary content of protein and minerals (Ca and non-phytin phosphorus, nPP) on finishing broilers. It should be noted that *Lactobacillus acidophilus* and *Lactobacillus casei* are not yet registered as zootechnical feed additives in the European Union Register of Feed Additives. Some of these *Lactobacilli* are registered as silage additives.

Table 4.23: Reductions in excretion with the direct-fed microbial strains of lactobacillus in finishing broilers

Type of diet	Age (d)	Probiotic dose kg/tonne	Reduction in total nitrogen g/bird	Reduction in P_2O_5 % ~~g/bird~~
Classic high level protein (19 %)	28 – 42	0.9	-0.54 ~~-5.4~~	-3.2
Medium level protein (17.3 %)	28 – 42	0.9	-4.1	-7.0
Medium level protein (16.8 %)	32 – 42	0.95 ~~0.45~~	-0.8	-8.2
Medium level protein (17.0 %), low Ca, low non-phytin P	32 – 42	0.45	-1.6	-2.7
NB:-Comparisons are made with the same diets without nutritional additive. *Source*: [303, Fefana 2010], Type of data = measured data, based on statistical analysis.				

Table 4.24 shows the feed conversion rates obtained with a dose of 2 kg of commercial product of probiotics per tonne of feed for broilers.

Table 4.24: Gains in feed conversion rates and value of ingested feed with the use of probiotics in broilers

	Test feed without probioticaddition	Feed added with Lactobacillus	Feed added with Bacillus	Feed added with Pediococcus
Feed conversion rate	0.408	0.510	0.476	0.427
Economic gain per bird (above feed cost)	0	+35.9 %	+23.7 %	+6.2 %
Source: [306, Fefana 2010]				

Applicability
Probiotics can be easily ~~are commonly~~ added to diets for poultry meat. Probiotics are easily mixed in feed for gestating sows ~~in gestation~~, milking sows, weaning piglets and growing and fattening pigs.

Lactobacillus effects in turkeys are in the line with those of broilers. The protection from pathogens (*Salmonella*) has been demonstrated. [307, Fefana 2010]

Economics
The increased efficiency in feed transformation into meat returns a higher economic gain due to the saved feed, as is reported in Table 4.24. [306, Fefana 2010]

Driving force for implementation
Probiotics are also used to improve the animal welfare by limiting pathogenic intestinal colonisation. This effect basically enhances the productive performances through ncreased nutrient retention. Consequently, a positive effect on piglet mortality (around 40 % ~~less of~~ fewer death losses) is produced, as well as a greater resistance to bone breaks in poultry.

Example plants
~~Probiotics are included in feeds of many farms around Europe.~~ The use of probiotics has increased significantly in the EU over the last 10 years, in particular after the ban of the use of antibiotics as growth promoters. The actual use of these additives varies by type of animal and by country, for technical and historical reasons. The rate of penetration into the pig feed market is estimated by producing companies at 10 % on average, with peaks of 20 % for liquid feeds and up to 40 – 50 % in specific countries. For the poultry feed market, the penetration of this product is estimated to be from 8 % for layers to 10 % for broilers and up to 15 – 20 % for turkeys. [472, FEFANA 2011]

Reference literature
[301, Fefana 2010] [302, Fefana 2010] [303, Fefana 2010] [306, Fefana 2010] [307, Fefana 2010]

4.3.6.3 Enzymes

Description
The principle that underpins this technique is to increase the digestibility of plant feed materials such as wheat and barley feed, to result in lower excreta and emissions.

The non starch polysaccharide degrading enzymes (NSP enzymes), such as xylanases, cellulases and glucanases, ~~The enzyme xylanase is~~ are incorporated into the feed to obtain more energy from non starch polysaccharides (NSP). Additionally, the enzyme protease is supplemented with the feed to increase the digestibility of the protein contained in the plant feed materials.

The use of NSP-enzymes and proteases allows increasing the digestibility of a number of feedstuffs with low digestibility, although this beneficial effect is demonstrated to be dependent on the wheat cultivar used. [485, Gutierrez del Alamo et al. 2008]

Enzymes can be used individually or in combination; their synergistic effect depends on the diet. [281, France 2010]. The efficacy of enzymes ~~of those feed additives~~ (see the annex to Directive 70/524/EEC) has been favourably assessed by SCAN (Scientific Committee on Animal Nutrition). **MOVED FROM INTRODUCTORY SECTION**

Achieved environmental benefits
Lower protein contents in feed normally result in lower nitrogen excretion and lower ammonia emissions. Therefore, practices that allow a reduction of crude protein content in feed, either by increasing the protein digestibility, as is the addition of the enzyme protease, or increasing the global animal performances (e.g. feed conversion) can in turn reduce ammonia emissions.

The use of feed enzymes often reduces feed ~~the digestibles'~~ viscosity by degrading non-starch-polysaccharides (NSP), thereby decreasing the moisture content of the faeces. Subsequently this results in a reduction of the potential development of fermentation in poultry litter, and thus a decrease in ammonia emissions. [543, FEFANA 2002]

Xylanases are currently added to commercial wheat-based compound feed for broilers in order to improve the growth and the feed conversion ratio. At the same time, a reduction of intestinal viscosity and of the quantity of nutrient excreted are produced.
MOVED FROM INTRODUCTORY SECTION

Protease-supplemented diets can produce improvements in weight gain and feed conversion rates. [479, Bedford et al. 2011] [480, Yu et al. 2007] [481, Thacker 2005] ~~promotes a better assimilation of nutrients~~.
MOVED FROM INTRODUCTORY SECTION

Supplementation of glucanase strains to chicken diets can reduce the intestinal fluid viscosity by 21 to 46 % (compared to unsupplemented feed diet). [478, Sieo et al. 2005]
MOVED FROM INTRODUCTORY SECTION

A combined provision of xylanase, amylase and protease improves the utilisation of feed and body weight by approximately 6 to 7 %. By improving the digestibility of some nutrients, enzymes might also improve the performance ~~correct performances~~ of broilers that are fed with suboptimal diets for Ca and P. [482, Cowieson et al. 2005] [483, Cowieson et al. 2010]
MOVED FROM INTRODUCTORY SECTION

Cross-media effects
No counter-effects have been reported ~~was shown~~.

Operational data
The response of individual added enzymes may be dependent on the composition of the diet. [479, Bedford et al. 2011] [481, Thacker 2005]

An improved protein digestibility for a wide range of natural ingredient is reported in the range of 3 – 8 %, when protease is added to broiler diets. [573, DSM NP, Knap I., Smith A. 2012]

The effect of mixtures of protease, xylanase and phytase produce a higher retention of nitrogen than that from non-added feed. Higher amounts of nitrogen can be fixed, hence lower amounts of nitrogen are excreted, due to the better digestion efficiency (see Table 4.25). [305, Fefana 2010]

Table 4.25: Average daily balance of nitrogen ~~(g)~~ in broilers with and without the addition of feed additives ~~nutritional~~ (enzymes)

Nitrogen (g/bird)	Control feed (no enzymes)	Feed added with NSP enzymes	Variation in nitrogen (%)
Ingested N	124.62	123.75	-0.7
Fixed N	68.52	71.63	+4.5
Excreted N	*56.10*	*52.12*	*-7.1*
Source: [305, Fefana 2010]			

According to some authors, the use of enzymes is beneficial only during the first phase of growth. The effectiveness of additives is summarised in Table 4.26, where the positive effect is shown with a '+' sign, and a '-' sign indicates no significant effect in that given stage.

Table 4.26: Effect of different zootechnical ~~nutritional~~ additives in poultry at various feeding stages

Animal	Type of additive	1-phase	2-phase	3-phase
Laying hen	Coccidiostatic	-	-	-
	NSP enzyme	-	+	+
	Phytase	+	+	+
Broiler	Coccidiostatic	+	+	-
	NSP enzyme	+	-	-
	Phytase	+	+	+
Duck	Coccidiostatic	-	-	.
	NSP enzyme	+	+	.
	Phytase	+	+	.
Turkey starter	Coccidiostatic	+	+	.
	NSP enzyme	-	+	.
	Phytase	+	+	.
Male turkey	Coccidiostatic	+	+	+
	NSP enzyme	+	+	+
	Phytase	+	+	+
Female turkey	Coccidiostatic	+	+	-
	NSP enzyme	+	+	+
	Phytase	+	+	+
Source: [327, Germany 2010]				

In commercial products, the xylanase activity per kg of complete feed ranges from 280 to 560 thermostable xylanase units, and for glucanase the range is from 125 to 250 thermostable gluconase units. [327, Germany 2010]

In the pig sector, from one tonne of standard feed at 16 % of crude protein, around 280 kg of pig carcass meat can be produced. Alternatively, the same meat can be obtained by a reduced amount of feed ~~that is added of~~ with xylanase added. With the saved feed, around 12.4 % of protein is saved compared to the untreated diet; this means that about 1.98 kg of nitrogen is excreted in the manure, from which, around 0.4 kg of NH_3-N and 4.6 g of N_2O are lost to the environment. [304, Fefana 2010]

Applicability

The technique is generally applicable. It can be used alone or in combination with other nutritional measures (e.g. industrial amino acid addition, phase feeding) for further reductions in excreted nitrogen. [573, DSM NP, Knap I., Smith A. 2012]

The response of individual added enzymes may be dependent on the composition of the diet, its activity and the origin of its strains. [479, Bedford et al. 2011] [481, Thacker 2005] [281, France 2010].

Economics

The addition of enzymes to broiler feed adds costs for ~~on average~~ less than 1 % of the untreated feed, on average. On this basis, in the case of broiler production, feed costs increase by 0.3 %, from EUR 6.78 feed cost per broiler place per year, (untreated feed) to EUR 6.80 with added enzymes. Cost savings are also feasible, depending on the market prices of rich protein feed ingredients. [305, Fefana 2010]. Cost savings of EUR 2 to 6 per tonne of feed are reported for the addition of protease to broiler diets. [573, DSM NP, Knap I., Smith A. 2012]

Driving force for implementation

The local availability of economical feed of relatively poor digestibility. Xylanase enzymes are convenient, most with ~~cheap~~ fibre-rich feed.

The use of enzymes allows a higher incorporation into the diets of feed materials with lower digestibilities. Therefore, it may allow the use of locally grown feed materials and by-products and, in turn, contributes to the reduction of costs for the compound feeds.

Example plants
This feeding strategy is already applied in pig and poultry production and can be used under any pig production process and does not lead to additional investments. The addition of NSP enzymes in feed is done by the feed millers and does not require any specific equipment for farmers.

Reference literature
[304, Fefana 2010] [305, Fefana 2010] [281, France 2010] [573, DSM NP, Knap I., Smith A. 2012]

4.3.6.4 Phytogenic feed additives ~~Natural growth promoters~~

Description
Phytogenic feed additives are products that are standardised for their plant-derived active ingredients and are used in animal nutrition mainly with the objective of improving performance and the health of the animals.

~~Bacteriostatic and bactericidal effects of natural plants are used to produce commercial growth promoters. Known plants such as~~
Active ingredients from *Oreganum vulgare, Piper Nigrum, Syzygium aromaticum,* ~~and~~ *Thymus vulgaris, Yucca schidigera* and *Quillaja saponaria* have proven effects on the stabilisation of animals' intestinal microflora. The specific effects are:
~~as well as the ingredients of essential oils (thymol, carvacrol, curcumine, piperine, and eugenol) are used for their~~

- An antagonistic activity to many subcultures of pathogenic enterobacteria, such as *C. perfringens* or *E. coli, S. typhimurium, L. monocytogenes, Y. enterocolitica* or of *S. aureus;*
- Improvement of animal metabolism by increased blood circulation (~~. Phytogenic bitter and~~ pungent substances)~~ as well as~~;
- Reinforcement of the immune system, of the growth and reproductive performance by a better permeability of intestinal cell walls;
- Inhibition of the activity of the urease enzyme and thus reduction of ammonia evaporation (saponins). ~~are also used as urease inhibitors.~~ ~~The basic effect produced by these substances is a stabilisation of animals' intestinal microflora.~~

The standardisation of the active ingredients and dosage recommendations of these additives are the basis for achieving reproducible results in animal nutrition. The leading substances are defined by product specification. ~~Registered products are commercialised with unknown exact compositions, and with full directions on their use.~~ The industrial standardisation guarantees that every batch delivered has the same profile and amount of active ingredients~~, having hence the same effectiveness~~.

Achieved environmental benefits
Due to the increased secretion of digestive juices, raw protein is increasingly digested in amino acids which are absorbed at a greater rate. Consequently, animals achieve higher rates of growth, and reduced amounts of protein are excreted through faeces.

Saponins contained in the products reduce the activity of the urease enzyme, that is formed by bacteria in the large intestine and that decomposes urea into ammonia and carbon dioxide. The reduction of activity leads to a lower production of ammonia.

However, it is also reported that the consistent effectiveness of these additives in poultry diets remains unproven. The available experimental results report data concerning commercial products made from blends of different phytogenic substances. Data on the efficacy of each type and dose of the active compounds contained in the commercial products and their possible interactions with other feed ingredients are not yet available. [484, Windisch et al. 2008]

Cross-media effects
No counter-effects have been reported.

Operational data
In poultry, reductions of indoor ammonia concentrations from 14.4 % to 53.8 % (compared to untreated feed) have been reported, along with an improvement of feed conversion of 2 % and final body weight of 3.2 %. [332, Delacon 2010] [333, Delacon 2010]

In another study for fattening pigs, the effectiveness of a phytogenic feed additive on the reduction of gaseous emissions, as well as the effects on animal performance were investigated. The results report the content of nitrogen (both total-N and NH_4-N) in the manure reduced by 60 % compared to that excreted by pigs that are fed with non-treated feed, and a consequent decrease in ammonia concentrations in ~~stables~~ houses of ~~are hence reduced by~~ around 38 % and ~~by~~ 34 % for odours. [331, Gumpenstein 2010]

Similar results have been reported for the addition of two different phytogenic additives to the feed of fattening pigs, with a reduction in ammonia concentration in the house in the range of 32 – 38 %. [458, Veit et al. 2011]

Tests carried out on lactating sows and piglets, indicate that body weight loss is decreased in sows fed with phytogenic additives compared to in sows fed without supplementation. Test results vary from 33 to 67 %, depending on the type of product. Also, the body weight gains of piglets were found significantly improved when diets of lactating mothers were supplemented from day 90 of gestation to day 25 postpartum. [455, Männer 2011]

A verified gas chromatographic protocol is normally used to detect the presence and concentration of the leading substances in the products.

Applicability
No particular management is needed, other than mixing additives to feed. The technique is generally applicable for both poultry and pigs.

Economics
Costs of ~~natural growth promoters~~ phytogenic feed additives in broilers range between EUR 0.06 per place per year, if performance benefits are not accounted for, and EUR -0.05 per place per year (a profit), if benefits are taken into account. [380, Delacon 2011]

In pigs, costs range between EUR 2.10 per place per year, if benefits are not accounted for, and EUR -1.92 per place per year (a profit), if benefits are taken into account. [456, Delacon 2011]

Driving force for implementation
The environmental benefits are a consequence of better growth performances that do not affect either slaughter performance or carcass quality ~~either~~.

Example plants
In 2010, across the EU, at least 427 million broilers were fed with the addition of one brand of natural phytogenic additive, mainly for performance improvement. In particular, about 80 % of broilers in Czech Republic and 60 % in the Netherlands are fed with supplemented diets. [381, Delacon 2011]

More than 600 thousand fattening pigs were fed in 2010 with more than 167 thousand tonnes of feed with added phytogenic additives. [457, Delacon 2011]

Reference Literature

[331, Gumpenstein 2010] [332, Delacon 2010] [31, MAFF 1999] [334, Lipinsky K. 2008] [484, Windisch et al. 2008] [458, Veit et al. 2011]

4.4 Techniques for the efficient use of water

4.4.1 Management of water use

Description

A reduction of water use on farms can be achieved by reducing spillage when watering the animals and by reducing all other uses not immediately related to nutritional needs. Sensible use of water can be considered ~~to be~~ part of good farming practice and may comprise the following actions:

- cleaning animal housing and equipment with high-pressure cleaners at the end of each batch of livestock, balancing~~ It is important however to find a balance between~~ cleanliness with minimisation of use of water; ~~and using as little water as possible~~
- regularly verifying the calibration and, if necessary, recalibrating ~~calibrating~~ the drinking-water installation to avoid spillages;
- keeping a record of water use through metering the consumption (e.g. every three months, by semester), possibly differentiating between the physiological phases of the rearing cycle and functional uses;
- detecting and repairing leakages;
- using separately collected ~~collecting~~ rainwater and recycling water ~~and +using it~~ for cleaning purposes, ~~only~~ if it is reasonable for the health ~~sanitary~~ implications to do so.

<u>Animal drinking and feeding consumption</u>

All animals must have permanent access to a suitable water supply or be able to satisfy their fluid intake needs by other means. ~~Reduction of the animals' water consumption is not considered to be practical. It will vary in accordance with their diet and, although some production strategies include restricted water access, permanent access to water is generally considered to be an obligation.~~

Watering equipment ~~must~~ should be adequately selected depending on animal production, verifying the current ~~proper~~ capacity to minimise the waste. The standard techniques and principles are described in Section 2.2.5.3 for poultry and in Section 2.3.3.3 for pig rearing.
~~For poultry, in principle three types of drinking systems are applied (see also Section0):~~
~~1. low capacity nipple drinkers or high capacity drinkers with a drip-cup~~
~~2. water troughs~~
~~3. round drinkers.~~
~~For pigs, three types of drinking systems are commonly applied are (see also Section 2.3.3.3):~~
~~1. nipple drinkers in a trough or cup~~
~~2. water troughs~~
~~3. biting nipples.~~
~~All of these, for pigs and poultry, have some advantages, as well as disadvantages.~~

Equipment exists for watering pigs where nipples are integrated with the trough. Table 4.27 shows the results of 5 tests comparing integrated feeders-drinkers with separated nipples used ~~as~~ for water consumptions of fattening pigs. Table 4.28 presents the results of similar tests carried out for gestating sows.

It can be seen that the water request from separated drinkers is almost double that of ~~compared to~~ integrated nipples, due to wastes caused by the animals; as a consequence, the production of slurry is much greater too~~heavily affected~~. The difference in growth rate, feed intake or feed conversion efficiency of the animals does not appear to be significantly influenced by the drinker designs or positions in the pen and the related increase in water consumption. <u>[534, AFBI 2007]</u>

It has been reported that placing drinkers apart, rather than side-by-side in the pen, leads to a reduction in water usage, due to a reduction in swapping between drinkers. <u>[534, AFBI 2007]</u>

Table 4.27: Examples of water consumption and slurry production ~~(l/animal per day)~~ of fattening pigs

Consumption/ production	Integrated drinkers			Separated drinkers	
	Test 1([1])	Test 2([2])	Test 3([2])	Test 4([3])	Test 5([4])
	l/animal/day	l/animal/day	l/animal/day	l/animal/day	l/animal/day
Animal consumption for drinking (water ingested + wasted by the animal)	6.88	5.40	5.97	13.52	19.51
Water for washing	0.47	0.29	1.31	0.5	0.16
Total water consumption	7.35	5.69	7.28	14.02	19.67
Slurry production	3.71	2.70	5.38	8.98	11.80

([1]) Feed is moistened.
([2]) Feed is not moistened.
([3]) Individual nipple drinker.
([4]) Drinking bowl.
Source: [376, Ferreira et al. 2010]

Table 4.28: Examples of water consumption and slurry production of gestating sows

Consumption/production	Vacuum trough flooding tube	Drinking bowl
	Test 1	Test 2
	l/animal/day	l/animal/day
Animal consumption for drinking (water ingested + wasted by the animal)	23.99	9.65
Water for washing	0.64	2.36
Total water consumption	24.63	12.01
Slurry production	11.51	5.3

Source: [376, Ferreira et al. 2010]

Nutritional measures which aim to reduce nutrient levels in manure have been described in Section 4.3. Their use has side-effects on water intake, which in fact can be considered ~~as~~ a cross-media effect associated with these nutritional measures.

Feed can be composed and delivered to the trough in a liquid form, therefore involving water addition. The volumes of added water depend on many factors and a general rule of quantification is not possible.

Cleaning water
Housing disinfection is necessary to minimise ~~for the minimisation of~~ infectious ~~infectuous~~ diseases and for this, provisions are given by Directive 1999/74/EC and Directive 2007/43/EC. For sanitary reasons, local or temporary regulations on the use or the treatment of cleaning waters may affect normal consumptions. [361, France 2010]

This consumption is very much related to farming habits and housing architecture (e.g. external lanes along perimeter walls that need to be frequently cleaned ~~for~~ to reduce the odour potential) and may average~~reach~~ more than 2 litres per animal per day~~ as average~~. [376, Ferreira et al. 2010]

Cleaning equipment are chosen in consideration that high-pressure cleaners, e.g. hot water or vapour cleaners, allow for reducing the water consumption in comparison with the use of cold water. [361, France 2010]

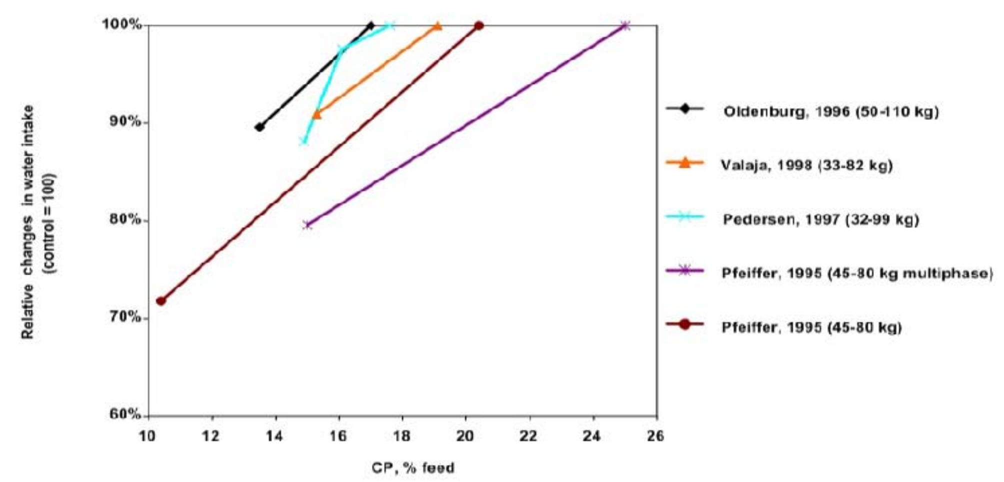
Cooling water
The water consumption and the efficacy of systems used for temperature control, e.g. fogging, is variable according to the adopted system. Great variability of consumption is related to the climatic conditions. Descriptions are given in Section 4.8.3.

Air cleaning systems
Air cleaning techniques may require the use of water. From biofilters to bitrickling beds to multistage scrubbers, water is lost mainly by evaporation and also by waste. The requirements for fresh water range from 5 to 7 litres per 1 000 m^3 of treated air.

Metering of water consumption
The practice of installing metering device is effective when a breakdown is obtainable per production stage. ~~The d~~Different features ~~that are~~ applicable ~~to~~ in the production stages, namely the flooring system, feeding and drinking devices, ventilation systems and building characteristics, can all affect the water consumptions.

Achieved environmental benefits
Section 4.3 presents the effects of nutritional measures on water consumption and consequently on the volume of slurry produced. For poultry, it was demonstrated that a reduced protein level of 3 percentage points resulted in an 8 % reduction of water intake.

When water is given *ad libitum* to pigs, they naturally reduce their water intake. Literature shows that reduced-protein diets contribute to a decrease in water consumption. The results are summarised in Figure 4.5.



Source: [34, Ajinomoto 2000]

Figure 4.5: Effect of reduced crude protein diets on the intake of water by pigs

Cross-media effects
Typically in pig housing, the wash-down water enters the slurry system, which means that a reduced water intake will lead to a reduction of slurry volumes to be applied.

Operational data
~~Results were obtained under different conditions and weight ranges.~~

Applicability

~~See Section 4.3. There are no serious limitations to the application of the nutritional measures reported.~~ No limitation exists to reduce water waste.

Economics

~~See Section 4.3.~~ Savings are possible as a result of conscientious habits and behaviours and the proper management of individual specific techniques. A reduction in water waste decreases the volume of liquid manure that will be applied in agriculture, thus reducing field application costs. The requirements for slurry storage capacity are reduced; thereby, a reduction of construction and operation of costs, associated with the pumping, transport or even energy recovery, may be achieved.

Driving force for implementation

Smaller volumes of waste water and slurry result in a reduced need for stocked and managed volumes of matter that can go under local or site-specific limitations.

Example plants

These measures are widely applied.

Reference literature

[34, Ajinomoto 2000] ~~[112, Middelkoop/Harn, 1996]~~ [376, Ferreira et al. 2010]

4.4.2 Treatment of lightly contaminated run-off waters

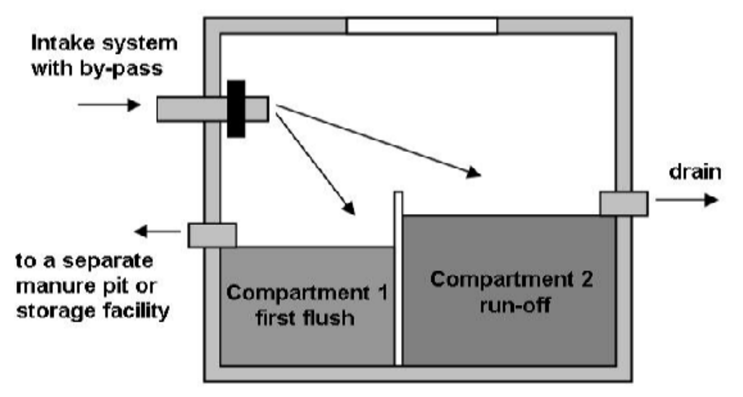
Description

Run-off water from livestock settlements can contain faecal matter, pathogens, heavy metals, feed, bedding, dander, feathers, disinfectants, veterinary medicines etc. Actual loads vary from gross contamination to traces. Authorisation permits ~~(e.g. 'Standard Farming Installation Rules' in the UK)~~ may require operators to appropriately handle and treat lightly contaminated run-off (see 'How to comply with your environmental permit for intensive farming. EPR Sector 6.09 Guidance note'). In some Member States (e.g. Austria), only rainwater is expected to be treated as described in this section.

It should be in the best interest of the operator to effectively separate relatively dirty and relatively clean run-off. It is also good practice to keep yards, concrete surfaces and roofs as clean as possible, so that any rainfall coming into contact with these surfaces can be treated as "lightly contaminated". Waters coming from areas contaminated ~~polluted~~ with manure ~~animal presence~~ need to be separated and stored in outdoor storage units (see Section 4.15).

Leakages can occur from silage stores. The first, highly concentrated fraction of silage run-off water is characterised by high organic pollution loads (e.g. COD, BOD and suspended solids) and usually by small volumes. Besides this fraction, a bigger volume of lightly contaminated silage run-off water can occur. The two fractions can be physically separated (using a combination of gravity, flowrate and inflowrate) by a dedicated 'first flush system'.

First flush systems consist of a brickwork pit, with a thin partition in the middle. The silage run-off water enters the system through an intake system with a by-pass. The highly contaminated fraction settles, under gravity, in compartment 1 (quick settling down), in combination with a limited flow and a low inflowrate (see Figure 4.6). From there, this fraction is transported to a separate storage facility. The lightly contaminated fraction settles, under gravity, in compartment 2 ~~(goes further before settling down)~~ in combination with a higher flow and a higher inflowrate. This fraction is removed by a second outlet from compartment 2 to a biological treatment, such as one of those described below.



Source: [462, VITO 2005]

Figure 4.6: Scheme of a first flush system

The treatment of lightly-contaminated waters can reduce the contaminant load or potency, by allowing pathogens to die off before they reach the natural surface or groundwater, and by trapping sediments containing nutrients and heavy metals, and allowing for controlled plant uptake of some of the nutrients, thereby keeping them out of the natural ecosystem. Treatment methods that mimic some of the properties of natural wetland systems are simple and effective.

The process chain of treating lightly contaminated site run-off water from a pig or poultry unit comprises collection, treatment and final discharge. Either one, or a combination of the methods described below can be tailored to meet the specific requirements associated with run-off types, loading, site characteristics (slope gradient, expected rainfall volumes, soil infiltration rate and space availability), and discharge standards.

Swales are shallow grass-lined channels designed to collect water and move it gradually away downslope. They encourage infiltration along their route ~~and~~ as the grass can filter ~~provide filtration~~ of suspended sediments, as well as take~~ing~~ up nutrients. Commonly, check dams are built along the swale length to increase the storage capacity and to slow the water flow.

Ponds are designed to be at the end of a swale or of another water collection system. They are intended to allow suspended solids to settle out of run-off and/or to store a storm water surge until it can pass through the extended system.

They are used as buffers for storm events by providing temporary storage and also allow biological treatment. Ponds can help remove excessive sediment but do not offer the full treatment potential of a constructed wetland, so they are often used in combination with constructed wetlands.

Constructed wetlands mimic natural systems of ponds and marsh zones, where degrading depths appear in a sequence, giving room for a variety of habitats and vegetation types. The different vegetation ~~gives~~ provides different biological treatments for nitrate removal, nutrient uptake and physical treatments such as sediment entrapment. A constructed wetland can provide excellent treatment potential but requires dedicated space.

Soakaways are used where soils are sufficiently permeable and the groundwater table is low enough. Treated waters must have very low contaminant levels, since soakaways permit the seepage of run-off through the surrounding soil above the water table. The soil provides the medium in which, bacterial treatment ~~by bacteria~~ takes place, and cleaned water eventually reaches the water table.

Achieved environmental benefits

These ~~sysetms~~ systems are effective at improving water quality by combining biological and physical treatment, avoiding nutrients being released into soil, groundwater, and/or surface water through leaching ~~at the height of the premises~~. They are cheaper to construct than piped systems, able to be incorporated into the landscape, a low-maintenance option, and easy to control.

Cross-media effects
Ponds need to be de-sludged from time to time.

Operational data
A long swale (70 m or more in length) gives time for the entrapment or settlement of suspended solids. Optimal parameters are: 5 ° of gradient, only gentle curves and not too steep sides (ratio 1: 3). An established grass sward is beneficial to avoid standing water.

The volume of the swale is calculated multiplying the area to be drained by 12 mm. This latter parameter represents the treatment volume and is the amount of rain that generally lifts any light contamination from the surface, so that further rain after that is likely to run clean. An increasing number of check dams are needed on the path for increasing slopes (one dam every 25 m for 2 % of slope, 10 dams for 5 % slope).

An example is given in Figure 4.7.

Source: [362, UK 2010]

Figure 4.7: Location of a system of swales and wetland for a poultry farms

Ponds are relatively deep water bodies with shallow margins. Vegetation ~~on~~ at the edges helps with sediment capture, habitat creation, and safety. Sediments (e.g. heavy metals) settle in the depth.

Constructed wetlands are intentionally flooded areas, with a combination of deep and shallow water. They can have a deeper channel running sinuously from inlet to outlet, or a gradually shallowing or stepped depth wetland, with the shallow water areas planted ~~up~~ with aquatic and/or emergent vegetation.

The deep pond always appears first and at the outlet marsh zone, waters can be as shallow as 10 cm.

Constructed wetlands for free-range poultry units ~~with free ranges~~ should be shallow with no open water to attract wild birds therefore reducing risks from avian influenza. An appropriate design might be a small four cell constructed wetland fully planted with reeds.

Soakaways only need to be dimensioned on maximum flows, at the lower level of the system and with the highest infiltration rate.

The choice of the system should be based on a number of variables including slope gradient, expected rainfall volumes, soil infiltration rate and space availability.

Applicability
For these systems, land availability ~~of land~~ is necessary. They should not be located close to natural sites of ecological importance, so as not to disturb the existing biodiversity. These ponds ~~basins~~ are designed to hold water and normally are not lined. They should lie ~~lay~~ on a water-tight deep area, preferably with a clay content of at least 20 %.

In cold climates, such as ~~like~~ in northern Europe, the described systems may work for part of the year only i.e. during the growing period. For this reason, a parallel treatment system (or a reservoir to collect and store waste water during winter) is needed.

These systems are more used in poultry installations, as pig farms, generally have the possibility to manage waste water in combination with slurry.

Economics
Costs vary significantly depending on site specific factors, but an indicative cost for a typical narrow swale ~~may be~~ is in the region of EUR 6.00 per metre. Wetlands constructed on suitable soil types will require excavation, fencing, gates, weirs, plants and professional fees for design. An indicative cost based on design parameters set out in the UK sustainable drainage system manual (SUDS) might be equivalent to EUR 0.9 – 1.1 per m^2 of impermeable area drained, the cost possibly reducing for larger wetlands.

One example of existing wetland system (Thornton Poultry Sheds, Glenrothes, Fife, in the UK) was designed to treat and attenuate an area of 22 005 m^2 and costed about EUR 70 000 to construct.

The cost of a separation system can vary depending on the embodiment, dimensions, etc. The investment costs (ecluding VAT, sumps and placement) is about EUR 750; the total investment and installation costs is ~~are~~ in the range of EUR 1 500 – 2 500.

Driving force for implementation
The systems provide a natural way to treat lightly contaminated run-off waters originating from a wide variety of sources and with varying contamination problems. These features can fit well into the landscape and offer shelter to wildlife.

Example plants
These solutions are increasingly common for new poultry units in the UK. ~~Thornton Poultry Sheds, Glenrothes, Fife, UK.~~

Reference literature
[363, EHS 2006] [462, VITO 2005]

4.5 Techniques for the efficient use of energy

4.5.1 Introduction

Measures to improve the efficiency in the use of energy involve good farming practice, as well as the selection and application of proper appropriate equipment and the proper design of the animals' housing. Measures taken to reduce the level of energy usage also contribute to a reduction of the annual operating costs. In this section, a number of general measures are described, followed by a few specific examples of reduction energy saving techniques. Energy saving methods measures are also closely related to the ventilation of livestock housing.

Control of ventilation rates is the simplest method of controlling the internal temperature of animal housing. Factors that affect the house temperature are: [176, UK, 2002]

- heat output from the animals the pigs, according to their weight and density;
- any heat supply input (e.g. gas heater or heat pads for newborn pigs, or lamps for piglets, input from lighting and sun radiation);
- ventilation rate;
- heat absorbed by the air in the house, including by fogging and spraying water;
- heat used to evaporate water from drinkers, feed troughs, spilt water and urine;
- heat loss through walls, roof and floor;
- external temperature.
- stocking rate.

The ventilation system should be designed to remove evacuate the extra heat in the building so that it has sufficient capacity to control the house temperature in the warm summer months when the animal stock is at full capacity it is fully stocked with the heaviest animals, and to also have the capability sufficient control to provide a minimum ventilation rate with the lightest stocking rate in colder winter months when the house is stocked with the lightest animals. For animal welfare reasons, minimum ventilation rates should be sufficient to provide fresh air, oxygen, and sufficient humidity, and to remove unwanted gases.

The most significant energy savings are achieved obtained by good management of air circulation to minimal flows (see Section 4.5.5.1 and Section 4.5.6.1). [339, ITAVI 1997] [349, ITAVI 1998]. For example, in pig housings, the yearly average losses associated with the renewal of air represent about 75 % of the total heat losses. A bad adjustment or mismanagement of ventilation rates can result in a significant waste of energy.

Electricity Energy demand can be significantly reduced if houses are equipped with natural ventilation, rather than with forced ventilation systems. However, this is not always possible or desirable for every livestock type and for all farming objectives. In fact, in France, buildings with natural ventilation used for broiler production record higher energy demands for heating than mechanically ventilated houses.

Energy savings are allowed by high efficiency motors that cost no more than standard motors, and should be considered when specifying or upgrading motors on feed or waste handling systems. [356, Carbon Trust 2005] **MOVED BELOW**

Where Many electrical heating and lighting installations in the livestock sector are still manually controlled, the adoption of simple thermostatic control with 'dimmers' can return considerable energy savings., and The use of electronic systems (now also widely available) yields further energy savings. Investment costs and cultural resistance to the use of such equipment (which is often viewed as complex and difficult to operate) are inhibiting uptake. [355, Warwick 2007]

Solar radiation can easily be converted into heat, but the technology is not yet cost-effective. Both techniques, the ‘indirect’ (panels contain hot water that transfers heat through a coil to the fluid to be heated) and the ‘direct’ (the hot water from the panel is directly used) have potential for their use in agriculture, but at the moment, the benefits do not justify the capital expenditure in the absence of government incentives for renewable heating. [355, Warwick 2007] Additionally, ~~However,~~ this technology is unsuitable for use in areas with very hard water.

Another source of electric energy consumption is represented by the feed preparation and distribution. In the pig sector, energy use in feed preparation can be reduced by about 50 % when meal is transferred mechanically, rather than pneumatically (blown) from the mill to mixing or meal storage. Liquid feed systems have higher power requirements for mixing and distribution than dry feeding systems. [350, France, 2010]. An increase in total electricity consumption of around 18 % is reported for an integrated farrow-to-finish farm using liquid feeding [344, ADEME 2008].

Energy management approach

Establishing an energy action plan is an essential foundation for the reduction of energy waste. Energy plans consider all of the information available to operators. Simple planned rules, a comparison of performances ~~to~~ with benchmark figures, and a selection of measures and actions are the key elements of energy action plans. A well-timed correction of the problem will lead to energy savings. In general, low-cost and no-cost measures, which require little or no capital expenditure, are the first to be implemented. In many cases, these measures give the best rewards and significant energy savings can often be achieved in a short time and with little effort.

An example of a benchmark approach applied for a pig farm is given in Section 4.5.3.

Basic elements of an energy action plan are given below:

Low-cost or no-cost measures

- To take regular meter readings, including to check fuel stock levels, and to record results in a systematic way. This measure allows understanding the changes occurring in the energy use and comparing performance. As much as ~~For what is~~ possible, readings need to be related to processes, production phases, houses, etc. Collected information needs to be related to production levels and external influencing parameters (e.g. weather), with sub-metering of separate buildings or processes.
- To carry out maintenance and repairs. Dust and corrosion are major problems for heaters, ventilation components and controllers. All components must be cleaned at the ‘end of batch’.
- To regularly check the proper working (operation, functioning) of ~~accuracy of temperature~~ sensors, e.g. those that are fitted for temperature, humidity, carbon dioxide and light.
- To use information from the control systems. A number of monitoring systems for environmental and feed control can be fitted with real time devices to deliver recorded and live data. Such information may be remotely accessed, e.g. via smart phone devices, and/or ~~Modern controllers store temperatures and ventilation settings that can be~~ used at a later date.

Potential energy savings associated with regular monitoring and benchmarking, are reported to be around 10 % of the total energy use, in both the poultry and pig sectors in the UK, with a payback period of 0 – 2 years. [355, Warwick 2007]

Medium and long-term measures

- To use improved controlling devices, like dimmers, thermostatic controls (e.g. for creep heating).

- To install efficient fans and ducts. [356, Carbon Trust 2005]
- To consider high efficiency motors, when specifying or upgrading motors on feed or waste handling systems, and to consider pumps with variable speed drivers, when supplying a variable demand [356, Carbon Trust 2005] **MOVED FROM ABOVE**
- To use a high specific oxygen transfer rate per unit of energy input (kg O_2/kWh), when aeration is applied.

The most important medium and long-term actions for energy saving in the intensive rearing sector are the following:

- insulation of the buildings (see Section 4.5.1.1)
- use of efficient lighting (see Section 4.5.1.2)
- optimisation of the heating and ventilation in the housing systems (see Section 4.5.1.3).

Complete reference to the efficient use of energy is given in the Reference Document on Best Available Techniques for Energy Efficiency (ENE BREF) that is available for download at the following web page: http://eippcb.jrc.ec.europa.eu/reference/.

4.5.2 Insulation

THIS SECTION HAS BEEN RE-ARRANGED IN ORDER TO SEPARATE RELEVANT INFORMATION CONCERNING THE REARING OF POULTRY FROM THAT CONCERNING THE REARING OF PIGS

Description
Thermal ~~Thermic~~ losses occur through house ~~stable~~ walls, roof, and floor, and are reduced by ~~the~~ interposing ~~of~~ insulating materials between the internal and external environment.

Insulation material~~s~~ should repel moisture and should be dry when being installed, because humidity is a major factor ~~of~~ in the deterioration of insulating material~~s~~. Insulation material should also be resistant to wild birds, rodents and insects ~~proof~~.

Achieved environmental benefits
A good insulation limits excessive cooling and heating through the walls, roof and floor; therefore, it help to keep buildings warm in winter and cool in summer. When the quality of the insulation and sealing of the buildings is improved, there will be substantial benefits of energy savings for both heating and ventilation.

Cross-media effects
Most materials are custom-fitted and non-reusable, hence are disposed of at the end of use.

Driving force for implementation
Reducing the variability of the indoor temperature ~~variability~~ preserves or improves the animal performances and welfare. Severe climatic conditions justify insulation even more. In littered housing systems, a decrease in temperature variations between the ground and the litter prevents unwanted condensation.

4.5.2.1 Insulation in poultry housing

Operational data
Approximately ~~50 –~~ 70 % of the heat losses occur from the roof, ~~that,~~ which therefore, needs to be well insulated ~~isolated. The amounts of losses from roofs that occur in a building of 1200 m² of area.~~ Losses depend on ~~For~~ the different levels of insulation and the outdoor temperature~~. the energy that is lost and the amount of propane needed to replace the losses are displayed.~~ moved from chapter 3.2.3

Sealing is also very important in the control of heating costs, especially in winter and in sites exposed to wind. The undesired air intake may come from hatches, curtains, doors, gates, and panel junctions. Older timber buildings are prone to leakage around structural joints, door openings and ventilation components. Remedies are quite easy at a reasonable cost. Simple and relatively cheap adjustments and repairs to ventilation flaps, fan ducts and doors will easily result in savings in heating costs.

Common insulation materials ~~that are~~ in use for livestock housing are ~~displayed~~ shown in Table 4.29, along with the average heat transfer coefficient (U)~~ coefficient.~~

Table 4.29: Heat transfer coefficients (U) ~~values~~ for 2.54 cm of thickness of each different insulation material used in poultry houses

Insulation Type	U (W/m^2 per °C)
Fibre glass, roll or batt ([1])	0.56
Loose-fill fibreglass	0.44
Loose-fill rock wool	0.49
Loose-fill cellulose	0.61
Perlite/vermiculite	0.47
Expanded polystyrene board	0.67
Extruded polystyrene board	0.84
Polyisocyanurate board, unfaced	1.02
Spray polyurethane foam	1.04

([1]) Batt is a standard commercial way to deliver pre-cut blankets of insulating material
Source: [459, Overults et al. 2008]

For north-western Europe, U-values of 0.4 W/m^2 per °C or better are recommended for building insulation where new poultry houses are planned, which approximates to about 50 – 60 mm of extruded polyurethane [95, UK 2010]. In France, the suggested insulation coefficients ~~for vertical walls of insulation is~~ are around 0.6 W/m² per °C for vertical walls, and 0.4 W/m² per °C for roofs.

~~In some countries, as the UK, buildings are mainly made of timber framed construction and their average age is estimated as at least 30 to 40 15 to 20 years.~~
In the UK, fibre wool insulation materials were widely used in the recent past because of their low cost, ~~but damage caused by vermin and moisture is very common, greatly reducing its efficiency.~~ are currently replaced by blown fibre and slab insulation products ~~are used to substitute older materials~~ when progressively deteriorating. [355, Warwick 2007]

A well insulated poultry housing system allows saving between 30 and 50 % of the gas consumption compared to a poultry building with and average degree of insulation. The reduction of energy consumption can range between 2 and 4 kg of propane gas per m^2 per year. [350, France 2010]

Table 4.30 shows the estimated thermal losses that may occur from roofs of buildings with an area of 1 200 m^2. Losses depend on the different levels of insulation and on outdoor temperature. The thermal energy loss needs to be compensated by an equivalent amount of propane gas. The savings in gas requirement can be calculated by difference.

From Finland, an example of insulation for broiler houses has been reported, with ~~as~~ 140 mm of mineral wool on vertical walls and 300 mm of cellulose mineral wool applied under the roof. [144, Finland 2010]

TABLE 4.30, REPORTED BELOW HAS BEEN MOVED FROM SECTION 3.2.3.1 (FORMER TABLE 3.18)

Table 4.30: Estimations of heat losses from roofs in poultry housing, and the requirements for energy replacement (building area: 1 200m²)

Outside temperature		Insulation with 40 mm of foam PU([1]) U= 0.780 ([2])		Insulation with 50 mm of foam PU U= 0.638		Insulation with 120 mm of fibreglass + 40 mm of foam PU U= 0.241	
		kWh	Kg of propane	kWh	Kg of propane	kWh	Kg of propane
Average Range	4.5 °C -4.1 to 21.6 °C	15 931	1 154	13 029	944	4 925	375
Average Range	8.5 °C -0.1 to 25.6 °C	13 410	972	10 967	795	4 146	300
Average Range	12.5 °C 3.9 to 29.6 °C	10 889	789	8 905	645	3 366	244
Average Range	16.5 °C 7.9 to 33.6 °C	8 380	607	6 853	497	2 591	188
Average Range	20.5 °C 11.9 to 37.6 °C	5 936	430	4 854	1 835	2 430	176

([1]) PU = Polyurethane
([2]) U= coefficient of surface loss, in W/1 000 m²
Source: [342, ADEME 2008]

Applicability
All new buildings can be ~~thermically~~ thermally insulated. Insulating older buildings may be difficult, as fitting insulated panels on the inner surfaces can be hampered by pipes, wires and other ancillaries. Alternative insulation solutions include filling roof voids with low-density injected polyurethane foam, or applying external insulation.

The further insulation of existing poorly-insulated buildings is possible but is assessed on a case-by-case basis at the time of renovation, taking into account the material choice and characteristics (thermal conductivity, thickness of the insultation), as well as the prevailing local climatic conditions.

Economics
Although renovations need to be studied case-by-case, and according to the state and age of the building, indicative costs for an upgrade of an average poultry house of 1 200 m² ~~might cost as~~ are reported in Table 4.31.

Table 4.31: Indicative costs for the renovation of insulation in a standard poultry house of 1 200 m²

Building element	Cost range EUR/m² ([1])	
	FR	UK
Roof	10 – 25	18 – 25
Floors	1 – 2	4 – 7
Side walls	15 – 19	18 – 25
Gables	3 – 11	8 – 15
Gates	1 – 3	NA
Doors	1 – 2	NA

([1]) Costs without taxes.
Source: [350, France 2010] [500, IRPP TWG 2011]

In the UK, the cost for renovation of the insulation in a turkey housing system is reported to be around 0.3 – 0.4 % of the total renovation costs. The broken-down costs for the renovation are the following: [500, IRPP TWG 2011]

- roof = EUR 6 000/m^2;
- side walls = EUR 3 500/m^2;
- gables = EUR 2 500/m^2).

In the poultry sector, in the UK, the potential energy savings, achievable with measures related to building insulation, are reported to be equivalent to 11 % of the total energy use, with a payback period of 2 – 5 years [355, Warwick 2007].

In France, the cost for renovation of the insulation is reported to be around EUR 1.5 to 2 per m^2. [342, ADEME 2008]

Example plants
Insulation is widely applied to poultry housing systems. In France, for several years now, poultry buildings are continuously being renovated.

Reference literature
[339, ITAVI 1997] [342, ADEME 2008] [350, France 2010] ~~[351, Marcon M. 2009]~~ [95, UK 2010]

4.5.2.1.1 Heat-reflecting membranes

Description
The technique represents a variation of the traditional insulating techniques applied to poultry houses.

Walls and ceiling are lined ~~i~~on the indoor side with laminated plastic foils, to seal ~~off~~ poultry housings ~~from~~ against air leakage and humidity.

More than 96 % of the infrared energy from outside can be blocked, ~~from the outside hence~~ allowing the indoor climate to be ~~is~~ better kept under control. Indoor energy is reflected back or is not radiated away from the membranes surface. Where lighting programmes are used, due to the reflective property of the material, the electrical power required for lighting the interior can be reduced.

Achieved environmental benefits
A better control on indoor temperature and air flow reflects in heating power savings.

Cross-media effects
Cleaning and disinfecting the housings are facilitated, since modern films can be continuously pressure washed. Insects and parasite habitats are unfavoured.

Operational data
Manufacturers claim energy (gas) savings of up to 34 %.

Applicability
This ~~solution~~ technique can be fitted ~~in~~ to new or existing ~~sheds~~ houses.

Economics
Costs per square metre are about EUR 33 for the insulating material and EUR 9 for the installation. [500, IRPP TWG 2011]

Driving force for implementation
This solution is most effective in the renovation ~~reparation~~ of old farms, as older timber buildings are prone to leakage around structural joints, door openings and components.

Farming in warmer climates benefits from the improved control over temperature.

Example plants
In the UK, a broiler farm of around 6 000 m^2 was renovated with heat reflecting membranes. [142, UK 2010]

Farms using heat-reflecting films are well known in the warmest regions of around the world, ~~as~~ e.g. in Thailand, Iran, India, Saudi Arabia and Japan, as well as in North America (US-Missouri) and Southern Russia.

Reference literature
[142, UK 2010] [143, UK 2010]

4.5.2.2 Insulation in pig housing

Operational data
Composite panels, containing solid polyurethane insulation, produce good results. These panels can be bought with plastic-coated steel cladding for durability and cleanliness and can also be used as effective structural components (e.g. kennel construction).

It has been reported that in pig housings thermal losses through walls account for 25 % of the total heat loss. [351, Marcon M. 2009]

Current recommendations in the UK are for an insulation level of better than 0.4W/m^2/°C (60 mm polyurethane). [356, Carbon Trust 2005]. Thermal transmission coefficients, recommended in France for pig housing, are presented in Table 4.32, for two different temperatures (5 ºC and 15 ºC).

Table 4.32: Recommended thermal transmission coefficients (K) for two different temperatures, applied in France

Type of floor	Physiological stage	Thermal transmission coefficient (W/m^2/°C)			
		Roof		Walls	
		T= 5 ºC	T= 15 ºC	T= 5 ºC	T= 15 ºC
Straw	Farrowing Post weaning Growing/finishing Breeding	1	0.6	1.2 – 1.5	0.8
Partly-slatted floor	Farrowing Post weaning	0.5	0.35	0.8	0.6
	Growing/finishing Breeding	0.8	0.5	1.0	0.7
Fully-slatted floor	Farrowing Post weaning	0.4	0.35	0.6	0.5
	Growing/finishing Breeding	0.6	0.4	0.8	0.6
Source: [345, France 2010]					

In the UK, fibre wool insulation materials, that were widely used in the recent past because of their low cost, ~~but damage caused by vermin and moisture is very common, greatly reducing its efficiency.~~ are currently being replaced by blown fibre and slab insulation products, ~~are used to substitute older materials~~ when ~~progressively~~ they deteriorate~~ing~~. [355, Warwick 2007]

Up to 218 kWh/sow per year can be saved compared to average buildings. Savings can be expressed also as about 19 % of the energy consumption, or approximately 10.4 kWh per produced pig.

In France, it is reported that pig houses with insulation rated as good to very good achieve energy savings of up to 218 kWh/sow/year or, approximately, 10.4 kWh per produced pig, compared to buildings with an average insulation; the savings accounts for about 19 % of the total energy consumption. [344, ADEME 2008]

Insufficiently insulated post-weaning fattening pig houses require up to around 45 % of more energy compared to well insulated houses, with 8 cm of insulation in the walls, as can be seen in Table 4.33, where the heat consumptions for buildings having 2 to 8 cm of insulation with insulation are shown. In particular, the heat consumption of a poorly insulated post-weaning house (2 cm of insulation) is 20 % higher than that for the same building with 8 cm of insulation in good condition; this is equivalent to 10 500 kWh (or 735 EUR/year) of potential annual savings. [350, France 2010]

Table 4.33: Effect of insulation thickness level on heat consumption in post-weaning houses

Thickness of insulation	8 cm	6 cm	4 cm	2 cm	0 cm
Heat consumption (kWh/place)	64.5	66.8	71.0	80.7	121.0
Heat consumption(kWh/produced pig)	9.9	10.3	10.9	12.4	18.6
Difference ([1]) (%)	Reference	3.4	9.1	20.1	46.6

([1]) The difference in percentage is given as a ratio to the reference of 8 cm of insulation thickness.
Source: [351, Marcon M. 2009]

In addition, it is also reported that in post-weaning houses in France, where the insulation has deteriorated over time, energy consumption is 9 % higher than the average situation [344, ADEME 2008]. In general, the age of the building reflects the quality of insulation and, therefore, the energy consumption of the housing system, as insulation is often based on fibre wool-type materials subject to compression and slipping, with a consequent decreasing over time of the thickness. [350, France 2010] [356, Carbon Trust 2005].

A study in France revealed that in farrow-to-finish houses built before 1992, which correspond to the development of new building panels, the energy consumption increased by 205 kWh/sow/year, in comparison with houses built after 1992 (19 % increased consumption from a value of 890 kWh/sow/year). [344, ADEME 2008]. Another study showed that by adding 1 cm of insulation (on the level of the ceiling and the walls), in a post-weaning building of 250 places, energy consumption for heating can be reduced by 11 to 18 % (for a minimum air flow at the beginning of batch of 3 m^3/h/animal up to 7 m^3/h/animal, respectively). [350, France 2010]

Applicability

All buildings can be thermically thermally insulated. The further insulation of existing poorly-insulated buildings is possible but is assessed on a case-by-case basis, at the time of renovation, taking into account the material choice and characteristics (thermal conductivity, thickness of the insultation) as well as the prevailing local climatic conditions.

Temperature variability within the Euroepan Union, but also within a single Member State, may lead to very different recommendations concerning the insulation of animal houses.

Economics

Investment costs for the renovation of the insulation in pig housing are extremely variable, depending on the age of the building, its maintenance and dimensions.

The application of a layer of 3 – 5 cm of standard polyurethane foam for a renovation of a pig house ~~stable~~ might cost EUR 18 – 35/m². The savings achievable by increasing insulation from 2 to 8 cm in a post-weaning house are ~~This would allow a savings of~~ equivalent to EUR 0.01 per kg of produced pig ~~for slaughter~~.

Potential energy savings, achievable with measures related to building insulation, have been reported in UK for the pig sector equivalent to 10 % of the total energy use, with a payback period of 2 – 5 years [355, Warwick 2007].

Example plants
Insulation is widely applied.

Reference literature
[350, France 2010][351, Marcon M. 2009]

4.5.3 Low-energy lighting

Description
General measures applicable to save energy for lighting are:

- to replace ~~apply fluorescent lights instead of~~ conventional tungsten incandescent ~~glowing~~ bulbs (although note that their 'biological' suitability is reported to be uncertain) with more efficient lighting, such as:
    - fluorescent lights
    - ~~to apply~~ sodium lights
    - LED lights;
- to use dimmers for adjusting ~~electrical~~ artificial lighting;
- to adopt lighting controls using proximity sensors or room entry switches;
- to apply lighting schemes, for example, using a variable lighting period such as an intermittent lighting ~~illumination~~ of 1 period of light to 3 periods of darkness instead of 24 hours light per day reduces the amount of electricity by 30 – 75 % ~~to one third~~; [500, IRPP TWG 2011]
- to improve the use of natural light, by allowing more natural light to enter, e.g. by the installation of vents or roof-lights;
- to adopt photoelectric cells to turn artificial lights on; in particular, in the poultry sector.

Incandescent ~~Non-efficient~~ light bulbs are ~~going to be~~ progressively removed from the European market. From September 2011 onwards, incandescent ~~bright~~ bulbs of over 60 watts ~~will all be~~ were placed out of the market. By 1 September 2012, all incandescent light bulbs over 7 watts were withdrawn. ~~including 25 and 40 watt bulbs.~~

~~There are different types of fluorescent lights on the market (type of code depending on the manufacturer). Some examples are:~~

1. ~~TL-lights (∅ 38 mm), range 20, 40 60 Watt, not adjustable~~
2. ~~TLM-lights (∅ 38 mm), 40 and 60 Watt, adjustable, application with low temperatures, high relative humidity, and quick ignition without starter~~
3. ~~TLD-lights (∅ 26 mm), 18, 36 and 58 Watt~~
4. ~~TLD-HF (high frequency), 16, 32 and 50 Watt, always in combination with electronic switch, dimmable~~
5. ~~SL-lights, 9, 13, 18 and 25 Watt, fluorescent lights with bent tube, can be used in bulb socket, not adjustable.~~

~~The use of different types of lamps than bulb lights in poultry houses can reduce energy consumption. Instead of the filament bulb,~~

Fluorescent lights (tubular shape: TL, TLM, TLD; compact shape: SL) ~~(TL lamps)~~ can be applied in combination with a device to adjust the frequency of microflashes (>280 000), so the animals will not be able to register the rapid fluctuations typical for this light.

Savings in electricity consumption, associated with the use of artificial lighting, can be foreseen at the time of planning a new house, or a complete rebuild of an existing house, ~~stables~~, by simply allowing more natural light to enter, though avoiding direct radiation (by placement of films or sun visors).

Achieved environmental benefits
Reduced electric energy consumption. In addition, an easier disposal of light bulbs due to the absence of mercury.

Cross-media effects
An increase in the use of natural light needs to be balanced by the possible heat losses through windows and should be considered in the context of the geographic climatic conditions, with special focus on the light duration per day.

~~Waste of lighting equipment must be correctly disposed of.~~

4.5.3.1 Lighting in poultry housing

Achieved environmental benefits
The use of a red light during rest time has been shown to have a positive effect on dust emissions in broiler housings. The light is visible to chicken that more settled and have less activity. [463, UR Wageningen 2010]

Cross-media effects
The number of hours of light and the intensity of the light can influence cannibalism behaviour of the birds (pecking, tearing and consuming of skin, tissues, etc.) [500, IRPP TWG 2011]

Operational data
Minimum light intensity and light periods (lighting duration per day) are regulated by the animal welfare Directive 1999/74/EC of 19 July 1999, laying down minimum standards for the protection of laying hens, and Directive 2007/43/EC of 28 June 2007, laying down minimum rules for the protection of chickens kept for meat production. In particular, the following requirements apply:

- In broiler houses a lighting intensity of at least 20 lux during the lighting periods and illuminating at least 80 % of the usable area is required. In addition, within seven days from the time when the chickens are placed in the building and until three days before the foreseen time of slaughter, the lighting must follow a 24-hour rhythm and include periods of darkness lasting at least six hours in total, with at least one uninterrupted period of darkness of at least four hours, excluding dimming periods.
- For the production of laying hen, all buildings shall have light levels sufficient to allow all hens to see one another and be seen clearly, to investigate their surroundings visually and to show normal levels of activity. After the first days of conditioning, the lighting regime must follow a 24-hour rhythm and include an adequate uninterrupted period of darkness lasting, by way of indication, about one third of the day. A period of twilight of sufficient duration ought to be provided when the light is dimmed so that the hens may settle down.

In general, natural light is suitable for all species of poultry meat and the laying stage for breeders [342, ADEME 2008]

Traditionally, in poultry egg production, 5 to 20 lux are provided, but the general replacement of tungsten by fluorescent lighting is contrasted by worries over the effects of changed light quality on egg laying. [355, Warwick 2007]

New compact fluorescent lamps last longer and are becoming cheaper. Low-energy fluorescent strip lamps, with high frequency electronic control equipment, can be used. They allow flicker-free dimming down to a very low output.

For lighting outside buildings it is better to use low-energy discharge lamps (high-pressure sodium or metal halide lamps) as these are much cheaper to operate than the commonly used tungsten halogen lamps.
Tungsten halogen lamps are better used where they can be controlled by passive infrared sensors and where they are expected to have very short operating times. [95, UK 2010]

LED lighting provides a reduced energy consumption and heat output, the opportunity to dim bulbs without affecting the spectrum, and a minimal flicker (unlike fluorescent lighting). LED technology offers solutions specifically tailored to the spectral sensitivity of poultry. [422, Taylor N. 2010]. Chicken require a more specific type of light with a preference for blue and green compared to red. [461, Glo 2010]

The non-adjustability of some types of fluorescent light makes them less suitable for the housing of animals. Within this group, TLM types are easily adjustable, but the TLD are not. However the high frequency version (TLD HF) has the highest specific 'stream of light' and is adjustable, but needs an adapting device. An indication of longevity is given in Table 4.34. Longevity is defined for filament bulbs as the moment when 50 % has broken down and for fluorescent lights when they give 20 % less light and 10 % has broken down. Dimming affects longevity and reduces economic life (of filament bulbs particularly).

Table 4.34: Indication of longevity of different types of light for poultry housing

Type of light	Longevity (hours)
Filament bulb	1 000
TLM lights	6 000
TLD lights	6 000 – 8 000
TLD HF lights	125 000
SL lights	8 000
Source: [24, LNV 1994]	

The effect of the application of different types of light on the animals' health has not been assessed, but should be taken into account, now and in the future.

Applicability
Low-energy lighting is generally applicable. Most type of the lights can be applied in existing housing, except for the TLD HF type.

Economics
~~Fluorescent lamps are generally more expensive than filament bulbs. TLD HF is 2 to 3 times more expensive than the TL D type~~.
At the replacement of different type of lights, annual operating costs (including amortisation of a new installation) clearly depend on electricity prices as well as on the number of replacements that need to be purchased.

The indicative investment needed to place an entire lighting system (installation of the material, accessories, wiring and protections, etc.) in a poultry house of 1 200 m^2 is between EUR 2.9 and 6.1 per m^2, taxes excluded. [350, France 2010]

Driving force for implementation
Savings on the ~~electrical~~ electricity bill are often significant.

It is reported that LED lights in poultry flocks reduce aggression because in poultry-specific LED lighting the red end of the spectrum has been decreased in order to favour poultry behaviour and welfare. [422, Taylor N. 2010] [461, Glo 2010]

Example plants
The technique is generally applied ~~applicable~~. Commercial LED equipment is on the European market and being adopted by poultry farmers.

Reference literature
[24, LNV 1994] [350, France 2010] [355, Warwick 2007] [422, Taylor N. 2010]

4.5.3.2 Lighting in pig housing

Operational data
Minimum lighting intensity and lighting periods are regulated by the animal welfare Directive 2008/120/EC of 18 December 2008, laying down minimum standards for the protection of pigs, which enforces that pigs must be kept in light with an intensity of at least 40 lux, for a minimum period of eight hours per day.

Pigs seem to rely more on olfaction and audition than on vision. In practice, pigs have a poor colour perception and are unable to perceive the flicker of normally functioning fluorescent lights.

In Table 4.35, ~~the~~ different types of lighting equipment applied in the pig sector are compared. In general, Fluorescent lights have a higher light capacity per energy unit (lumen/watt) than conventional bulbs. Power rating and the number of hours used will determine the annual energy use. The replacement of filament bulbs by compact fluorescent lights could save up to 75 % of the energy used. The replacement of 38 mm fluorescent tubes with 26 mm tubes of lower wattage could save up to 8 % of energy used.

Table 4.35: Typical lighting equipment applied in pig housing ~~for livestock stables~~

Lighting type	Efficiency characteristics	Energy use (kWh/pig place)
Tungsten bulbs	Cheap but very inefficient. Can be dimmed for dual stockman/stock use	2 to 4
Compact fluorescent bulbs	Often used as a direct replacement for tungsten lights but cannot be dimmed	0.4 to 0.8
Fluorescent strip lighting	T8 (11/4 inch) tubes are more efficient than T12 (11/2 inch) tubes. Electronic control gear gives a 20 % energy saving over conventional ballasts. Extend lamp life by 50 %. Electronic dimmable types are available	0.4 to 0.8
Source: [356, Carbon Trust 2005]		

Applicability
Low-energy lighting is generally applicable.

In general, the use of lighting controls (photoelectric cells) is not commonly applied. Proximity sensors are better used for technical areas or corridors than areas with animals.

It is reported that the use of LED lights in the pig sector should not be problematic. [422, Taylor N. 2010]

Economics
Annual operating costs associated with the replacement of lights depend on electricity prices as well as on the number of replacements that need to be purchased
The indicative investment needed to place an entire lighting system (installation of the material, accessories, wiring and protections, etc.) in a pig farm (taxes excluded) are the following:

- low-energy lamp 70 W, 5 200 lumens: EUR 290 to 340, per unit.
- round port-hole seals 11 W: EUR 11.80 – 11.90, per unit.
- fluorescent tube from 36–40 W: 1.60 – 6.20, per unit.
- adjustable fluorescent dimmer: 44.90 – 61, per unit. [350, France 2010]

In general, the necessary investment to equip a pig farm with low-energy lighting has to be studied on a case-by-case basis. The cost will depend on the farm size and the organization of the building (use of natural light, size of the rooms, corridor organisation, etc.)

Examples show that the use of improved heat lamps in farrowing houses could reduce energy use from 330 kWh per sow per year down to 200 kWh per sow per year.

~~It has been observed that the SL-type or similar has been applied in many installations, as this type can be easily applied in an existing filament bulb installation.~~

Driving force for implementation
Savings on the ~~electrical~~ electricity bill are often significant. Manufactures of LEDs claim also an improved animal physical performance.

Example plants
The technique is generally applied ~~applicable~~. Commercial LED equipment is on the European market and being adopted by pig farmers.
~~Energy saving illumination is known to have a wide application.~~

Reference literature
[24, LNV 1994] [350, France 2010] [355, Warwick 2007] [422, Taylor N. 2010]

4.5.4 Heating and ventilation optimisation in poultry and pig farms

Introduction
Thermal losses from animal housing may be reduced by an optimised and well balanced management of heating and ventilation, adapted to the physiological needs of the animals.

This is obtained by optimising the minimum rates of air flows (manual or automated management), taking into account the minimum levels required for the animal performance and welfare (fresh air supply, sufficient humidity, removal of undesirable gases). A bad management of ventilation will have negative consequences on growth performance of the animals and then on the economics of the farm.

An overview of the main measures for minimising energy consumption by optimising heating and ventilation in poultry and pig farms is given below.

Poultry farms

A building where meat poultry is reared has specific requirements for heating (32 ºC for chicks weighing only a few grams) and for cooling (20 ºC for bird stocking densities of up to 34 kg per m^2 floor area). All buildings are fitted with large heating and ventilation systems to maintain these conditions [95, UK 2010].

A considerable reduction in energy consumption for heating and ventilation can be achieved by paying attention to the ~~following~~ points given below.

- Energy ~~fuel~~ consumption can be reduced by separating heated spaces from other spaces, ~~and~~ by limiting their size, and by optimising heating taking into account ~~considering~~ the necessary volume.
- In the heated space, energy ~~fuel~~ use can be reduced by correct regulation of ~~the~~ equipment and by an even ~~promoting equal~~ distribution of warm air through the housing, i.e. by spatially distributing the heating equipment adequately. An equal distribution would also mean not placing sensors in ~~prevent a sensor from being located within a cold~~ spots that are too cold or too warm in the housing, which would unnecessarily activate heating or ventilation. ~~the heating installation~~
- Control sensors need to be regularly ~~should be~~ checked ~~regularly~~ and kept clean to correctly ~~so that they are able to~~ detect the temperature at the stock level (maximum 1 metre high).
- For poultry farms equipped with gas heaters, regular maintenance ~~(with each batch)~~ of heating devices and substitution of worn out parts (full replacement every 5 – 6 years) allows for better combustion and savings in energy. The necessary number of ~~quantity~~ of heating equipment to be installed should be carefully adapted to the heating needs. ~~must correctly be determined.~~ Equipment should ~~must be~~ run at correct (full) power, since the ~~reduction of~~ temperature decrease is not proportional to the reduction of power.
- Warm air from just below the roof level can be circulated down to floor level. Air flows directed towards animals should be of a sufficiently low velocity to avoid compromising the animal welfare. ~~must not have excessive speeds not to affect the thermal comfort and eventually origin sanitary problems.~~
- Minimising the ventilation rates, as far as the indoor climate requirements allow, further reduces heat losses.
- Placing ventilation vents low down on the walls (as heat tends to rise) will reduce heat losses.
- ~~putting down~~ Further insulation with loose material (e.g. sand used in the Netherlands) on the floor or, ~~i.e.~~ on top of the built-in insulation ~~material specific insulation already applied in the floor construction~~, will reduce heat losses and therefore fuel input (especially with high groundwater levels).
- Cracks and open seams in the housing construction should be repaired.
- In a layer house, heat may be recovered with a calorifier between the incoming and outgoing air. This type of system is used to warm the air to dry the manure on the belts under the cages to reduce the emissions of ammonia.
- Control of minimum ventilation also requires well-sealed buildings. If heating is required to maintain the moisture content of litter, all sources of unnecessary wetness should be rectified (e.g. spillage from drinkers).
- Fans that operate intermittently should be fitted with back-draught shutters to reduce heat loss.
- The most significant energy savings are obtained by good management of minimum flows. Over-ventilating heated poultry meat housing during cold weather can dramatically increase heating costs. As small errors in winter minimum ventilation rate will have a big impact on running costs for heating, it is essential to invest in a good control equipment and ventilation systems, which are capable of delivering low-level and accurate amounts of ventilation.
- Concentrating chicks at the start of the cycle: barriers can be placed in the house to avoid the chicks spreading everywhere in the house to keep them tight and warm.

- Minimising and controlling losses and run-offs of water. A good evacuation of rainfall around the building prevents water from rising indoor by capillarity (especially where floors are not made of concrete), requiring additional energy.
- The use of heat exchangers to recover heat is another solution to minimise energy consumption.
- Optimising air homogenisation and air circuits, e.g. in buildings with mechanical ventilation, the aim is to heat the entering air by forcing it, following the under-roof way, inside the room; while, in buildings with natural ventilation the homogenisation is achieved using a mixing fan, which will allow pulling down the warm air from the ridge of the building towards the animal living area, without generating excessive air flow.
- Many control systems used in poultry housing often rely on a single sensor to operate the complete heating or ventilation system for the whole house. Better systems have multiple electronic sensors, positioned just above bird height, to give a representative reading of the true temperature. Control systems which give good feedback in terms of temperature records, as well as information on the historical operation of fans and heaters, help to manage energy more effectively.
- Buildings fitted with separate thermostats for heating and ventilation run the risk of the two systems operating at the same time and, therefore, wasting energy. Where cooling fans and heaters are installed within the same building, interlocked controls should be used to stop the operation of heating when fans are running at anything above their minimum ventilation setting.

<u>Pig farms</u>
The rate of air exchange is primarily responsible for energy requirements for heating. That is why it is crucial to control the flow of air, in particular, minimum flowrate. It is reported that heating accounts for 46 % of total energy consumption for an integrated breeding-to-fattening farm and for approximately 80 % of total energy consumption for the farrowing and post-weaning stages. Optimisation of the balance of heating and ventilation, adapting it to the animal needs, may reduce energy consumptions by up to 50 %.
The opportunities for savings in energy use in pig farms can be ranked in priority order as reported below:

1. heating
2. ventilation
3. lighting
4. feed preparation and distribution.

General operational measures to reduce the energy consumption in pig farms are:

- better use of the available housing capacity
- optimising animal density
- ~~lowering the temperature as far as animal welfare and production allow.~~ Moved below

Some possibilities for reducing energy consumption for heating are:

- reducing ventilation, taking into account the minimum levels required for animal performance and welfare reasons
- lowering the temperature as far as animal welfare and production allow
- insulating the building, particularly lagging the heating pipes
- optimising the position and adjustment of heating equipment
- considering heat recovery
- considering using high-efficiency boilers in new housing systems
- natural ventilation and natural ligh.

In the operation of biogas facilities, the energy generated (power and heat) from the biogas produced can be used (recovered) to replace that generated by ~~from~~ fossil fuels. However, it is reported that only post-weaning houses ~~swine nurseries and agricultural distilleries~~ are capable of utilising the heating energy throughout the year.

Some examples of operational measures applied in the pig sector for reducing heat requirements and/or achieving energy savings are indicated below.

In sow keeping, a zone heating system is installed for heating the piglet creep area. Hot water floor heating is more energy efficient (if the hot water is resulting from a production of renewable energy) than an electric floor heating system or the use of infrared radiators.

For houses with natural ventilation, the lying area is located in heat-insulated boxes (~~so-called~~ 'box and bed stalls') to avoid the need for additional heating.

Electric floor heating with warming plates allows for a reduction in ~~the~~ energy consumption by 30 %, compared to over-floor heating; however, the technique still remains expensive for existing housing systems, and will usually only be applied in the occasion of a major renovation.

With the use of kennels for piglets, the different thermal needs of sows and newborn piglets can be matched simultaneously, providing a temperature ~~that are~~ around 30 °C for piglets and not over 24 °C for sows. [350, France 2010]

In post-weaning, adjustable infrared heaters are more energy efficient than the standard ones. Moreover, the positioning of the temperature sensor is essential.

A single probe, for simultaneously controlling the ventilation and heating should be applied. It is essential not to define a set point for heating higher than the instruction for the ventilation; otherwise, overconsumption for heating will occur. ~~To regularly check the calibration of the~~ The same negative effect may arise if thermal sensors are not calibrated regularly. ~~otherwise that, if not working correctly, can generate heat over-consumption.~~

4.5.4.1 Heating of the housing systems

4.5.4.1.1 Gas-fired infrared heaters and air blowers

Description
Propane or natural gas-fired infrared heating system generates electromagnetic (infrared) radiation which is transferred to a body with a lower temperature where it is ~~radiant energy that is~~ converted into heat ~~when absorbed by objects in its path~~. In animal houses a ceiling-hung gas-fired heater transfers energy directly to the animals and the floor instead of heating the surrounding air. Eventually, ~~the infrared energy~~ heat is stored ~~absorbed~~ in slab ~~by~~ floors and the air is secondarily heated as it passes over the warm concrete ~~then heat is re-radiated upward to the surrounding air.~~

In a forced air heater, air is drawn through the heater and blown into the house. The circulating heated air transfers heat to whatever it flows over, including the animals and the litter, provided that air circulation in the house is good.

~~State-of-the-art heaters are preferred to non progressive gas infrared heater.~~
~~In sealed and isolated buildings, warm air generators might be effective, but also require electricity to induce the air movement.~~ **MOVED BELOW**

Achieved environmental benefits
The use of gas-fired radiant heaters ~~are useful since they~~ allow providing concentrated heat to the animals without having to heat the rest of the house; therefore, fuel savings are achieved. ~~house temperature to be reduced and to provide concentrated heat where needed~~.

Cross-media effects
Fossil fuel (propane, natural gas) is a non-renewable energy. Safety considerations have to be implemented with the use ceiling-hung gas-fired radiant heaters.

Operational data
Modulated radiant heaters are much more efficient in gas consumption than the conventional non-modulated heaters. In the modulated heaters, the gas flow and the combustion air is continuously adjusted, allowing gas savings of around ~~higher than~~ 20 – 40 % compared to ~~older apparatuses~~ conventional systems, which correspond to ~~that is to say~~ 1.4 to 3.1 kg of gas/m^2 per year.

Modulated ~~State-of-the-art~~ radiant heaters, with automatic regulation can operate gradually over a pressure range between 20 and 1 400 mbar, ~~are~~ showing a better performance in comparison with ~~a preferred~~ two-stage ~~non progressive gas infrared~~ radiant heaters working at two pressure levels between 50 and 150 mbar.

In a well insulated and sealed ~~and isolated~~ buildings, warm air generators (blowers) ~~might be~~ are more effective than gas-fired infrared heater, but the latter are more appropriate in larger, not well insulated buildings, in particular for the production of turkeys. Warm air blowers ~~but also~~ require electricity to induce the air movement; while, gas-fired radiant heaters can, in principle, operate without electricity and, in some cases, be controlled manually.

Applicability
This technique is generally applicable as long as ~~burning~~ gas supply is available on farm. It is mostly employed in poultry rearing but can also be used for in pig houses, where it may represent a good alternative in the case not sufficient electric power is available.

Economics
Indicative ~~recent~~ investment costs for the equipment ~~indicatively cost~~ are EUR 4 – 9.2/m^2 (tax excluded) for the gas-fired infrared heater with modulated gas flow ~~*with progressive gases*~~ and EUR 3.4 – 11 per m^2 for gas hot air blowers. In the case where ~~For the installation of~~ a warm water heating circuit is also installed, the price for the related hot air blowers lies between EUR 5.8 and 6.7 per m^2. These prices are evaluated for a building of 1 200 m^2 and vary according to the type and the number of equipment installed as well as the selected options.

Maintenance cost for radiant heaters, by periodic replacing of wearing parts, is reported to be about EUR 100 (every 6 to 10 years) for a 1 200 m^2 house.

Driving force for implementation
The difference in prices for electricity and gas can play a role in choosing this technique. Gas heating may be the alternative for installations that are not connected to the electrical network.

Example plants
The technique is widely ~~diffuse~~ applied

Reference literature
[339, ITAVI 1997] ~~[341, Amand et al. 2008]~~ [342, ADEME 2008] [349, ITAVI 1998] [350, France 2010]

4.5.4.1.2 Wood and biomass-fired boilers

Description
Standard boilers or combined heat and power systems (CHP) are fuelled with wood and other biomass for heating up water to warm up animal houses. ~~Heating~~ Heat exchangers serve the heating circuit, where hot water is produced and circulated in the building to warm it up (e.g. by

means of fins, hot plates). Straw, poultry litter and peat, where convenient, are used to replace oil for combustion. [144, Finland 2010]

Achieved environmental benefits
Wood use has a neutral impact on the greenhouse effect. The economical value is given by adding value to available copses, farm woodland and agricultural residues ~~and secondary materials~~ that are not fully exploited or by cropped biomass (e.g. miscanthus).

Cross-media effects
~~This system allows for efficient heating and a good temperature control. Heat is well distributed in all the building.~~ Moved below

When peat is used as fuel, indirect environmental effects of peat exploitation should be taken into account.

Operational data
This system allows for efficient heating and a good temperature control. Heat is well distributed in the building. This heating system is profitable when heat needs are large and stable, as is the case ~~happens~~ with multiple houses or users. An example is reported in Table 4.36 of a mixed poultry and dairy farm combined with the farmer's house.

Table 4.36: Example of mixed farm benefitting from warm water heating served by a wood boiler

Heated houses	Boiler power
3 000 m^2 poultry housing + 230 calf places	300 kW
1 800 m^2 poultry housing + farmer's house	240 kW
600 m^2 poultry housing + farmer's house + heated water in the milking room	100 kW or 60 kW + 8 infrared supplement heaters
Source: [346, CA Bretagne 2009]	

Information on the quality of fuel (size of particles, humidity, biomass species, absence of wood treated with chemicals) is essential for the proper operation of wood and biomass boilers. [345, France 2010]

Applicability
Boilers need to be close to animal housings; otherwise expensive underground district heating pipe networks ~~circuits~~ are needed. Thus, optimal planning of the system is necessary.

In the pig sector, it is reported that only pig nurseries are capable of utilising the heating energy throughout the year. [350, France 2010]

Economics
Wood is less expensive than fossil fuels and its price is more stable.

Poultry farms
In France, the investment cost for a wood-fired boiler of 240 kW of power is around EUR 90 000 (installation in 2006). This boiler consumes 110 tonnes of wood per year, coming from a nearby sawmill and supplies heat to a broiler house of 1 200 m^2 and a turkey house of 600 m^2. In France, this investment may be subsidised for about 40 – 50 %, in which case the return on investment is around 7 years. Without subsidies, the return on investment would have increased by 3.5 years. [346, CA Bretagne 2009]

Pig farms

For a pig ~~installation~~ house of ~~about~~ 3 300 m^2 (approximately 220 sows), 85 kW of power are needed at a total cost of EUR 400 per installed kW (except the equipment for the hot water circuit). Requirement of wood would be around 45 tonne per year, which is obtainable by utilisation of 9 – 14 km of copse hedges.

Driving force for implementation

The economic value is incremented by the use of available copse and secondary matters that are not otherwise fully exploited e.g. wood resources produced in the farm.

Example plants

~~This system is in fast development~~ In France, about 15 poultry farms are already equipped with biomass boilers.

Reference literature

[342, ADEME 2008] [344, ADEME 2008] [346, CA Bretagne 2009]

4.5.4.2 Heat recovery

4.5.4.2.1 Heat exchangers

Description

There are three major types of heat exchangers that exploit different principles (see Section 2.14.1):

- air-air heat exchangers
- air-water heat exchangers
- air-ground heat exchangers.

The fundamental principle of both air-air and air-water systems is to recover heat from the exhaust air extracted by houses, that otherwise is lost in the outdoor environment.

In the air-air heat exchanger, the incoming air absorbs heat from the exhaust air from the house.

In the air-water heat exchanger, water flows through aluminum plates located in the exhaust ducts and absorbs heat from the exhausted air. Then, the water feeds the fan coil placed at the air intake of the housing system.

In the air-ground heat exchanger, fresh air is circulated through pipes buried to a depth of about 2 metres. Air-ground heat exchangers can take advantage of the combination of the two characteristics of heat variation in soils. From one side, the thermal variations of soil horizons decrease with the depth and on another side, the deep soil average temperatures are negatively correlated to the seasonal temperatures. This means that these exchangers can produce heat in the cold season and keep relatively cool in summer.

Heat recovery is also possible from scrubbing waters of air cleaning systems or from exhaust gases of biogas engines; however, these types of application are not always practicable.

Achieved environmental benefits

Heat recovery allows reductions in energy consumption for heating by providing adjustable support. In buildings with mechanical ventilation (dynamic buildings), heat exchangers might replace the ventilation system. In buildings with natural ventilation (static buildings), heat exchangers aid ventilation.

Heat exchangers allow improving ventilation in mechanically or naturally ventilated buildings, without decreasing ambient temperature, while improving the ambience for the animals.

Reduction in energy expenses is obtainable as a result of the following:

- shorter heating periods
- reduced total energy consumption for heating.

A positive effect that is not directly environmental is on the indoor control of humidity by:

- maintenance of the desired temperature
- lower relative humidity by about 10 %.

In the broiler breeding sector, the use of air-air heat exchangers coupled with circulating fans, to evenly distribute the heated air over the litter, have shown promising ammonia emission reductions. This technical combination is described in Section 4.5.5.1.2.

Cross-media effect
For air-ground heat exchangers relatively ~~vast~~ large soil areas are bound and used intensively.

Operational data
For air-air and air-water systems, the theoretical maximal yield of an annual cycle ranges from 50 to 55 %, meaning that from exhaust air at 24 °C, the entering air can be heated up to +12 °C (starting from 0 °C).

At the time of writing (2013), no data concerning the performance of air-water heat exchangers applied in the poultry or pig sectors was available and a limited number of applications is reported. The performance of this type of heat exchanger will mainly depend on the technical dimensioning of the system (e.g. surface of fins, water flow) and proper maintenance (e.g. control of dust contamination of fins).

Heat exchangers need to be often cleaned in order to avoid clogging.

Pig farms
According to a study on energy consumption, 36 % of the total energy of an integrated pig farm (breeding and fattening pigs) is used up in weaners production, with the majority of it (80 %) used to heat the rooms, i.e. approximately 14 kWh per produced pig. [344, ADEME 2008].

Air-air heat exchangers allow a reduction of the electricity consumption for heating of 30 to 50 % in post-weaning houses. On the basis of the theoretical heat recovery achievable with the application of air-air, air-water heat exchangers, the necessary higher temperatures ~~that are~~ needed in post-weaning, at the entry of the piglets or in cold periods, ~~need~~ have to be reached with a complementary heating system.

Heat exchangers allow for a recovery of 4 – 7 kWh per produced pig for slaughter. They are considered to work better in the cold season when heat is required the most (see Table 4.37).

Table 4.37: ~~Working features~~ Example of operational data of air-air heat exchangers

Outdoor temperature (°C)	Incoming air temperature (°C)	Indoor warmed air (°C)	Recovered energy (W/pig)
-9.4	2.6	12.0	97
-4.9	6.4	11.3	89
0.0	9.2	9.2	69
4.4	11.6	7.2	46
7.8	13.9	6.1	41
Source: [350, France 2010]			

The air-ground heat exchanger requires a careful dimensioning in order to ensure a good performance. Air is circulated in underground pipes (at approximately 2 metres depth); one pipe of 16 cm in diameter and 25 m of length is necessary for every three fattener pigs.

Poultry farms

In the Netherlands, air-air exchangers applied in litter-based broiler houses are reported having a capacity of 0.35 m^3 per animal place/hour for a normal type of heat exchanger, and up to 1.0 m^3 per animal/hour for an improved type. [464, NL 2010]

Results of an investigation carried out over one year of operation showed the following achievements:

- a decrease in propane consumption for birds aged 6 days and over
- radiant heaters were turned off 10 days earlier in the test building, for turkeys.

Test results concerning propane and electricity consumption in three different farms applying air-air heat exchangers are summarised in Table 4.38.

Applicability

There are no serious limitations to the application of heat exchangers, this system, except the cost of the equipment which is still rather high and the cost for additional cleaning (see Economics). The ventilation design becomes a limitation when retrofitting the technique in non-dynamic naturally ventilated existing houses; a centralised ventilation is normally required for the application of heat exchangers.

Air-ground heat exchangers are not convenient for pig farming cannot be implemented when there is not enough available space in the farmyard, due to the high demands on soil surface. Heat recovery from scrubbing waters and from exhaust gases of engines is often not practicable. In the poultry sector, air-air heat exchangers are mainly applied. [350, France 2010]

Economics

In the poultry sector, for a standard poultry building house of 1 200 m^2, two heat exchangers of with a capacity of 5 000 m^3/h are needed. This implies an investment of about EUR 8.3 – 10/m^2 and additional running costs for electricity of about EUR 0.13/m^2 per year. In this case, the monetary savings for the propane that is not consumed sums are to around EUR 1/m^2 per year, for a total return of the investment in the range of 9.5 – 11.4 years. For a standard density of 22.8 birds/m^2 [418, ITAVI 2010], the investment costs would be EUR 0.36 – 0.44 per animal place, running costs EUR 0.006 per animal place and savings around EUR 0.167 per animal place.

Test results report that yearly savings in propane gas range between 18 and 27 %. The additional electric energy consumption, due to the heat exchangers, would cost only 8 – 27 % of the monetary saving in gas propane. [466, Bonnouvrier et al. 2009]. Data concerning propane and electricity consumption and related costs are reported in Table 4.38, for three different applications of air-air heat exchangers in the poultry sector.

Table 4.38: Propane and electricity consumption and costs, in three different poultry farms applying heat recovery by air/air heat exchangers

Parameters		Unit	Trial 1	Trial 2	Trial 3
Surface area of building		m^2	1 200	1 300	1 200
Animal type			turkeys	broilers	broilers
Batches/year			2.5	7.5	7.6
Heating system			adjustable radiant heaters	indoor space heaters	adjustable radiant heaters
Ventilation			mechanical	natural	natural
No. of heat exchangers			2, on long wall, opposite fans	3, on long wall	2, on long wall
Heat exchanger operation			cyclical	cyclical	progressive
Propane consumption	control building	$kg/m^2/year$	4.73	12.4	5.6
	test building	$kg/m^2/year$	3.47	10	4.6
Propane saving achieved		kg/year	1 572	3 107	1 125
		%	27	18	20
		EUR/year (1)	1 165	2 300	832
Additional electricity consumption due to heat exchangers		kWh/year	2 185	7 946	2 918
		EUR/year	98	486	230
Return on investment (2)		years	7.7 – 9.2	NA	NA
Return on investment with 40 % subsidy		years	4.6 – 5.5	NA	7.6

NA: not available
(1) Gas price: EUR 740/t
(2) Investment cost for two heat exchangers: EUR 10 000 – 12 000
Source [466, Bonnouvrier et al. 2009]

For one heat exchanger of 15 000 m^3/h, serving two buildings with 1 200 m^2 each (total surface of 2 400 m^2), the investment costs amount to approximately EUR 23/m^2; the related additional electricity consumption is 0.06 to 0.09 EUR/m^2 per year, and the annual saving in gas consumption 2 to 2.4 EUR/m^2 (50 – 60 % savings). The return on investment for the heat exchanger will be between 9.5 and 11.4 years. [350, France 2010]

In the poultry sector, cleaning and checking operations are done at the end of each cycle and require 1.5 – 2 hours per unit. [464, NL 2010]

The ~~price~~ costs of air-ground systems vary depending on the method of drilling the soil, the type of tubes and fans, surface necessary, etc. ~~Pipes must be buried at approximately 2 metres depth~~.

In the pig sector, the cost of ~~material~~ an air-ground heat exchanger is reported between EUR 60 and 80 per animal place (fattening pig), which includes the excavation (20 % of the price), a concrete pit of reception (55 %), the purchase of the tubes (15 %) and ventilation (10 %).

Driving force for implementation
~~The~~ A reduction of ~~power~~ energy bills may induce the adoption of this technique.
Heat exchangers present the advantage of warming the air before it enters the building, which reduces the risks related to the effects of cold air on animals and offers more flexibility in the management of ventilation.

At the start up of the rearing cycle in a broiler farm, an ambient temperature of around 32 °C is necessary in order to ensure thermal comfort of young chicks. At the same time, a minimum air flow is required to remove undesirable gases and allow fresh air to enter. Introducing cold air into the building, and heating it up to replace the heat extracted with the exhaust air, consumes large amounts of energy. As a result, options for recovering energy from the outgoing air, in order to heat the incoming air, represent an attractive solution.

In the poultry sector, benefits to the litter and air quality are also claimed, as well as to bird physical performance.

Example plants
In France, UK and the Netherlands, ~~these solutions~~ these techniques are spreading in poultry rearing.

In France, air-air heat exchangers are already developed in the pig sector; some air-water heat exchangers are connected to water scrubbing systems.

Reference literature
[344, ADEME 2008] [352, Bartolomeu 2005] [353, CA Pays Loire 2009] [350, France 2010]

4.5.4.2.2 Heat pumps

Description
The principle of this technique is based on the recovery of heat from various environmental media (water, slurry, ground, air, etc.) and its use on-farm, usually in buildings (see Section 2.14.2). For this purpose, a fluid is used in the sealed circuit of the pump to transfer the heat from one medium to another, transforming in turn from a liquid to a gaseous state (see Figure 2.52). Fluids used in other functional circuits are preheated with the energy that is recovered, to produce sanitary water, or to feed a heating system and even be used in cooling systems.

Heat pumps mostly recover heat in air-air and air-water circuits; they can also be connected to water scrubbers from air cleaning systems and slurry treatment units.

In Denmark, this technique is frequently combined with slurry cooling systems, adding benefit one another (see Section 4.7.1.8).

Geothermal energy
Calories are transferred from underground soil level or from shallow aquifers (less than 100 m).

Scrubbing water recovery
Heat is recovered from washing waters of end-of-pipe air cleaning systems ~~treatment~~, that must be collected in sufficiently large basins.

Biological reactors
They can provide working temperatures as high as 25 °C.

Engines exhaust gases
Heat can also be ~~is~~ recovered from the exhaust gases exiting biogas engines in combined heat and power units (see Section 4.12.5). The recovered heat is normally used for heating ~~to heat up~~ piglet areas. [373, UBA 2009]

Achieved environmental benefits
Every thermal calorie that is recovered is deducted from the farm's economical balance related to energy.

Cross-media effects
Please TWG submit information on geothermal recovery and biological reactors
~~Heat recovery from scrubbing waters and engine exhausts seems not having inconvenients.~~

Operational data
Compared to classic heating applied in the pig sector (9 kWh/piglet per year), with geothermal heat recovery, savings of about 50 % (4.4 kWh/piglet per year) are possible, and up to 69 % (6.21 kWh/pig per year) can be recovered from a biological reactor or from scrubbing waters. [350, France 2010] Systems based on exhaust gases of biological reactors and water of ~~scrubber~~ scrubbing systems for air cleaning are more stable and efficient than those based on geothermal energy.

The efficiency coefficient of a heat pump is the proportion of the recovered heat with the energy that is needed to run the pump (recovered kW/consumed kW). The efficiency of a geothermal ~~geothermic~~ pump is about 2 – 3 (1 kWh electric consumed, 2 – 3 kWh recovered), the same as that related to biological reactors. Scrubbing waters are provided at about 20 °C and the heat pump efficiency is up to 4.

Applicability
In general, the technique is only applied in the pig sector.

The installation of the heat pumps fed with the water of wet scrubbers is only possible if large quantities of water can be stored ~~are possible~~. Consequently, this technique is normally intended for new housing systems and for existing houses already equipped with centralised air extraction.

For the geothermal heat recovery, the principal constraint is that a surface approximately twice as large as the surface of the building to be heated is required. As a consequence this technique is still not very frequent and is not suitable for farms with relatively small land availability which cannot meet the surface requirements ~~farms~~.

Economics
The indicative investment cost for a geothermal heat pump is EUR 45 – 55 (taxes excluded) per post-weaning place, which must be compared to the standard heating investment of around EUR 35 per place.

The reduction of energy consumption allows savings that are estimated about EUR 0.01 per kg of pig produced for slaughter.

Driving force for implementation
Heat pumps are successfully coupled to underfloor heating, hence reducing the inconveniece of the traditional air-convection systems.

Incentive payments for renewable energy use can justify the adoption of this technique. Ground and water source heat-pumps are included in the Renewable Heat Incentive (RHI) financial support programme in the UK

Example plants
Please TWG provide information

Reference literature:
[344, ADEME 2008] [348, Bartolomeu 2008]

4.5.4.2.3 Heat recovery in broiler housing with heated and cooled littered floor (combideck system)

IN ORDER TO FACILITATE THE READING OF THIS SECTION, THE OLD TEXT (ENTIRE PARAGRAPHS IN BLACK COLOUR) ALREADY DELETED IN DRAFT 1 HAS BEEN ELIMINATED

Description

Two closed water circuits are connected by a heat pump. A water circuit is installed below the floor where broilers are housed. The water in the underground circuit is used to heat the floor at the expenses of heat exchanged with the other circuit or alternatively to cool down the floor and simultaneously heat up the other circuit. The second circuit is built at a deeper level (see Figure 4.8) and is used to store the excess heat or to return it to the house when needed. The heat pump serves the connection between the two water circuits.

At the beginning of the growth cycle, chicks are heated for 24 days with the stored heat (about 28 °C). Then, 6 days follow in thermal balance, and in the following final 16 days of growth, broilers produce an excess of heat that is preserved in the storing circuit while cooling down the floor at about 25 °C, as is described in Figure 4.9.

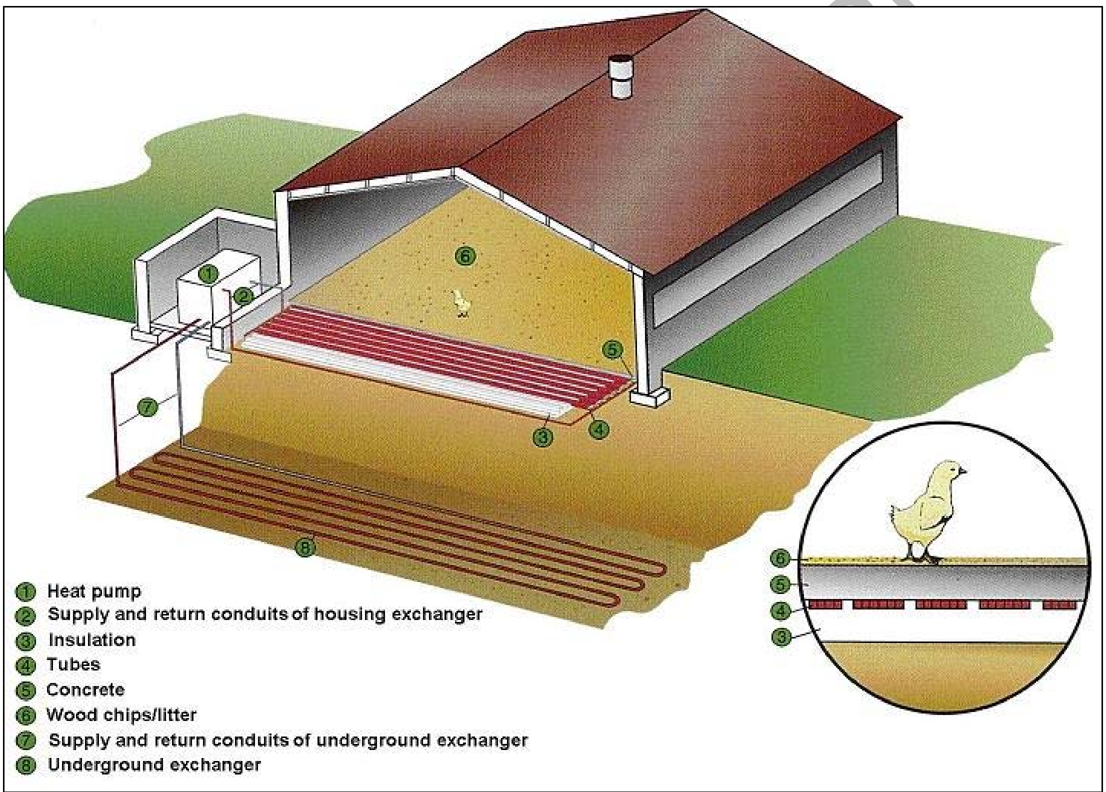


Figure 4.8: Schematic representation of the installation of the heat recovery system in a broiler house

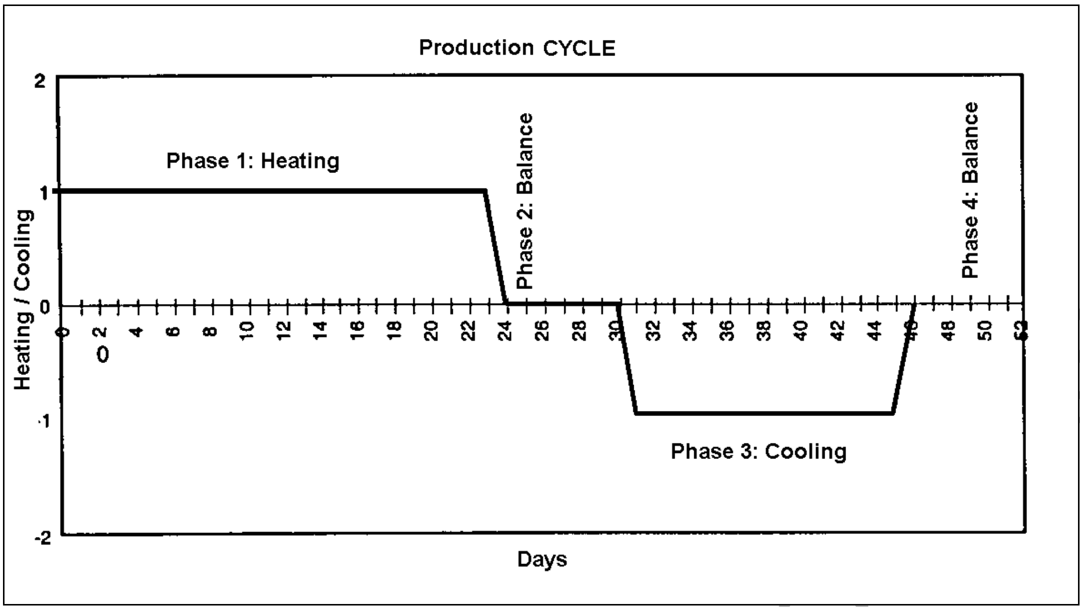


Figure 4.9: Graphic representation of the working principle of the "combideck-system" during one broiler production cycle

Achieved environmental benefits

The reduction of energy use is the main achieved benefit. Also, preheating the floor, prior to littering and introducing poultry, prevents humidity from moistening the litter, hence preventing ammonia volatilisation. will avoid condensate from forming on the floor and moistening the litter. The dung-litter mixture is not shredded, e.g. at the end of a housing period, as this leads to high emissions.

Cross-media effects

The re-use of heat generated in an earlier production cycle reduces ventilation rate by around (14 %). The amount depends on the installation, but Up to 50 % The storage of heat is made at the (electrical) expense of the heat pump. The needed power affects the coefficient of performance of the pump that is usually between 2.5 and 3. In general, there is an increased consumption of electricity for the pumps which is offset by the reduced heat and ventilation requirements. The coefficient of performance of ground-source heat pumps is usually between 2.5 and 3; however, for the specific application presented in Table 4.39, the coefficient of performance has been reported equivalent to 4.4.

Reduction in energy used of up to 50 % has been achieved. Data to illustrate the results of a combideck application are presented in Table 4.39.

Table 4.39: Results of the application of the combideck system

	Fuel type/ fuel use	Input	Energy-equivalent (MWh/yr)	Costs([1]) (EUR)	CO_2 (tonne) ([2])
Reference situation	Fuel oil	49.5 m^3	549	6 273	65.0
	Natural gas	36.1 m^3	321	9 277	158
	Electricity	40 MWh	40	3 757	14.8
		Total	**910**	**19 307**	**237**
Combideck system applied	Heating	63.6 MWh	63.6		23.5
	Ventilation	34.4 MWh	34.4		12.7
	Heat pump([1])	189 MWh	189		44.4
		Total	**287**	**9 194**	**80.6**
Reduction (as percentage of reference)			**623 (70 %)**	**10 113 (52 %)**	**156.4 (66 %)**

([1]) coefficient of performance heat pump: 4.4([1]) Reference year 1999, corrected for low and peak tariffs on electricity prices in the Netherlands.
([2]) CO_2-equivalents: oil 3.2, gas 1.8, electricity 0.37.
Source: IRPP BREF 2003 [36, R&R 2000]

Operational data

The under-floor circuit is made of hollow strips cast at 10–12 cm in the concrete floor. The storing circuit is made of tubes placed 2–4 metres deep below the housing.

For 80 000 broilers three heat pumps were used, each of 0.1 kW_e are used. Broilers can be were stocked at a density of 18 birds/m^2.

In a test comparison with The reference a standard installation emitting emitted 0.066 kg NH_3 per broiler place per year, the average ammonia emissions over 4 measured production cycles were was 0.045 kg NH_3 per broiler place per year. Hence, the reduction of the NH_3 emission of this system with heated and cooled air is was about 32 %. The summary of the achievable performances is given in Table 4.40.

Table 4.40: Comparison of performances for identical houses with and without the combideck system.

	House 1	House 2 (Combideck)
Total birds	33 000	34 000
Mortality (%)	4.97	2.85
Harvesting weight (grams) 1st time with 35 days	1 681	1 692
Harvesting weight (grams) 2nd time with 42 days	2 250	2 236
Surplus payment per kg (euro-cents)	0.2	0.4
Feed ratio (1 500 grams)	1.55	1.40
Heating costs (per broiler in euro-cents)	3.13	2.10

Source: IRPP 2003, Farm Henk Wolters, Dalfsen, the Netherlands

Applicability

This system can be applied in both new and existing houses. If constructed in existing houses, the costs are slightly higher because floors need to be ripped up and reconstructed in order to lay the of the insulation needed under-floor circuits. Construction and ground works will be needed in the farmyard, depending on the position of the broiler house.

With several broiler houses, it may be possible to use heated water from one house (being emptied) to warm another (to be stocked), which may even further reduce the energy needed for pumping. However, this idea has not yet been put into practice.

Soil condition must allow the installation of closed underground storages of circulated water. The technique is less suitable in areas with hard and rocky soils. The system is applied in the Netherlands and in Germany at a depth of 2–4 metres.

So far no information has been presented on the Application of the combideck system in climates where the frosts are longer and harder and penetrate the soil is still unknown.

The system can be applied only if soil conditions allow the installation of closed underground storage of the circulated water.

Economics
Investment costs (for new houses) are EUR 2 per broiler place with 20 broilers per m^2. Operational costs (depreciation, interest and maintenance) are EUR 0.20 per broiler place year. The annual increased yields reportedly outweighed the yearly operational costs by a factor of about 3. For instance, veterinarian costs were reduced by about 30 %. Energy costs were reduced by about 52 %. The payback time is about 4 – 6 years. [544, Netherlands 2002] [178, Netherlands, 2002]
Where low electricity prices apply during certain parts of the day, a further cost reduction may be possible.

Driving force for implementation
The system has a better performance on broiler production (reduction of mortality, higher meat price, better feed ratio) and a positive effect on animal welfare (less heat stress, lower mortality, less veterinary services needed). [178, Netherlands, 2002]

Example plants
In the Netherlands, around 2 million places were available in 2008 that were built with this technique. [468, CBS 2011] In 2001, five enterprises applied this system with a total of 500 000 broilers (4 enterprises in the Netherlands and 1 in Germany). In 2002, a and another system for 500 000 broiler places was is currently under construction. By the end of 2002 the total available broiler places in the Netherlands with this system is expected to be 1 – 1.5 million, equating to about 2 – 3 % of the total production in the Netherlands.
10 systems are reported also to be built in Germany and Russia in 2010

Reference literature
[36, R&R 2000]

4.5.4.3 Management of ventilation

4.5.4.3.1 Management of ventilation in poultry houses

Ventilation is one of the main sources of energy consumption in the poultry sector; thus, the management of air circulation in the housing systems is important in controlling energy costs.

For animal welfare reasons, minimum ventilation rates should be always sufficient to provide fresh air, oxygen and sufficient humidity and to remove unwanted gases. General measures to reduce electricity for ventilation use are:

- to select the correct type of fans and to consider their position in the building;
- to install fans with a low energy use per m^3 of air;
- to use the fans efficiently, e.g. operating one fan on full capacity is more economical than operating two on half their capacity;

- to maintain and keep clean ducts, fans and controlling apparatuses devices;
- to select the appropriate size and shape of air ducts and preserve internal smoothness, in order to maintain maximum air throughput, and consider new plastic conical profile fan ducts;
- to ensure that ventilation cowls have smooth, slow internal bends to avoid restricting airflow;
- to use adjustable flap windows to optimise the ventilation needs;
- to use a variable speed drive for three phase electric motors. Reducing the speed of the fan, by tailoring the speed to the exact requirement at any time, may allow significant energy savings (about 20 % and up to 50 %). [95, UK 2010]

Optimisation of energy consumption can be pursued by the use of (fixed) single-speed fans that are adequately organised in space. Additional regulation cases give this type of equipment the possibility to obtain flows and speeds that match the variable needs for age, species, animal load and climatic conditions. [339, ITAVI 1997] [342, ADEME 2008] [349, ITAVI 1998] [355, Warwick 2007]
Energy-saving fans can reduce power consumption by up to 70 %. [144, Finland 2010]
SEE NEW SECTION BELOW

Fan efficiency generally increases with the impeller diameter. Efficiency is obtained by adequate sizing of ventilation inlet and outlet and by providing smooth and clean internal surfaces with slight bends. [356, Carbon Trust 2005]

OLD TABLE 4.12 AND RELATED INTRODUCTORY TEXT (REFERENCE YEARS 1994-1997) HAVE BEEN DELETED

4.5.4.3.2 Circulating fans

Description
Circulating fans generate air flows that are homogeneous in speed. Several types of circulating fans can be placed: horizontal, vertical, oscillating (sweeping) with scavenging etc.

Achieved environmental benefits
Air flow in the houses is homogenised at the animal level without increasing the volume of air supply by the central ventilation.

Fans are mainly used in finishers meat poultry housing during summer, at the last stage of production. The air flows that are created allow poultry for a better thermal comfort by increasing the heat losses by convection. The air flow cools the birds by increasing heat loss through convection. [350, France 2010]

In the Netherlands, circulating fans are integrated into the housing system to reduce the ammonia emissions. Details on this technique are given in Section 4.6.4.1.1.

Cross-media effects
Dust problems may arise.

Operational data
Circulating fans are held approximately at 1 m over the litter and provide air speeds of at least 0.8 m/s to every point of the living area, since 1 m/s is the advised air speed. According to the climatic conditions, 8 to 12 circulating fans of 15 000 – 20 000 m^3/h of capacity are needed for every 1 000 square metres. [350, France 2010]

The effect of surface drying of the litter in broiler houses has a consequence on emission reduction. In the Netherlands, with this solution and an installed capacity of 1.8 m^3 per animal per hour, ammonia emission can be reduced down to levels of 0.037 kg NH_3/birdplace per year in broiler houses, and 0.183 kg NH_3/birdplace per year, in parent houses (broiler breeders). [469, NL 2011]

Applicability

Circulating fans cannot be installed where there are many obstacles in the buildings that could affect their efficiency or where the movement of people or nearby receptors may limit their use ~~over the surface or where the movement of people and material may limit their installation~~.

Driving force for implementation

Where the electrical market is favourable, such as in France, the electrical consumption for circulating fans make even more economic savings in heating that are favoured.

Economics

Investments for the installation of ~~one~~ vertical circulating fans of 20 000 m^3/h of capacity every 15 metres in length and every 2 metres in width are estimated at EUR 5/m^2. [350, France 2010]

Example plants

In France, 10 % of poultry buildings are equipped with circulating fans.

Reference literature

[339, ITAVI 1997] [349, ITAVI 1998] [350, France 2010] [354, ITAVI 2004]

4.5.4.3.3 Circulating fans in combination with heat exchangers

Description

This technique is fully described in Section 4.6.4.1.2, since it makes part of an integrated housing system. The technique consists of heating and drying the litter by the combined use of heat exchangers and ventilators. Incoming air is warmed up in a heat exchanger by using the heat recovered from the indoor air. The ventilators spread the warm air equally over the litter.

Achieved environmental benefits

The reduction of energy requirements is achieved by means of heat exchangers. Additional environmental advantages consist of ammonia emissions reduction and manure dryness, achieved by the use of the combined system (heat recovery and circulating fans).

Cross-media effects

Refer to Section 4.6.4.1.2.

Operational data

Refer to Section 4.6.4.1.2.

Applicability

Refer to Section 4.6.4.1.2.

Driving force for implementation

Refer to Section 4.6.4.1.2.

Example plants

Refer to Section 4.6.4.1.2.

Economics

In the Netherlands, at typical climatic conditions, the savings in heating costs achievable with the heat exchangers amount to 50 %, equivalent to about EUR 0.38/ap/year.

Reference literature

[465, NL 2011]

4.5.4.3.4 Equal spreading of re-circulated air by indoor fans

Description
This technique is fully described in Section 4.6.4.1.3, since it makes a part of an integrated housing system. The technique consists in heating the house by a combination of heaters and indoor ventilators. Ventilators drive warm air from the top of the building down to the floor level. The air is warmed up by thermal exchange with hot water produced by indirect-fired thermal heater using propane or natural gas or by a central heating. The ventilation system is completed with equipment to draw the air out in a horizontal direction, spreading all over the litter.

Achieved environmental benefits
An optimal indoor climate is achieved at low heating costs and ammonia emissions are reduced by the effect of drying the litter due to the warm aeration.

Cross-media effects
Refer to Section 4.6.4.1.3.

Operational data
Refer to Section 4.6.4.1.3.

Applicability
Refer to Section 4.6.4.1.3.

Driving force for implementation
Refer to Section 4.6.4.1.3.

Example plants
Refer to Section 4.6.4.1.3.

Economics
Investment and running costs depend on the choice of fuel and are estimated as follows:

- Investment requirements: EUR 1.5 per animal place/year, (from 1.3 to 1.7);
- Annual running costs: EUR 0.22 per animal place/year, (from 0.15 to 0.28);
- Total annual cost: EUR 0.45 per animal place/year, (from 0.41 to 0.48).

Reference literature
[470, NL 2011]

4.5.4.3.5 Energy saving fans

Description
The housing ventilation system is automatically controlled according to CO_2 concentration, resulting in a reduced air exchange.

Achieved environmental benefits
Heat losses due to the ventilation of buildings, and thus the extra consumption of energy for heating, can be minimised by optimising the air renewal, in order to reach minimum rates of ventilation in winter. In a litter-based system for the rearing of broilers, the energy consumption is 70 % lower than in the conventional (old) housing system; while, ammonia and odour emissions are reduced by 20 – 30 %, due to the reduced air exchange.

Cross-media effects
No reported cross-media effects.

Operational data

The operating conditions and related energy consumptions of a farm for the rearing of broilers, equipped with 'energy saving fans', are presented in Table 4.41. The housing system has a capacity of 120 000 bird places and consists of two insulated buildings; each building with two compartments for 30 000 birds.

Table 4.41 Operating conditions and energy consumption of a broiler housing system equipped with energy saving fans, in Finland

Parameter	Characteristics/consumption
Insulation	walls: 140 mm mineral wool; ceiling: 300 mm blown wool (cellulose) floor: not insulated
Cold season ventilation ([1])	from 1 500 to 150 000 m^3/h per animal place
Warm season ventilation ([1])	from 15 000 to 300 000 m^3/h per animal place
Annual fuel consumption for heating	1.42 kWh/ap/yr
Electricity	0.29 kWh/ap/yr

([1]) Depending on the size of the birds.
Source [144, Finland 2010]

Applicability

No information submitted

Economics

The investment cost of a new broiler rearing installation is reported equivalent to EUR 11.67 per animal place, and EUR 12.5 per animal place if it is equipped with the energy saving fans; namely, the extra cost is equivalent to EUR 0.83 per animal place.

Driving force for implementation

Improved animal performance due the achieved temperature uniformity. The average daily gain is reported at approximately 3 – 4 g/d higher than the average value observed in Finland.

Example plants

Commonly applied in new installations of broiler rearing in Finland.

Reference literature

[144, Finland 2010]

4.5.4.3.6 Management of ventilation in pig houses

IN ORDER TO FACILITATE THE READING OF THIS SECTION, THE OLD TEXT (ENTIRE PARAGRAPHS IN BLACK COLOUR) ALREADY DELETED IN DRAFT 1 HAS BEEN ELIMINATED

Description

Ventilation accounts for about 40 % of the total energy consumption at integrated breeding-to-fattening farms and about 90 % of the total energy consumption in the fattening pigs housing systems. Electricity consumption and associated costs are reduced by installing energy saving fans or equipment. Ventilation is directly adjusted to the physiological needs of the pigs, in order to ensure their welfare. A bad management of ventilation generates negative consequences on the growth performance of the animal and, therefore, on the economics of the farm.

Dynamic ~~Forced~~ ventilation systems are designed, built and operated so that the flow resistance of the ventilation system is kept as low as possible, e.g.:

- having short air ducts

- incorporating no sudden changes into air duct cross-sections
- limiting the changes in duct direction, or application obstructions (e.g. baffles)
- removing any dust deposits in the ventilation systems and on the fans
- avoiding having rain protection covers above the discharge points.

Fans with the lowest possible ~~power~~ specific consumption of power (W/m^3 of extracted air at 40 Pa), for a given air rate and air pressure rise, should be selected. Fans with low-rated rpm (low-speed units) use less energy than those that operate at high rpm (high-speed units). Low-speed fans can, however, only be used if the ventilation system exhibits a low flow resistance (<60 Pa).

Fans designed on the basis of EC (electronic commutation) technology exhibit a significantly lower power requirement, particularly over the regulated speed range, compared with ~~than~~ transformer-regulated or electronically regulated fans. Slightly higher purchase prices are justified by significant consumption reductions.

Frequency converter

In practice, most ~~of the~~ ventilators are powered by a 230 Volt triac controller. ~~One disadvantage of this controller is that a triac-powered ventilator working at low speed leads to energy losses, which leads to a higher energy consumption per cubic metre of air replacement. Another~~

An efficient controlling system that ~~type of controller which~~ can be used to power a ventilator is a frequency converter, where the ventilators can work at low speeds without any decrease in energy efficiency.

Fans must be of the type 3 × 400 Volt AC and can be installed in each compartment of any livestock pig and poultry shed.

Benefits of the system are include less energy consumption and less fan wear-out for less heat produced. Above all, ~~that~~ all the compartments can be adjusted between 5 % and 100 % ventilation, regardless of the influences of the weather (e.g. even in windy weather). The system works with the aid of measuring fans installed in the shed compartments that measure the need for ventilation. In connection to the main frequency controller, each compartments' ventilating fans are run at reduced speeds to produce the volume of air that is detected by the measuring fans.

~~Usually~~ In fact, ~~the~~ fans do not work at 100 % rpm. at most times of the year ~~the fans work at a lower RPM. For example,~~ and during the winter period, ~~the~~ fans seldom work above 25 % rpm (round per minute). The power reduction achievable by using a frequency converter system is ~~was~~ up to 69 %, compared to the 230 Volt motors with the conventional system.

End-of-pipe air cleaning systems

~~These for exhaust air cleaning can~~ The installation of air cleaning equipment significantly increases the flow resistance of forced ventilation systems. In order to deliver the requisite air rates, particularly in summer, higher-capacity fans with a higher specific power requirement may be necessary. In addition, power is required to operate the pumps for water circulation in bioscrubbers and for humidifying operations in biofilters (Section 4.9).

Other general measures

Additional measures for optimising ventilation are given below.

- To design the system well. Centralised extraction is possible in new buildings. The waste air is extracted from the building by only one turbine whose specific consumption (W/m^3 of extracted air) is definitely lower than the sum of the consumptions of single fans required in a room-by-room dynamic ventilation. By applying centralised ventilation, reported reductions of the energy consumption are generally between 20 and 30 % [343, ADEME 2008]. ~~possible op up to 60 %. [344, ADEME 2008]~~

- To yearly monitor fan clogging before the warm season. Consumption wastes and equipment life span are improved.

Achieved environmental benefits
The optimisation of the balance of heating and ventilation adapting it to the animal needs may reduce energy consumptions by up to 50 %.**Information moved to Section 4.5.4.**

Energy-saving fans can reduce power consumption in pig farms by up to 60 %. [350, France 2010]

With a minimised ventilation at the beginning of the post-weaning cycle (3 m^3/h per pig), the energy consumption per produced pig is 6.7 kWh, in comparison with 12.3 kWh needed by the standard ventilation (5 m^3/h per pig). [350, France 2010] **Moved to operational data**

Cross-media effects
No reported cross-media effects.

Operational data
Ventilation is characterized by a variable consumption depending on the characteristics and regulation of fans.
The rate of air exchange is primarily responsible for energy requirements for heating; therefore, That is why it is crucial to control the flow of air and, in particular, the minimum flowrate.
With a minimised ventilation at the beginning of the post-weaning cycle (3 m^3/h per pig), the energy consumption per produced pig is 6.7 kWh, in comparison with 12.3 kWh needed by the standard ventilation (5 m^3/h per pig). [350, France 2010]

From Table 4.42, it can be deduced that increasing the ventilation flow from the minimum recommended (in France) flowrate, at the beginning of the post-weaning cycle, of 3 m^3/h per animal (which fulfils the physiological needs of the piglets), to a standard ventilation of 5 m^3/h per animal, can result in a double energy consumption for heating up the mass of air; the energy consumption per produced pig will be increased from 6.7 to 12.3 kWh). [344, ADEME 2008] [350, France 2010]. The combined effect of insulation in reducing heat consumption is also presented. A good control of the ventilation rates can thus allow appreciable savings on heating costs without degrading the ambience and without additional investment.

Table 4.42: Heat consumption according to minimum ventilation flows and added insulation, for piglets in early post-weaning age Moved from Chapter 3

Ventilation	Heat consumption	Heat consumption with 1 cm of insulation added
m^3/h per animal	kWh per produced pig	kWh per produced pig
3	6.68	6.00
4	9.02	8.22
5	12.29	11.00
6	14.82	12.79
7	17.40	14.35
Source: [344, ADEME 2008]		

The application of different ventilation rates involves, first of all, a modification of the indoor environment. Tests have been carried out in France, in order to determine the effect of ventilation rate on the performance and health status of growers/finishers. Minimum and optimum ventilation rates were tested as presented in Table 4.43. Temperature (24°C) and relative humidity (65 %) were kept constant throughout the experiment. It was found that the application of an optimum air flow made it possible to decrease by half the ammonia concentration (emissions). It was also found that for the same type of floor, there were more germs in the environment when the minimum air flow was applied. Minimum flow was associated also with increased dust levels (20 to 30 %).[261, France, 2010]. The results of the investigation are presented in Table 4.43.

Table 4.43: Ammonia emissions and germs concentration in relation to the ventilation rate

Parameter	Floor characteristics	Optimum flow	Minimum flow
Ventilation rate (m^3/hour/pig)		15 to 50	8 to 19
NH_3 (ppm)	Iron slats	7.5	15.1
	Concrete slats	6.6	16.8
Germs (number/l)	Iron slats	73	103
	Concrete slats	166	206
Source: [261, France, 2010]			

Applicability

Centralised ventilation can be applied only to new buildings. ~~can benefit from centralised ventilation.~~ An adjustable regulation of temperature and ventilation can be applied in both existing and new housing systems. [261, France 2010]

The application of electric floor heating, in combination with optimised ventilation, is quite expensive in ~~houses~~ retrofitting existing housing systems.

Economics

The investments required for ~~costs of the~~ a frequency converter system is ~~are~~ quite similar to a conventional system. The purchase and installation of one or more regulation devices largely compensate the potential economic losses generated by a bad control of the indoor climate. [261, France, 2010]

Energy-saving fans are still quite expensive and their lifespan is short. ~~as well.~~

The ~~general~~ potential savings from energy costs, achievable by optimising the ventilation rate from 5 m^3/h to 3 m^3/h per pig, in an integrated breeding-to-fattening farm of 200 sows is equivalent to EUR 1 650 per year. The annual indicative costs for the purchase and installation of large dimension fans with a capacity of 100 000 m^3/h is estimated between EUR 0.03 and 0.04/produced pig, ~~or in other words,~~ equivalent to less than EUR 0.001 per kg of fattened pig produced. This value is calculated with a paid-off period of 10 years. [350, France 2010]

Driving force for implementation

Even though centralised ventilation appears to be 5 to 10 % more expensive than conventional ventilation, it allows for the installation of end-of-pipe ~~treatments~~ air cleaning systems and of heat exchanging equipments (Air-Air and Air-Water).

Example plants

These measures are widely applied.

Reference literature

[44, IKC 1993] and [395, ADAS 1999] [350, France 2010] [355, Warwick 2007] [343, ADEME 2008]

4.6 Techniques for the reduction of emissions from poultry housing

IN ORDER TO FACILITATE READING OF THIS SECTION, SOME EXISTING TEXT FROM THE ORIGINAL IRPP BREF, ALREADY DELETED IN DRAFT 1, HAS BEEN REMOVED

This section ~~reflects the information submitted and~~ focuses on measures to reduce emissions, mainly to air, from poultry housing. These emissions, ammonia being the ~~most concerning~~ compound of most concern, depend on the amount of droppings that is present indoors. Ammonia emissions can be reduced ~~by reducing the amount of droppings,~~ by changing the ~~their~~ composition of the droppings and/or by removing them from the housing. The early drying of ~~the~~ droppings prevents the nitrogen from volatilising ~~evaporating~~. Consequently, the nitrogen content in the manures is higher.

Emission data reported in the tables may be accompanied (when the information is available or considered relevant) by a note indicating the 'type of data' which they refer to. When available, this information is intended to qualify the origin of the values and it should be read as indicated in the footnotes to the tables.

4.6.1 Techniques for cage housing of laying hens

Emission reductions in enriched cages are mostly obtained by frequent ~~quick~~ manure removal from the house (e.g. twice a week) or ~~and~~ by drying ~~the droppings~~ manure on belts with less frequent (e.g. weekly) removal. Emissions of ammonia from ~~layer~~ hen droppings result from chemical reactions in the manure that start immediately after deposition. The organic nitrogen (uric acid) is quickly transformed into ammonia by reactions that are ~~and is~~ enhanced by ~~its~~ manure temperature and moisture content. ~~although~~ Drying the manure is a way to inhibit the chemical reactions and thus reduce ~~the~~ emissions. The quicker the manure is dried, the lower the emission of ammonia. ~~Various techniques are applied that create an airstream over the manure belt, which enhances the drying of the droppings.~~ A combination of frequent removal and the drying of manure give the best reduction of ammonia emissions from ~~the~~ housing and also reduces emissions from ~~the~~ storage facilities, but at an associated energy cost.

Equipment for managing manure is integrated into the manufactured cages, such as manure belts and optional ventilation systems.

Conversely, adding water to form a slurry will reduce ammonia emissions. ~~Adding~~ Flushing water for easier pumping of the slurry is still practised, but it is declining due to the smell and excessive volume.

~~Scientific literature reports~~ It is reported that farmers could reduce ammonia emissions from housing by almost 50 % by scraping the belts twice a week rather than weekly. [146, DEFRA 2002] Equivalent or better results can be achieved with weekly removal of manure if manure dryers are present. Pre-dried manure from ventilated belts presents the advantage of being easier to stacked and also to heat up considerably in the covered store with consequent further drying.

A summary of the reported emissions ~~that have been measured and reported,~~ associated with the different housing systems, is given in Table 4.44. Where relevant, information concerning the operating conditions and the type of emission data (i.e. measured, estimated) are also given.

Table 4.44: Summary of relevant reported achievable emissions in cage systems for laying hens

Description	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	(kg/ap/yr)				(ou_E/ap/s)	
Section 4.6.1.1 Enriched cages						
Two removals per week. No manure drying	0.035-0.038 (1)				0.37	[57, Denmark 2010] [56, Denmark 2010]
Three removals per week. No manure drying	0.028 (1)					
One or two removals a day. No manure drying	0.020 (1)					
One or two removals per week. No manure drying	0.035 (2)	0.078 (2)	-	0.01 (2)		[84, UK 2010] [500, IRPP TWG 2011]
One removal per week. With dried manure on belt	0.035 (2)			0.01 (2)		
Two or three removals per week. With dried manure on belt	0.010–0.040 (2)	0.078 (2)		0.01 (2)		[84, UK 2010]
One removal per week (with fogging). No manure drying (3)	0.079 (1)	0.037 (1)	0.0024 (1)			[68, Spain 2010]
Two removals per week (with fogging). No manure drying (3)	0.039 (1)	0.034 (1)	0.0017 (1)			[69, Spain 2010]
Section 4.6.1.2 Small groups in enriched cages						
One removal per week. With dried manure on belt	0.017–0.040 (1)			0.023 (1)	0.350 (1)	[67, Netherlands 2010]
Two removals per week. No manure drying	0.150 (1)			0.04 (1)	0.102 (1)	[63, Germany 2010] [500, IRPP TWG 2011]
One removal per week. With dried manure on belt)	0.040 (1)			0.04 (1)	0.102 (1)	[63, Germany 2010]

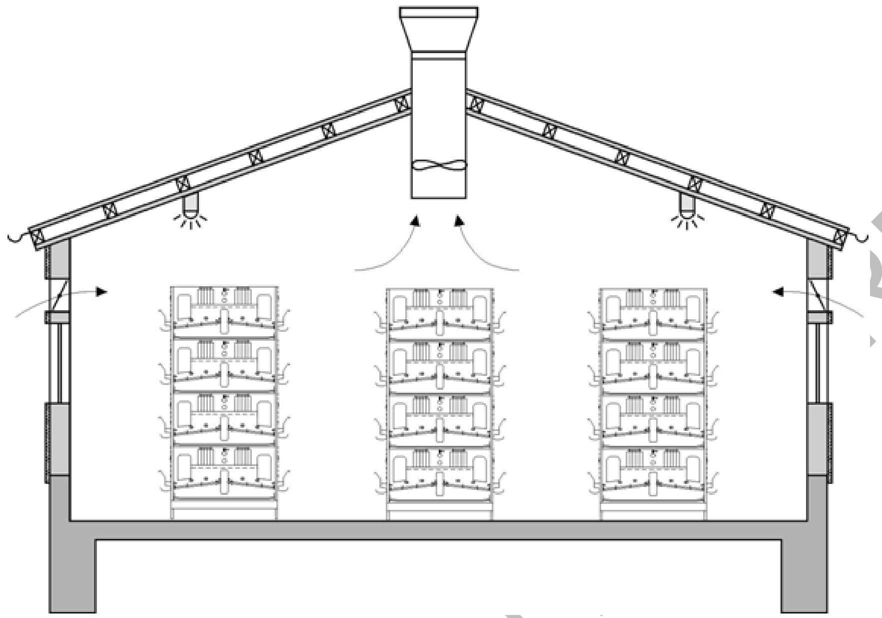
(1) Measured values.
(2) Modelled values (e.g. results based on N balance).
(3) Fogging (see Section 4.8.3) was occasionally used during measurements.

THE FULL SECTION CONCERNING TRADITIONAL CAGE SYSTEMS, ALREADY DELETED IN DRAFT 1, HAS BEEN ELIMINATED

4.6.1.1 Enriched cages

Description

Cages are enclosures with sloping floors made of welded wire mesh or plastic slats. In 'furnished' or 'enriched' cages, laying hens are provided with increased space and additional ~~more~~ equipment ~~is provided~~ ~~than~~ for feeding, drinking, egg collection, manure removal, insertion and the removal of hens. The additional equipment enables hens to ~~provide~~ exibit/perfom their natural behaviour ~~for some of their strong behavioural priorities~~, and includes perches, nest boxes, litter areas, claw shortening devices and extra height. The system is described in Section 2.2.1.1 and a cross-section is illustrated ~~pictured~~ in Figure 4.10.



Source: [63, Germany 2010]

Figure 4.10: Scheme of rows of enriched cages for laying hens

The cages are arranged on three or more tiers and often organised in two groups, with an intermediate platform between the 4th and 5th tier. [368, France 2010]

A belt is placed under each tier for the removal of manure. When the collection belt is aerated by an air duct system, ~~Normally, enriched cages are equipped with drying, collecting belts, that dry~~ dried droppings are obtained, with a dry matter content of at least 55 % ~~from a of dry matter to a dry content of 60 – 80 %.~~, compared to a dry matter content of 25 – 35 %, without drying. High drying levels are difficult to reach when very frequent removal of the manure is performed.

The reference system for manure removal from enriched cages consists of a belt underneath the cages, with regular removal without drying. [508, TFRN, 2012]

Achieved environmental benefits

Ammonia, odour, methane and N_2O emissions are reduced as a consequence of the frequent manure removal and of the possible forced drying. Reductions are higher with more frequent removal, but the effect is not directly proportional ~~less than proportionally~~.

Cross-media effects

The energy consumption increases with ~~as a consequence of the~~ increasing frequency of use of the operating conveyer belt and manure drying ~~operation~~.

As ~~Since~~ the removed manure has a high N content, N_2O emissions during storage, handling and application as fertiliser are ~~made~~ possible.

~~Around 2 kWh/animal per year are needed to run the manure drying belts. [368, France 2010]~~

Operational data

Ammonia emissions from enriched cage housing systems have been reported between 0.010 and 0.079 kg NH_3 per hen per year. The range of emissions is due to different frequency of manure removal, by non-ventilated or ventilated manure belts placed underneath the cages. In forced ventilated houses with two or three manure removals per week, the ammonia volatilisation ranges from. It has been estimated that increasing the frequency from twice a week to three times a week or to a daily removal allows for the reduction of ammonia emission by 19 % and 43 % respectively. Examples of the effect of manure removal frequency on ammonia emissions are reported in Table 4.45 and Table 4.46.

The effect on ammonia emissions of the frequent removal of manure without drying, has been reported from Denmark and presented in Table 4.45. Measured emission levels were compared to a reference emission factor of 0.083 kg NH_3/ap/yr, corresponding to one removal of manure per week.

Table 4.45: Effect of manure removal frequency, without manure drying, on ammonia emissions from enriched cages

Parameter	Manure removal frequency		
	Twice per week	Three times per week	Daily removal or twice per day
Ammonia emissions reduction (%)	54 – 58	66	76
Source [56, Denmark 2010] [57, Denmark 2010]			

The effect on ammonia emissions of frequent removal of manure (and associated costs), when belts are equipped with drying fans is presented in Table 4.46. Values are compared with a technique which removes manure twice per week, with no ventilated belt (no drying), associated with an emission factor between 0.05 and 0.1 kg NH_3/ap/yr.

Table 4.46: Effect of manure removal frequency, with manure drying on ventilated belts on ammonia emissions from enriched cages, and associated costs

Parameter	Manure removal frequency	
	Twice per week, with ventilated belts	More than two times per week, with ventilated belts
Ammonia emission reduction (%) ([1])	30 – 40	35 – 45
Associated costs (EUR/kg NH_3-N abated/year)	0 – 3	2 – 5
([1]) Reduction percentage depends on the ventilation rate of the drying fan. *Source*: [508, TFRN, 2012]		

In Spain, it was measured that increasing manure removal frequency from once to twice per week, reduced ammonia emissions by 49 %, from an emission factor of 0.079 kg NH_3/ap/yr to 0.039 kg NH_3/ap/yr. In Spain, Methane and nitrous dioxide were also measured for weekly and bi-weekly manure removal from belts. Methane emissions were not affected by frequent manure removal but from manure drying (31 % reduction), with a variation of the emission factor from 0.035 kg CH_4/ap/yr to 0.024 CH_4/ap/yr. The increase in manure removal frequency showed a reduction of N_2O emissions by 29 %, from 0.0024 kg N_2O/ap/yr to 0.0017 kg N_2O/ap/yr. results per animal place per year were 0.037 and 0.0034 kg of methane respectively, and for N_2O

In From the UK, emissions per bird place per year are reported estimated for methane at 0.078 kg CH_4/ap/yr and for PM_{10} at 0.01 kg/ap/yr. In the UK, water addition is also used to flush droppings.

Measured odour emissions are ~~estimated~~ reported equivalent to ~~at~~ 0.037 ou_E/s per hen (219 ou_E per 1 000 kg of live weight for an average weight of 0.68 kg). [57, Denmark 2010]

Energy consumption should not be significantly different from the values reported in Section 4.6.1.2, for the housing system 'Small groups in enriched cages'.

Applicability
These systems are applied in both new and existing houses. The technique can replace conventional cages, without the need for significant alteration of existing building. [508, TFRN 2012]

Economics
Increasing manure removal from once to twice a week is~~, all things considered~~, more efficient than increasing the number of removals from two to three times per week. The economic effect of this practice is estimated in Table 4.47. The economic value of the savings for mineral fertilisers that are allowed for by the increased nitrogen content in the manure are also taken into consideration. The annual cost of applying frequent manure removal (twice per week compared to once per week) is estimated to be less than 1 % of the total production costs [57, Denmark 2010].

Table 4.47: Economic consequences of removing manure two or three times per week compared to once a week

~~Animal units~~	Combined additional cost excluding value of saved N		Combined additional cost including value of saved N		Additional costs excluding value of saved N	
	EUR/layer hen/yr		EUR/layer hen/yr		EUR/kg N reduced	
No. hens (1)	Frequency: twice/week	Frequency: three times/week	Frequency: twice/week	Frequency: three times/week	Frequency: twice/week	Frequency: three times/week
~~60~~ 12 000	0.08	0.16	0.05	0.12	2.8	4.7
~~120~~ 2 4000	0.07	0.12	0.03	0.08	2.1	3.5
~~150~~ 30 000	0.07	0.13	0.03	0.09	2.1	3.7
~~240~~ 48 000	0.05	0.11	0.01	0.07	1.7	2.9

(1) For converting the reported Danish animal units to number of hens, a factor of 200 was used.
Source: [57, Denmark 2010]

The investment required varies from EUR 10 – 15 per bird place in Italy [83, Italy 2010] to EUR 12 – 15 in France, where an entire replacement of the existing sheds, with house rebuilding and equipment may cost EUR 25. [368, France 2010]

From Spain, it is reported that the extra cost associated with increasing the frequency of manure removal, without drying, from once to twice per week is equivalent to 0.013 EUR/ap/yr. [69, Spain 2010]

Driving force for implementation
The frequent removal of the manure reduces the flies' contamination and ~~increases~~ improves animal welfare.

Example plants
Several installations in the UK are equipped with this type of system.
At the end of 2010, in France approximately 35 % of the laying hens were raised in enriched cages [365, France 2010]. One housing system with 60 000 places was reported for Spain and two housing systems of 100 000 places were reported for Italy, in the Veneto region.

Reference literature
Agrotech A/S- Ammoniakreduktion i buraegsstalde. Landbrugs Info – Artikel nr.2 – Fjerkræ, 2009. Forfatter: Amparo Gómez Cortina.
[56, Denmark 2010] [57, Denmark 2010] [67, Netherlands 2010] [68, Spain 2010] [69, Spain 2010] [83, Italy 2010] [84, UK 2010]

4.6.1.2 Small groups in enriched cages

Description
This is a colony system in enriched cages that exceeds Directive 1999/74/EC requirements and in Germany is commonly called 'kleingruppenhaltung'. The cages are tiered vertically (four row or even more) and their dimensions depend on brand and type. The difference with enriched cages is a larger surface area per animal, higher cages and more defined areas with litter and nests.

Manure belts placed under the cages allow for frequent manure removal from the shed. Forced manure drying can be performed on the manure belts by means of pipes that blow air over the droppings that are placed above or along the belts.

Achieved environmental benefits
Ammonia emissions are reduced by frequent droppings removal, and even more with forced drying. Dust emissions are lower compared to non-cage systems (but it mainly depends from the dust bath material).

Cross-media effects
The increased animal movement and the operation of belts cause higher dust emission. The energy use is higher with forced air drying.

Operational data
This ~~The small group~~ housing system exceeds EU welfare requirements for an enriched cage and was developed to be associated with small groups. Nevertheless, the colony size is not fixed. A total area at least 2.5 m^2 is provided, of which 800 cm^2 are usable without restriction (if the hen weight is over 2 kg, then 900 cm^2 of space is made available). The littered and the nest areas cover 900 cm^2 for every group of ten (for 30 animals or more, an additional 90 cm^2 per animal are given). The cage height is at least 50 cm and at the trough side is 60 cm. Each animal is provided with 15 cm on perches and 12 cm of feed trough.

The manure from ventilated belts is removed weekly, otherwise twice a week. Dry matter content of the manure at the time of removal is at least 55 %, in the case of air drying. The manure removed by the belts is stored outside the housing. When the store ~~storage~~ is not covered, a further displacement to a storage depot is performed.

The air used for the forced air drying system should be fresh. In the Netherlands, the ventilation rate for the air drying system is reported equivalent to 0.7 m^3/h/bird, with a minimum temperature of 17 ºC.

For each bird place per year, emissions of 0.15 kg of ammonia and 0.04 kg of PM_{10} can be associated with this system (see Table 4.44). If the manure ventilation is applied, emissions are reduced to a range of 0.017 to 0.040 kg of ammonia and to 0.023 kg of PM_{10}. Odour emissions are estimated ~~as~~ in the range of 0.102 – 0.350 ou_E per bird place per second ~~year~~ [67, Netherlands 2010] [63, Germany 2010].

Ventilation rates vary depending on the season: in the cold season air volumes from 0.5 to 3.2 m^3/bird place per hour are provided, and in the warm season volumes from 3.1 to 6.9 m^3/bird place per hour are provided.

In Germany, labour requirements have been estimated at 0.085 – 0.12 hours/ap/yr, on the basis of a housing system with 30 000 bird places.

Energy consumption is considered to be proportional to the number of manure removals [434, ITAVI 2001]. In Germany, the reported energy requirements are in the range from 1.1 to 1.8 kWh/ap/yr for two removals per week, with additional consumption for the manure belt ventilation ranging from 0.6 to 1.3 kWh/ap/yr. Energy consumption for lighting is reported at around 0.52 kWh/ap/yr.

Applicability
The system is in use in consumer egg production only.

Economics
The investment requirement varies from EUR 16.00 – EUR 20.00 per bird place in the Netherlands and about EUR 31.00 per bird place in Germany, for a housing system with 5 000 – 10 000 bird places. The corresponding annualised investment costs have been reported at 2.4 – 3 EUR/ap/yr for the Netherlands and 3.6 EUR/ap/yr for Germany. The average extra-cost for a new installation reported by the Netherlands is equivalent to 7.9 EUR/ap/yr, ranging from 5.5 to 9.5 EUR/ap/yr. Annual running costs have been estimated in the Netherlands as EUR 0.1 per bird place.

Driving force for implementation
National or local cage ban programmes (Netherlands, Germany). The animal welfare is improved compared to conventional cages and standard enriched cages.

Example plants
In 2009 about 1 % of the Dutch layers were housed in this housing systems.
Since conventional enriched cages are not allowed in the Netherlands and in Germany, small group housing in enriched cages is used.

Reference literature
[63, Germany 2010] [67, Netherlands 2010]

KTBL (Hrsg.) (2008): Datensammlung Betriebsplanung Landwirtschaft 08/09. KTBL-Datensammlung, Darmstadt KTBL (Hrsg.) (2006): Nationaler Bewertungsrahmen Tierhaltungsverfahren - Methode zur Bewertung von Tierhaltungsanlagen hinsichtlich Umweltwirkungen und Tiergerechtheit. KTBL-Schrift 446, Darmstadt.

Van Emous, R.A., B.F.J. Reuvekamp & T.G.C.M. Fiks, 2003.Ammoniakemissie bij verrijkte kooien (Ammonia emission of enriched cages). PraktijkRapport Pluimvee, nr 8. Ellen, H.H. & N.W.M. Ogink, 2009. Emissie-afleiding Kleinvoliere. Rapport/Animal Sciences Group, nr 234. Wageningen UR, Animal Sciences Group.

4.6.2 Techniques for non-cage housing of laying hens

Non-cage housing systems for egg production require a different management regime to egg production, and therefore need to be considered separately from the caged housing systems. The legal requirements set with Directive 1999/74/EC on the welfare of laying hens welfare and the market acceptation of systems that are considered animal-friendly have motivated the recent proliferation diffusion of these systems. There is little reported experience of any of these systems, so they are all given equal consideration. Therefore, no reference system has been identified, but the basic design described in Section 4.5.2.1.1 is used. A summary of the results of emission measurements is presented in Table 4.48 and Table 4.49.

Table 4.48: Summary of relevant reported achievable emissions in deep-litter based non-cage systems for laying hens.

Description	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	(kg/ap/yr)				(ou_E/ap/s)	
Section 4.6.2.1.1 Deep litter system for layers, with manure pit, manure belt or scraper						
Deep litter, with deep pit	0.320 (1)		0.006 (2)	0.12 (1)	0.143 (1) (3)	[64, Germany 2010]
Deep litter, with deep pit and veranda	0.320 (1)			0.12 (1)	0.143 (1) (3)	[65, Germany 2010]
Deep litter, with deep pit, veranda and free range	0.352			0.12	0.143 (1) (3)	[66, Germany 2010]
Deep litter, partly-slatted, with manure belts	0.052–0.068 (1)			0.084 (1)	0.34 – 0.61 (1)	[70, Netherlands 2010]
Barn system, ventilated	0.290 (4)	0.078 (4)		0.020 (4)		[85, UK 2010]
Section 4.6.2.1.2 Deep litter system with forced air manure drying						
Deep litter system with forced air manure drying	0.125					IRPP BREF 2003
Section 4.6.2.1.3 Deep litter system with perforated floor and forced drying						
Deep litter system with perforated floor and forced drying	0.110					IRPP BREF 2003

(1) Measured values.
(2) Modelled values (e.g. results based on N balance).
(3) Values have been calculated from an emission of 42 ou_E/s per LU and an average weight for laying hens of 1.7 kg.
(4) Values derived by expert judgement on the basis of few measurement results.

In general, emissions from laying hen housing systems equipped with manure belts will depend on the following parameters [508, TFRN 2012]:

A. length of time that the manure is on the belts;
B. drying systems;
C. poultry breed;
D. ventilation rate at the belt (low rate = high emissions)
E. feed composition.

Table 4.49: Summary of relevant reported achievable emissions in aviary-based non-cage systems for laying hens

Description	NH_3	CH_4	N_2O	PM_{10}	Odour	Reference
	(kg/ap/yr)				(ou_E/ap/s)	
Section 4.6.2.2.1 Aviary system with manure bels, with or without veranda and forecourt free ranges						
Non ventilated belts						
Aviaries, perch design, manure belts, removal once per week	0.250 (1)	0.200 (1)	0.180 (1)	0.10 (1)		[82, Austria 2010] [373, Austria 2010]
Litter-based with aviaries, veranda and free range	0.08 (2)	0.078 (2)		0.02 (2)		[86, UK 2010
Aviaries, one removal a week	0.090 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[60, Germany 2010] [474, VDI, 2011]
Aviaries, two removals a week	0.060 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[60, Germany 2010] [474, VDI, 2011]
Aviaries, veranda, one removal a week	0.090 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[61, Germany 2010] [474, VDI, 2011]
Aviaries, veranda, two removals a week	0.060 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[61, Germany 2010] [474, VDI, 2011]
Aviaries, veranda, outdoor, one removal a week	0.100 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[62, Germany 2010] [474, VDI, 2011]
Aviaries, veranda, outdoor, two removal a week	0.066 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[62, Germany 2010] [474, VDI, 2011]
Ventilated belts						
Aviaries, one removal per week	0.050 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[60, Germany 2010] [474, VDI, 2011]
Aviaries, veranda, one removal per week	0.050 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[61, Germany 2010] [474, VDI, 2011]
Aviaries, veranda, outdoor, one removal per week	0.055 (3)		0.002 (3)	0.15 (3)	0.102 (3) (5)	[62, Germany 2010] [474, VDI, 2011]
Aviaries system, perch design, ventilated manure belts, ventilation 0.7 m^3/h (30 – 35 % slatted floor)	0.019–0.025 (3)			0.065 (4)	0.34 (4)	[71, Netherlands 2010]
Aviaries, perch design, ventilated manure belts ventilation 0.7 m^3/h (55 – 60 % slatted floor)	0.037 (3)			0.065 (4)	0.34 (3)	[72, Netherlands 2010]
Aviaries system, perch design, ventilated manure belts, ventilation 0.2 m^3/h	0.055 (3)			0.065 (4)	0.34 (3)	[73, Netherlands 2010]

(1) Modelled values (e.g. results based on N balance).
(2) Values derived by expert judgement, based on few measurement results.
(3) Measured values.
(4) Values derived by expert judgement based on conclusions by analogy.
(5) Values have been calculated from an emission of 30 ou_E/s per LU and an average weight for laying hens of 1.7 kg.

4.6.2.1 Deep litter or floor regime systems

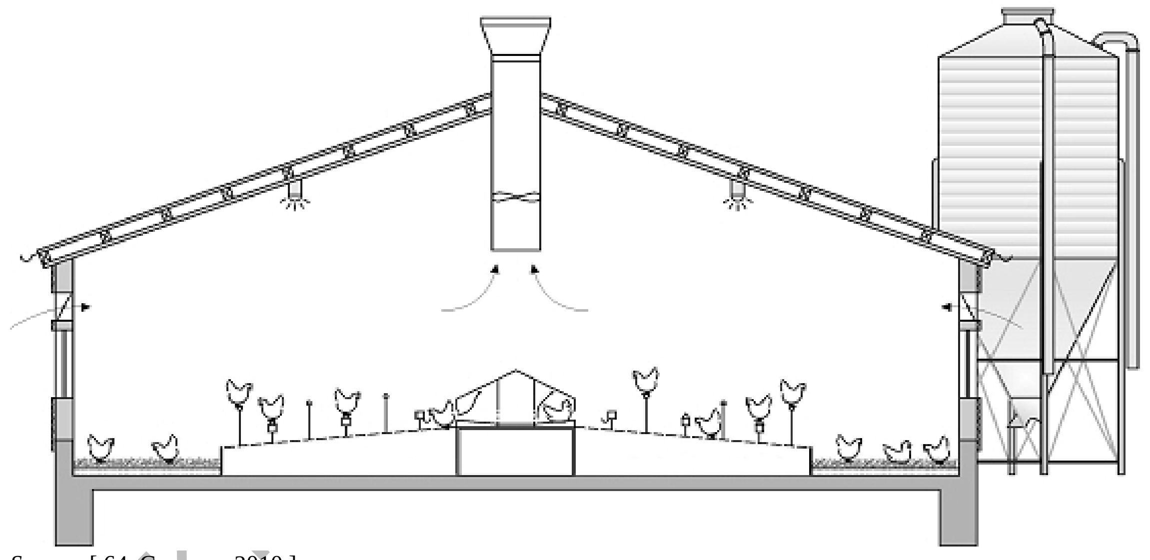
4.6.2.1.1 Deep litter system for layers with deep pit, manure belt or scraper, ~~or without veranda and forecourt free ranges~~

Description

The house floor is all or partly covered with litter, such as sand, wood shavings or straw that used for scratching and dust-bathing. The littered floor occupies at least one third of the total surface. The remaining consists of a ~~and partly~~ slatted floor, which area is at a maximun, two thirds of the available space, as required by Directive 1999/74/EC. The difference in height, between the bedding and slatted floor is maximum 50 cm. Each compartment (level) can have its climate control system. [70, Netherlands 2010] Perches are situated above the manure pit and functional areas for the birds are provided.

Underneath the slats there is a deep pit for manure of 80 to 90 cm in height [508, TFRN 2012], which can be equipped with scrapers or belts, with or without aeration. The removal by scraper is periodical. If the belts are ventilated, the manure removal can be weekly; otherwise, it takes place twice a week. The bedding over the solid area is distributed at the beginning of the laying cycle and litter is collected at its end, by mobile means.

The feeding and drinking systems are placed above the slatted floor (deep pit or the manure belts). A schematic representation of a deep litter system, with deep pit and partly-slatted floor is shown in Figure 4.11.

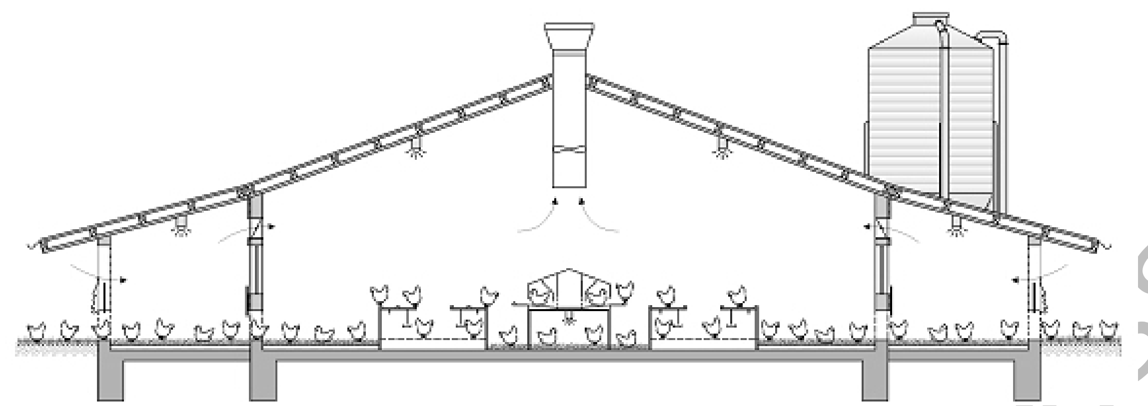


Source: [64, Germany 2010]

Figure 4.11: Schematic representation of a deep pit housing system for laying hens, equipped with partly-slatted floor

In general, the stocking density in these housing systems is up to 9 hens per m^2 of floor area.

Additional structures can be added inside or outside the house for better animal comfort, like verandas and free-court ranges. A schematic representation of the system is shown in Figure 4.12.



Source: [64, Germany 2010]

Figure 4.12: Schematic representation of a deep pit housing system for laying hens, with veranda and forecourt free range

Achieved environmental benefits

Ammonia emissions are reduced by a frequent removal of the manure from the belts, in particular when combined with manure drying on the belt through forced ventilation, and by reaching a high dry matter content of the litter ~~manure/bedding~~ in the top compartment.

No differences of emissions have been reported ~~from systems~~ with the use of verandas~~ or forecourts~~. Where forecourts are available, ammonia emissions are expected to be about 10 % higher than those produced indoor.

Cross-media effects

~~If natural ventilation is applied, the energy input is relatively low~~ **moved below**
As manure is obtained with a dry matter ~~dm~~ content of up to 80 %, a lot of dust can develop in the house as the birds move around freely.
The use of manure belts for the removal and forced ventilation for manure drying are associated with energy consumption and related indirect emissions for the production of electricity.

Operational data

For the birds, this system offers an almost full opportunity to display natural behavioural patterns. The house interior can be ~~is~~ structured to offer ~~in such a way that it has~~ different functional areas. This makes the system more bird-friendly than cage confinement. Also from a technical perspective, uniform house ventilation and lighting can be achieved more easily than in a cage house, and bird observation is simple.

The ammonia emissions vary from 0.052 to 0.320 kg ~~is approximately 0.315 kg~~ NH_3/bird place per year and to 0.352 kg/bird place per year in the case forecourts are available (see Table 4.48). In the case of a free range forecourt, an increase of NH_3 emission about 10 % is estimated.

In the UK, methane emissions have been estimated at 0.078 kg/bird place per year. In Germany, nitrous oxide emissions are estimated at 0.006 kg N_2O/bird place per year, for a deep litter system without manure belt or scraper. Odour emissions have been measured from 0.34 to 0.61 ou_E/bird place/second ~~per year~~ [70, Netherlands 2010]. Emissions of ~~The~~ PM_{10} fraction of dust that originate in belt systems can vary from 0.020 to 0.084 kg and to 0.240 kg per bird place per year.

Feeding and drinking features as well as the space per animal comply with Article 4 of Directive 1999/74/EC. The ventilation rates vary ~~are different~~ depending on the season: in the cold season from 0.5 to 2.8 m^3 per bird per year are applied, whereas in the warm season 3.5 to 6.9 m^3 per bird per year may be needed. Some examples of ventilation rates applied in Germany and in the Netherlands are reported in Table 4.50.

Table 4.50: Ventilation rates applied in deep litter housing systems for laying hens, equipped with deep pit, manure belts or scrapers

	Applied ventilation rates	
	Germany	**The Netherlands**
	m^3/h per bird place	m^3/h per bird place
Cold season	0.5 – 0.8	1.5 – 2.8
Warm season	3.1 – 6.9	3.5 – 4.4
Source: [63, Germany 2010] [64, Germany 2010] [65, Germany 2010] [70, Netherlands 2010]		

If natural ventilation is applied, the energy input is relatively low; however, under the climatic conditions of most areas in the European Union, natural ventilation is not applicable.

In Germany, the energy consumption is reported at 0.52 kWh/ap/yr for lighting and 2.2 kWh/ap/yr for ventilation, when non-ventilated belts are used. In the case of ventilated belts, the energy consumption is reported at 3.18 kWh/ap/yr.

Applicability

~~The system has been installed in existing constructions.~~ A change from a cage system to this floor regime would require a complete revision of the system. The width of the existing house is the most limiting factor for retrofitting existing constructions.

In existing houses, the placement of a manure belt or scraper in a manure pit underneath the slatted floor is not always possible and requires additional costs.

Economics

The basic investment required is in the range of EUR 20.40 to EUR 37.00 per bird place. If additional verandas or free ranges are added, the investment increases to EUR 44.40 per bird place. Reported information on costs associated with the implementation of a deep litter housing system with deep pit and partly littered floor is presented in Table 4.51. Data on resources demand are presented in Table 4.52.

Table 4.51: Cost data associated with different alternatives of deep pit in combination with partly littered floor, for laying hen housing

System configuration	Investment costs	Annualised investment costs	Annual running costs	Total Costs	Source
	EUR/yr	EUR/ap/yr			
No manure belt or scraper	37	3.9	3.2	7.1	[64, Germany 2010]
With manure belt and veranda	from 38 to 59	4.7	3.7	8.4	[65, Germany 2010]
No manure belt or scraper, with veranda and free range	44.4	3.9	NA	-	[66, Germany 2010]
With non-ventilated manure belt	20.4 (from 18.9 to 21.9)	3.05 (from 2.85 to 3.3)	0.05	3.1	[70, Netherlands 2010]
NA= not available					

Table 4.52: Resource demand associated with the different alternatives of deep pit in combination with partly littered floor, for laying hen housing

System configuration	Labour	Bedding material	Source
	h/ap/yr	kg/ap/yr	
No manure belt or scraper	0.21	0.29	[64, Germany 2010]
No manure belt or scraper, with veranda	0.19 – 0.26	0.5	[65, Germany 2010]
No manure belt or scraper, with veranda and free range	0.24 – 0.41	0.5	[66, Germany 2010]

Driving force for implementation

Proliferation of alternative systems ~~diffusion~~ has been stimulated by welfare legislation on laying hens and by some changes in the market towards the consumption of eggs from more animal friendly systems.

Non-environmental benefits are achievable; the housing system is animal friendly due to more space provided to the birds (compared to enriched cages) and to additional characteristics, like perches, separate functional areas, scratching areas, dust bath and external/climate stimuli.

Example plants

In the Netherlands, about 5 % of the laying hens in 2009 were reared with this system. In Germany the system is widespread.

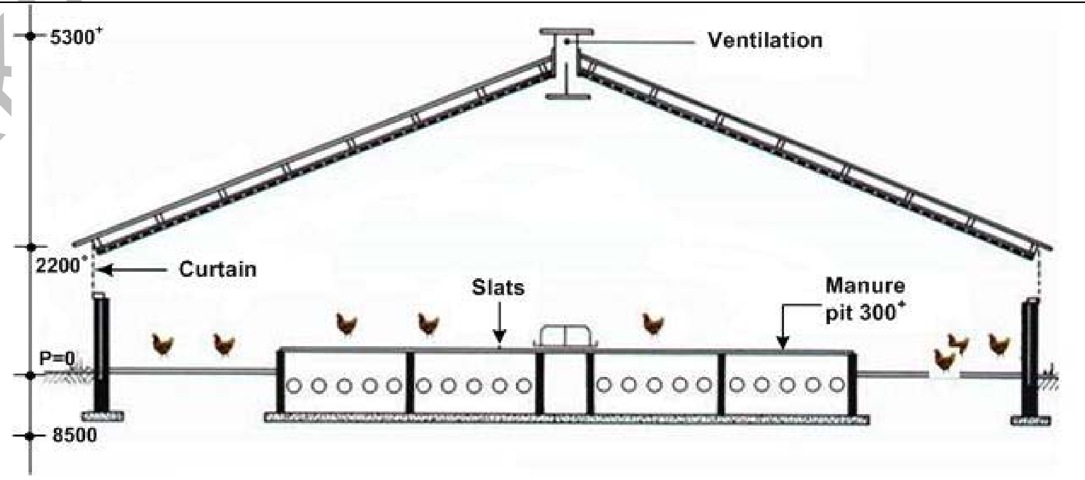
Reference literature

[39, Germany 2001], [44, Netherlands 2000], [506, TWG ILF BREF 2001], [64, Germany 2010] [65, Germany 2010] [66, Germany 2010] [70, Netherlands 2010] [85, UK 2010]

4.6.2.1.2 Deep litter system with forced air manure drying

Description

The deep litter system with forced air manure drying ~~This~~ is based on the previous system but here the ammonia emissions are ~~is~~ reduced by applying forced ventilation as shown in Figure 4.13. Forced ventilation is applied through tubes that blow 1.2 m^3 of air per bird place per hour at a temperature of 17 – 20 °C (pullets and layers have different requirements) over the manure stored under the slats or over the manure being removed by the (aerated) belts. [467, BE 2010]



Source: [44, Netherlands 2000]

Figure 4.13: Deep litter systems with forced drying via tubes under the slatted floor

Achieved environmental benefits

The application of forced ventilation and the quick drying of the manure reduce~~s~~ ammonia emissions. ~~to 0.125 kg NH_3 per bird place per year for the pit storage. The ammonia reduction of this system is 60 % compared to the reference system (0.315 kg NH_3).~~ Frequent removal with (aerated) manure belts can be expected to give even lower emission levels.

Reduced odour levels can be expected. ~~compared to the reference system.~~

Cross-media effects

The energy input in this system is high, because a heating system must be installed to achieve the 20 °C temperature necessary in the tubes. Extra energy is also required to maintain the airflow. Air is drawn in through inlets in the side walls and though an open ridge construction in the roof.

Aeration may trigger nitrification reactions that may result in an increased emission of N_2O. In general, due to the dried manure higher dust emissions are expected.

Operational data

Management of this system is principally the same as ~~of~~ the reference deep litter design. Ammonia emissions of 0.125 kg NH_3 per bird place per year are associated with this system.

Applicability

The system can only be used in laying hen houses with enough space underneath the slats. Traditionally the manure pit has a depth of 80 cm, but when using this system it is necessary to add an extra 70 cm. The experience of ~~from~~ farmers already using the deep floor system is that ~~they like~~ this type of system ~~because it~~ requires very little change to the traditional design.

Economics

~~Compared with the reference system (Section 4.6.2.1.1), the extra investment costs are EUR 1.10 per bird place. The extra annual costs are EUR 0.17 per bird place. This means that with a 60 % ammonia reduction (0.315 to 0.125 kg NH_3), the cost is about EUR 5.78 per kg NH_3 abated.~~

The total cost for implementing this system in Belgium-Flanders is 32 EUR/bird place (VAT excluded), which corresponds to 3.15 EUR/bird place extra-cost in comparison with a conventional deep pit system (11 % higher). The additional energy requirements for the ventilation amount to 0.17 EUR/ap/yr. [265, BE Flanders 2010]

Example plants

In the Netherlands, around 1 129 000 birds are housed in this type of system, about 3 % of the total Dutch laying hens population. [468, CBS 2011] In Belgium-Flanders, 10 systems (including farms above and below the capacity threshold set by Dircetive 2010/75/EU, Annex I) have been built since 2004.

Reference literature

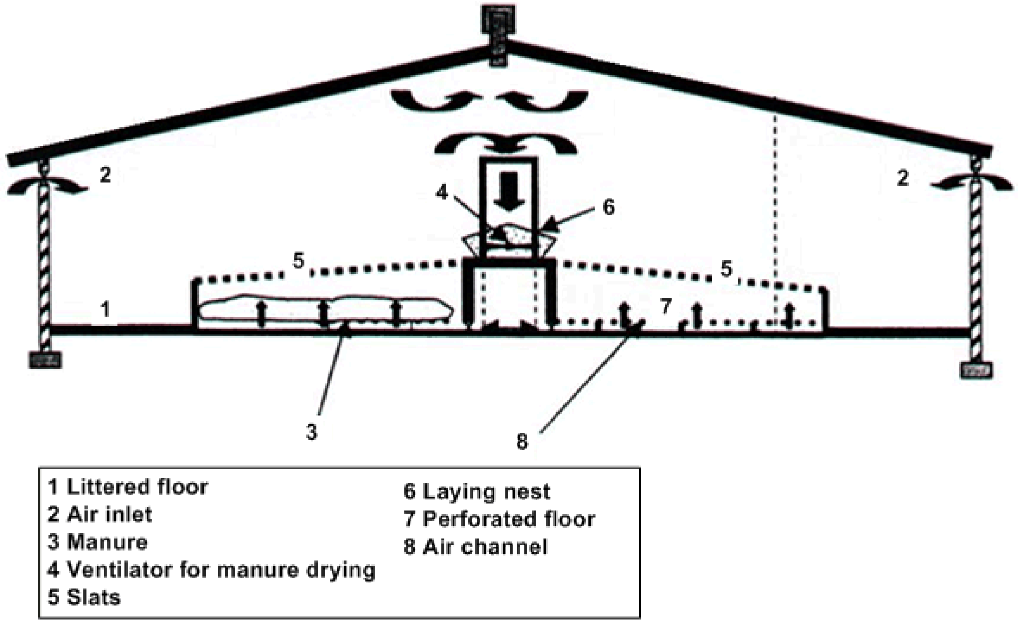
[41, Netherlands 2001], [39, Germany 2001] [467, BE 2010] [506, TWG ILF BREF 2001]

4.6.2.1.3 Deep litter system with perforated floor and forced drying

Description

~~There is~~ A perforated floor is placed in the manure pit underneath a partially elevated slatted floor ~~and the slats~~, which allows for forced air blowing from below ~~transportation of the air used~~ in order to dry the manure on top of it (Figure 4.14).

The ~~layer~~ house is a simple traditional building. ~~(walls, roof, etc.)~~ The ratio of litter to ~~"~~slatted floor~~"~~ is 30: 70; the bedding area is 30 % and slatted floor 70 % of the total area. The laying nest area is included in the slatted floor area. ~~The distance between and~~ The perforated floor (air channel) is situated at least ~~must be~~ 10 cm from the the bottom of the pit (aeration space). The manure pit available under the slatted area must be large enough to store and dry the manure generated during the entire production period, so that the total available height between the slats and perforated floor should be at least 80 cm. perforated floor must be able to support a weight of 400 kg/m² (including weight of the dry manure) The construction of the ~~The maximum load of this~~ perforated floor must be able to support a weight of about ~~is often~~ 400 kg/m^2 (including the weight of the dry manure). This false floor should be evenly perforated and. ~~The perforated floor has a~~ the total area of air openings should be at least ~~of~~ 20 % of the surface ~~area~~.



Source: [44, Netherlands 2000]

Figure 4.14: Deep litter system with perforated floor and forced manure drying

Achieved environmental benefits

~~It is possible to obtain a 65 % reduction in NH_3 emissions (0.110 kg compared to the 0.315 kg NH_3 per bird place per year of the reference system).~~

Ammonia emissions are reduced as an effect of ~~drying the~~ manure drying.

Cross-media effects

Higher energy input is required because of the forced ventilation. Manure aeration may trigger nitrification reactions that may cause an increase of N_2O. In general, due to the dried manure higher dust emissions are expected.

Operational data

The layer droppings fall through the slats onto the perforated floor. At the beginning of the laying period, on top of the perforated floor ~~is provided with~~ a 4 cm thick bed of wood shavings or sawdust is scattered. ~~The (preheated)~~ Air from the shed is blown from beneath through the small openings in the perforated floor under the manure. To dry the manure properly, at least two ventilators with ~~a total~~ minimum capacity of around 7 m^3 air/hour and capable to overcome a high pressure resistance (minimum 90 Pa) ~~P Pascal~~ need to be ~~are~~ installed. Different placement options are possible for the ventilation units (see Section 4.6.5.4).

The manure stays on the perforated floor for about 50 weeks (laying period) and is then taken out of the house. ~~The minimum distance between the perforated floor and the slats is 80 cm.~~ The manure is dried constantly by the continuous flow of air. The dry matter content of the manure is about 75 %.

Bedding is spread at the start of the flock and two more times during the rearing period, in order to maintain a 0.7 kg/m^2 bed density of wood shavings. Functional areas are above the dropping area

~~The farmer should protect himself from breathing dust with a face mask~~ **(see under cross-media effects).** Reported values of ammonia emissions are 0.110 kg/bird place per year.

The drinking facilities must be installed on top of the slats, but a good design of the tubes prevent the ~~should avoid~~ loss of water.

Applicability
The application of this technique in new installations ~~situations~~ is ~~more~~ likely, but it could also be installed in existing houses, but at an additional cost.

Economics
Investment required is ~~costs are~~ EUR 1.20 per bird place and annual costs are EUR 0.18 per bird (see also Section 4.6.5.4).

Driving force for implementation
Please TWG provide information

Example plants
In the Netherlands, about 276.000 bird places are built with this technique that represents 1 % of the total Dutch availability. [468, CBS 2011]

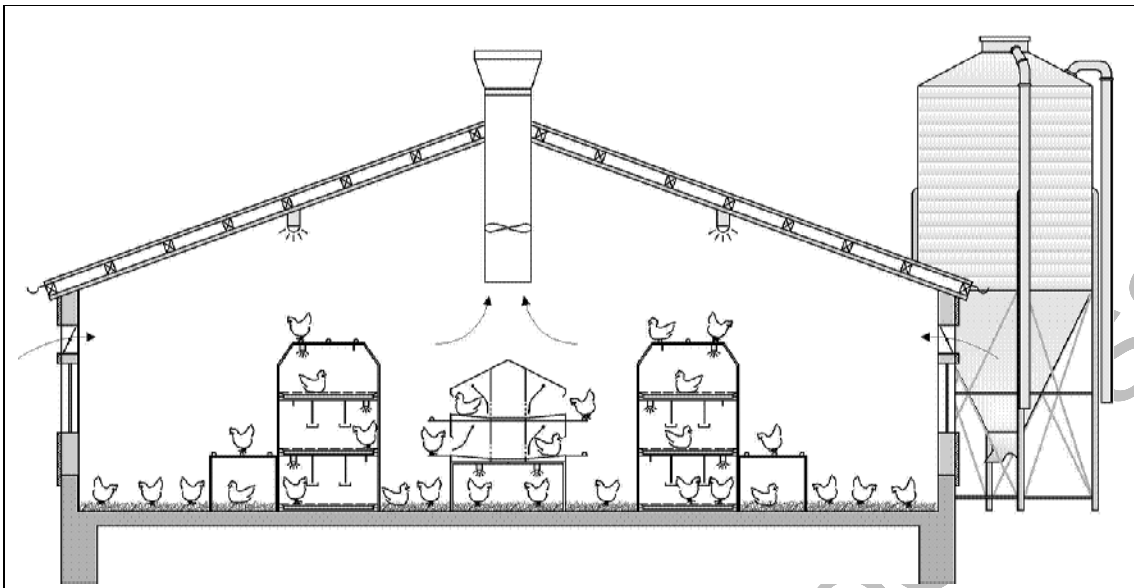
Reference literature
[44, Netherlands 2000] [506, TWG ILF BREF 2001] [545, Netherlands 2002] [108, BE Flanders 2010] [111, Netherlands 2010]

4.6.2.2 Aviary systems

~~The housing space is divided into different functional areas for feeding and drinking, sleeping and resting, scratching and egg-laying. The available surface area is increased by means of elevated floors combined in stacks. General descriptions are given in Sections 2.2.1.2.2, 2.2.1.2.3 and 2.2.1.2.4.~~ **MOVED BELOW**

4.6.2.2.1 Aviary system with manure belts, with or without veranda and forecourt free ranges

Description
The building is divided into different functional areas used for feeding and drinking, laying eggs, scratching and resting. Nests to lay eggs can be integrated or non-integrated into the equipment (see Sections 2.2.1.2.2 and 2.2.1.2.3). Functional areas for feeding, drinking and resting are arranged above the dropping area. The indoor available surface area is increased by means of elevated slatted floors, combined with stacks, allowing a stock density of up to 18 hens per m^2 of floor area. ~~About 50 % of the indoor usable area is on slatted floor and~~ A minimum of two tiers are ~~present.~~stacked over the slatted floor. The slat coverage can range from 30 – 35 % up to 55 – 60 % of the total available area. The remaining of the floor is typically littered. Manure belts collect and remove the droppings under the slatted floors. ~~and~~ The belts can be equipped with plastic pipes through which forced air ~~drying~~ ~~dries~~ is ventilated in order to dry the manure (0.2 m^3/h per animal, at a minimum temperature of 18 °C, or 0.7 m^3/h per animal at a minimum temperature of 17 °C). Typically, manure is removed at least ~~once or~~ twice a week, with non-ventilated belts, and once per week, when pre-drying is carried out on ventilated belts. The housing system can be combined with veranda and free ranges. A scheme of the system is given in Figure 4.15.



Source: [60, Germany 2010]

Figure 4.15: Scheme of a litter-based aviary for laying hens

Achieved environmental benefits

The ~~quick drying and the~~ frequent removal and the possible fast pre-drying of manure allow ammonia emissions reduction. The additional droppings ventilation through the belts enhances the manure drying and therefore the emission reduction. If the system is designed such that the hens have only access to the litter via the lowest aviary level, less dust is emitted.

Aviary systems with manure belts for frequent collection and removal of manure to closed storage reduce ammonia emissions by 70 % compared to the deep litter systems. [508, TFRN 2012]

Cross-media effects

~~Separated functional areas are available to birds that therefore offer more possibilities to carry out natural behaviour. Little labour for cleaning is needed.~~ **Moved to driving force for implementation**

If the access to the litter is not restricted, more dust is emitted compared to cage systems due to the presence of litter material and to the increased animal activity.

Additional electric energy consumption is needed for the ventilation of the manure belts, which is associated with indirect emissions.

Operational data

Depending on the manufacture and whether the manure is removed once or twice per week, ammonia emissions with the use of ventilated manure belts are in the range of 0.019 and 0.055 ~~0.060 kg~~ per animal place per year. Emissions from non ventilated belts have been measured between 0.060 ~~0.090~~ and 0.290 kg per animal place per year. Refer to Table 4.49 for a complete summary of provided emission data.

Nitrous oxide emissions have been estimated in Germany to be about 0.002 kg N_2O per animal place per year. PM_{10} emissions are in the range of 0.065 to 0.150 kg per animal place per year. In the Netherlands, odour emissions are estimated at 0.34 ou_E per animal place per year.

Emission data concerning an Austrian n aviary system operating with manure belts and removal once per week, and manual removal of the litter every three months, storage of the manure in a closed barn until further transport have been calculated. ~~easured as the following: (figures per~~

animal place per year): The results of the calculation showed ammonia emissions at 0.25 kg/ap/yr, methane at 0.2 kg/ap/yr, N_2O at 0.18 kg/ap/yr and PM_{10} at 0.1 kg/ap/yr.. [82, Austria 2010] [373, Austria, 2009]. In the UK, emissions are estimated as follows (figures per animal place per year): ammonia: 0.08/ap/yr, 0.09 to 0.29 kg, methane: 0.078 kg/ap/yr;PM_{10}: 0.02 kg/ap/yr.

If the access to the litter is not restricted, more dust is emitted compared to cage systems, due to the presence of litter material and to the increased animal activity; e.g. from Germany it is reported that for a system designed to allow the hens only have access to the litter via the lowest aviary level, dust emission is lowered (PM_{10} decreases from 0.15 kg/ap/yr) to 0.039 kg/ap/yr. [474, VDI, 2011]

The typical bird densities of the aviary systems with manure belts are between 0.11 and 0.134 m^2/bird.

Compared to the cage systems, there are higher more management is needed requirements. On a daily basis these operations must should be performed: control of animals and bedding; collection of eggs that have been laid from the nests; access to the free range during the daytime. Additionally, a regular routinary care of the forecourts and of the parasitological conditions must be carried out.

The removal of the manure that is not conveyed by belts is done every three months [82, Austria 2010] or at the end of the cycle.

Electric consumption per animal place per year is around 0.52 kWh for lighting and 2.1 kWh for running the system. Additional consumption for the ventilation of the manure belts is around 1.6 kWh/animal place per year. [60, Germany 2010]. The typical ventilation rates reported for aviary systems equipped with manure belts are presented in Table 4.53.

Table 4.53: Reported ventilation rates for aviary systems for laying hens equipped with manure belts

	Ventilation rate (m^3/ap/h)	
	Germany	**The Netherlands**
Cold season	0.5 – 0.8	1.9 – 2.26
Warm season	3.1 – 6.9	2.8 – 3.46
Source: [60, Germany 2010] [61, Germany 2010] [62, Germany 2010] [71, Netherlands 2010] [72, Netherlands 2010] [73, Netherlands 2010]		

In the case of aviary systems equipped with a free range, an increase of NH_3 emissions of about 10 % is estimated; however, in general no major differences are reported for ammonia emissions for different configuration. [571, DE, 2011]

Applicability
No limitation exists for applying the systems either in small or large farms. In the planning of new farms the system and the size of the building can be adapted to each other. Retrofitting an aviary in existing houses depends mostly on the shed width.

Economics
In the Netherlands, an investment of EUR 13.50 to EUR 16.50 per animal place is required. With an annual running cost of EUR 0.11 per animal place, the total annual cost is estimated around EUR 2.36 per animal place.

In Germany costs have been calculated in relation to the additional facilities that might be installed. The bare investments for aviary with or without a veranda are estimated at EUR 31 per animal place, and they may rise to EUR 38 if free ranges are provided. Hence, for normal depreciation and rate, the annualised investment is in the range of EUR 3.60 to EUR 4.40 per animal place. The annual running costs are estimated as EUR 2.80, EUR 2.90 to EUR 4.40 for the basic facility, for housing with verandas and for the version with additional free ranges respectively. A summary of cost data related to different configurations of the aviary systems equipped with manure belts is given in Table 4.54.

Table 4.54: Summary of cost data for different configurations of aviary systems for laying hens

System configuration	Investment costs	Annualised investment costs	Annualised running costs	Total costs	Source
	EUR/yr	EUR/ap/yr			
No ventilated belt, 1-2 removals per week	31	3.6	2.8	6.4	[60, Germany 2010]
Ventilated belt with 0.7 m^3/h/bird, removal once per week	14.1 (from 12.6 to 15.6)	2.1 (from 1.9 to 2.3)	0.2	2.3	[71, Netherlands 2010] [72, Netherlands 2010]
Ventilated belt with 0.2 m^3/h/bird, removal once per week	15 (from 13.5 to 16.5)	2.25 (from 2 to 2.5)	0.11	2.36	[73, Netherlands 2010]
No ventilated belt, with veranda, 1-2 removals per week	31	3.6	2.9	6.5	[61, Germany 2010]
No ventilated belt, with veranda and free range, 1-2 removals per week	28 – 38	4.4	4	8.4	[62, Germany 2010]

Labour demand associated with the implementation of aviary systems is reported between 0.16 and 0.19 h/ap/yr. Energy consumption is reported at 0.52 kWh/ap/yr for lighting, 2.1 kWh/ap/yr for the use of non ventilated belts and 3.7 kWh/ap/yr for ventilated belts.

The quantity of bedding material used with non ventilated belts and 1 or 2 manure removals per week is between 0.075 and 0.16 kg/ap/yr; values increase in the case of configurations that include a veranda (0.26 kg/ap/yr), or a veranda plus a free range (0.29 kg/ap/yr).

Driving force for implementation

The system allows reasonable egg losses and high stocking densities. Aviaries are more animal friendly compared to enriched cages due to more space provided per bird and for the improved benefits of perches, functional areas, scratching areas, dust bath and external/climate stimuli.

Separated functional areas are available to birds, ~~that~~ therefore, ~~offer~~ there are more possibilities for the birds to manifest ~~carry out~~ their natural behaviour. ~~Little labour for cleaning is needed~~

Example plants

In the Netherlands, about 15 % of the farms in 2008 were equipped with systems of this type. About 50 installations in Belgium-Flanders are equipped with this system.

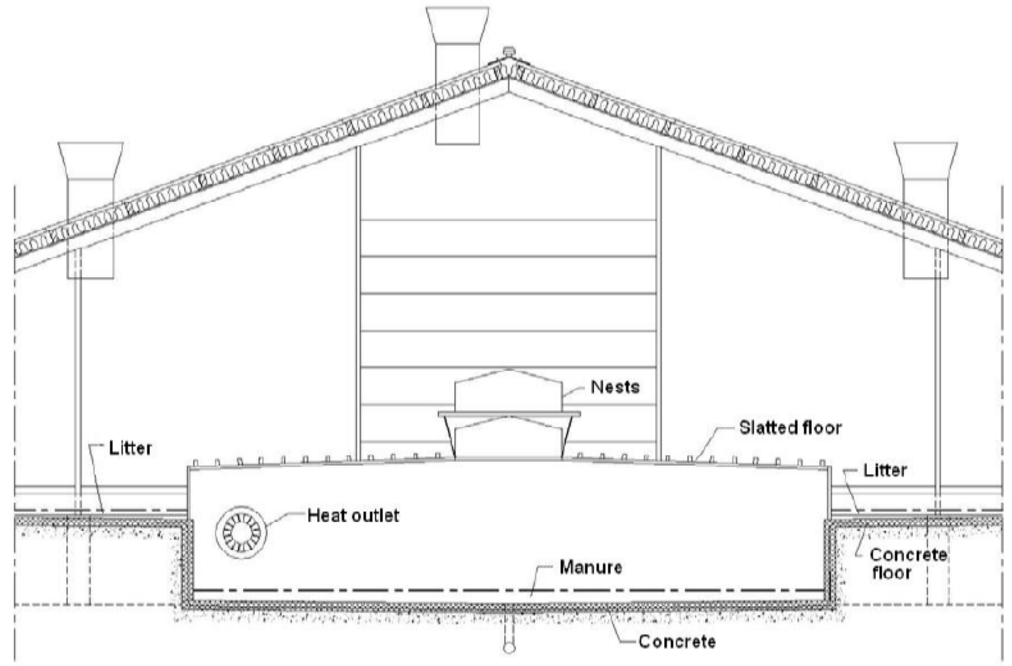
Reference literature

[60, Germany 2010] [61, Germany 2010] [62, Germany 2010] [71, Netherlands 2010] [72, Netherlands 2010] [73, Netherlands 2010] [82, Austria 2010] [86, UK 2010] [467, BE 2010]

4.6.2.2.2 Aviary system with underfloor manure drying

Description

Aviaries are built with a deep litter under a slatted floor. In the pit, manure drying is performed and the manure is stored during the egg-laying period that lasts typically 13 – 15 ~~18~~ months. The system differs from traditional houses ~~stables~~ by having a manure pit at least 70 cm deep (see Figure 4.16). A ventilation outlet circulates heated air in the manure pit to dry the droppings. Drying ~~The crust that it~~ creates a crust on top of the manure which reduces the degradation of urea to ammonia and ammonium.



Source: [59, Denmark 2010]

Figure 4.16: Scheme of the manure drying system in aviaries with a deep pit

Achieved environmental benefits

A reduced volatilisation of ammonia and odour compounds is achieved and as a consequence better indoor air quality is achieved ~~possible~~. A higher nitrogen content in the fertilising manure results.The increase in nitrogen content of the manure can substitute chemical fertiliser.

Cross-media effects

Additional energy to heat and blow air onto the pit surface is required.

Operational data

With the droppings drying, the manure dry matter content is ~~raised~~ increased from the ~~initial~~ typical 40 % (without drying) to about 80 %. The ~~power~~ energy consumption related to ~~this operation~~ manure drying is ~~estimated~~ reported at 130 kWh per 'animal unit' (one Danish 'animal unit' is defined as the livestock that produces manure with a content of 100 kg of N), which corresponds to approximately 0.65 kWh per bird (an equivalent of 200 laying hens to one Danish animal unit is assumed). The required energy consumption is also reported from Denmark at 0.78 kWh/ap/yr.

Heated ventilation is only required when the indoor house temperature falls below 20 °C. The best results are achieved by ventilating 1.2 m^3 of air per animal unit per hour, ~~making a~~ allowing a possible reduction of 60 % of ammonia emissions in comparison with a similar system without the underfloor manure drying.

Applicability
The system is typically implemented in new constructions. Manure drying can be installed in existing buildings but deepening manure pits is a prerequisite for this technique.

Economics
The accumulated additional cost of the manure drying is estimated to be approximately 2 % or 1.5 % of the total annual cost of maintaining each layer hen, whether in the calculation the value of the saved N is excluded or included. Reported cost data from Denmark indicate an additional investment cost of 0.40 EUR/bird/yr, excluding the benefits from saved nitrogen (less chemical fertiliser), corresponding to 3.9 EUR/kg N reduced. Annual costs, including the benefits from saved nitrogen are reported at 0.23 EUR/bird/yr corresponding to 2.13 EUR/kg N reduced. [58, Denmark 2010]

Driving force for implementation
Improved indoor environment, due to reduced ammonia and odour, as a consequence of dry manure below the slats, and resulting in improved animal welfare. Dried manure is easier to handle and remove. Increased fertiliser value, due to higher nitrogen content.

Example plants
Different configurations of the manure drying technique are applied in the Netherlands and in Germany.

Reference literature
[58, Denmark 2010] [59, Denmark 2010]

4.6.3 Techniques for the housing of pullets

The systems used to rear pullets of laying hens are practically the same as those used to house laying hens. The differences in the management induce different environmental impacts, as a consequence of different heating needs, of the different live weight and of the different metabolisms of the animals.

In the following sections, for each technique only data related to the specific pullet rearing are given, since techniques have already been described in Section 4.6.1 and Section 4.6.2 for layers rearing. The emission values that are associated with pullet rearing and that have been measured are reported in Table 4.55. In Germany, typically the emission factors associated with the rearing of pullets (until 18^{th} week) are considered equivalent to 70 % of the values applied for the same technique in laying hen housing. [474, VDI, 2011]

Table 4.55: Summary of reported achievable emissions in systems for rearing pullets

Description	NH_3 kg/ap/yr	PM_{10} kg/ap/yr	Odour ou_E/s/ap	Source
Traditional cage system, without forced air drying	0.045			Reference system (NL)
Section 4.6.3.1.1 Small groups in enriched cages				
Small groups in enriched cages	0.016 (1)	0.008 (1)	0.18 (1)	[80, Netherlands 2010]
Section 4.6.3.1.2 Aviaries				
Aviaries on solid floor with litter. Non-ventilated manure belts, one removal per week ~~Deep litter with aviaries~~	0.064 (2)	0.080 (2)	0.042 (2)	[81, Germany 2010]
Aviaries on solid floor with litter. Non-ventilated manure belts, removal twice per week	0.04 (2)	0.080 (2)	0.042 (2)	[474, VDI 2011]
Aviaries on solid floor with litter. Ventilated manure belts, removal once per week	0.03 (2)	0.080 (2)		[474, VDI 2011]
Aviaries on at least 55 % slatted floor. Non-ventilated manure belts, removal once per week	0.050 (1)	0.023 (1)	0.18 (3)	[79, Netherlands 2010]
Aviaries on at least 65 – 70 % slatted floor. Ventilated manure belts (0.2 m^3/h/bird at 20 °C), removal once per week	0.029 – 0.030 (3)	0.023 (1)	0.18 (3) 0.181-0.227 (3)	[74, Netherlands 2010]
Aviaries on at least 45-35 slatted floor. Ventilated manure belts (0.1 m^3/h/bird at 18°C), removal once per week	0.030 (1)	0.023 (1)	0.18 (3)	[75, Netherlands 2010]
Aviaries on at least 30-35 slatted floor. Ventilated manure belts (0.4 m^3/h/bird at 17°C), removal once per week	0.014 (1)	0.023 (1)	0.18 (3)	[76, Netherlands 2010]
Aviaries on at least 55-60 slatted floor. Ventilated manure belts (0.4 m^3/h/bird at 17°C), removal once per week	0.020 (1)	0.023 (1)	0.18 (3)	[77, Netherlands 2010]
Section 4.6.3.1.3 Deep litter with or without manure pit				
Deep litter without manure pit	0.210 (2)	0.120 (2)	0.056 (2)	[49, Germany 2010]
Deep litter with manure pit	0.170 (1)	0.030 (1)	0.18 (3)	[48, Netherlands 2010]

(1) Values derived by expert judgement based on conclusions by analogy.
(2) Modelled values (e.g. results based on N balance).
(3) Measured values.

4.6.3.1.1 Small groups in enriched cages

Description
Refer to Section 4.6.1.2.

Achieved environmental benefits
Refer to Section 4.6.1.2.

Cross-media effects
Refer to Section 4.6.1.2.

Operational data
Under the vertical tiered cages a manure belt is installed. Air is blown through the forced air drying system at 0.4 m^3/h/bird, with a minimum temperature of 17 °C, and it should be fresh. Functional areas for feeding, drinking and resting are arranged above the dropping area. Manure is removed weekly, with a minimum dry matter content of 55 %.

~~Animals~~ Birds are kept at a density of 350 – 450 cm² per head. In the Netherlands, the minimum available space per bird is reported at 450 cm^2 per head.

In the Netherlands, estimations were derived from data of laying hens housed in the same system. Ammonia emissions of 0.016 kg and of PM_{10} emissions of 0.008 kg can be associated with each animal place per year when the manure is dried on belts, with an air flow of 0.4 m^3 per animal per hour at 17 °C and removed daily.

Applicability
Refer to Section 4.6.1.2.

Driving force for implementation
Pullets should be raised in the same system they are placed in during laying period. It is expected that the use of small group enriched cages, as an alternative system, will increase in the future due to animal welfare legislation.

See also Section 4.6.1.2.

Example plants
At the time of writing (2013), no enriched cage housing systems for rearing pullets are yet in use in the Netherlands. Also in Germany, the system is not yet described as a technique for rearing young hens [[474, VDI 2011]

See also Section 4.6.1.2.

Reference literature
[80, Netherlands 2010]

4.6.3.1.2 Aviaries

Description
Refer to Section 4.6.2.2.

Achieved environmental benefits
Refer to Section 4.6.2.2.

Cross-media effects
Higher dust emissions compared to enriched cage systems, due to litter material and increased animal activity; dust exposure could be a problem for the farmer and the birds.

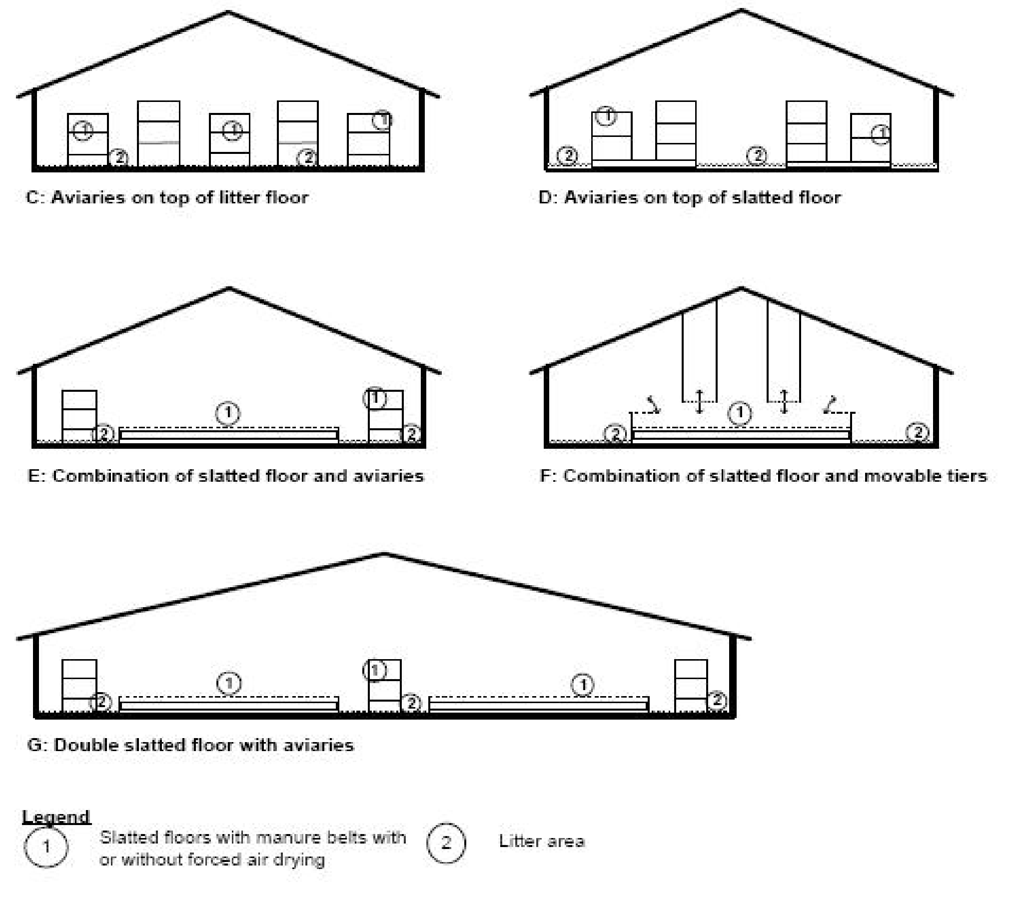
See also Section 4.6.2.2.

Operational data

Elements typical of the aviary systems are placed in the house; birds can use the entire available space. Variations with fully solid floor or partly-slatted floor are reported. In the first case the aviaries ~~can~~ rest over a continuous solid littered floor; ~~but more frequently~~ in the second case, aviaries ~~they~~ are associated with a slatted floor in various combinations as explained in Figure 4.17. The extension of the slatted floor in relation to the total available surface is also variable. In the case of partly-slatted floor, manure belts are installed underneath the floors where manure can be dried with forced air through pipes placed above, or along the belts, after the first two weeks of the rearing period. In the variation of solid floor, the dropping area is equipped with a manure belt. The scratching area is cleaned by mobile means.

When manure belts are equipped with forced air drying (0.2 m^3/h/bird at 20 °C, with removal once per week), a minimum dry matter content of 55 % is reported.

The housings are not equipped with veranda or free outdoor ranges. The birds ~~animals~~ are kept at variable densities, from 0.030 to 0.062 m^3 per head.



Source: [78, Netherlands 2010]

Figure 4.17: Combinations of slatted floors in aviaries

The emission levels that are achievable depend on the extension of the slatted floor, on the frequency of manure removal and on the temperature and volume of the air that is blown over the droppings to dry them. The more surface is slatted, the more manure is periodically removed by the belts that underlie the raised floors. The figures for different combinations of manure belts management are given in Table 4.56.

Table 4.56: Emissions associated with combinations of slatted floor extension, characteristics of the drying air and frequency of manure removal, for the rearing of pullets

Combination	Animal density	Air volume	Air temp.	Slatted floor	Removals per week	NH_3 emission	PM_{10} emission	Reference
	m²/animal	m³/ap/h	°C	%		kg/ap/yr	kg/ap/yr	
Without forced air drying	0.062	-	-	55	1	0.050 (1)	0.023 (1)	[79, Netherlands 2010]
Fresh forced air	0.062	0.4	17	35	1	0.014 (1)	0.023 (1)	[76, Netherlands 2010]
Fresh forced air	0.062	0.4	17	60	1	0.020 (1)	0.023 (1)	[77, Netherlands 2010]
Low ventilation	0.062	0.1	18	50	1	0.030 (1)	0.023 (1)	[75, Netherlands 2010]
Warm forced air	0.062	0.2	20	70	1	0.030 (2)	0.023 (1)	[74, Netherlands 2010]
Forced air	0.030	NA	NA	0	1	0.030 (3)	0.080 (3)	[474, VDI 2011]
Solid floor	0.030	-	-	0	1	0.060 (3)	0.080 (3)	[81, Germany 2010]
Solid floor	0.030	NA	NA	0	2	0.040 (3)	0.080 (3)	[474, VDI 2011]

NA = not available
(1) Values derived by expert judgement based on conclusions by analogy.
(2) Measured values.
(3) Modelled values (e.g. results based on N balance).

Applicability
Refer to Section 4.6.2.2.

Economics
In the Netherlands, the investment required is estimated in EUR 7.35 per animal place on average (from 6.25 to 7.8 EUR/ap) corresponding to annualised investment costs of 0.92 EUR/ap/yr (from 0.78 to 0.98 EUR/ap/yr). In Germany, investment costs are reported at EUR 11.20 per animal place, on average, corresponding to annualised costs of 1.25 EUR/ap/yr.

Driving force for implementation
Refer to Section 4.6.2.2.

Example plants
In the Netherlands, in 2008 about 33 % of pullets were housed in aviary systems. At least 15 farms in Belgium-Flanders are equipped with this system [467, BE 2010]

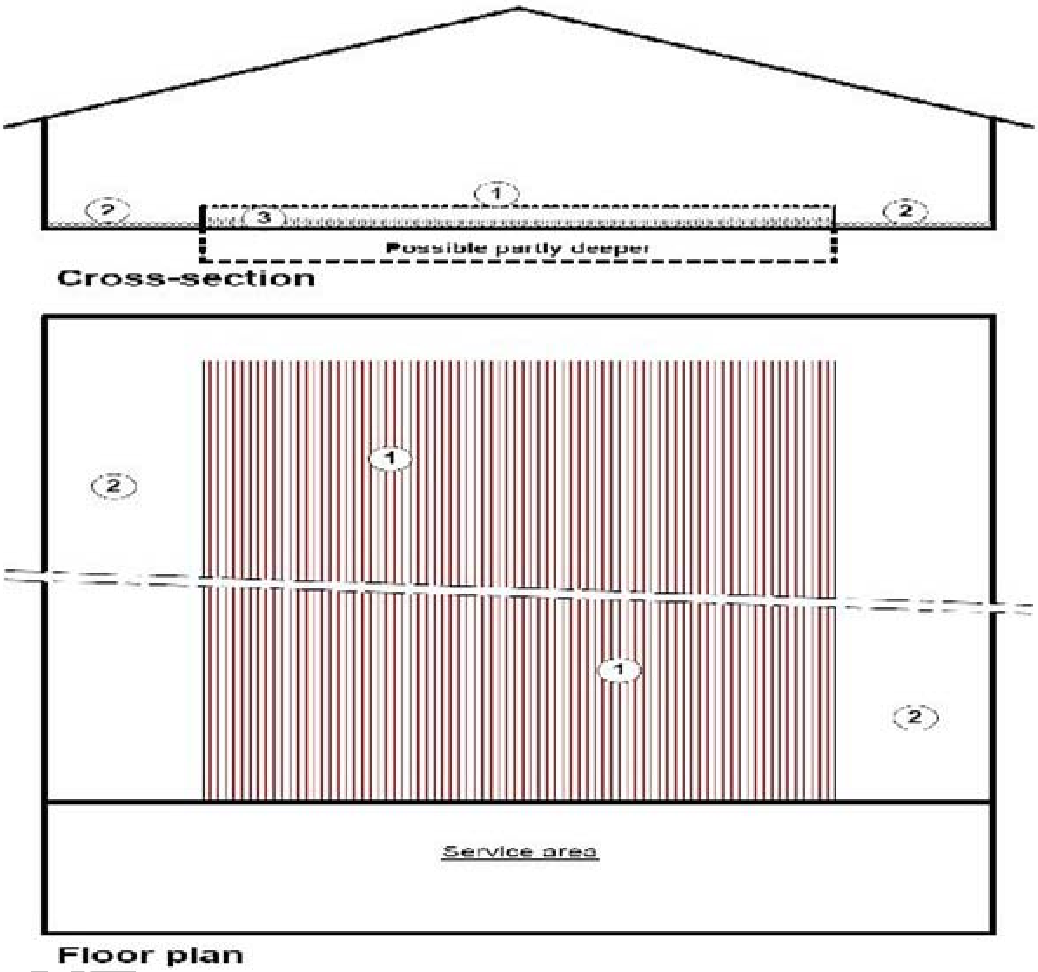
Reference literature
[74, Netherlands 2010] [75, Netherlands 2010] [76, Netherlands 2010] [77, Netherlands 2010] [79, Netherlands 2010] [81, Germany 2010]

4.6.3.1.3 Deep litter with or without manure pit

See also Section 4.6.2.1.

Description
Pullets are raised in a house with a concrete floor with bedding material (wood shavings or chopped straw). It is possible that in the middle of the house there is a manure pit with a slatted floor above it. Slatted surface is reported not to exceed two-thirds of the total area. The manure is stored beneath the slatted floor and is removed after delivery of the flock. For configurations without a manure pit, manure is removed by mobile means.

A cross-section of a housing system with deep litter and manure pit, for the rearing of pullets is shown in Figure 4.18.



Legend
pendix 1. Slatted floors
pendix 2. Littered area
pendix 3. Manure pit
Source: [1876 not a reference, Netherlands 2010]

Figure 4.18: Cross-section of the housing system with a deep litter and a manure pit

Achieved environmental benefits
Refer to Section 4.6.2.1.

Cross-media effects
Higher ammonia and odour emissions, due to manure storage in the housing system and only removal at the end of the rearing period. Higher dust emissions compared to cage systems, due to litter material and increased animal activity; dust exposure could be a problem for the farmer and the bird.

Operational data
Functional areas for feeding, drinking and resting are arranged above the dropping area. The system has increased management requirements, in particular for the rearing in confinement rings, during the first days after birth (up to 7 days), when several checks are necessary on a daily basis, during the first days (e.g. control of chicks and temperature). Later, at least a daily control of the birds and the bedding is sufficient.

The available space provided per bird is reported between 0.0625 and 0.07 m^2 and the duration of the growing period is reported between 16 and 18 weeks; the animal weight at the end of the rearing period is around 1.3 kg.

Applicability
Refer to Section 4.6.2.1.

Driving force for implementation
Pullets should be raised in the same system they are placed in during the laying period.
The system is more animal friendly, due to more space availability (compared with cages).

Economics
In Germany, for the configuration without a manure pit, the demand for bedding material is reported equivalent to 2.3 kg/ap/yr, the labour demand 0.03 h/ap/yr, and the energy consumption is reported at 0.52 kWh/ap/yr for lighting and 2.2 kWh/ap/yr for ventilation.

In the Netherlands, for the configuration with manure pit, investment costs are reported from 2.65 to 4 EUR per animal place, with an average value of 3.35 EUR per animal place, and the annualised investment costs vary from 0.33 to 0.5 EUR/ap/yr, with an average value of 0.42 EUR/ap/yr.

Example plants
In the Netherlands, the deep litter system with manure pit is the reference housing system for raising pullets. The deep litter technique without manure pit is also widespread in Germany

Reference literature
[48, Netherlands 2010] [49, Germany 2010]

4.6.4 Techniques for the housing of broilers

Traditionally, broilers are kept in houses with a fully littered floor ~~(see Section 2.2.2)~~. Both for animal welfare reasons and to minimise ammonia emissions, wet litter should ~~must~~ be avoided. The dry matter content of the litter depends on:

- the drinking system
- the length of the growing period
- the stocking density
- the use of floor insulation
- the direction and volume of the flowing air
- the seasonal and climatic conditions
- the management of rain water
- sanitary condition of animals (e.g. diarrhoea)

- the bedding material.

In general, ammonia emissions decrease with the increase of the dry matter, but for percentages of dry matter higher than 65 % approximately, the emission reduction is more than proportional [90, Italy 2010].

The stocking density also has an effect on ammonia emissions in the sense that the increasing ~~animal~~ bird body weight during the rearing implies that increasing manure ~~dejection~~ volumes are produced as well as increased bedding compaction.

The rearing systems that have been developed to reduce emissions perform either a fast removal of the manure or a forced drying of the droppings.

~~The emission level 0.08 kg NH_3 per broiler place per year is considered as the reference level. It has been reported that by proper nutrition and ventilation management, in the medium weight broiler production (2.1 kg of live weight reached in 7 weeks), emissions of 50 g NH_3, 25 g of PM_{10} and 32 OU per animal place per year can be obtained in the UK under normal conditions. [99, UK 2010] [100, UK 2010] [101, UK 2010] [98, UK 2010]~~

~~In the heavy weight broiler production (3 kg of live weight in 7.5-8.5 weeks), emissions can be of 0.034 kg NH_3 and 0.078 kg of methane per animal place per year. [96, UK 2010] [97, UK 2010]~~ **Moved to Section 4.6.4.1**

A summary of the emission measurements that have been reported is presented in Table 4.57.

Table 4.57: Summary of reported emissions from broiler housings with different system configurations

Description	Slaughter weight	NH_3	PM_{10}	Odour	Source
	kg	kg/ap/year		ou_E/s/ap	
Cross ventilation	2.1 (6-7 weeks) 3 (7.5-8.5 weeks)	0.034 ([1])	0.025 ([2])	0.032 ([2])	[98, UK 2010]
Tunnel ventilation					[99, UK 2010]
Side ventilation					[100, UK 2010]
Ridge ventilation					[96, UK 2010] [101, UK 2010]
Tunnel ventilation w/ or w/out free range or veranda	1.5 (34 days)	0.035 ([4]) ([1])	0.015–0.025 ([1])	0.09([1])	[87, Germany 2010]
	2 (42 days)	0.049 ([4]) ([1])	0.015–0.025 ([1])	0.12([1])	
Wood shaving bedding, animal load of 35 kg/m^2	2.5 – 3.3	0.096 – 0.127 ([1])	.	.	[92, Italy 2010] [90, Italy 2010]
Straw bedding, animal load of 35 kg/m^2	2.5 – 3.3	0.114 – 0.126 ([1])	.	.	
Wood shaving bedding, animal load of 30 kg/m^2	2.5 – 3.3	0.064 – 0.142 ([1])	.	.	
Straw bedding, animal load of 30 kg/m^2	2.5 – 3.3	0.086 – 0.116 ([1])	.	.	
Straw, summer/winter observations		0.055 – 0.102 ([1])	.	.	[91, Italy 2010]
Non-leaking drinking and tunnel ventilation (DM 61 %)	1.6 (39 days) 3.3 (57 days	0.069 – 0.073 ([1])	.	.	[89, Italy 2010]
Non leaking drinking and cross ventilation	2 (41 days) 3.3 (62 days)	0.082 – 0.090 ([1])	.	.	[88, Italy 2010]
Deep litter not slatted (0.05 m^2/bird)		0.180			[50, Austria 2010]
Perforated floor with forced air drying system		0.014			IRPP BREF 2003
Tiered floor system with forced air drying	1.86-2.25	0.02 ([1])	0.022 ([3])	0.24 ([1]) (0.19-0.7)	[585, Netherlands 2010]
Patio 13 days, finishing in low emission houses		0.018 – 0.040	0.020 ([2])	0.22	[93, Netherlands 2010] [500, IRPP TWG 2011] [473, Infomil 2011]
Patio 13 days, finishing in standard emission houses		0.070	0.020 ([2])	0.22	
Patio 19 days, finishing in low emission houses		0.015 – 0.038	0.017	0.19	[94, Netherlands 2010] [500, IRPP TWG 2011] [473, Infomil 2011]
Patio 19 days, finishing in standard emission houses		0.060	0.017	0.19	
Litter based systems with circulating fans	2.1 – 2.34	0.037 ([1])	0.022 ([3])	0.24 ([1]) (0.11-0.41)	[586, Netherlands 2010]
Litter based systems with circulating fans and heat exchanger	2.5	0.021 ([1])	0.019 ([1])	0.24 ([3])	[464, NL 2010]
Litter based systems with (equally spread) re-circulated air by indoor fans (and heat exchanger)	2.26 – 2.37	0.035 ([1])	0.022 ([3])	0.24 ([3])	[470, NL 2011]

([1]) Measured values.
([2]) Modelled values (e.g. results based on N balance).
([3]) Values derived by expert judgement based on conclusions by analogy.

4.6.4.1 Deep litter systems

Description
A bedding is spread uniformly over the housing floor at the beginning of each growing period and is removed at the end of the cycle together with the manure produced over it. Bedding is mainly made up of chopped straw, wood shavings, or other lignocellulosic matter. The absorbent material binds urine and faeces in the litter and provides a dry area.

The description is given in Section 2.2.2.1, where the functional areas that can be combined with the house are also described.

Reported variations of the basic deep litter system are:

- combination with free range and/or veranda
- open climate house (natural ventilation)
- use of peat as a bedding material

Achieved environmental benefits
The bedding absorbs the dropping humidity limiting the excess of ammonia emissions.

Cross-media effects
Higher dust emissions due ~~is increasingly raised~~ to the presence of litter and increased ~~by the animals'~~ birds movement.

Operational data
Ammonia is emitted through an enzymatic decomposition (hydrolysis) reaction of urea.

$(NH_2)_2CO + H_2O$ (urease) $\rightarrow NH_3 + H_2NCOOH \rightarrow 2NH_{3(gas)} + CO_{2(gas)}$

At humidity levels below 30 – 35 %, the reactions responsible for ammonia volatilisation are practically ceased. [91, Italy 2010]

~~The~~ A typical emission level ~~that was traditionally~~ associated with this technique, regardless ~~of~~ the effect of the nutritional management on the manure composition, was 0.08 kg NH_3 per broiler place per year. In fact, ammonia emissions depend on the specific housing system; proper ventilation management and non-leaking watering systems ~~can~~ are other important parameters for reducing ~~reduce~~ ammonia emissions.

~~Dust levels are normally quite high, in the range of 0.119 g to 0.182 g per animal place per year for PM_{10}, and from 0.014 g to 0.018 g per animal place per year for $PM_{2.5}$.~~
Dust emissions are reported in the range of 0.015 – 0.025 kg/ap/yr, significantly reduced from traditional levels (generally quite high of 0.119 – 0.182 kg PM_{10}/ap/yr, and 0.014 – 0.018 kg $PM_{2.5}$/ap/yr.

Reported data for methane emissions ~~are~~ range from 0.02 to 0.078 kg CH_4/ap/yr. ~~known from 0.004 kg to 0.006 kg per animal place per year~~ (see also table Table 3.49). N_2O emissions have been ~~recenty evaluated~~ reported between 0.025 kg and 0.032 kg N_2O/ap/yr.~~per animal per year.~~

The effects of ventilation on ammonia emissions have been studied for two different settings of the mechanical ventilation. Reported results and operating conditions applied on two fully littered housing systems for broilers are given in Table 4.58.

During summer months, when high ventilation flowrates allow reaching higher levels of dry matter in the litter, regardless the type of ventilation, ammonia emissions are expected to be lower.

A good regulation of the ventilation system, avoiding cold air drafts and water vapour condensation on the litter, a good control of the water leakage from the drinking line and a computerized control system contribute to a higher ammonia reduction. Based on results reported from Italy, an ammonia emission reduction of 20 – 30 % can be achieved with an appropriate management system [88, Italy 2010] [89, Italy 2010].

Table 4.58: Effects on emissions by controlling mechanical ventilation in deep litter broiler housing systems

Parameters	Units	Housing system	
		Cross ventilation	Tunnel ventilation
Final weight	kg	2.1 (standard) – 3.3 (heavy)	1.6 (standard) – 3.3 (heavy)
Breeding time	days	39 (standard) – 57 (heavy)	41 (standard) – 62 (heavy)
Bird places		19 300 (9 000 female + 10 300 male)	12 100 (6 000 female + 6 100 male)
N content of three-phase feed	%	3.9 – 3.5	4.4 – 3.3
Cold season, ventilation rate	m^3/ap/h	1.1 (0.4 – 2)	1.4 (0.5 – 3.6)
Warm season, ventilation rate	m^3/ap/h	9.7 (1.2 – 28.8)	10 (1.6 – 23.7)
Manure DM content	%	61	78
NH_3 emissions	kg/ap/yr	0.082 – 0.09	0.069 – 0.073
Reduction of NH_3 emission compared to reference	%	20	30
Source: [88, Italy 2010] [89, Italy 2010]			

Data reported by Finland, concerning deep litter broiler houses equipped with energy saving fans, show a reduction of ammonia emissions by 20 - 30 %, as well as a reduction in odour emissions (see Section 4.5.4.3.5). [144, Finland 2010]

Mechanically controlled ventilation is widely applied, and is modulated in relation to external climatic conditions taking into account the animal welfare. Data reported from the UK show that no difference in ammonia emission is to be expected depending on the position that fans and openings have in the house. Tunnel ventilation or cross ventilation seem to have little or no effect on emissions.

Naturally ventilated/open climate houses are also in use. As relatively lower average temperatures are achieved compared to houses with mechanically controlled ventilation, also lower ammonia emissions are expected, as well as better indoor climate, lower energy demands and lower investment and running costs.

Italy and UK reported very similar air flowrates in the warm season which are on average in the range of about 10 – 15 m^3 per ~~animal~~ bird place per hour. Averages recorded in the colder seasons differ between the countries, being around 1.1 to 1.4 m^3 per ~~animal~~ bird place per hour in Italy and 7.5 to 11 m^3 per animal place per hour in the UK. Peaks of maximum air flows in the summer have been reported at 23 – 28 m^3 per animal place per hour in Italy. The German welfare standards require minimum airflows of 4.5 m^3/kg live weight per hour on hot days; hence peaks were recorded up to ~~and of~~ 8 m^3 per ~~animal~~ bird place per hour ~~in Germany~~.

Energy requirements have been reported by Germany, per type of operation, and are displayed in Table 4.59.

Table 4.59: Breakdown of resource demand in kWh per bird ~~animal~~ place per year in deep litter broiler rearing (Cycles of 38–42 days)

Operation	Base system	Open climate housing	With forecourt	With veranda and forecourt
Lighting	0.330	0.200	0.330	NA
Ventilation	0.730	0.100	0.730	NA
Heating	4.500	NA	5.500	NA
Feeding	0.140	0.140	0.140	0.140
Removal/cleaning	0.140	0.140	0.140	0.140
Total	5.84	-	6.84	-
NA= Not available *Source*: [87, Germany 2010]				

The floor of the deep litter housing system should be insulated to avoid the condensation of air moisture on the litter that may cause increased ammonia emission.

In Finland, data for the consumption of ~~The need for~~ resources have been reported for ~~has been expressed per animal place per year: electricity, is consumed~~ electricity, from 0.29 to 1.26 kWh/ap/yr, water from 4 to 34 litres/ap/yr and labour from 0.016 to 0.040 hours/ap/yr. Around 1.42 kWh/ap/yr ~~per animal place per year~~ are needed from fuels; in the reported case, straw is used as fuel. ~~that can be replaced e.g. by straw or peat used as litter (8.9 litres of peat/ap per year).~~

Applicability

This is by far the most widely used ~~rearing~~ housing system for broiler production.

Economics

Investment figures have been calculated in Germany on ~~common~~ sheds of different sizes, as reported in Table 4.60.

Table 4.60: Investment details for deep litter houses for broilers

Type of housing	Housing for 35 000 – 37 000 bird places		Housing for 26 500 bird places	
	Investment cost EUR/ap	Annualised investment cost EUR/ap	Investment cost EUR/ap	Annualised investment cost EUR/ap
Base housing	12.00	1.04	17.00	1.45
Open climate facility	12.00	0.99	16.00	1.38
Base with additional forecourt	NA	1.74	NA	NA
NA = not available *Source*: [87, Germany 2010]				

The annual running cost is reported equivalent to EUR 3.5/bird place for the standard system and for the alternative with an open climate house. [87, Germany 2010]

Investment data reported from Finland for an installation of 30 000 birds ~~animals~~ are comparable with the data presented above, being at EUR 11.67 per bird ~~animal~~ place for what concerns the initial investment and EUR 0.93 the annualised cost (20 years amortisation, 5 % interest rate). From UK, investment costs have been reported in the range of 14 and 16 EUR/bird place.

The cost per bird, for abating ammonia emissions through a reduction in temperature by 1 °C, has been calculated in UK in the range of EUR 0.27 – 0.28 per bird. **moved from Section 3.3.2.1**

Driving force for implementation
Animal friendliness can be ~~is easily~~ improved by the possible combination with verandas and/or free ranges, ~~producing~~ offering valued non-environmental benefits such as external/climate stimuli, functional areas, more space and more bird locomotion. The alternative design with veranda and/or outdoor forecourt offers a space per bird of 0.085 m²/bird, in comparison with 0.043m²/bird of the standard housing system.

Example plants
This type of housing is the most widespread.

Reference literature
[87, Germany 2010] [88, Italy 2010] [89, Italy 2010] [90, Italy 2010] [91, Italy 2010] [92, Italy 2010] [95, UK 2010] [96, UK 2010] [97, UK 010] [98, UK 2010] [99, UK 2010] [100, UK 2010] [144, Finland 2010] [145, Finland 2010]

4.6.4.1.1 Litter-based systems with circulating fans

Description
The deep litter system, without manure pit, is equipped with vertical shafts and a ventilator hanging from the ceiling. At the bottom of the shaft, at a maximum height of 1.20 m above the litter, a special element is placed to direct the warm air from the roof of the house horizontally over the litter. In addition, circulating fans homogenise the air flows at the bird level, without increasing the volume of air supplied by the central ventilation. This system is used in the Netherlands to reduce the ammonia emissions.

The principles of ventilation management and technical details of this technique are described in Section 4.5.4.3.2.

Achieved environmental benefits
Drying of the surface litter is achieved and, consequently, ammonia emissions are reduced. The positive effect in terms of ammonia emission is calculated at 54 % less than the emissions from a non-cage reference system used in the Netherlands. [586, Netherlands 2010]

Because of mixing the warm ceiling air with the colder air just above the floor a slight benefit (10 %) is calculated on heating costs, from reduced energy consumption. [586, Netherlands 2010]

Cross-media effects
Due to the ventilators in the shafts, an extra use of electricity can be expected.

Operational data
Vertical shafts should be placed every 150 m^2, in two rows by the length of the house and should not be placed right opposite of each other, in order to ensure equal spreading of air. The fans work continuously with a reported minimum capacity of 1.8 m^3/hour per bird place. At the beginning of the cycle (pullet of one day of age) the ventilators start at a capacity of 10 % and progressively reach 100 % capacity on day 40.

Data concerning the emission values associated with the application of deep litter housing systems equipped with circulating fans, in the Netherlands, are reported in Table 4.61. For the same systems, typical ventilations rates are reported in the range between 1.1 and 1.3 m^3/ap/h, during the cold season and between 1.9 and 2.8 m^3/ap/h, during the warm season, combined with an inlet air cooling system by water fogging.

Table 4.61 Reported emissions from broiler production in deep litter housing systems, with circulating fans

Parameter	Unit	Emission levels
Ammonia	kg NH_3/ap/yr	0.037 (from 0.0102 to 0.0418)
PM_{10}	kg PM_{10}/ap/yr	0.022
Odour	ou_E/s/ap	0.24 (from 0.11 to 0.41)
Source: [585, Netherlands 2010]		

Surface drying of the litter in broiler houses reduces NH_3 emissions. Emission factors adopted in the Netherlands for an installed ventilation capacity of 1.8 m^3/hour per bird place are 0.037 kg NH_3/ap/yr in broiler houses and 0.183 kg NH_3/ap/yr in parent houses (broiler breeders). [469, NL 2011] These ammonia emission levels can only be achieved if the system fully complies with the operational requirements.

Applicability
The technique is applicable to new housing systems for broilers and in most existing houses; where, limitations to the applicability may be associated with a very low ceiling of the building. [586, Netherlands 2010]

Example plants
In 2008, in the Netherlands, the housing system with deep litter and circulating fans was applied at about 10 % of total bird places. [586, Netherlands 2010]

Reference literature
[339, ITAVI 1997] [349, ITAVI 1998] [350, France 2010] [354, ITAVI 2004] [469, NL 2011] [586, Netherlands 2010]

4.6.4.1.2 Litter based systems with circulating fans and heat exchanger

Description
This technique is intended for ammonia and dust reduction and is based on heating and drying the litter by the combined use of heat exchangers and ventilators (see Section 4.5.4.3.3 for information on circulating fans in combination with heat exchangers). Incoming air is warmed up in a heat exchanger by using the heat recovered from the indoor air. The ventilators spread the warm air equally over the litter. An improved version, with a heat exchanger of higher capacity, is intended for extra dust abatement. Description of heat exchangers is given in Section 4.5.4.2.1.

Achieved environmental benefits
In addition to a reduced energy requirement, achievable by using a heat exchanger (see also Section 4.5.4.3.3), ammonia reductions are achieved and dust is removed with improved exchangers.

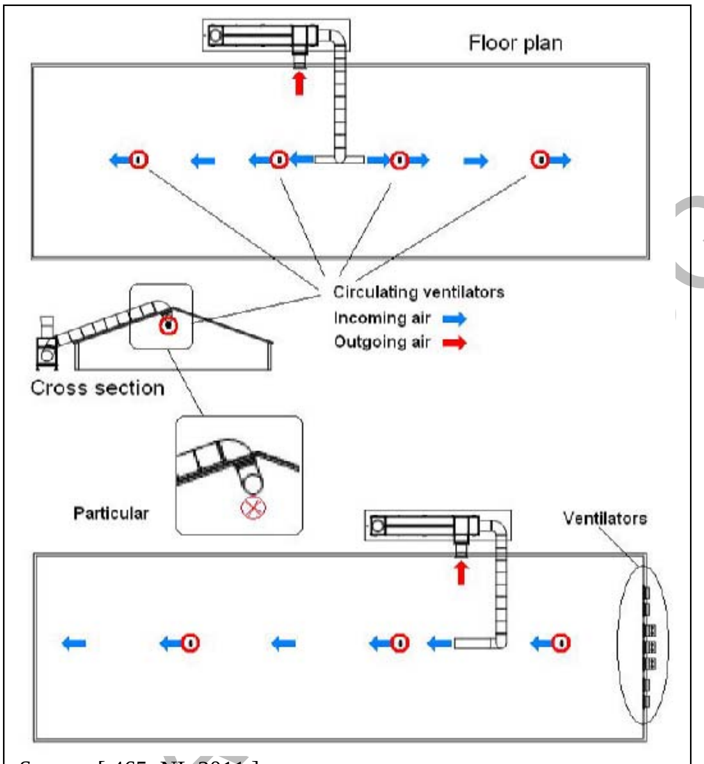
The resulting manure is drier and lighter which implies less transport weight and consequently lower associated costs.

Cross-media effects
No direct counter-effects have been reported.

Operational data
The capacity of the heat exchanger is at least 0.35 m^3/bird place per hour; whereas, the capacity of the improved heat exchanger for extra dust removal is 1.0 m^3/bird place per hour. A removal

of fine dust equivalent to 13 % is reported for the normal type of heat exchanger and 31 % reduction for the improved type.

The placement of the outlet of the heat exchanger depends on the type of ventilation (see Figure 4.19). The ventilators must be placed at most 20 m from each other and at a maximum distance from the ceiling of 1.5 m. A capacity of 6 000 m^3/h per ventilator is reported, with at least 23 m^3 per square metre of litter.



Source: [465, NL 2011]

Figure 4.19: Examples of layouts for systems of circulating fans and heat exchanger

Measurements were carried out in four farms, with capacities from 21 000 to 39 000 birds, fed with three or four feeding phases to a final weight of kg 2.5 (one farm final weight was kg 1.9), with ventilation rates in the range of 0.3 – 0.9 m^3/bird place per hour in the cold season, and 2.1 – 4.8 m^3/bird place per hour in the warm season. Recorded ammonia emissions showed a maximum of 0.061 kg NH_3/ap/yr and an average value of 0.021 kg NH_3/ap/yr, which is 74 % lower than the standard reference in the Netherlands.

Measurements of dust emissions ranged from to 0.02 kg/ap/yr, with normal equipment and 0.0176 kg/ap/yr, with improved equipment (10 % and 20 % less respectively compared to the Dutch reference).

Applicability
The system can be implemented in any new broiler house and in most of the existing ones.

Driving force for implementation
This solution allows for better climate control that is especially beneficial during the first days of rearing, since it leads to stronger and healthier animals.

Economics
In a house with a capacity of around 40 000 birds, the investment requirements are in the range of EUR 0.7 – 1.0 per bird place and annual running costs are around EUR 0.005 per bird place.

Cleaning and checking of the heat exchangers will take 1.5 to 2 hours work per round per exchanger.

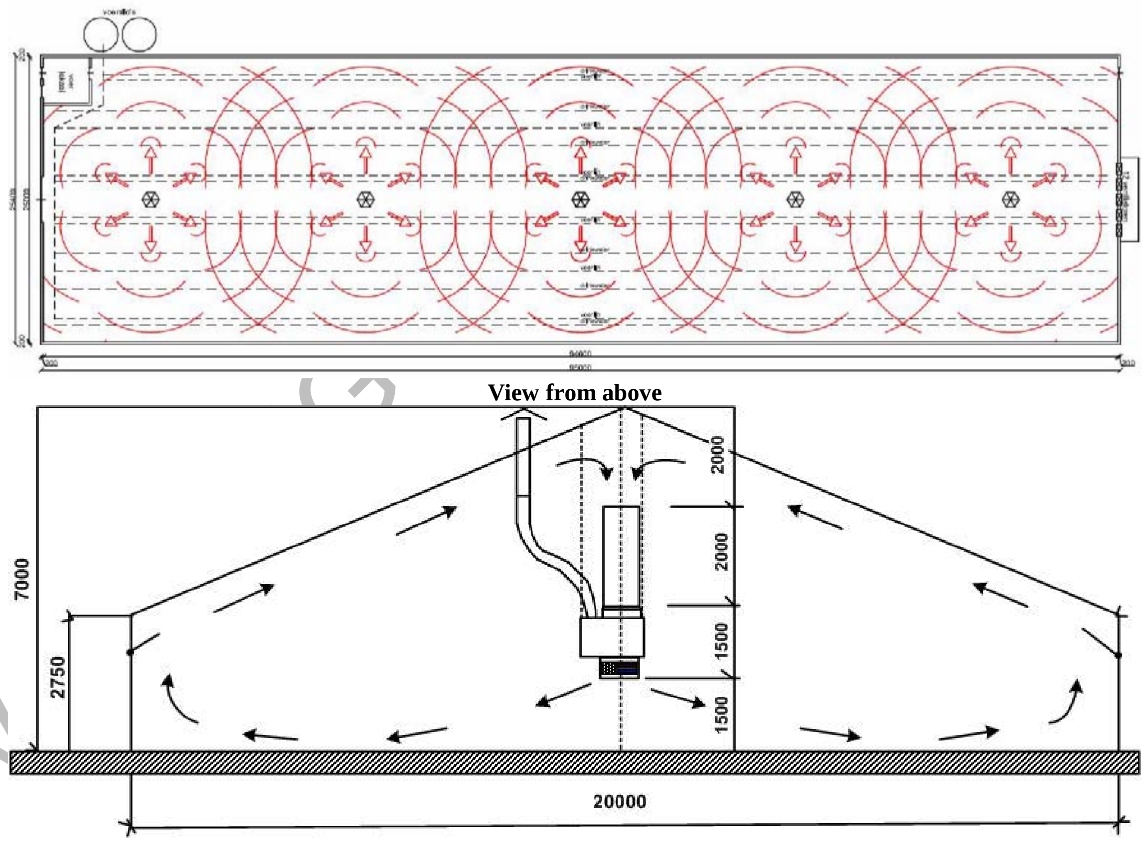
Under Dutch climatic conditions, the savings in heating costs that heat exchangers allow can reach 50 %, corresponding to about EUR 0.38/ap/yr (prices of 2011).

Example plants
Heat exchangers are well known and becoming widespread in the Netherlands.

Reference literature
[464, NL 2010]

4.6.4.1.3 Litter based systems with (equally spread) re-circulated air by indoor fans

Description
A combination of heaters with indoor ventilators is used to heat the house (see also Section 4.5.4.3.4). Ventilators drive warm air from the ceiling down to the floor level. The air is warmed up by thermal exchange with hot water produced by an indirect-fired thermal heater using propane or natural gas or by central heating. The heaters are provided with equipment to let the air come out horizontally, spreading it all over the litter. A schematic representation of the housing system with recirculating indoor fans, combined with indirect-fired thermal heaters is given in Figure 4.20.



View from above

Section for the configuration with individual heaters

Source: [471, NL 2011]

Figure 4.20 Plan and section of horizontal ventilation with re-circulated air by indoor fans

Achieved environmental benefits
Ammonia reduction is achieved by drying the litter through warm aeration. Ammonia emissions are reported to be 56 % lower than those corresponding to the reference system used in the Netherlands. An optimal indoor air climate is achieved at low heating costs. A reduction of energy consumption for heating of around 20 % is achievable, with related costs reduction, as a result of the good mixing of warm air from the ceiling with colder air just above the housing floor.

Cross-media effects
Around 20 % additional electricity is used by the ventilators compared to the basic litter-based housing systems. However, because of the absence of CO_2 and moisture inside the house, produced by heaters, the minimum ventilation rate at the start of the rearing period can be reduced. This saving can compensate for the extra electric energy use of the ventilators.

Operational data
The number of heaters installed depends on their heating capacity. In general, each heater should cover a maximum area of 450 m^2 and the distance between two heaters should not exceed 25 m. The maximum distance from the rooftop, where the suction of warm air is installed in order to convey it to the heater, is 2 m, whereas the heated-up air entering the housing system is released at 1.5 m, at the most, from the floor.

Normally, the ventilators are running at least at 20 % of their maximum capacity. When the temperature is low and air needs to be warmed up, the heating is turned on and then the ventilators will run at full capacity.

In the Netherlands, the following measured ammonia emissions are associated with the application of this housing system:

- broilers: from 0.005 to 0.128 kg NH_3/ap/yr, with an average value of 0.035 kg/ap/yr;
- broiler breeders: 0.180 NH_3/ap/yr;
- turkeys: 0.489 NH_3/ap/yr;
- guinea fowls: 0.058 NH_3/ap/yr. [471, NL 2011]

Dust and odour emissions associated with broiler rearing are equivalent to 0.022 kg PM_{10}/ap/yr and 0.24 ou_E/s per animal place.

Applicability
This system can be installed in new houses for broilers. When retrofitting existing houses, the applicability might depend on the height of the ceiling.

Driving force for implementation
The continuous mixing of warm air from the ceiling with the colder air at lower heights allows energy savings corresponding to about 20 % of heating costs. The system can help to create a better indoor climate.

Economics
Investment and running costs depend on the choice of fuel and are estimated as follows:

- Investment requirements: EUR 1.5/ap ~~per year~~, (from 1.3 to 1.7 EUR/ap);
- Annualised investment costs: EUR 0.23/ap/yr, (from 0.20 to 0.26 EUR/ap/yr);
- Annual running costs: EUR 0.22/ap/yr, (from EUR 0.15 to 0.28 EUR/ap/yr);
- Total annual cost: EUR 0.45/ap/yr, (from 0.41 to 0.48 EUR/ap/yr). [470, NL 2011]

Example plants
Around 15 % of the Dutch bird capacity was equipped with this system at the end of 2009.

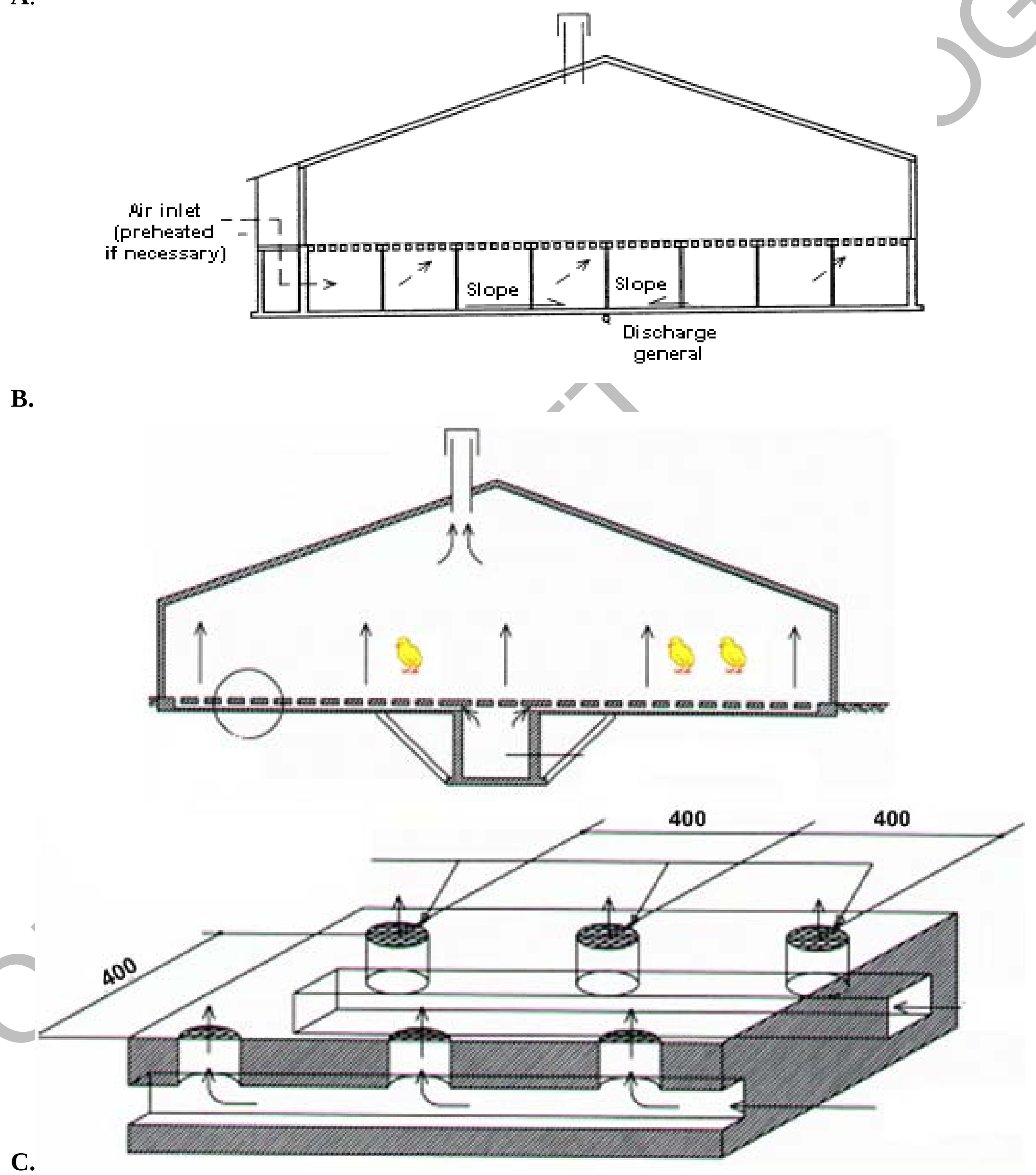
Reference literature
[470, NL 2011] [471, NL 2011]

4.6.4.2 Perforated floor with forced air drying system

Description

Birds are raised on an elevated and perforated double floor that is covered with litter. Through perforations, air is continuously blown to dry the litter.

Perforations have ~~with~~ a minimum surface area of 4 % of the total floor area. ~~The perforations~~ and are protected by a plastic or metal grid. A continuous upward air stream flows through the perforated floor with a minimum capacity of 2 m^3 per hour per broiler place. ~~The perforated floor is covered with litter.~~ Manure and litter remain on the floor for the whole growing period (about 6 weeks). The continuous airflow dries the litter (>70 % dry matter) and this results in reduced ammonia emissions. Improved designs can improve the distribution of the drying air by channelling the air stream. See Figure 4.21.



Source:[44, Netherlands 2000]

Figure 4.21: Schematic representation of a forced drying system with a perforated floor for broilers (A), an improved design (B), and a detail of the floor of the improved design (C)

Operational data
The associated emission level for ammonia is ~~at~~ 0.014 kg NH_3 per broiler place per year.

~~As the~~ Dry matter content of the manure is as high as ~~at~~ 80 %, causing ~~there is~~ a lot of dust in the broiler house. The birds ~~animals~~ are cleaner, but the farmer needs to protect himself with a protective mask. Mucking out and cleaning between growing periods requires more labour compared with other housing systems for broilers.

Applicability
The system can only be used in new buildings, as a sufficient pit depth (2 m) under the perforated floor is necessary and that will not normally be available in existing buildings. With an improved design a lower depth will be required.
Animal welfare considerations and high levels of dust emissions may preclude the application of this technique, unless it is combined with other measures, such as air cleaning systems. In fact, the system is no longer applied in Germany, due to high dust loads in the air and increased energy demand for aerating the litter.

Economics
~~Compared with the~~ With the deep litter system taken as a reference, this housing system ~~has~~ requires an extra investment ~~cost~~ of about EUR 3 per broiler place, which means that it is about 25 % more expensive. This ~~is equal~~ corresponds to an extra investment of EUR 45.5 per kg NH_3 emissions reduced [~~1000 gram/(80 gram-14 gram)* EUR 3~~]. A further calculation can be made ~~including~~ to determine the extra investment costs for the perforated floor, which are equivalent to ~~of~~ EUR 65.90 per m^2 and a stocking density of 20 broilers per m^2. In this case the extra running costs are EUR 0.37 per broiler place per year. Extra costs associated with cleaning out should also be considered.

~~Only a few farms are currently applying~~ This system implies ~~because of the~~ high energy costs and ~~because the~~ benefits are limited to a reduction in the NH_3 emissions only. [506, TWG ILF BREF 2001]

Driving force for implementation
None reported. An increase in DM of the manure may be associated with other advantages, such as lower storage space, and volume to be transported.

Example plants
In 2012, about 1 695 000 bird places in the Netherlands (2 % of the national broiler population) are built using with this technique. [468, CBS 2011]

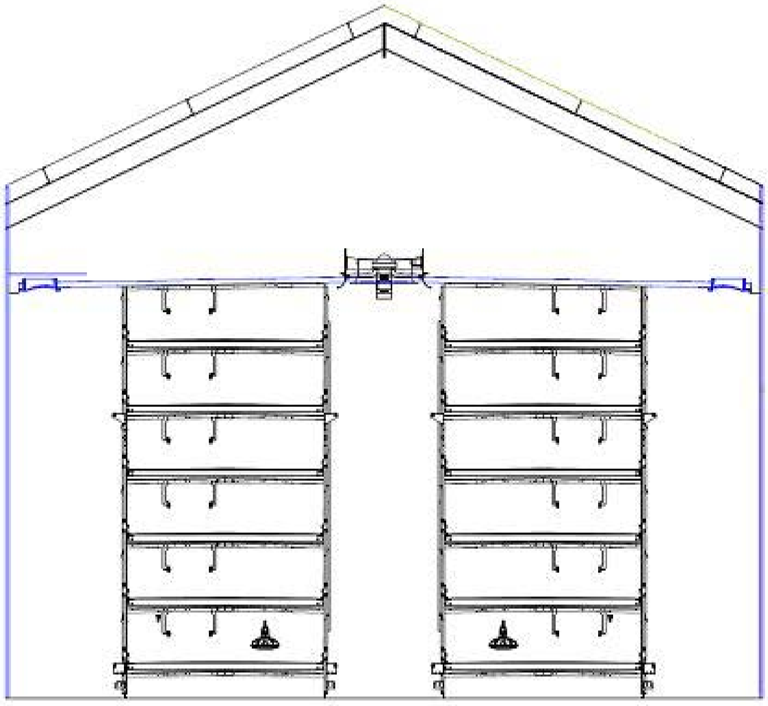
Reference literature
[44, Netherlands 2000]

4.6.4.3 Tiered floor system with bedding on manure belt and forced air drying for broilers

Description
The broilers are kept in a multi-floor system on tiers, where.~~ The system is characterised by~~ a continuous downward or upward draught through the tiered floor arrangement is applied.
Bedding is added on the manure belts before placing the birds in the tiers. Corridors for ventilation are left between the rows of tiers. One corridor is used to bring the air to the tiers; the air is then conveyed towards the other corridor by means of the pressure drop generated by the ventilators. The air is directed towards the bedding material on the manure belt. The litter is removed together with the flock, at the end of the cycle. The manure belts are also used to remove the fattened broilers at the end of the cycle.

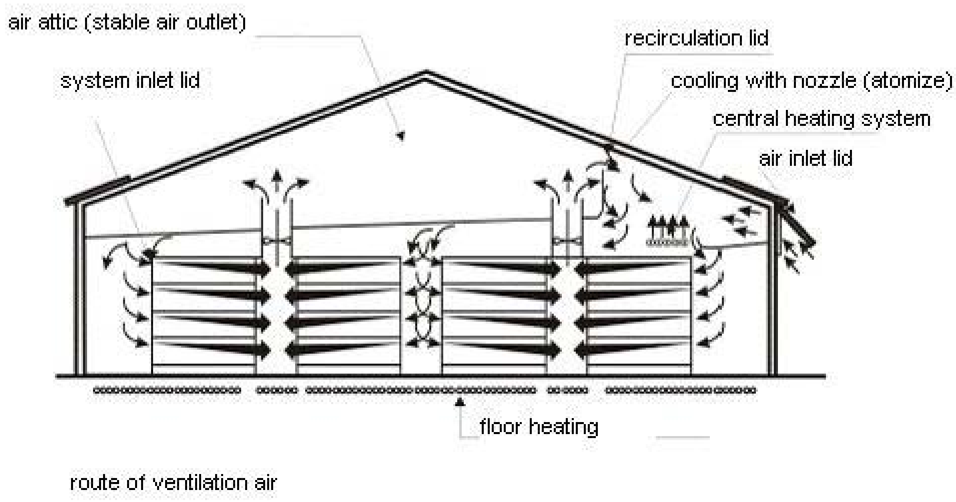
The technique is used in combination with the patio system (described in Section 4.6.4.4) as the second phase, where broilers are brought up to their final weight [473, Infomil 2011]

A schematic overview of the tiered-floor system, with bedding on manure belts and forced air drying, is shown in Figure 4.22. A cross-section of the system, with the indication of the air flows is presented in Figure 4.23.



Source: [473, Infomil 2011]

Figure 4.22 Schematic cross-section and principle of a tiered floor system with forced drying (upward flow) for broilers



Source: [473, Infomil 2011]

Figure 4.23: Schematic cross-section of a tiered floor system for broilers, with air flows

Achieved environmental benefits
Ammonia emissions are reduced as a result of the drying of the litter with forced air.

Cross-media effects
More electricity is needed to operate the ventilation air fans.

With the upward movement of the air and a manure dry matter dm content of 80 %, dust problems might arise and the use of a face mask is recommended for farmers. Dust is less of a problem with the downward flow design.

Operational data
The amount of bedding material needed is 0.6 kg/m^2. Ventilation is reported to vary from 0.5 m^3/ap/h in cold season to 2.4 m^3/ap/h in the warm season. Space per bird is reported equivalent to 0.045 m^2 (22 birds per m^2).

Ammonia emissions are is reduced to 0.02 0.005 kg NH_3 per broiler place per year (94 corresponding to a reduction of 75 % compared to the reference system used in the Netherlands, for which has an emission of 0.080 kg NH_3 per broiler place per year is considered.

Because of the tiered floor configuration, the number of birds per m^3 of house is lower than in traditional Dutch housing systems; the heat distribution is improved by air blowing and the heating costs per bird place are reduced by 50 %. [587, Netherlands 2010]

Applicability
This system can be applied to in new and existing broiler houses. As the system is built up in tiers, existing the buildings must have a sufficient height to install accommodate the system.

Economics
Compared to the reference, costs for The downward flow design requires need an extra investment of EUR 2.27 per broiler place, which means EUR 36 per kg NH_3. The extra annual costs are EUR 0.38 per broiler place.
An extra investment of EUR 2 per broiler place (equivalent to an annualised cost of EUR 0.6/ap/yr) is required compared to a conventional housing system. The technique offers a benefit of EUR 0.6 per bird place per year, due to less energy use, which fully compensates the extra costs.

Driving force for implementation
In summer there is less heat stress on the animals because there is an of the air stream close to them. The system improves indoor climate in the direct surroundings of the animals. Less labour is needed to keep more broilers.

Example plants
This system has recently been developed. In the Netherlands two farms with a reported number of 359 000 bird places were equipped with this system, in 2008.

Reference literature
[44, Netherlands 2000] [585, Netherlands 2010].

4.6.4.4 Patio system for hatching and growing broiler chicks for a limited time

Description
This is a recently developed housing system technique. It is a combination of two housing systems; the first consists of a system where the eggs are hatched and chicks are reared for a limited time. The second system is where the broilers are brought up to their final weight; it

may consist of a traditional house or the tiered floor system, as described in Section 4.6.4.4, where bedding is used on the manure belts [473, Infomil 2011]

Achieved environmental benefits

~~The manure produced in the initial rearing phase is removed early hence produces lower ammonia emissions. The optimisiation of the spaces reduces the heat losses.~~
The patio system, combined with a second rearing stage for broiler, allows a more effective use of low-emission (but expensive) systems. The overall ammonia emissions from the two combined rearing stages are significantly reduces.

Cross-media effects

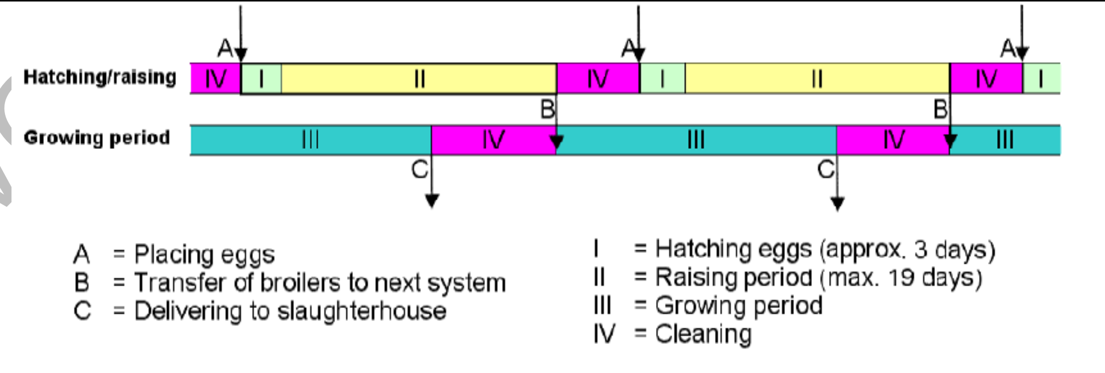
~~Little energy is needed to run the system and the belts, and for the including extra transportation to the house where the second phase takes place~~
No specific cross-media effects have been reported.

Operational data

In this first system, eggs are placed ~~brought~~ ~~in~~ three days before hatching until ~~and after~~ 13 or 19 days of age, when they ~~broilers~~ are moved to the second housing~~s~~ system, where they will reach ~~slaughter~~ their final weight. The chicks are kept in a multifloor system on tiers, with bedding on the manure ~~over bedded~~ belts, which are also used to transport them out of the house. ~~After~~ At the moment of the transfer, the maximum bird density is 71 or 48 birds per $m^{2,}$ for 13 or 19 days of age respectively. The longer the chicks stay in the patio system, the shorter they stay in the second system.

The corridors between the stacks of tiers are used to direct the air flow ~~created by a pressure drop~~. The side of the stacks facing the corridor, where the air is coming from, is closed, except for the air inlets; in this way the flow is directed along the bedding material on the manure belt and then to the other side, where it is collected by ventilators placed on the top of the house. The manure belts are emptied and then covered with new bedding each time a new flock is placed. The collected manure is stored in covered containers and removed from the farm within two weeks.

The system optimises the start of young broilers in the first hours after hatching as ~~has advantages for the animals because~~ they have immediate access to water and feed, as soon as the eggs are hatched ~~they first leave the egg.~~ Additionally, chicks ~~do not~~ need less ~~much~~ heating since they live in a small boxed place. ~~The~~ Birds ~~animals~~ are moved at an age when they are more robust and only over a very short distance, since the next ~~the further~~ rearing system ~~is normally run~~ should normally be in the same farm (in the Netherlands the patio system is only allowed under this condition). The two housing occupations are synchronised through all production stages, depending on the length of the stages, in order to optimise the occupation and displacements (see Figure 4.24).



Source: [93, Netherlands 2010] [94, Netherlands 2010]

Figure 4.24: Example of a time flow pattern synchronising the patio hatching/raising cycle (19 days) with the finishing cycle in the different houses

Due to the very early stage of animal life, the emissions arising from this system are very low, even though up to 48 animals per m^2 on each level can be reared. Ammonia emission from the patio system are 3 or 9 g per bird animal place per year, respectively for the 13 days and 19 days management, including the periods when the system is necessarily empty between cycles. These levels do not include emissions from the second system (second rearing stage) which are reported between 0.05 and 0.118 kg NH_3/ap/yr, for low-emitting housing systems, and 0.208 kg NH_3/ap/yr for standard housing systems, in the case of 13 days management in the patio system; while the emissions for the 19 days management are reported between 0.021 and 0.066 kg NH3/ap/yr for low-emitting housing systems and 0.111 kg NH_3/ap/yr for standard housing systems respectively [473, Infomil 2011]. See also Table 4.57.

The effect of the reduced emissions in the initial phase hence reduces emissions along the entire cycle. , for which results are
Total ammonia emissions are calculated as the sum of the emissions over the total standard length of rearing (6 weeks) in the two housing systems used in combination, and largely depend on which system is used for the second rearing stage low-emitting or standard housing system. This variation is vary as reported in Table 4.57. Depending on the housing systems that are used in the finishing period, the total emissions from the entire cycle are in the range of 15 to 38 g or 18 to 40 g for the cycle of 13 or 19 days respectively.

Not only is the total space needed at the farm level smaller for the same number of reared birds animals, but also cycles in the house for the second stage are run in shorter turns. The ratio between the numbers of animal bird places in the two systems depends on the duration of growing phases, and can vary from 1: 1 to 1: 2.

Applicability
This system can be built in new houses, or can be retrofitted only in existing houses that have high side walls.

Economics
Expectations of durability are is 15 – 20 years. More birds can be managed by one person. In general, the economic benefit of the farm is optimised by keeping more animals.

Driving force for implementation
Increased productivity due to the higher number of flocks per year which is the result of raising young birds while there are also broilers present at the farm at the end of the growing period. The start of chicks in the first hours after hatching is optimised.

The technique fulfils the requirements of Directive 2007/43/EC concerning the animal welfare.

Example plants
Two Some farms in the Netherlands are equipped with these systems. Permitting authorities request that the housings where birds animals are moved to reach slaughter weight be equipped with low emission systems.

Reference literature
ASG; report: Afleiding emissiefactor Patio-systeem (Mosquera and Hol, 2007)
[93, Netherlands 2010] [94, Netherlands 2010]

OLD SECTION 4.5.3.3 ON TIERED CAGE SYSTEM, ALREADY DELETED IN DRAFT 1, HAS BEEN ELIMINATED

4.6.5 Techniques for housing of broiler breeders (parental lines)

The chain for producing broiler meat starts with the fertilised eggs that are produced in the broiler breeder farms. Hatching eggs are delivered to the hatchery plant, which normally return one day old chicks to the broiler farms. The two groups of males and females must be ~~uniformily~~ uniformly bred up in order to have successful management.

In the reproduction phase, animals need to be reared together but should be fed separately to maintain reproductive efficiency. Separate feeding is done by means of feeding lines at different heights that hence are accessible only to animals of proper sizes.

Traditional systems were previously used to house breeders, like cages and fully littered floor (see Section 2.2.2). New systems allow lower emissions and more effective management, and are derived from enriched cages, deep litter housings and aviaries. Descriptions in this section are simplified, since basic systems are described in Section 4.6.1 and Section 4.6.2 for the rearing of laying hens.

A summary of reported achievable emission levels from housing systems applied for the rearing of broiler breeders is presented in Table 4.62.

Table 4.62: Summary of reported achievable emissions in systems for rearing broiler breeders

Description	NH_3	PM_{10}	Odour	Source
	(kg/ap/yr)		(ou_E/ap/s)	
Section 4.6.5.1 Group-cage with manure belt and forced manure drying				
Group cage, manure belt, forced drying	0.080 (1)			[108, BE Flanders 2010]
Section 4.6.5.2 Partly littered floor with deep pit and frequent removal of manure				
Deep litter with manure belts	0.216 – 0.310 (2)	0.049 (3)	0.930 (3)	[110, Netherlands 2010]
Deep litter with ~~perforated floor and~~ scraper	0.290 (3)			[108, BE Flanders 2010]
Section 4.5.5.3 Deep litter system with manure aeration				
Deep litter with slatted floor and forced manure drying by horizontal pipes	0.25 (0.183 – 0.287) (2)	0.049 (3)	0.930 (3)	[112, Netherlands 2010]
Deep litter with slatted floor and vertical tubes for forced manure drying	0.435 (0.343 – 0.528) (2)	0.043 (3)	0.930 (3)	[109, Netherlands 2010]
Section 4.5.5.4 Deep litter with perforated floor and forced drying (perfosystem)				
Deep litter with perforated floor and forced drying	0.210–0.248 (2)	0.043 (3)	0.930 (3)	[111, Netherlands 2010]
Section 4.5.5.5 Deep litter system with ventilators				
Deep litter system with circulating ventilators	0.183 – 0.188 (2)	0.028 (2)	0.180 (2)	[114, Netherlands 2010]
Section 4.5.5.6 Aviary housing with manure aeration				
Aviary with manure aeration on belt	0.170 (1)	0.043 (3)	0.930 (3)	[108, BE Flanders 2010] [113, Netherlands 2010]
Aviary with manure aeration on belt and on litter	0.130 (1)			[108, BE Flanders 2010]
~~Aviary with extra level over the nests~~	~~0.130–0.202~~	~~0.043~~	~~0.930~~	

(1) Modelled values (e.g. results based on N balance).
(2) Measured values.
(3) Values derived by expert judgement based on conclusions by analogy.

Disease prevention is an aspect particularly critical for parent stock farms (breeders). Biosecurity requires the application of practices and procedures (e.g. cleaning, disinfection, 'all-in, all-out') aiming to prevent or reduce the entrance to the housing system and spread of microorganisms that might cause a disease. In the evaluation of individual housing techniques, the possible interaction with biosecurity must be considered.

4.6.5.1 Group-cage with manure belt and forced manure drying

Description
The ~~animals~~ birds are housed in enriched cage systems ~~like those described in Section 2.2.1.1.~~ The manure falls through the floor on the underlying manure belt and is dried with preheated air

Achieved environmental benefits
Refer to Section 4.6.1.1.

Cross-media effects
Refer to Section 4.6.1.1.

Operational data
The drying system and the manure removal from the belt must be dimensioned to allow for dry matter content in the manure of at least 50 %. Emissions are estimated at 0.080 kg NH_3 per ~~animal~~ bird place per year.

Applicability
Refer to Section 4.6.1.1.

Driving force for implementation
Refer to Section 4.6.1.1.

Economics
Refer to Section 4.6.1.1.

Example plants
In Belgium-Flanders, two installations of broiler-breeders were reported to use a cage-system in 2009. [467, BE, 2010]

Reference literature
[108, BE Flanders 2010]

4.6.5.2 Partly littered floor with deep pit and ~~Deep litter system with the~~ frequent removal of ~~the~~ manure

Description
This system is derived from the system described in Section 4.6.2.1.1. The housing consists of a concrete littered floor where the birds can move around freely. Part of the floor is elevated and slatted, under which manure storage takes place. Wet droppings are removed by a manure belt to a covered outside storage. The frequency of manure removal is at least twice per week. The dry matter content of the manure at the time of removal is at least 30 %.

~~Alternatively the pit is substituted by a shallow manure storage. It has a polished concrete bottom with the surface that is very smooth and non-adherent, where a scraper tightly fits and covers its entire width, removing the manure to a closed external storage.~~ **Moved to Section 4.6.2.1.1.**

Achieved environmental benefits

The ammonia emissions are reduced by the frequent removal of the droppings, in combination with the ~~that can be enhanced by the droppings~~ aeration of the manure over the belts.

Cross-media effects
~~Manure drying with forced preheated air is an expensive technique in terms of energy.~~
Increased energy consumption for operating the frequent manure removal by belts, with associated indirect emissions for electric energy production.

Operational data
The maximum ~~animal~~ bird density is restricted to 7 – 8 animals per m². The available area is about half slatted and half bedded floor.

The drinking, feeding and resting equipment is situated above the slatted floor. At the start of each production cycle, a layer of litter of at least 3 cm has to be applied. The manure is removed at least twice a week from the belts, and at least once a day where the scraper is installed. In order to minimise the emissions originating from the droppings in the littered area, the average dry matter content of the bedding should be maintained at least at 70 %.

Ammonia emissions equivalent to 0.216 – 0.310 kg NH_3 per ~~animal~~ bird place per year have been reported for the ~~belt~~ system using manure belts. [110, Netherlands 2010] In case ~~Where~~ the scraper is installed, NH_3 emissions of less than 0.290 kg NH_3 per ~~animal~~ bird place per year have been estimated, based on measurements performed in similar installations for laying hens. [108, BE Flanders 2010]. The average reported ammonia emissions from the housing system with frequent removal by manure belts (0.245 kg NH_3/ap/yr) are 58 % lower than the emission levels of the reference system, corresponding to the traditional deep litter system used in the Netherlands (0.580 kg NH_3/ap/yr).

Applicability
~~The technique is generally applicable.~~ The placement of a manure belt or scraper underneath the slatted floor in an existing manure pit is not always possible and involves additional costs, if compared with the application of the technique to a new housing system.

Economics
In the Netherlands, in the case of housing systems equipped with manure belts, the investment per ~~animal~~ bird place is evaluated ~~at~~ in the range of EUR 14.40 – EUR 19.80 and the extra-cost for new installations is equivalent to EUR 3.5/ap/yr. ~~in the case of belts.~~. [110, Netherlands 2010]

Driving force for implementation
See Section 4.6.5.3.

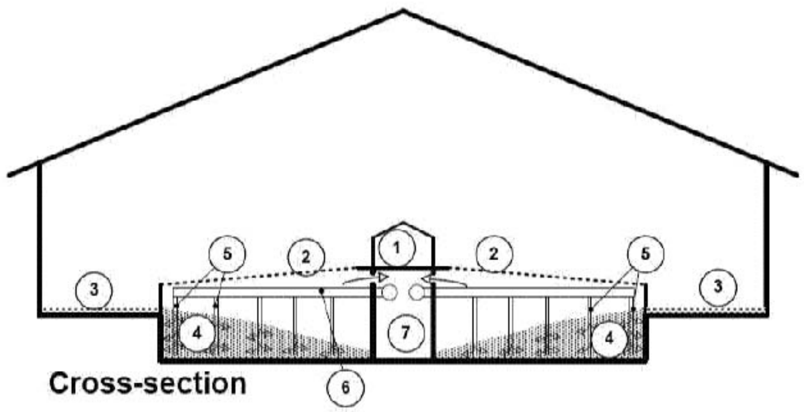
Example plants
In the Netherlands, in 2008 around 8 % of ~~this type of animal~~ broiler breeders was reared in ~~such~~ houses with frequent manure removal by belts. [110, Netherlands 2010]. An application with the alternative version with scraper is reported in a new farm in Belgium-Flanders [467, BE 2010].

Reference literature
~~Van Emous, R.A. van, A. Lourens & J. van Harn, 2004. 'Vitaliteit vleeskuikenouderdieren en ammoniakmetingen (Vitality of broiler breeders and ammonia measurements)'. *PraktijkRapport Pluimvee 13*. Praktijkonderzoek Veehouderij, Lelystad, 2004.~~
~~Van Emous, R.A. van, 2009. 'Innovatie in huisvesting van vleeskuikenouderdieren: onderzoek en evalutatie (Innovation for broiler breeder housing: research and evaluation)', Rapport 251. Wageningen U.R., Lelystad, The Netherlands, 2009.~~
[108, BE Flanders 2010] [110, Netherlands 2010]

4.6.5.3 Deep litter system with manure pit aeration through pipes underneath the slatted floor

Description
This system is derived from the housing system described in Section 4.6.2.1.2. It consists of a concrete littered floor where the animals can move around freely. Part of the floor is elevated and has a slatted floor under which the manure pit is situated. ~~The~~ Ammonia emissions are reduced by the aeration of the manure collected in the pit with air from an air mixing cabinet or a heat exchanger. The pipes through which the air is blown are situated underneath the slatted floor and can be placed horizontally or vertically.

In the horizontal version ~~one solution~~ the pipes are installed under the slatted floor ~~hung~~ parallel to the laying nests and can move vertically according to the manure level in such a way that the vertical distance between the pipes and the manure is always close to 20 cm ~~mm.~~ Alternatively, the aerating tubes can be installed vertically under the slatted floor (see Figure 4.25). The functional areas for feeding, drinking and resting are arranged are ~~The drinking equipment is~~ situated above the slatted floor.



Legend: 1) Laying nests 2) Slatted floor
3) Litter area 4) Manure pit
5) Forced air tubes 6) Air supply pipes
7) Drain away canal → Direction of air flow

Figure 4.25: Section of system with forced air drying by vertical tubes

Achieved environmental benefits
Refer to Section 4.6.2.1.2.

Cross-media effects
The system with the horizontally placed tubes implies additional energy consumption depending on the air temperature and the amount of forced air used for drying the manure.

Operational data
The maximum animal density is restricted to 7 – 8 animals per m², including roosters. At least one third of the available area has to be littered floor.

The volume of air blown over the manure by horizontal pipes is reported ~~around 1.5~~ at 2.5 m^3 ~~of~~ per bird ~~animal~~ per hour, at a minimum temperature of 24 ºC; while 50 % of the inlet air is coming from outside the house (fresh air).

The tubes installed vertically are robust and not impressible. They blow air through small holes at a minimum rate of 1 m^3 per hour per animal. At least 50 % of the used air comes from outside and is heated at a minimum temperature of 20 °C.

Ammonia emissions have been reported for the versions with horizontal pipes ranging from 0.183 to 0.287 kg/ap/yr, and from 0.343 – 0.528 kg/ap/yr for the versions with vertical pipes. The reported average values for ammonia emissions for the vertical configuration of pipes (0.435 kg NH_3/ap/yr) and for the horizontal configuration (0.25 kg NH_3/ap/yr) are respectively 57 % and 25 % lower than the emissions associated with the reference housing system in the Netherlands, consisting of a traditional deep litter system (0.580 kg NH_3/ap/yr).

Applicability
Refer to Section 4.6.2.1.2.

Driving force for implementation ~~and Example plants~~
Refer to Section 4.6.2.1.2.

Economics
~~The normal costs per animal place in the version with horizontal pipes are: from EUR 14.00 to EUR 19, 30 for the investment, EUR 0.51 for annual running, and EUR 2.18 and EUR 2, 18 for total annual cost (investments annualised to EUR 1.67)~~

Cost data concerning deep litter systems with manure pit aeration for both configurations, with horizontal and vertical pipes, are presented in Table 4.63.

Table 4.63: Cost data for deep litter systems equipped with manure pit aeration through pipes

System configuration	Investment costs	Annualised investment costs	Annual running costs (energy)	Total Cost
	EUR/ap	EUR/ap/yr		
Horizontal pipes (drying from above)	17 (from 14.3 to 19.7)	1.7	4.6	6.65
Vertical pipes	16.6 (from 14 to 19.3)	1.67	0.51	2.18
Source: [109, Netherlands 2010] [112, Netherlands 2010]				

Data concerning extra-costs on investment and running costs, in comparison with a reference traditional deep litter system, are also reported from the Netherlands and presented in Table 4.64.

Table 4.64: Extra costs for deep litter systems equipped with manure pit aeration through pipes, in comparison with a reference system

System configuration	Extra investment costs	Annualised extra investment costs	Total extra running costs
	EUR/ap	EUR/ap/yr	
Horizontal pipes (drying from above)	3.40	0.36	4.96
Vertical pipes	3.05	0.31	0.82
Source: [589, Netherlands 2010]			

Example plants
In Belgium-Flanders, 10 housing systems are using the technique, including farms above and below the IED capacity threshold. [467, BE 2010] In the Netherlands, 8 % of the birds are housed in systems equipped with aerated manure pit aeration, applying the configuration with horizontal pipes.

Reference literature
[108, BE Flanders 2010] [109, Netherlands 2010] [112, Netherlands 2010]

4.6.5.4 Deep litter with perforated floor and forced drying (perfosystem)

Description
Refer to Section 4.6.2.1.3.

Achieved environmental benefits
Refer to Section 4.6.2.1.3.

Cross-media effects
Refer to Section 4.6.2.1.3.

Operational data
In Belgium and in the Netherlands, values from 0.210 to 0.248 kg NH_3 per animal place per year ~~of~~ for ammonia emissions are associated with this system.

Applicability
The system is applicable to new and existing houses for broiler breeders.

Economics
Costs have been reported from the Netherlands: investments costs ~~per animal place are necessary~~ from EUR 12.90 to EUR 17.80 per bird place; with annual running costs ~~of~~ around EUR 0.25 EUR/ap/yr. The annualised investment costs are equivalent to 1.5 EUR/ap/yr and the ~~so that~~ total annual costs are about 1.75 EUR/ap/yr. The extra-costs for a new installation are estimated equivalent to 1.8 EUR/ap/yr.

Driving force for implementation
Refer to Section 4.6.2.1.3.

Example plants
In Belgium-Flanders, one farm for broiler-breeders is reported to use this system. [467, BE, 2010]

Reference literature
[111, Netherlands 2010] [108, BE Flanders 2010] [589, Netherlands 2010]

4.6.5.5 Litter based systems with circulating fans ~~Deep litter system with ventilators~~

Description
In ~~the~~ a deep litter system ~~house~~, without manure pit and where a centralised ventilation is not fitted, vertical shafts equipped with ventilators are hung from the ceiling. ~~wich each have a ventilator hung. The ventilation is not on pressure drop.~~

At the bottom of the shaft, at a maximum of 1.20 m above the litter, a special element is placed to let the air come out in a horizontal direction.

Please refer to Sections 4.5.4.3.2 and 4.6.4.1.1, for a full description of the technique.

Achieved environmental benefits
The ventilators mix the indoor air and allow for ammonia reductions and a better environment for the animals.

Cross-media effects
Refer to Section 4.6.4.1.1.

Operational data
The shafts are placed in two rows by the length of the house at a rate of one ventilator every 150 m^2. Ventilators have a minimum capacity of 1.8 m^3/hour per bird, without any pressure drop. At the beginning of the cycle (pullet of one day of age) the ventilators start a at a capacity of 10 % and progressively reach 100 % capacity on day 40.

Associated emissions per animal place per year are 0.183 – 0.188 kg ap/yr of ammonia, 0.028 kg/yr of PM_{10} and 0.18 ou_E/s/ap.

Applicability
Refer to Section 4.6.4.1.1.

Economics
From the Netherlands, the extra investment costs for the ventilation system are reported equivalent to EUR 1 per bird place. The operating costs are reported equivalent to EUR 0.135 per bird place per year.

Driving force for implementation
Refer to Section 4.6.4.1.1.

Example plants
Refer to Section 4.6.4.1.1.

Reference literature
[114, Netherlands 2010] [469, NL 2011]

4.6.5.6 Aviary housing with manure aeration

Description
The system is basically an aviary system where the animals can move freely throughout the entire house which consists of different levels (tiers) of slatted floor and littered area on concrete solid floor. (see Section 4.6.2.2.1). Manure removal belts are installed underneath the slatted floor remove the manure under the elevated floors, The manure collected on belts where it can be dried by (preheated) forced air, conveyed through pipes above or along the belts. Additionally, the manure on the littered floor area can be dried by preheated air (e.g. from heating units), as is the manure on the belt, allowing additional higher emissions reductions. Conversely, An extra level can be built on top of the laying nest (see Figure 4.26), allowing to place more birds (10 – 15 %) in the same house.

Functional areas for feeding, drinking and resting are arranged above the dropping area.

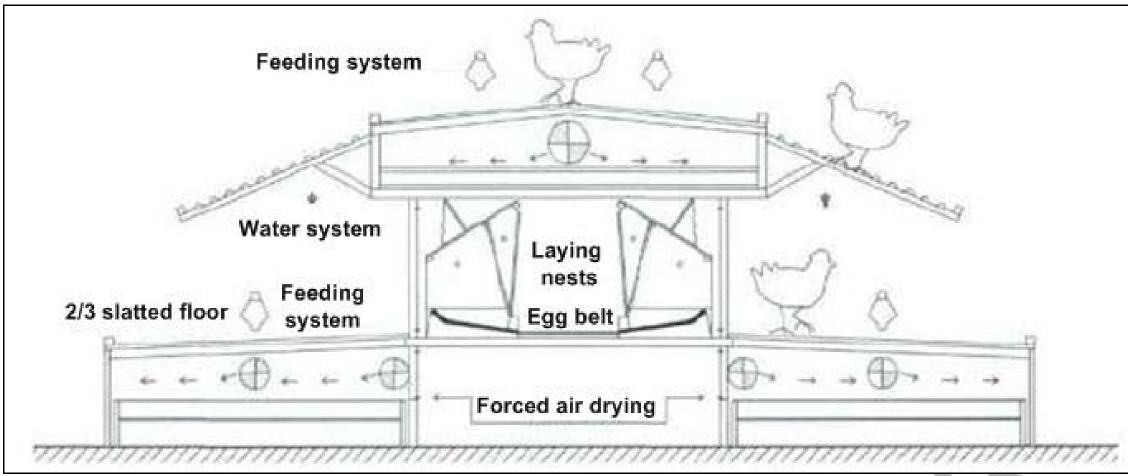


Figure 4.26: Scheme of an additional tier over the nests in an aviary system

Achieved environmental benefits
Ammonia emissions are reduced by the frequent removal and by the manure drying on the belts.

Cross-media effects
The additional tier above the nest gives the possibility to the females to hide from the males. This can decrease the fertility and hatchability of the eggs.

Operational data
The manure on the manure belt ~~must~~ should be removed from the housing at least once a week and ~~must~~ should have at that time a dry matter content of at least 50 %.

Ammonia emissions were measured ~~are estimated~~ at 0.170 kg of NH_3 per ~~animal~~ bird per year (ranging from 0.130 kg to 0.202 kg NH_3/ap/yr, achieved with at least a weekly manure removal and manure drying with preheated air. ~~in the version without preheating. From 0.130 kg to 0.202 kg of NH_3 are emitted per animal per year if litter heating is applied or if the tier over the nest is added.~~ The reported emissions of ammonia are 71 % lower than those associated with the use of the traditional reference system adopted in the Netherlands (deep litter), equivalent to 0.580 kg NH_3/ap/yr.

Applicability
Refer to Section 4.6.2.2.1.

Economics
The ~~most expensive version, the one~~ system configuration with the added tier, is associated to investments costs from EUR 15.00 to EUR 20.60/ap, annualised investment costs of 1.85 EUR/ap/yr, annual running costs of ~~around~~ EUR 0.50/ap and total annual costs of ~~about~~ EUR 2.35/ap.

Driving force for implementation
Refer to Section 4.6.2.2.1.

Example plants
Refer to Section 4.6.2.2.1.

Reference literature
[113, Netherlands 2010] [108, BE Flanders 2010]

4.6.6 Techniques for housing of turkeys

4.6.6.1 Solid fully littered floor in forced ventilated closed houses

Description

Young Turkeys are reared in a closed, well-insulated buildings, with forced ventilation. The solid floor is fully bedded with wood shavings and/or straw. If necessary, additional straw is added during the fattening period. No separate functional areas exist. The Manure is removed at the end of the cycle. The cycle consists of rearing all turkeys of both genders for 4 to 6 weeks which and can be prolonged, after separating the stags, with the finishing period of the hens at until week 16. After sex separation, stags can be fattened reared in this system too, but more often they are reared in similar houses with natural ventilation, until the end of the their fattening period (see Section 4.6.6.2).

Achieved environmental benefits

The absorptive material (e.g. straw) binds urine and faeces in the litter and provides a dry area. The bedding, by absorbing the humidity of the droppings, reduces the emissions of ammonia.

Cross-media effects

Dust emissions are typically increased in deep litter housing systems.

Operational data

From France, it is reported that bedding is added in quantity of 9 – 12 kg/m^2, considering possible top-up additions during the fattening period. In Germany, the amount of required bedding material for the initial mixed gender rearing period is reported to be 2.2 kg/ap/yr) of chopped straw, and for the fattening period 0.8 kg/ap/yr of wood shavings plus 5.8 kg/ap/yr of chopped straw.

In the first seven days after arrival, the birds animals are reared in confinement rings that are further progressively made wider. Daily controls are needed for temperature, litter moisture and for the height of the feeding and drinking equipment.

The ventilation is controlled in order to provide the birds animals with the air volumes as reported in Table 4.65.

Table 4.65: Ventilation parameters in turkey rearing m^3 per animal per hour

Period	Young turkeys	Fattening hens	Fattening stags
	m^{3}per animal per hour		
Cold season	0.1 – 1	1 – 3.6	1 – 5.5
Warm season	0.6 – 14.6 6	6 – 32	6 – 48.6
Minimum on hot days	NA	4.5	8 – 32
Source: [62, Germany 2010] [61, Germany 2010] [118, Germany 2010] [500, IRPP TWG 2011]			

Reported emission levels associated with the rearing of turkeys are presented in Table 4.66.

Air cleaning systems used for the reduction of ammonia emissions from the rearing of broilers can be applied to turkey housing systems based on deep litter. However, except for scrubbers, the efficacy of the techniques will be lower than that achievable with broilers, due to the larger amount of manure and higher dry matter content of the litter. In the Netherlands, the effectiveness of air cleaning techniques applied on turkey housings is considered half of that achievable in broiler housings. [508 TFRN]

Table 4.66: Emissions from turkey rearing systems, with deep litter and forced ventilation

Rearing phase and parameters	Emission levels			Source
	Ammonia	**PM_{10}**	**Odour (1)**	
	kg NH_3/ap/yr	kg PM_{10}/ap/yr	ou_E/s/ap	
Mixed gender start-up rearing period (4 – 6 weeks; weight: 2 kg)	0.15 (2)	0.07 (2)	0.007	[118, Germany 2010] [474, VDI, 2011]
Female fattening period, hens (16 weeks; weight: 10 – 11 kg)	0.387 (2)	0.3 (2)	0.400	[118, Germany 2010] [474, VDI, 2011]
	0.045 (3)	0.5 (3)	-	[500, IRPP TWG 2011]
Male fattening period, stags (20 – 21 weeks; weight 21 kg)	0.680 (2) (4)	0.8 (2)	0.710	[118, Germany 2010] [474, VDI, 2011]
	0.138 (3)	0.9 (3)	-	[500, IRPP TWG 2011]
Start-up rearing period plus male fattening (0.05 to 18 kg in 20 weeks)	0.44 (5)	-	-	[102, UK 2010],

(1) Values have been calculated from an emission of 32 ou_E/s per LU and an average weight of 1.1 kg for the start-up rearing period for turkeys, 6.25 kg for female fattening, and 11.1 kg for male fattening.
(2) Measured values.
(3) Values derived by expert judgement based on conclusions by analogy.
(4) An emission level of 0.68 kg NH_3/ap/yr is considered as the reference.
(5) Modelled values (e.g. results based on N balance).

Applicability
Applicable to both new and existing installations. The technique is used for rearing of young turkeys and, afterwards, for the fattening of female turkeys; optionally, the technique may also be applied for the fattening of male turkeys.

Economics
Figures that have been modelled in Germany indicate the required investments ~~at~~ between EUR 53.00 and 84.00 per ~~animal~~ bird place, ~~that are~~ corresponding to annualised costs between ~~as~~ EUR 1.70 and 7.30 per ~~animal~~ bird place per year. Annual running costs are reported at EUR 4.70 per ~~animal~~ bird place per year.

From Germany, labour demand is reported at 0.1 – 0.13 h/ap/yr, energy consumption for heating at 0.12 kWh/ap/yr and for lighting 0.5 kWh/ap/yr.

Driving force for implementation
Increased productivity with structural flexibility combined with good indoor climate is achieved at low investment and running costs, since energy requirements are low.

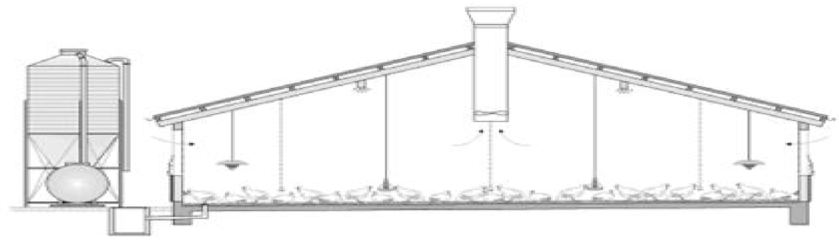
Example plants
The system consisting of the start-up rearing phase and the fattening period of hens is normally used in Germany, in rotation with the system for rearing stags as in Section 4.6.6.2.

Reference literature
[102, UK 2010] [118, Germany 2010]

4.6.6.2 Solid fully littered floor in naturally ventilated houses, with or without free ranges

Description

After sex separation, stags are usually reared in thermally insulated houses, with natural ventilation (with open sidewalls) until the end of the fattening period. The slaughter weight for stags is about 18–21 kg, achieved at an age of 20 – 21 weeks. A backup ventilation system can be placed by installing extraction fans on one side of the shed. In the UK, the animals can often access open free ranges. Manure is removed at the end of each growing period. This type of housing system can be optionally used for fattening hens. A scheme of the deep litter housing system for turkeys, with natural ventilation is shown in Figure 4.27.



Source: [119, Germany 2010]

Figure 4.27: Scheme of a natural ventilated house for turkeys fattening

Achieved environmental benefits

Naturally ventilated houses demand lower energy consumption. A reduction of emissions is considered possible, due to lower indoor average temperatures, associated with the open climate design of the housing system.

Operational data

The bedding needs frequent top-up addition that can be applied daily. Reported emissions from naturally ventilated turkey houses, with or without free ranges, ~~rearing~~ do not show a difference from forced ventilated houses ~~do not depend on the housing system used nor on the presence of free ranges, and are those~~ Emission level for both naturally ventilated an forced ventilated housing systems are presented in Table 4.66.

Economics

The same cost figures as for the previous system have been reported. In addition, the annual running cost, calculated for a house of 8750 bird places, in Germany, is reported equivalent to 4.7 EUR/ap/yr.

Driving force for implementation

Open climate houses provide a better indoor climate, due to lower average indoor temperatures.

Example plants

It is the most widespread system for stags in Germany~~, and hence it is seen as a reference~~.

Reference literature

~~[108, BE Flanders 2010]~~ [103, UK 2010][119, Germany 2010]

4.6.7 Techniques for the housing of ducks

4.6.7.1 Solid floor with deep litter

Description
Ducks are reared on solid floors with bedding, without separate functional areas. ~~with automatic feeding and drinking systems.~~

Two different rearing systems may be used: 'all-in, all-out' or two separate growing periods. ~~The production can be divided into~~. In the 'all-in, all-out' system, the complete rearing of the birds is carried out and birds and litter are removed at the end of the cycle. With the two separate growing periods system (starting and finishing rearing periods), the birds are moved to another house after the first period. In the starting rearing period, the space per animal is reported to vary between 0.067 and 0.072 m^2/ap. In the 'all-in, all-out system and in the fattening period for the two separate growing stages, the space per animal is reported to vary between 0.143 and 0.21 m^2/ap.

Houses can be forced or naturally ventilated and ~~the~~ manure is always removed at the end of the cycle. Houses that are used for the starting rearing period and for the 'all-in, all-out' system ~~and where and the finishing period may take place~~ are of a closed type, well insulated, with forced ventilation and are equipped with automatic feeding and drinking systems. If the finishing period is run separately, it may take place in a simpler open climate house, with natural ventilation. ~~until the weight of 3 – 3.35 kg per head is reached at an age of around 45 days.~~

Achieved environmental benefits
Emissions are reduced as a result of daily topping-up with bedding material and a consequent increased absorption of humidity.
~~This is the reference system for ducks for meat production.~~ ~~No special technique for reducing emissions is applied~~.

Cross-media effects
None reported.

Operational data
The amount of bedding material used for the fully littered floor is reported from Germany equivalent to 7 kg/ap/yr for the starting rearing period, and 28 kg/ap/yr for the finishing period. From the Netherlands, the amount of bedding material is reported to be 1 kg of wheat straw per m^2 and from UK 4 kg/bird, corresponding to around 23 kg/per bird place per year for 4.7 cycles/yr.

~~With a daily base, the bedding is added on top of the existing bedding, for a total use of approximately 1 kg per square metre [DE] or 7 kg of straw per animal place per year [NL].~~

Where forced ventilation is applied, the volumes of air that are supplied to the birds ~~animals~~ range from 0.1 to 0.8 m^3 per animal per hour in the cold season and up to 8 ~~6.3~~ m^3 per animal per hour in the warm season. [500, IRPP TWG 2011] For the finishing period, air volumes are ~~needed~~ in the range of 0.6 to 1.3 m^3 per animal per hour in the cold season and up to 11.3 m^3 per animal per hour in the warm season.

In general, the drier the litter, the lower the level of ammonia emitted. [152, Link CR 2006] Emissions have been measured in Germany for the two rearing periods and resulted in 0.05 kg of ammonia and 0.01 kg of total dust per animal place per year for the starting period and 0.15 kg of ammonia and 0.04 kg of total dust per animal place per year for the finishing period. Emission figures for the complete cycle ~~come~~ reported from the Netherlands and UK (estimated) ~~and~~ are in the range of 0.11 to 0.227 kg for ammonia and ~~are~~ 0.078 kg for methane. Emission data for different deep litter housing systems used in the rearing of ducks are presented in Table 4.67.

Table 4.67: Reported emission data from deep litter systems for the rearing of ducks

Production system and rearing phase	NH_3 kg/ap/yr	Odour ou_E/s/ap	PM_{10} kg/ap/yr	Source
Deep litter with forced ventilation Pekin ducks rearing (from 0.05 kg to 1.2 – 1.5 kg in 1 to 21 days)	0.05 (1)	0.098 (1) (2)	0.01 (1) (3)	[117, Germany 2010]
Deep litter with forced ventilation Pekin ducks fattening (from 1.2 – 1.5 kg to 3 kg in 21 to 47 days)	0.15 (1)	0.29 (1) (2)	0.04 (1) (3)	[116, Germany 2010]
Deep litter with forced ventilation All-in, all-out (from 0.05 kg to 3.35 kg in 49 days)	0.21 (1) (from 0.199 to 0.227)	0.49 (4)	0.084 (4)	[115, Netherlands 2010]
Deep litter with forced ventilation All-in, all-out (from 0.04 kg to 3.3 kg in 49 days)	0.11 (4)	-	-	[106, UK 2010]
Deep litter with natural ventilation All-in, all-out (from 0.05 kg to 3.6 kg in 47 days)	0.11 (4)	-	-	[104, UK 2010]

(1) Measured values.
(2) Values have been calculated from an emission of 75 ou_E/s per LU and an average live weight of 0.65 kg for duck rearing and 1.9 kg for duck fattening [474, VDI 2011].
(3) Values refer to total dust.
(4) Modelled values (e.g. results based on N balance).

Relatively small slatted areas are also incorporated for accommodating the drinkers for the birds, with the aim to minimise litter moisture levels, but at the same time to meet all the welfare regulations on drinker provision for the ducks. [152, Link CR 2006]

Air cleaning systems used for the reduction of ammonia emissions from the rearing of broilers can be applied to duck housing systems on deep litter. However, except for scrubbers, the efficacy of the techniques will be lower than that achievable with broilers, due to the larger amount of manure and higher dry matter content of the litter. In the Netherlands, the effectiveness of air cleaning techniques applied on duck housings is considered half of that achievable in broiler housings. For ducks provided with water bowls (for the welfare of water birds) the efficacy may be even lower. [508 TFRN]

Applicability
Applicable to both new and existing installations.

Economics
Comparable cost data are reported from Germany and the Netherlands, ~~Dutch figures match~~ showing an investment of EUR 34.00 – 35.00 per ~~animal~~ bird place, for the 'all-in, all-out' housing systems and for the finishing period of the two-phases rearing system. The investment cost for the starting period of the two-phases system is reported from Germany equivalent to EUR 14 per bird place. In the UK, in forced ventilated housing systems, one operator ~~person~~ is expected to attend 24 000 ~~16 000~~ birds in a 40-hour working week. In Germany, labour demand is reported at 0.25 h/ap/yr.

Driving force for implementation
The version of deep litter with natural ventilation allows better indoor climate, lower energy demand, lower investment and running costs than the closed version with forced ventilation.

Example plants

The technique is widely applied. It is the most widespread system used in Germany for the production of ducks.

Reference literature

[116, Germany 2010] [117, Germany 2010] [115, Netherlands 2010] ~~[107, UK 2010]~~ [104, UK 2010] [106, UK 2010]

4.6.7.2 Littered floor combined with partly-slatted floor

Description

Ducks are reared on solid floors with bedding topped up every day. Around 25 % of the surface is covered by a slatted floor. ~~The~~ Manure is ~~all~~ completely removed ~~after~~ at the end of the 'all-in, all-out cycle.

Achieved environmental benefits

Keeping the litter dry by adding new bedding material daily, reduces NH_3 emissions. The incorporation of slatted areas in the housing system, for accommodating the drinkers for the birds, allows minimising moisture levels in the litter, meeting at the same time all welfare regulations concerning drinker provision for the ducks. [152, Link CR 2006]

~~This is the reference system for ducks for meat production. No special technique for reducing emissions is applied.~~

Cross-media effects

More water is necessary for cleaning the houses at the end of the cycle, compared to fully-slatted floor housing systems.

Operational data

The slatted area is ~~opened~~ available to birds ~~animals~~ when they reach 14 days of age, when the gas brooders stop heating the young birds ~~animals~~. All the environmental conditions are adjusted automatically or manually depending on the age of the birds. In the UK, in one year 6 – 7 batches of birds ~~animals~~ are grown.

As reported from UK, an example farm of 120 000 birds ~~animals~~ would require annually 2 160 tonnes of bedding material, around 152 000 kWh of electrical power, 75 tonnes of fuel and more than 10 000 m^3 of water.

Emissions are estimated at 0.11 kg of ammonia and 0.078 kg of methane per ~~animal~~ bird place per year.

Applicability

Please TWG provide information

Economics

Costs for this technique have been ~~calculated~~ reported for ~~in~~ an example farm that rears 120 000 birds ~~animals~~ and produces six batches in cycles of 45 days (from 0.05 to 3.6 kg); under these conditions, the annual running cost is around EUR 700 000 for the production of 1728 tonnes of meat.

Driving force for implementation

Please TWG provide information

Example plants

Please TWG provide information

Reference literature
[105, UK 2010] [107, UK 2010]

4.6.7.3 Fully-slatted floor

Description
In the buildings, slats cover the pit from where the manure is stored and evacuated to external stores ~~storages~~ with variable frequency. Common slurry management systems in pits are:

- storage in the pit throughout the whole cycle
- permanent gravitating flow to an external store ~~storage~~
- scraping with variable frequencies to an external storage.

Achieved environmental benefits
From deep stores ~~storages~~ the highest ammonia emission develops. The gravitating flow and the scraping removal allow reduced times of slurry exposure to air by the more frequent removal.

The emission reduction effect is higher in winter than in summer, and on the contrary odour emissions are prevented in the warm season.

Cross-media effects
More water for cleaning is needed compared to litter based housing.

This technique was evaluated for the carbon footprint over the whole system in a comparative study against litter-based systems. It was shown that despite higher greenhouse gas emissions due to the manure management, the fully-slatted floor housing has same or better performances than systems based on straw-bedded housing, especially where straw is supplied from longer distances. [475, Merlet et al. 2010]

Operational data
Manure removal by scraping is very common with this housing system. Scrapers are very reliable; ~~and widespread.~~ the frequency of scraping must be adapted according to the age of animals, the season (temperatures and ambient humidity ~~hygrometry~~) and the state and ~~the~~ volume of droppings. Too dry droppings and too low volumes degrade the state of the scrapers and ground; whereas, too high volumes might harm the functioning of the scrapers. ~~too dry droppings or too low volumes might damage the scraper's functionality.~~

Applicability
Please TWG provide information.

Economics
The indicative cost for the purchase of a scraper (electrical connections and ~~workmanship~~ labour demand included) is around EUR 8.3/m^2, excluding taxes.

In the UK, the cost for the purchase of a scraper is around EUR 35 – 40 per bird place, for a housing system equipped with natural ventilation, and EUR 40 – 45 per bird place with forced ventilation.

Driving force for implementation
In France, the majority of farms for the production of ducks use fully-slatted floors with scrapers. The system is considered as the best way to rear Barbary ducks that are subjected to sanitary problems. Local shortage of straw, due to competition from other livestock (frequent for the major French basin of production, Pais de la Loire and Brittany) favours this technique as an alternative to deep litter housing.

Example plants
This system is the reference in France for the rearing of Barbary ducks (*Chairina Moschata*).

~~Scrapers are very reliable and widespread. Frequency of scraping must be adapted according to the age of animals, the season (temperatures and hygrometry) and the state and the volume of droppings: too dry droppings or too low volumes might damage the scraper's functionality~~

Reference literature
[368, France 2010] [475, Merlet et al. 2010]

4.7 Techniques for reducing emissions from pig housing

ORIGINAL TEXT, ALREADY DELETED IN DRAFT 1, HAS BEEN REMOVED FROM THE FOLLOWING SECTIONS

This section reflects the information submitted on techniques that aim to reduce emissions from pig housing facilities. The information available mainly ~~entirely~~ focuses on ~~the~~ NH_3 emissions to air ~~of NH_3~~ whilst dust, odour and greenhouse gas emissions are also taken into consideration.

The relationship between housing systems and animal welfare must be considered, since some techniques may entail potential disadvantages. Directive 2008/120/EC on the welfare of pigs requires that 'pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals.' (Point 4 of Annex I, Chapter I). Based on these requirements, the use of fully-slatted floor is not recommended in Finland.

A high stocking density, associated with lack of enrichment and fully-slatted floors, has been assessed as a significant risk for tail biting. [495, EFSA 2007] Tail-biting may cause poor welfare and neither tail-docking nor reduction of corner teeth must be carried out routinely (Point 8 of Annex I, Chapter I of Directive 2008/120/EC).

~~Techniques can be divided into the following categories:~~
~~integrated techniques:~~

~~In the houses, a close integration of~~ In pig housing, although techniques may be ~~that are~~ managed separately, they all produce ~~produces~~ an integrated environmental impact ~~effect~~. Those techniques are:

- nutritional measures to reduce the amount and the N content of manure (see Section 4.3)
- control of the indoor housing climate
- optimisation of pig housing design
- ~~end-of-pipe techniques.~~

Nutritional measures, as described in Section 4.3, ~~were described in Section 4.3~~ for preventing ~~the~~ emissions from ~~the~~ housing by reducing the concentration of nitrogen in manure and slurry, produce a reduction of emission in all stages ~~below~~ of the production chain. ~~Measures are described in section 4.3.~~ In most cases, emissions reported in this section are based on pigs reared on ~~considered to be produced with a 'normal diet'~~ a standard diet, in other words a diet without any effect ~~not considering the effects~~ of nutritional management, such as phase feeding..

Indoor environmental management, particularly with regard to temperature, essentially conditions the behaviour of the pigs in relation to their zones of excretion and their cleanliness (see Section 3.3.2.2) and in relation to the efficiency of feed utilisation. Relatively low temperatures are effective but are difficult to be kept during the warmer seasons. [261, France 2010]

Controlling ~~of~~ the indoor ventilation rate, as well as the airflow patterns, in order to reduce the air flow over the slurry surface ~~the indoor housing, in terms of reducing the air velocity at the manure surface and having~~ and to lower ~~low~~ the indoor temperatures (less fouling of floors), can reduce emissions ~~even more~~. Nevertheless, the minimum levels of ventilation rate and temperature required for animal welfare and health reasons needs to be ensured, e.g. if a too low ventilation rate is applied the indoor environment may become highly concentrated in ammonia, even though the overall emissions will be reduced. Optimum control of the housing environment, particularly during summer, can contribute to ensuring that the animals drop their excrement in the defecating ~~dunging~~ area while the lying and exercise areas remain clean and dry. Low volume flows, low air inlet temperatures, and low air velocities in the livestock area and above the housing floors all reduce the occurrence and release of air-polluting substances in the housing. The flow pattern of the air in the housing can be favourably influenced by the position and dimension ~~dimensioning~~ of the supply and waste air apertures (e.g. side wall or gable extraction, or linear extraction through waste air ducting). Incoming air conduction through perforated ducts and porous ceilings results in low air velocities in the livestock area. Air inlet temperatures and volume flows can be reduced by, for example, locating the fresh air intake in shady zones, or ducting the air via the feeding passage or through a ~~via an earth (or water)~~ heat exchanger.

These factors must be controlled to meet the pigs' needs and often require a certain energy input. The evaluation and quantification of emission reductions through the application of these techniques is complex and clear conclusions have not been reported.

~~A lot of attention is paid to~~
Animal houses ~~design~~ are carefully designed, paying attention to ~~i.e.~~ the combination of the floor system, manure collection and the manure removal system, but also considering the variables influencing the indoor environment. The housing systems described ~~basically~~ involve some or all of the following principles:

- reducing emitting manure surfaces;
- reducing ~~removing~~ the manure (slurry) permanence indoors and removing manure from the pit or channelling to an external ~~slurry~~ storage;
- applying an additional treatment, such as aeration, to obtain flushing liquid;
- cooling the manure surface;
- changing the chemical/physical properties of the manure, such as decreasing the pH;
- using surfaces which are smooth and easy to clean;
- controlling the characteristics of the indoor air: flow volumes, speed, temperature and in/outlet surfaces;
- steering excretory animal manure behaviour to minimise the fouled areas;
- absorbing excretions into bedding material and properly managing the litter.

A few general remarks can be made. ~~The relative~~ Reducing the surface area of the slatted floor reduces the emitting slurry surface and, consequently, reduces NH_3 emission. However, due to fouling of the solid floor, the reduction in NH_3 emissions ~~of the application of solid flooring to slatted flooring allows for a reduction in emissions that nevertheless~~ is not always proportional with the reduction of the slatted floor area, since emissions also depend on other operating parameters. For example, the reduction of fully-slatted floor~~ing~~ to 50 % slatted floor surface reduces the emitting manure surface by approximately 20 %, where any manure remaining on the solid floor part also has to be taken into account. The 50 % slatted floor system works well in the winter, but not so well in the summer. Furthermore, pen fouling increases towards the end of a growing period, which will also increase emissions, due to an increased surface area emitting ammonia. [439 , Sommer et al. 2006]

On the other hand, there are cases when the excretory behaviour of the pigs that tend to foul the solid area under specific conditions, such as hot temperature or high animal density, do not allow a reduction in emissions with partly-slatted floor compared to fully-slatted floor systems. For example, it is reported from France that NH_3 emissions may increase by around 30 %, in comparison to fully-slatted floor systems, when fattening pigs tend to excrete on the solid floor at around 24 ºC. In this case, additional economic implications may occur when dirty pigs are not well accepted by slaughter companies. [261, France 2010] [590 , BATFARM , 2013].

The installation of a sprinkler to cool the animals, or sufficient available space area could prevent increasing of emissions. Moreover, the proper design of housing conditions (e.g. the appropriate location of the feeding and watering facilities, induced air drafts), respecting the natural excretory/lying behaviour of the pig, may contribute to limited emissions by preventing fouling the solid areas. [590 , BATFARM , 2013]

In systems with litter, the pen is sometimes divided into solid areas with litter and slatted dunging areas. However, pigs do not always use these areas in the desired way, using the littered area to dung and the slatted area to cool off in warm weather. Generally, pens should be designed to accommodate desired excreting behaviour of pigs to minimise fouling of solid floors. This is more difficult in regions with a warm climate. [508, TFRN, 2012]

Based on the results of a study in France, it was concluded that if lower indoor temperature conditions (i.e. 18 °C) are applied with partly-slatted floors, compared to higher temperature with fully-slatted floors (i.e. 24 °C), emissions of ammonia and greenhouse gases are similar, but a significantly higher feed intake, growth rate, carcass backfat thickness and a slightly higher Feed Conversion Rate (FCR) was observed for the lower temperature combined with partly-slatted floors. However, a pronounced indoor temperature reduction with the aim of reducing ammonia emissions would not be possible due to a potential deterioration of FCR and carcass quality. [493, Guingand et al. 2010]

Practically, the implementation of partly-slatted floors implies a wider surface needed per animal, leading to a reduction of the farm capacity compared to the fully-slatted floor.

~~Also the effect of slatted floors was found to be larger when the ratio of the slat width and the opening between the slats was closer to 1: 1.~~
A slight effect of slatted floors on increasing ammonia emissions has been observed when the ratio of the slat width and the opening between the slats was closer to 1:1. In general, material characteristics (e.g. concrete roughness), slat design (e.g. trapezoidal cross section favours manure drainage, transverse slats are considered to perform better) and width of openings influence drainage properties of the floor. The application of a ~~softer~~ smoother material (cast iron or plastic-coated instead of concrete) to slats with a same width, ~~for these floors~~ allowing manure to fall faster into the pit below without sticking, was reported to reduce ammonia evaporation by nearly 30 %. [486, Pelletier et al. 2005] [487, Aarnink et al. 1997] [488, Pedersen et al. 2008] [590 , BATFARM , 2013]

~~In underfloor extraction, higher emissions occur if the distance between the slurry surface and the bottom edge of the slatted floor is less than 50 cm.~~

In principle, ~~the~~ emissions are lower where there is ~~smaller with~~ a smaller slatted surface area and ~~with~~ a smaller emitting surface area of the manure, but it is important to choose the optimum ratio between slatted and non-slatted surface area. Increasing the non-slatted area will result in more manure remaining on the solid part and possibly a rise in ammonia emissions. Animal welfare and health along with the meat quality may be affected by increased dirtiness. Whether this happens or not depends largely on the amount of urine and the speed with which it can run off, as well as with the distance to the pit. A convex smooth floor will enhance urine removal, but ~~the~~ animal safety needs to be taken into account.

Manure removal is considered ~~to be~~ an effective technique for reducing ammonia emissions (e.g. by scrapers ~~(80 % reduction),~~ ~~or~~ flushing or vacuum ~~(70 % reduction)~~), but in some categories the effect is not always clear (e.g. with finishers and gestating sows). The physical structure of the manure and the smoothness of the pit floor surface may affect the reducing effect on the ammonia emissions that the removal through scraping usually causes ~~provides~~.

Limited information is available from scientific literature concerning the effect on ammonia and odour emissions of the pit depth underneath fully-slatted floors. In general, a shallow pit will have the same surface area of slurry as a deep pit and therefore the same potential as regards ammonia emission [605, E.Magowan, AFBI 2010]. On the other hand, a correlation between the depth of the pit (or channel) and ammonia emissions has been observed, with higher emissions for a deep pit where manure may be stored for the whole year and lower emissions for shallow pits (60 cm) and regular removal of manure (every few weeks).

An increase of the distance between slats and slurry, or an increase of ventilation rate, will have an effect on the average air speed and the airflow pattern over the exposed slurry surface. Reducing the headspace (height) in the manure pit increases the air exchange, with an expected increase in ammonia emissions. However, a good correlation between ammonia emissions and headspace in the manure pit is not established and the effect of the distance from the slats to the surface of slurry on ammonia emissions may be considered modest, especially if the slurry pit walls are vertical [439, Sommer et al , 2006]. In the case of underfloor air extraction, ammonia emissions do not only depend from the distance between the slurry surface and the bottom edge of the slatted floors, but also on the design of the under floor extraction system. [606, Z.Ye et al. 2011] [605, E.Magowan, AFBI 2010]

From a practical point of view, the frequency of manure removal is the variable that is used the most to reduce housing emissions (e.g. rapid removal of manure from pits can be achieved by vacuum removal systems, gravity systems operated at least twice a week or flushing systems). In fattening pigs, emptying slurry every 15 days reduces ammonia emissions by some 20 % compared to storing the manure in the pit throughout the finishing period. [491, Guingand N. 2000] Conversely, with systems that produce turbulence in the slurry flow, peaks of odours, which have higher importance for farms close to sensitive receptors than for isolated farms, are generated each time slurry pits are emptied.[261, France 2010]

~~With respect to litter, it is expected that~~ The use of litter in pig housing has increased in recent years ~~will increase~~ in many Member States ~~throughout the EU~~ due to an increased ~~the raised~~ awareness of animal welfare and a consumer demand for better brand image of livestock production. However, in some countries, particularly in Denmark, the number of litter systems is reported having declined dramatically during the recent years, due to cross media effects and economic considerations. [500, IRPP TWG 2011]

Litter can be applied in conjunction with (automatically) controlled natural~~ly~~ ventilation ~~ventilated~~, in housing systems where the litter would allow the animals to control their own temperature, and would thereby reduce the amount of energy needed for ventilation and heating. On the other hand, this technique is associated with increased costs principally due to the straw used and the labour for litter management even if building costs are usually reduced. [590 , BATFARM , 2013]

The production of solid manure instead of slurry manure is considered an advantage from the agronomical point of view, in so far as organic matter incorporated into the fields improves the physical characteristics of the soil, thereby reducing run-off and the leaching of nutrients to water bodies.

Water consumption is important especially in countries where the resource is limited. Consumption increases when moving from a slatted to a ~~Consumptions always increase when a substitution is made from slatted floor to~~ solid floor, due to the cleaning requirements associated with solid floors.

It is assumed that techniques ~~that~~ to reduce NH_3 emissions will also reduce gaseous emissions of ~~the~~ other ~~gaseous~~ substances. [391, Italy 1999]

All integrated measures to reduce emissions of NH_3 from pig housing will lead to a higher amount of nitrogen in manures ~~the slurry to be applied~~ and in the amount that may potentially be emitted during storage and landspreading as aerial emissions or as leaching and run-off in liquid form/phase.

In housing design, some basic recognisable characteristics are common for rearing various categories of production ~~producing~~ pigs. Pig production categories that are considered are:

- mating and gestating sows
- farrowing sow (with piglets)

- weaned piglets
- fattening (growing and finishing) pigs.

On farms, additional features can be added if convenient to the basic housing techniques.

Techniques that are applied almost identically across several pig productive categories are described first in Section 4.7.1, and then the techniques that are specific to each pig category are described in Sections 4.7.2, 4.7.3, 4.7.4 and 4.7.5.

For each production category, a table is also given to allow for the comparison of housing techniques, including all considered possibilities.

The first technique that is described is the fully-slatted floor with a deep pit, which was generally considered the worst performing system ~~one~~, and it was commonly taken as the reference to calculate variations in parameters for other techniques (e.g. IRPP BREF 2003, [508, TFRN 2012]. For example, economic data is often given as ‘extra costs’ meaning the additional costs that would be required compared to applying fully-slatted floors with a deep pit.

In the following sections, housing techniques are described in groups defined on the basis of a common operating principle.

~~These principles are mainly:~~

- ~~manure removal by a vacuum system~~
- ~~reduction of the manure surface by the use of partly-slatted floors~~
- ~~further reduction of manure surfaces by reduced pits, slanted walls in the manure channel or separated channels~~
- ~~reduction of ammonia evaporation by cooling the slurry~~
- ~~efficient manure removal by flushing the manure~~
- ~~adsorption of dejections by the use of bedding materials.~~

~~Emission data in the tables are usually accompanied by a note indicating the ‘type of data’ which they refer to. This code is intended to qualify the origin of the figures and it must be read as indicated below:~~

~~* = reported from the previous IRPP BREF of 2003.~~
~~D = measured data based on statistical analysis.~~
~~E = expert judgement based on few measurement results.~~
~~M = modelled figures (e.g. results of N-flow processing).~~
~~A = expert judgement based on conclusion by analogy.~~

4.7.1 System-integrated techniques for housing various categories of pigs

4.7.1.1 Fully-slatted floor (FSF) with deep pit

Description

~~This system has long been used as the reference technique for all types of pigs. For sows, this is~~ A deep pit lies under a fully-slatted floor with concrete slats. The slurry manure is removed at variable intervals, usually ~~either in frequent intervals, only~~ after every fattening period, or even less frequently.

Forced ventilation removes gaseous components emitted by the stored slurry manure. Exhaust air is normally expelled through roof or side wall vents. ~~Artificial Under-floor~~ Underfloor ventilation may also be applied; it is frequently used in some geographical area, e.g. France. ~~This type of housing is equipped with mechanical~~ Forced ventilation (normally with ~~either~~

negative-pressure) - ~~or balanced pressure ventilation plants~~ or automatically controlled natural ventilation (ACNV) are used in Austria and the UK.

~~When~~ In ~~place for~~ farrowing pens ~~sows~~, the position of the piglet area and the slats material can vary.

Weaners are group-housed. Pens and flat decks are comparable designs and are both made up of ~~it is~~ a combination of the classic pen ~~crate~~ with a fully-slatted floor made of plastic or metal elements, with manure removal at the end of the cycle. ~~Ventilation is dimensioned for maximum output of 40 m^3 per hour per place~~. Auxiliary heating is also applied in the form of gas radiant heaters, electric fan or convection heaters or by a central heating plant with heating pipes.

One housing variant for fattening pigs is reported from Germany, with a manure removal interval of 1 – 2 months, instead of the standard removal at the end of the cycle. Another alternative is the application of the technique to groups with more than 100 pigs applied (sorting lock). The reported available space per fattening pig is 0.68 – 0.75 m^2.

For the growers/finishers, ~~slits~~ slat openings should not exceed 18 mm. However, ~~slits~~ openings wider than 20 mm are less subjected to sealing by faeces. Clogging causes the floors and animals to be less clean and results in increased emissions of ammonia. [261, France 2010]

Achieved environmental benefits
Since the emitting surface, which is a key factor concerning ammonia emissions, is as wide as the surface at the animals' disposition, emissions are considered the highest, hence this system was normally taken as the reference for expressing emission reductions brought about by other techniques.

Cross-media effects
The use of this housing technique makes it difficult to fully comply with the animal welfare Directive 2008/120/EC, for not enabling proper investigation and manipulation activities of the pigs.

Operational Data
The energy required for ~~artificial~~ forced ventilation is variable, but on average in Italy this has been estimated at 42.2 kWh per sow per year and ~~Italy reported an energy requirement for artificial ventilation estimated at~~ 21.1 kWh per grower/finisher place per year. [292, Italy 2001]

Resources demand ~~Consumptions have been studied in~~ for fattening pigs and the breakdown for the different uses ~~types of consumption have been determined for fattening pigs and results are~~ reported from Germany, are presented in Table 4.68.

Table 4.68: Resources demand for the rearing of fattening pigs in houses with fully-slatted floor and deep pit

Resources	Unit	Average	Range	Breakdown values
Energy	kWh/ap/yr	26	21 – 31	Lighting: 4 (3 – 5) Ventilation: 20 (16 – 24) Feeding: 1 (0.8 – 1.2) Cleaning: 0.3 (0.2 – 0.5) Manure removal: 0.1
Fuel (kWh)	kWh/ap/yr	70	60 – 80	Heating
Cleaning water	litres/ap/yr	55	45 – 65	If a sorting lock is used: 45
Labour	hours/ap/yr	0.9	0.88 – 0.94	Routine: 0.66 – 0.72 Special work: 0.22
Source: [189, Germany 2010]				

~~The rates of~~ Ventilation rates that are applied at each ~~along the growing~~ physiological stage of pigs rearing ~~phases~~ (post-weaning, growing and finishing) depend on the ~~may be different at different~~ the climate of each geographic region/area. ~~latitudes.~~ Table 4.69 shows the figures reported from Spain, France and Germany.

Table 4.69: Ventilation rates (m^3/h per animal place) applied to FSF pens in countries at different latitudes for the weaning and the growing/finishing production phases

Animal	Cold season		Warm Season		
	Spain	Germany	France	Spain	Germany
Weaners	18.2 (7.5 – 57.8)([1])	3.5 – 7.0([3])	28.7([5])	39.2 (10.7 – 50.3)([1])	20 – 50([3])
Fatteners	15.7 (1 – 64)([2])	7 – 15([4])	28.6([5])	66.6 (15 – 120)([2])	50 – 115([4])
Gestating sows		14 – 18 ([6])			86 – 128 ([6])

([1]) [179, Spain 2010] Vacuum system.
([2]) [187, Spain 2010] Vacuum system.
([3]) [182, Germany 2010] Vacuum system.
([4]) [189, Germany 2010] Overflow channel ~~Deep Pit~~.
([5]) [269, France 2010] Deep Pit.
([6]) [156, Germany 2010] Vacuum system.

The maximum required ventilation rates, on which the design of fattening pig houses is based, are reported to be equivalent to 80 m^3/h/ap in the Netherlands, 100 m^3/h/ap in Denmark and 120 m^3/h/ap in Germany.

From France, it is reported that ~~According to Corpen,~~ ammonia emissions during the post-weaning phase are between 70 and 120 mg/h per piglet, with an average of 97 mg/h per piglet. This figure ~~would mean~~ corresponds to 130 grams per piglet produced in the 56 days of the cycle (6 batches/yr), ~~that is to say an emission of~~ equivalent to 0.78 kg per post-weaning place per year. [261, France 2010]

In Table 4.70, an overview of the reported emission data, including some data already included in the original IRPP BREF 2003 is presented.

~~The summary of emissions that have been collected from the previous version of this BREF, and those that were recently measured or are in use for estimations in different locations are reported~~

Table 4.70: Emissions associated with fully-slatted floor systems with a deep pit for the various categories of pigs

Description	NH_3	CH_4	N_2O	Odour	Source
	(kg/ap/y)			(ou_E/ap/s)	
Farrowing sows with piglets					
Individual housing	8.30 – 8.70				IRPP BREF 2003
	9.0 (1)				[261, France 2010]
	8.6 (3)				[159, Austria 2010]
Weaners					
	0.6 – 0.8				IRPP BREF 2003
	0.78 (1)				[261, France 2010]
	2.39 – 3.0				IRPP BREF 2003
Fatteners					
Manure removal every two months	4.6 (3)				[266, Austria 2010]
Manure removal at the end of cycle	3.6 (3) (2.0 – 7.0) (1)	1.0 - 6.0 (1)	0.02 – 0.15 (1)	6.5 1.2 (1)	[189, Germany 2010] [474, VDI 2011] [269, France 2010]
	2.91 (1) (1.37 – 3.95) (4)	2.1 (1)	0.035 (1)		[270, France 2010]
	2.56	10.5 (2) (5)	1.1 (2) (5)		[373, Austria 2009]

(1) Measured values.
(2) Modelled values (e.g. results based on N balance).
(3) Values derived by expert judgement based on conclusions by analogy.
(4) The reported range corresponds to the minimum and maximum values measured at the beginning and at the end of the fattening period.
(5) Values include emissions during storage.

Applicability
The technique is widely in use ~~diffuse~~ around the world.

This flooring system is not applicable to gilts after service and pregnant sows (Directive 2008/120/EC, article 3, paragraph 2(a)).

Economics
Cost calculations need to be made considering the additional working time related to the operations and the cost of the additional external slurry store ~~storage~~. [261, France 2010]

The costs for a new installation for mating and gestating sows are estimated to be more than EUR 600 per ~~sow~~ place per year, including both investment costs (interests, allowances, etc.) and running costs (energy, maintenance, etc.). [292, Italy 2001]

~~To build a new installation for fattening pigs, around EUR 270 per animal place are needed in the UK~~ **Moved to vacuum removal** ~~and EUR 350 – 420 are needed in Germany. Annual running costs of EUR 375 – 383 raise the total annual cost (with investments annualised to EUR 30 – 34) to about EUR 410 in Germany. [189, Germany 2010]~~ **See Table below**

In Table 4.71, the reported investment and operating costs for fattening pig houses with fully-slatted floor and deep pit, are presented, as well as the breakdown values.

Table 4.71: Investment and operating costs for fattening pig houses with fully-slatted floor and deep pit

Parameter	Average	Range	Breakdown values
Investment costs (EUR/ap)	350	350 – 420	If a sorting lock ([1]) is used: 324
Annualised investment costs (EUR/ap/yr)	31	30 – 34	If a sorting lock ([1]) is used: 33
Annual operating costs (EUR/ap/yr)	379	375 – 383	Feed: 200 Animal: 138 Water, energy, heating: 13.5 Other: 12 Labour: 14
Total Cost (EUR/ap/yr)	410		

([1]) Sorting lock: large group over 100 animals.
Source: [189, Germany 2010]

Example plants

In Germany, ~~and Belgium~~ almost all ~~finishers~~ fattening pigs are reared using this system; in Belgium around 85 %, in France more than 80 % of the fattening and post-weaning animal places are on fully-slatted floors [269, France 2010] and in Spain about a half. [264, Loyon et al. 2010]

Driving force for implementation

The system is simple to run. Pigs remain clean and good conditions prevail for animals and workers. [269, France 2010] [270, France 2010]

References

[189, Germany 2010] [261, France 2010] [269, France 2010] [270, France 2010]

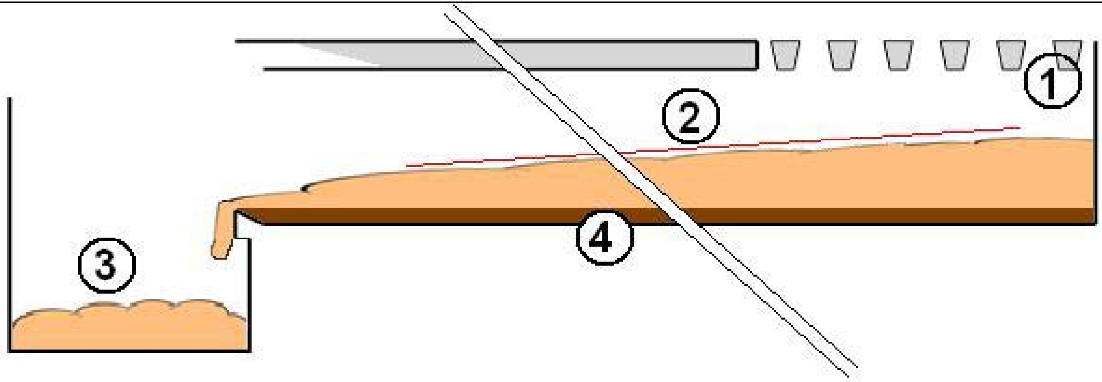
4.7.1.1.1 Partly-slatted floor (PSF) with infrequent manure removals ~~deep pit~~

Description

Partly-slatted floored pens are equipped with manure pits of a sufficient depth that allows for the storage of the slurry between infrequent removals.

In France, pits of less than 1 metre depth are emptied 1 to 3 times per cycle. In Germany, overflow channels are preferred, with removal every 1 – 2 months (twice per cycle) or after every fattening period. ~~An integrated system has been reported from France where a deep pit storage is built under a partly-slatted floor for infrequent slurry removals.~~

In overflow discharge systems (see Figure 4.28), the slurry flows continuously out into a receiving pit (or external slurry store). At the discharge end of the pit below the slatted floor, a 15 cm high lip is built to retain a layer of slurry in the flat bottom of the pit. The slurry forms a 1.5 – 3 % slope towards the discharge maintaining a freeboard of at least 25 – 30 cm below the slats. [498, Cernåk 1977]



1. Slatted floor
2. 1.5 – 3 % slope on slurry surface
3. Reception pit
4. Lubricating layer of slurry retained by the lip

Source: Elaboration from [498, Cernåk 1977]

Figure 4.28: Principle of operation of the overflow slurry channel

Achieved environmental benefits

This housing system ~~The adopted solution~~ present~~s~~ environmental performances comparable to those ~~on an FSF~~ observed with fully-slatted floors with deep pit.

Cross-media effects

A partly-slatted floor system may entail increased ~~management~~ requirements in temperature and general management, as solid floors can get soiled in particular at high temperatures. Dirty floors have also implications on pig hygiene and health, on odour emission and on working conditions, causing discomfort. See also general introduction in Section 4.7.

Extra costs are also associated with extra times needed for cleaning rooms.

Water consumption increases with reduced slatted floor areas, due to the cleaning needs of the solid floor. [500, IRPP TWG 2011]

Operational data

In France, above-floor air ventilation is applied for volumes of around 34 – 37 m^3/hour of air per animal place ~~per year~~, in order to maintain the indoor temperature between ~~23.6~~ 20.1 and ~~24~~ 23.6 °C. The space given to each animal is 0.85 m^2.

Values reported from Germany, indicate a ventilation rate in the range of 7 – 15 m^3/h/ap in the cold season and 50 – 115 m^3/h/ap in the warm season. [192, Germany 2010]

~~The manure~~ Slurry is removed at 2 or 3 times per cycle; in general, higher ammonia emissions are reported for longer storage of the slurry in the pit.~~, hence emissions are higher if the manure permanence is longer, as~~ A summary of reported emission data associated with partly-slatted floor systems for fattening pigs is presented in Table 4.72.

Table 4.72: Emissions from partly-slatted floor systems for fattening pigs, in relation to the frequency of manure removal

Frequency of manure removal	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	Kg/ap/y				ou_E/s/ap	
At least twice (2 – 3 times) in the cycle	2.63 (1)	2.42 (1)	0.0432 (1)			[271, France 2010]
Twice in the cycle (every 1 – 2 months)	3.6 (2) (2 – 7) (1)	4 – 30 (1)	0.02 – 0.15 (1)	0.24 (2)	7 (3)	[192, Germany 2010]
Twice in the cycle	3.6 (1)				1.14 (4)	[272, France 2010]

(1) Measured data
(2) Values derived by expert judgement based on conclusions by analogy.
(3) Values have been calculated from an emission of 50 ou_E/s per LU and an average weight for fattening pigs of 70 kg.
(4) Value derived from an emission of 36 × 10^6 ou_E/year per animal place.

Applicability
~~This system is widely applied.~~
The system is generally applicable; however is not commonly used.

Economics
Investment costs are reported in Germany the same as for fully-slatted floors. [192, Germany, 2010]

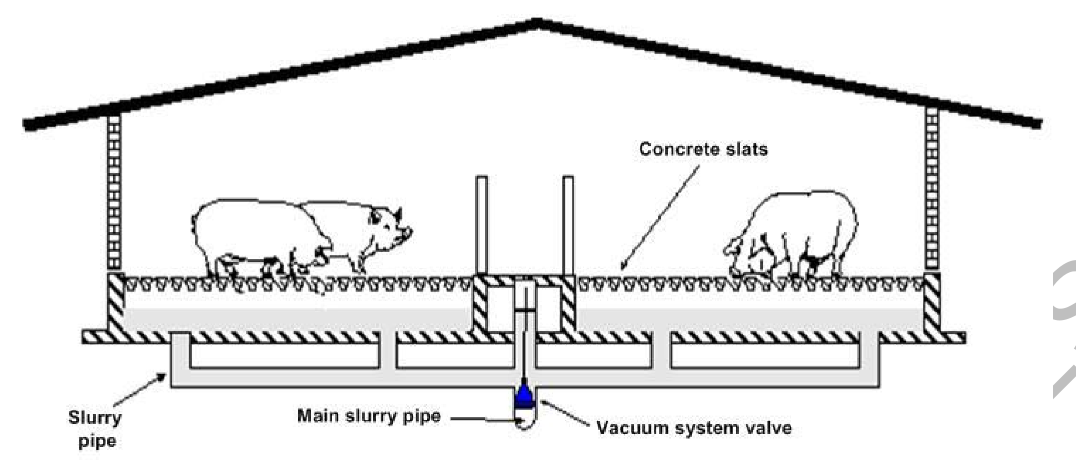
Driving force for implementation
~~Partly-slatted floors have the advantage that the feed conversion ratio tends to be higher in comparison to fully-slatted floors.~~
Improved animal welfare and lower ammonia emissions. See also general information in Section 4.7.

Example plants
~~The system is rarely applied,~~ In France only 10 % of fattening pigs are reared this way; generally, in small and very old houses. It is also reported to be rarely applied in Germany.

Reference literature
[271, France 2010] [272, France 2010] [192, Germany 2010].

4.7.1.2 Fully-slatted floor with a vacuum system

Description
On the bottom of the pit under a fully-slatted floor, outlets are placed ~~every 10 m² and~~ that are connected to a discharge ~~sewerage~~ system moving the slurry to the external storage units (see Figure 4.29). Slurry is discharged by opening a valve in the main slurry pipe. A slight vacuum develops and allows for ~~the~~ a thorough slurry removal, better than by gravity alone. A depth of slurry needs to be obtained before the system can operate properly to allow the vacuum to develop and empty more slurry. The ~~pit can be emptied once or twice a week,~~ evacuation frequency ~~of emptying~~ is variable depending on the capacity of the pit ~~itself~~ and on the size of the pigs in the pens above, i.e. the same pit is filled up more quickly by 100 kg pigs than 20 kg pigs. The frequency of emptying will determine ~~has a direct effect on~~ the volume of the external slurry storage required ~~that must consequently be dimensioned~~. [261, France 2010] [175, Ecodyn 2010]



Source: [292, Italy 2001]

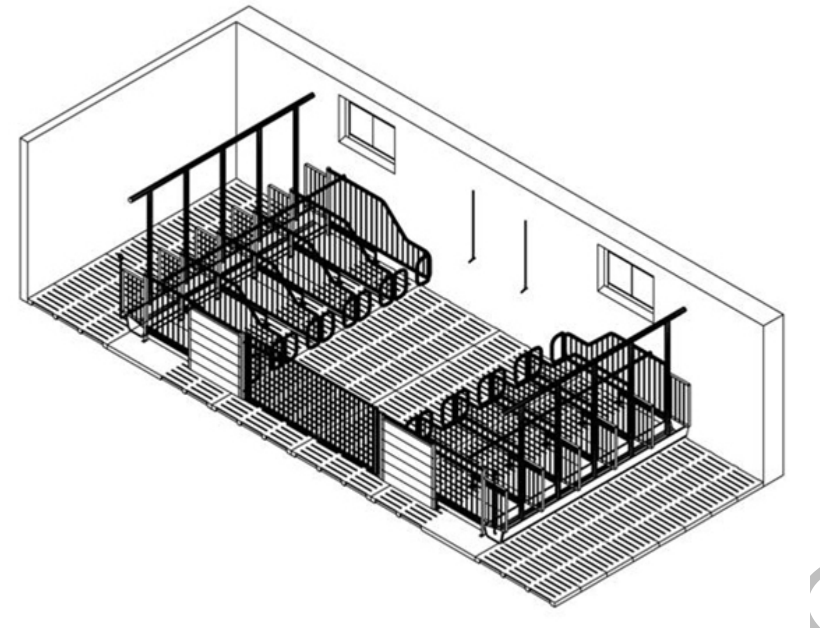
Figure 4.29: Fully-slatted floor with vacuum system

The exact area covered by each pipe outlet depends on the dimension of the pen. In general, for every 10 – 11 metres in length ~~m^2~~, one ~~a~~ pipe outlet is placed to discharge the slurry ~~manure~~ contained over the corresponding ~~that~~ surface. An excessive number of outlets might increase the leakage possibility. ~~This area can vary depending on the length of each pen,~~ The pen area served by each outlet is not considered to affect the emptying capability, as the optimum height of slurry required for the system to work is considered to be the same regardless of the area covered. As a larger pen area will accommodate a proportionately larger number of pigs, the optimum height will not take longer to reach. ~~whilst the slurry depth is considered not to affect the emptying capability of the system.~~ An optimal depth of slurry is ~~of~~ approximately 800 mm, regardless of the number of days it takes to reach it. It should be noted that slurry can be removed at a smaller depth, at a minimum of 500 mm; however, this does not allow a sufficient vacuum to develop and results in more slurry being left in the system. ~~An additional height of 300 mm of free space under the slats and the slurry level decreases NH3 volatilisation.~~

High-powered submersible pumps are also used for infrequent intensive cleaning (every two years) with high pressured water to remove crusting from around the tank edges. [175, Ecodyn 2010] New houses can be fitted with a slopped bottom pits for an easier and complete emptying.

For a better comfort of sows, although not for environmental improvement, the lying area can be arranged with floors having openings for less than 15 % of the surface, [156, Germany 2010] or lying pens can be arranged on concrete [162, Germany 2010]. Feeding-lying pens can be built or automatic feeding stations can be placed over the wider slatted areas.

The same type of floors and manure removal systems are used for setting up specialised rooms for artificial insemination of mating sows, where sows are grouped or individually housed (service center) with the equipment of individual stalls with temporary fixing (see Figure 4.30).



Source: [607, KTBL 2010]

Figure 4.30: Mating room for group housing, with temporary fixing stalls

Achieved environmental benefits

~~The main aim of the system is to allow for a frequent removal of the slurry to reduce aerial emissions.~~ The frequent removal of slurry reduces ammonia and methane emissions.

Cross-media effects

As the system is manually operated, no additional energy is required nor ~~However,~~ is the additional working time significant. ~~necessary for operation must be considered [261, France 2010]~~. Less water is needed to clean the floor compared with partly-slatted or solid concrete floors. It is suggested that any aerosols which develop during the discharge of the slurry are removed by the vacuum created when opening the valves.

Because of the reduced storage period of the slurry inside the buildings, an additional capacity/volume of the external slurry store may be needed.

This technique can generate peaks of odours at the time of emptying the slurry pits. It is proposed that emptying should not be higher than one or two times per month. [261, France, 2010]

Former Table 4.45 and related introduction have been moved under operational data and integrated (re-designed) with additional information.

Operational data

Frequent emptying of the slurry channel and flushing the channel with water or the liquid fraction of separated slurry (see Section 4.7.1.10) may only reduce ammonia emission by 20 – 28 %, because the emitting surface remains the same. In contrast, frequent emptying of slurry from pits with slanted walls will reduce the emitting surface, due to lowering of the slurry level, and NH_3 emissions are reduced up to 50 % (see Section 4.7.1.4) [439, Sommer et al. 2006].
It is reported by France that in fattening pig's houses, emptying the slurry every 15 days reduces ammonia emissions by 20 %, compared to housing where slurry is stored throughout the whole fattening/finishing period. [261, France 2010]

~~This technique is easy to operate compared to the reference technique [184, TWG ILF, 2002].~~
Reductions of NH_3 emission between 30 and 60 % are reported from Spain for fattening pigs [187, Spain 2010]. In UK, a reduction of ammonia emission of about 25 % has been estimated,

compared to ~~an~~ fully-slatted floors with a deep pit, ~~has always been considered,~~ due to the frequent removal of slurry.
Frequent removal of slurry from the pit or channel reduces the pool of methanogenic bacteria within this environment [443, Chadwick et al. 2011]. A reduction on methane emissions equivalent to 65 % has been measured in Spain. [187, Spain 2010]

Emissions values available for production categories are reported in Table 4.73.

Table 4.73: Aerial emissions associated with frequent manure removal by vacuum, in various types of pig production

Reared animal	Frequency of removal	NH_3	CH_4	PM_{10}	Odour	Source
		kg/ap/yr	kg/ap/yr	kg/ap/yr	ou_E/s/ap	
Mating/gestating sows (group)	NA	2.77				[292, Italy 2001] IRPP BREF 2003
Mating/gestating sows (group)	2 – 8 weeks	5.00 (1)		0.16 (1)	6 (1) (3)	[156, Germany 2010] [474, VDI, 2011]
Mating/gestating sows (individual)	2 – 8 weeks	4.8 (1)		0.16 (1)	6 (1) (3)	[163, Germany 2010] [474, VDI, 2011]
Weaned piglets, plastic slats (8 – 28 kg)	4 – 8 weeks(vacuum) 2 weeks (scraper)	0.5 (1) (0.2 – 0.70) (2)		0.08 (1)	3 (1) (4)	[182, Germany 2010]. [474, VDI, 2011]
Weaned piglets, plastic slats (6 – 25 kg)	Continuous	0.06 – 0.40 (2)	2.81–5.86 (2)			[180, Spain 2010].
Fattening pigs	NA	2.25				[292, Italy 2001] IRPP BREF 2003
Fattening pigs (25 – 100 kg)	Weekly	0.54 – 1.85 (2)	0.42–2.35 (2)			[187, Spain 2010]
Fattening pigs (25 – 100 kg)	NA	3.64 (1)	1–6 (1)	0.24 (1)	7 (1) (5)	[474, VDI 2011]

NA not available
(1) Values derived by expert judgement based on conclusions by analogy.
(2) Measured data.
(3) Value has been calculated from an emission of 20 ou_E/s per LU and an average weight of 150 kg for non-pregnant and pregnant sows.
(4) Value has been calculated from an emission of 750 ou_E/s per LU and an average weight of 20 kg for weaned piglets.
(5) Value has been calculated from an emission of 50 ou_E/s per LU and an average weight of 70 kg for fattening pigs.

Nitrous oxide emissions, from fully-slatted floor housing systems with frequent removal of manure by vacuum, have been estimated in Germany for fattening pigs in the range of 0.02 – 0.15 kg N_2O/ap/yr. [474, VDI 2011]

Reported ventilation rates used with this housing system are presented in Table 4.74.

Table 4.74: Reported ventilation rates applied in fully-slatted floor systems with frequent removal of manure (by vacuum)

Animal category	Cold season	Warm season	Reference
	m^3/ap/h	m^3/ap/h	
Fattening pigs	15.7 (1 – 64)	66.6 (15 – 120)	[187, Spain 2010]
Weaned piglets	3.5 to 7	20 to 50	[182, Germany 2010]
Waiting-mating sows	14 to 18	86 to 128	[156, Germany 2010]
Mating/gestating sows (individual)	16	220	[163, Germany 2010]

Average reported consumption data for energy, water and labour that have been reported, are shown in Table 4.75.

Table 4.75: Consumptions related to the management of FSF systems equipped with vacuum manure removal

Animal category	Cleaning water	Electricity	Fuel	Labour	Source
	l/ap/yr	kWh/ap/yr	kWh/ap/yr	h/ap/yr	
Weaned piglets	150	12 9 (ventilation) 2 (lighting)	170	0.99	[182, Germany 2010]
Waiting-mating sow	210	60	160	0.7 ([1])	[156, Germany 2010]
Mating/gestating sows (individual)	340	60	160	2.6	[163, Germany 2010]
Fattening pigs	127	NA	NA	0.6	[267, UK 2010].
NA= Not available. ([1]) 0.55 h/year per productive sow.					

Applicability

In existing houses, this technique seems is difficult to apply as the number of outlets per room cannot be modified [261, France 2010]. It may be applicable with:

- solid concrete floors and with sufficient height to build on top of the existing floor
- renovation of an FSF with a storage pit underneath.

Economics

Italy reported a negative extra cost (i.e. a benefit) of EUR 8.60 per sow place per year, when applied in new housing, compared to the costs of the reference system.

Labour at a rate of 0.7 hours per animal place per year is required.
The frequent removal of manure has practically no extra cost if it is manually operated. [187, Spain 2010]

From Germany, it is reported that investment costs for the implementation of this technique in weaned piglets are equivalent to 195 EUR/ap/yr; the corresponding annualised investment costs are EUR 18 per animal place per year [182, Germany 2010]. From UK, it is reported that the investment costs for the implementation of the technique, in automatically controlled natural ventilated houses (ACNV) for fattening pigs are equivalent to 270 EUR/ap/yr [267, UK, 2010].

Extra costs may also be associated with the need for additional external slurry storage capacity. [261, France 2010]

Driving force for implementation
The vast diffusion of this technique makes it simple and economical to implement and run.

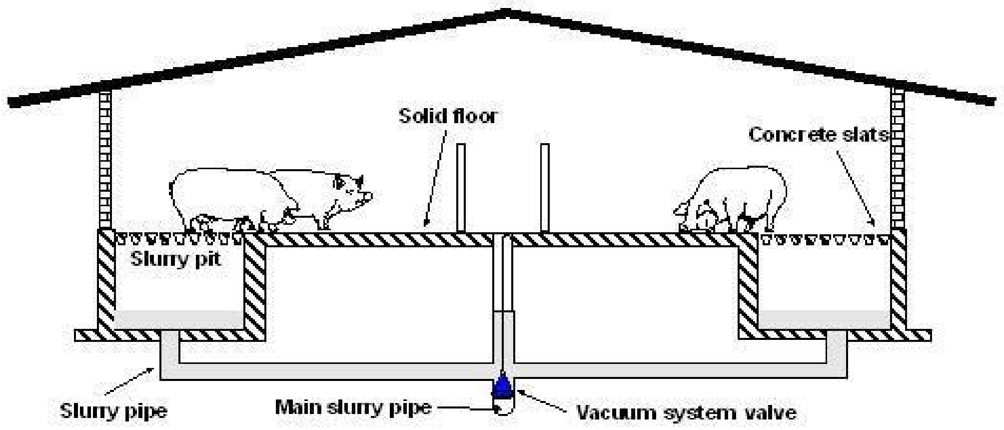
Example plants
In France, this is the most used system; in Germany, it represents the standard system for fattening pigs.

In Finland, the housing system with fully-slatted floors with a vacuum removal of manure is not recommended, since pigs should be given the possibility of rooting.

Reference literature
[156, Germany 2010] [162, Germany 2010] [261, France 2010][180, Spain 2010] [182, Germany 2010] [187, Spain 2010] [292, Italy 2001] [175, Ecodyn 2010].

4.7.1.3 Partly-slatted floor with a vacuum system

Description
The way manure is collected below the slatted floor and removed is the same as the one described in Section 4.7.1.2, with the only difference being that the dimensions of the manure channels are reduced in the same proportion as the ~~walking~~ slatted floor area is reduced in favour of solid floor.



Source: [292, Italy 2001]

Figure 4.31: Partly-slatted floor with a vacuum system

Achieved environmental benefits
The principles that lead to emission reductions, in comparison with a fully-slatted floor with deep pit, are the reduction of the emitting surface by reducing the manure exposed surface and the frequent removal of slurry. ~~, made possible by the automatised collection system~~

No significant difference in ammonia emissions is anticipated in comparison with a fully-slatted floor with a vacuum system. [500, IRPP TWG 2011]

Cross-media effects
Due to the fact that pigs reared on partly-slatted floor, particularly the finishing pigs tend to excrete on the solid floor when a critical temperature is reached, the cleanliness of the area may deteriorate and ammonia emissions may increase compared with fully-slatted floors. For this reason, a more pronounced reduction of room temperature in the room is often required. Dirty

floors have also implications on pig hygiene and health, on odour emissions as well as on working conditions.

Because of a shorter storage period of the slurry inside the buildings, an additional capacity of outside storage should be considered.

This technique can generate peaks of odours at the time of emptying the slurry pits. From France, it is proposed that the rate of emptying should not be higher than one or two times per month. [261 , France, 2010]

~~As the system is manually operated, no additional energy is required. However, the additional working time~~

A slight increase of water consumption is associated with a reduction of the slatted-floored area, due to higher cleaning needs of the solid floor. [500, IRPP TWG 2011][261 , France, 2010]

Operational data:

With a partially-slatted floor and a vacuum system, the NH_3 emissions are ~~is~~ reduced to 2.77 kg NH_3 per sow place per year on concrete slats, and to 2.40 kg NH_3 per sow place per year on metal slats for ~~loose-housed~~ gestating sows. ~~This solution~~ The system was credited to allow emission reduction, compared to fully-slatted floors with deep pit, ~~of 25 % on the fully-slatted floor and reductions~~ of 25 % with concrete slats or 35 % with metal slats, where less manure is retained ~~on the partly-slatted floor whether the slats are made of concrete or metal~~. [IRPP BREF 2003]. In Table 4.76, the most recent available emissions or reduction data are reported for the categories of reared animals and the solutions in use with the vacuum manure collection.

Table 4.76: Ammonia emission effects of the manure removal system in combination with a PSF

Reared animal	Slats type	NH_3 reduction(1)	NH_3 emission	PM_{10}	Odour
		(%)	(kg/ap/yr)	(kg/ap/yr)	(ou_E/s/ap)
Mating/gestating sows, grouped	Concrete	2	2.77	NA	NA
	Metal	35	2.40	NA	NA
Mating/gestating sows, individual	Concrete	NA	4.8	0.16 (2)	6 (3)
Weaning piglets	NA	25 – 35	0.45 – 0.60 0.39 – 0.52	NA	NA
Fattening pigs	Concrete	25	1.80 – 2.25	NA	NA
	Metal	35	1.55 – 1.95	NA	NA

NA= Not available.
(1) Comparisons are made with the FSF with deep pit.
(2) PM_{10} share is 40 % of total dust content [474, VDI, 2011].
(3) Value has been calculated from an emission of 20 ou_E/s per LU and an average weight of 150 kg for non-pregnant and pregnant sow.
Source: IRPP BREF 2003, [474, VDI 2011]

A consumption of around 330 l/ap/yr of water is reported from Finland, representing about 1 % of the total water consumption (99 % drinking water); a labour demand of 1 h/ap/yr is also reported. [276, Finland 2010]

As the system is manually operated, no additional energy is required. This technique is considered easy to operate. ~~compared to the reference technique~~ [291, IRPP TWG 2002].

Applicability

Since the number of outlets per room cannot be modified, it is almost impossible to implement this technique in existing buildings, at least for piglets and fattening pigs housing systems. For sows, plates could be disposed on the floor to create a partially slatted floor, but the total surface of the pit will remain unchanged. the adaptation of existing building is very difficult. [261, France 2010] Moreover, in existing housing applications, it's the technique is applicability is limited to applicable only in the case of substitution of a housing with partially slatted floor combined with and a storage pit of with a sufficient depth. of at least 2.75 m.

Economics

There are no data available on capital costs, but the annual operational costs are thought to be the same as for growers/finishers and this is represents an estimated negative extra cost (i.e. a benefit) of EUR 4/ap per year when concrete slats are applied and EUR 1.50 (also a benefit) when metal slats are applied in a new housing [291, IRPP TWG 2002].

Costs associated with the use of partly-slatted floors with frequent manure removal by vacuum are considered higher than for a system with fully-slatted floors with deep pit, considering the additional working time related to the operations (i.e. additional cleaning) and the cost of the additional external slurry storage capacity. [261 , France, 2010]

In the Netherlands, the investment costs for a housing system that comprises 4 200 fattening pig places (0.8 m^2 pen surface per pig place with 40 % solid floor and 0.8 m deep manure channels) are reported equivalent to EUR 370 per fattening pig place [589 , Netherlands , 2010]. The investment costs for an integrated sow house in the Netherlands are reported at EUR 2 240 per sow place. The house consists of:

- 130 farrowing pens (with fully-slatted floor 4.5 m^2 per pen)
- 2 016 weaner places (0.4 m^2 total surface per animal place, partly-slatted floor with 60 % convex solid floor of fully-slatted plastic floor)
- 477 mating and gestating sow places (2.25 m^2 total surface per animal place, with 60 % solid floor)
- 0.8 m deep manure channels. [589 , Netherlands , 2010]

Driving force for implementation

The provision of areas with solid floor makes pens more comfortable to animals hence some regulations make the PSF solution mandatory. The system improves animal welfare.

Example plants

The system is widely diffuse.

Reference literature

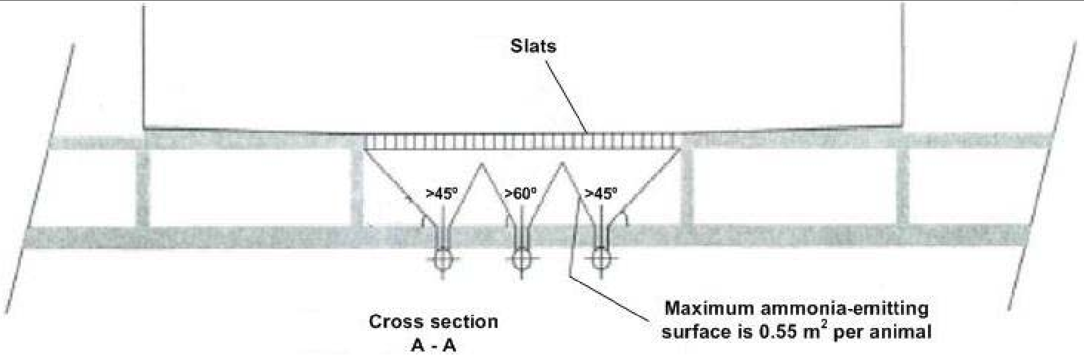
[292, Italy 2001] [261, France 2010] [276, Finland 2010].

4.7.1.4 Partly-slatted floor with slanted walls in the manure channel

Description

The operating principle of this technique solution is to reduce the manure surface from where ammonia is emitted. Instead of being squared, the channel section is V-shaped and the discharge sewerage is placed at the bottom of the V.

The slanted walls are built with a manure-resistant material and are smooth surfaced. Slopes vary from 45 to 60 degrees (see Figure 4.32): the slope that is adjacent to the wall of the solid floor is a minimum of 45 degrees, and slopes at the centre of the slatted area are placed with a minimum of 45 degrees.



Source: [167, Netherlands 2010]

Figure 4.32: Section of slanted walls for manure channel

Distances between discharge openings are around 2 metres or less. The slurry is discharged before reaching a depth of 10 cm and a layer of manure of 2 cm is left to prevent the manure from sticking to the channel. Hence discharges occur at least twice a week and the manure is transferred to a closed store storage. To guarantee the maximum depth, an overflow discharge system is installed in the manure channel. Every manure channel has a central valve.

Slats are triangular shaped and can be iron/metal, plastic or concrete. No bedding is applied. Farrowing sows are kept in individual crates.

Achieved environmental benefits
Slanted walls applied in the manure channel result in a decreased emitting surface when the height of slurry is lowered, due to frequent emptying of the channel. As a consequence, ammonia emissions are reduced By decreasing the emission surface, there is less contact of air with sludge, and hence lower ammonia emissions. Emissions are also reduced by the frequent manure removal from the channel by means of the sewerage system.

Cross-media effects
On walls that are not sloped enough, manure retention may occur, leading to poor cleanliness and an increase of emissions.

A PSF may entail increased requirements in temperature and general management, as solid floors can get soiled in particular at high temperatures (see general remarks in section 4.7). Dirty floors have implications on pig hygiene and health and on odour emission. The impact of partly-slatted floor on pig cleanliness and the management of low ambient temperature have been described in Section 4.7.1.3, in relation to achieving a reduction of ammonia emissions without deteriorating growth performance of the animals.

Operational data
The vacuum discharge sewerage system has an outlet gap of at least 150 mm, and PVC pipes are at least 200 mm wide.

Gestating sow are reared in groups on partly-slatted floored pens, where the minimum surface per sow is 2.25 m^2, of which at least 1.3 m^2 (60 %) per sow is solid floor. A surface of 0.55 m^2 in the reduced channel corresponds to each animal. From the Netherlands, the reported room temperature in housing systems for gestating sows is reported around 20 ºC.

A potential reduction of ammonia emissions up to 50 % is reported. [439, Sommer et al. 2006]

Emissions that have been reported as associated with this technique are shown in Table 4.77.

Table 4.77: Emission levels associated with partly-slatted floors with sloped walls in the manure channel

Animal	NH_3	CH_4	Dust	Odour	Slurry removal frequency	Source
	kg/ap/yr			ou_E/s/ap		
Gestating sows, metal slats	2.15 (1.76 – 2.53) (1)		0.22 (1)	18.7 (1)	Once every two weeks	[166, Netherlands 2010]
Gestating sow, concrete slats	2.5 – 2.6 (1)		0.22 (1)	18.7 (1)	Once every two weeks	[165, Netherlands 2010] [186, BE Flanders 2010]
Farrowing sows	3.2 (1)				Every two days	[186, BE Flanders 2010]
Weaners	0.17				NA	[589 , Netherlands, 2010]
Fattening pigs	1.23 – 1.61 (1)	0.59 – 1.46 (1)			Monthly	[188, Spain 2010]
	1.0 – 1.2					[589, Netherlands, 2010]

NA= Not available.
(1) Measured data.

Applicability

In general, the system can be easily adapted to existing gestation pens, especially when individual housing is converted into group housing and the free run area between the rows of crates is wide enough. If this area is not wide enough, the crates can be replaced above the control corridor. The surface per sow can reach 2.25 m^2. The solution can also fit other group housing systems without crates, for example those equipped with feeding stations. [166, Netherlands 2010]. When the technique is adapted to existing gestation pens, and in case the existing manure pit is already shallow (0.80 m to 1.2 m), the location of the already existing discharge openings will be crucial for retrofitting this system.

The conversion of an existing stable for weaned piglets to this system is only possible if the pen has a ~~depth~~ length of at least 2.75 m ~~is provided~~. [273, BE Flanders 2010]

Economics

Reported investment costs for the implementation of this technique vary between ~~differ by~~ Member States and type of reared animal.

Mating/gestating sows

In the Netherlands, depending on the material the slats are made from, extra-investment costs, compared to standard housing, are reported at about EUR 130 per animal place for gestating sow ~~gestation,~~ for iron triangular slats, and EUR 100 per animal place for concrete slats ~~other materials~~. The corresponding annual costs are EUR 15 and 10 EUR/ap/yr respectively (including depreciation, interest, maintenance and all other operating costs, such as energy etc.).[165, Netherlands 2010] [166, Netherlands 2010] [589, Netherlands, 2010]

In Belgium-Flanders, an extra cost (compared to ~~the former reference of~~ a fully-slatted floor with deep pit) is reported at EUR 292 per place for gestating sow ~~animal place~~ [300, Belgium-Flanders 2010]. In case the existing manure pit is already shallow and existing discharge openings are usable, retrofitting costs are reported to amount to EUR 472 per gestating sow place (group housed). If the existing discharge openings cannot be used, costs will be substantially higher. [273, BE Flanders 2010]

Weaned piglets
From Belgium-Flanders, investment costs for implementing the technique in existing housing systems, having a manure pit with a water and manure channel, are reported equivalent to 51 EUR/ap, for houses equipped with partly-slatted floors and 44 EUR/ap for houses equipped with fully-slatted floors. Reported extra costs for installation in to build new houses for weaners in Belgium-Flanders are EUR 19 per piglet [265, BE Flanders 2010]. and to retrofit existing sheds are EUR 51 44. [273, BE Flanders 2010]

In the Netherlands, the reported extra-investment costs to standard housing are equivalent to 13 EUR/ap and the total annual costs are 2 EUR/ap/yr (including depreciation, interest, maintenance and all other operating costs, such as energy etc.). [589 , Netherlands, 2010]

Fattening pigs
Extra costs for fitting the system in existing fatteners installations have been reported from Spain equivalent to are EUR 6.45 – 7.74 per animal place and year (costs are referred to 5 % interest and 20 years of amortisation), in comparison with a reference system consisting of partly-slatted floors with deep pit. Referring to the produced meat, costs are in the range of EUR 0.0219 – 0.0263 per kg of produced meat per year [188, Spain 2010]. For new installations, the corresponding extra investment cost is reported from Spain in the range of EUR 0 – 0.73 per animal place or EUR 0 to 2.5 per tonne of produced pork meat.

In Belgium-Flanders, the investment costs for retrofitting this system in existing houses, operating with fully-slatted floor with deep pit, is reported at EUR 344 per animal place, including also the modification of the manure pit to a water and manure channel system (see Section 4.7.1.6) [273, BE Flanders 2010]. In case that floor remains fully-slatted after rebuilding, the above costs are reported equal to EUR 168 per animal place.

In the Netherlands, the reported extra-investment costs for implementing the technique to standard housing are EUR 39 per animal place, when slats are triangular and made of metal, and EUR 30 per animal place, when slats are made of concrete. The corresponding annual costs are 5 and 3 EUR/ap/yr, respectively (including depreciation, interest, maintenance and all other operating costs, such as energy, etc.). [589, Netherlands, 2010]

Driving force for implementation
It is considered a simple, effective and inexpensive solution for adapting housing systems with reduced manure surfaces.
The technique offers an efficient solution for adapting existing sow housing systems from individual housing to group housing (in compliance with Directive 2008/120/EC). With this housing system, the pens and the crates can be used for the group housing by using the central slatted floor between the rows of crates as free run for the sows.

Example plants
In the Flanders part of Belgium, this technique is widely applied, with a total of 244 sow farms authorised (including farms below and above the threshold production capacity set by Directive 2010/75/EU). It is also widely applied throughout the Netherlands.

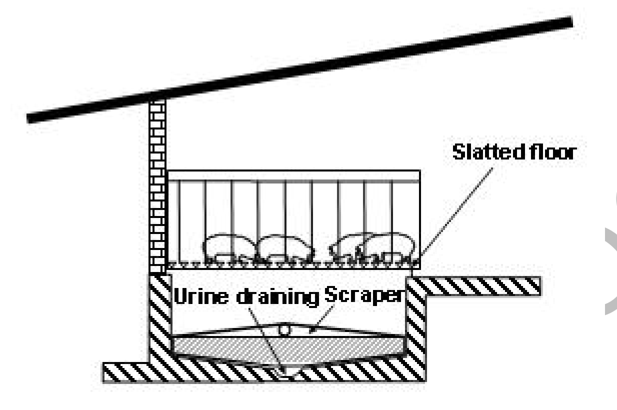
Reference literature
[165, Netherlands 2010] [166, Netherlands 2010] [265, BE Flanders 2010] [188, Spain 2010].

4.7.1.5 Partly-slatted floor or fully-slatted flat decks with a scraper

Description
The pen or the farrowing crate or the weaner flat deck is divided into a slatted concrete part (defecating dunging area) and a solid concrete part (laying area) with a slope towards the slats. Slurry manure is collected in a pit underneath the slats, from which the solid manure is removed

very frequently by a scraper to the manure pit outside. Urine can drain directly to a collection pit through a drain in the bottom of the manure channel (see Figure 4.33). See also the remark on external alley designs in Section 4.6.1.4.

Concrete slats are used for mating-gestating sows and for fattening pigs. In crates for farrowing sows and pens and flat decks for weaners, plastic and metal slats are used. Due to the relatively light weight of weaners, flat decks can be fully fitted with slatted bars. the slats can be made of iron metal or plastic (no concrete slats).



Source: [292, Italy 2001]

Figure 4.33: Flat deck system with a scraper under a fully-slatted floor

Achieved environmental benefits

A reduced slurry surface and the frequent removal of slurry to an external store storage reduce NH_3 emissions. Slat material, additional urine separation, frequency of removal and smoothness of the pit floor all contribute to the reduction that can be achieved.

A study carried out in Interestingly, data reported by Denmark regarding grower/finishing pigs, showed show no difference in ammonia emissions between systems with scrapers and a slurry system which was emptied regularly by a vacuum system. was effect from scraping a reduced manure pit compared with a fully-slatted floor, each having similar associated emissions levels of 3.12 kg NH_3 per sow place per year

Cross-media effects

Operating the scraper requires energy. Although data are not available for fattening pigs, the power consumption of scraping varies by with the frequency, with consumption being reported as 2.4 (IT) and 3.5 (NL) kWh per farrowing sow per year, as 0.24 kWh per weaner place per year on fully-slatted floor and about 0.15 kWh per weaner place per year in the case of partly-slatted floor.

From the previously mentioned Danish study, it was also observed that odour emissions are higher in systems with scrapers compared to a slurry system which was emptied regularly by a vacuum system.

Frequent maintenance is required for this type of equipment, with consequent increase in demand for labour resources.

Operational data

The removal frequency of manure, as reported from Germany, is 1 – 2 times per day (for the same housing system without scraper it is 1 – 2 times per months) [192, Germany 2010]. The use Application of metal slats gives lower emissions as slurry is dropped removed faster into the pit. A possible influence of the design of slatted floors on the performance of this technique is also reported (transverse slats are considered to perform better).

Achievable ammonia emissions mostly date to the 2003 edition of the BREF and are summarised in Table 4.78. where for fattening pigs, figures are not available as emission, but are reported as an emission percentage reduction (Red. %) in comparison to the reference of the FSF with manure pit. Weaned piglets on fully-slatted floored flat decks are associated with ammonia emissions of 0.39 kg NH_3/ap/yr.

Table 4.78: Ammonia emissions associated with partly-slatted floored pens with manure removal by a scraper, and related reduction in comparison with an FSF with deep pit

Animal	PSF concrete slats		PSF metal slats	
	NH_3 (kg/ap/yr)	Reduction (%)	NH_3 (kg/ap/yr)	Reduction (%)
Gestating sows	2.22 – 3.12	15 – 40	1.85	50
Farrowing sows	4.0 – 5.65	35 – 52		
Weaners			0.18 – 0.36	40 – 70
Fattening pigs	1.4 – 1.8 ([1])	40	1.2 – 1.5 ([1])	50

([1]) Values have been calculated on the basis of the emission factor for the reference system, FSF with deep pit (3.6 kg NH_3/ap/yr) and the reported % reduction of ammonia emissions.
Source: IRPP BREF 2003 [192, Germany 2010]

The working functioning of the system is vulnerable due to the wear of the top floor. Emissions have been obtained under average conditions. The frequency of scraping was once a day. In general this system works well, but operability is difficult because crystals can be formed on the pit floor which hinder the scraper [291, IRPP TWG 2002]. More research is required to optimise the operability of this system.

Applicability
The system with a partly or fully-slatted floor Although to implement this system some alterations are needed in the manure pit, and in existing houses the applicability depends on the design of the existing manure pit. However,

Scrapers can be applied in new houses. In general, it is mostly difficult to apply the technique to existing housing as the cost will be equal to the construction of new buildings. Although to implement this system some alterations are needed in the manure pit, and In existing houses the applicability depends on the design of the existing manure pit.

The scraper technique in Germany is applicable when slurry has a high dry matter content, or when the construction of a shallow pit is necessary because of solution is preferably applied in buildings located in vulnerable areas with high hydrostatic level of groundwater. flows locations close to ground water (reduced construction depth of the slurry channels) [192, Germany 2010]

Economics
Data on capital costs for sow houses are not available, but the operational costs per pig per year are considered to be high [291, IRPP TWG 2002]

For farrowing sows, relatively high costs have been reported, although Italian information reports lower costs than the FSF with a deep pit reference (no data). Compared to a fully-slatted floor, the ammonia reduction can be 52 %, but requires an extra investment of EUR 785 per sow place or EUR 182.55 per kg NH_3 abated. The extra annual costs are EUR 147.20 per sow place or EUR 34.20 per kg NH_3.

For weaner houses, extra investment costs are EUR 68.65 per weaner place. This means that with a 70 % reduction (0.60 to 0.18 kg NH_3), costs are EUR 163.5 per kg NH_3 abated. The extra annual operational costs are EUR 12.30 per weaner place or EUR 29.30 per kg NH_3. [IRPP BREF 2003]

Driving force for implementation
Scrapers are effective both with slurry and drier manure. They require little power and human labour.

Example plants
There are very few applications with the external alley design in Italy. This system is also applied in Italy and in Denmark. and In the Netherlands it is no longer allowed in new buildings. Scrapers in France are only associated with fully-slatted floors, where the technique is implemented in some new buildings. [261, France 2010]

Reference literature
[42, Netherlands 1999] [391, Italy 1999] [412, Italy 2001] [192, Germany 2010]

4.7.1.6 Partly-slatted pens with convex floor and separated manure and water channels

Description
At the opposite sides of a solid concrete floor, a manure channel and a water channel are built as is pictured in the schemes of Figure 4.34 and Figure 4.35. The floor pen consists of three parts, as follows:

- The floor that separates the channels can simply be sloped or convex and is sized to give each animal a minimum available surface area space of 0.1 m^2 in pens for at least 30 piglets, or 0.30 m^2 per fattening pig. The reported width is 1.3 m.
- The front channel is placed under the feeding system, is a maximum 0.6 m wide and is partly filled with water (minimum 5 10 cm). As the pigs do not normally defecate in the front area, the water channel is meant to collect only non-drunk spilled water and spoiled feed. The main function of the water filling is to prevent flies from breeding, and to clean the other channel at the end of the cycle. A maximum width of 0.65 m is reported. Water for cleaning the pens may be used to fill the water channels.
- The back channel is the manure channel. In order to reduce the emitting surface, the channel can be built with flushed gutters (see Figure 4.34) or with slanted walls (see Figure 4.35). Gutters have a slope of 60 degrees (see Section 4.7.1.10) and should be flushed twice a day with the liquid fraction of the manure (after separation) having a dry matter content not higher than 5 %. The surface of the slanted walls must be smooth, with no slurry sticking effect. Slanted walls sloping in the channel should have a certain angle follow the same rules of inclination seen in (see Section 4.7.1.4).

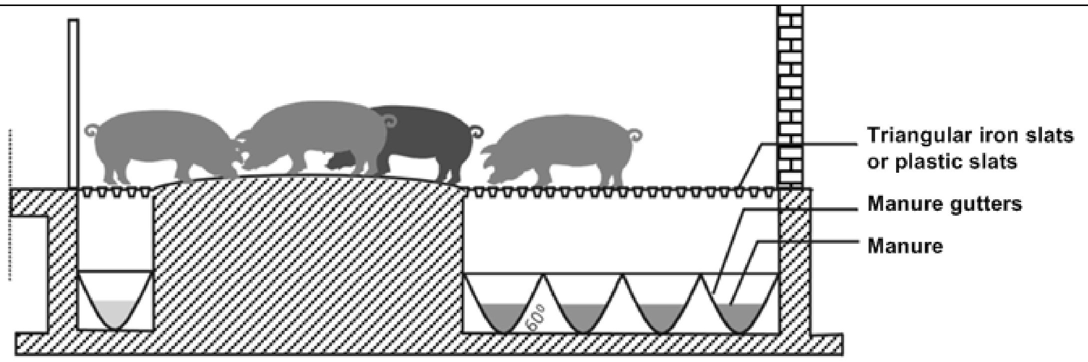
In pens for fattening pigs, the manure channel has a width of at least 1.10 metres, and is larger than the water channel. In pens for weaners, the minimum width reported is 0.6 – 0.9 m.

The maximum emitting surface per animal, in the manure channel, is reported between 0.18 m^2 and 0.27 m^2 per fattening pig and The channel is sized for a maximum 0.10 m^2 area per piglet place. If two slanted plastic walls are placed, the emitting surface can be reduced to 0.11 m^2 per fattening pig.

After each breeding cycle, a complete outflow of the channel(s) is done and the pens are cleaned.

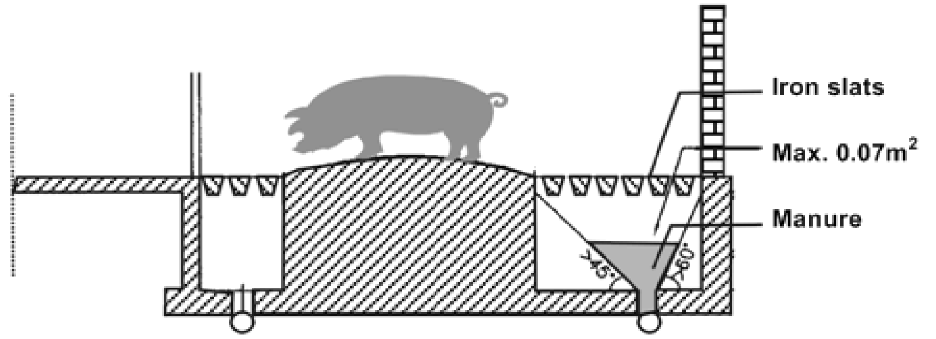
With this system, the total space available per piglet is reported at 0.4 m^2 with at least 0.12 m^2 solid floor corresponding to each piglet. A maximum of 37 % slatted floor for fattening pigs is reported.

~~The emitting and the manure surface in the channel is dimensioned between 0.11 m² and 0.27 0.18 m² per pig place.~~
~~The manure channel is sized for a maximum 0.10 m² area per piglet place. In fatteners pens, the manure channel has a width of at least 1.10 metres, and the manure surface in the channel is dimensioned between 0.11 m² and 0.27 0.18 m² per pig place.~~



Source: [42, Netherlands 1999]

Figure 4.34: Convex floor with triangular iron slats in combination with a gutter system



Source: [42, Netherlands 1999]

Figure 4.35: Convex floor with triangular ~~iron~~ metal slats in combination with discharge ~~sewerage~~ system and side walls on a slope in the manure channel

Over the manure channel slats are normally triangular shaped and made from iron. The use of plastic bars is an alternative for weaners rearing, whereas for fattener pens, concrete slats are also used.

Achieved environmental benefits
Reduction of ammonia emissions is achieved by decreasing the emitting surface per animal place, through the application of water and manure channels and by measures applied to the channel(s). In addition, ammonia emissions are further reduced by the non-adherent metal triangular slats that quickly release the dung to the channel, ~~by the limited manure surface in the channel~~, and by the frequent removal of the manure by means of flushing or a discharge ~~sewerage~~ system.

Where the pit is further reduced in dimension, emissions are also reduced.

Cross-media effects
Energy consumptions vary depending on if manure is flushed or removed in a discharge ~~sewerage~~ system. Twice a day flushing has an extra energy consumption of 0.75 kWh per weaner place per year. Odour peaks due to flushing may cause a nuisance when residential areas are near the farm. On a case by case basis it has to be decided whether an overall load (thus

applying a no-flushing system) or peak values are more important. [291, IRPP TWG 2002] The sewerage system does not need extra energy, and if the manure is frequently removed, it can be used for biogas production.

Operational data

Ammonia emissions vary depending on the manure collection system and the ~~ratio per animal of~~ emitting surface per animal in the channel. Table 4.79 summarises the figures that have been provided.

Table 4.79: Emissions (kg/ animal place per year) reported for different types of flooring systems by animal category

Animal category	System	NH_3	PM_{10}	Odour	Reference
		kg/ap/yr	kg/ap/yr	ou_E/s/ap	
Weaner	Discharge	0.26			IRPP BREF 2003
	Flushing	0.21			IRPP BREF 2003
	Slanted walls, metal bars	0.18			[497, BE-Flanders 2010]
	Slanted walls	0.18 ([1]) (0.14 – 0.22) ([2])	0.132 ([1])	5.4 ([1])	[176, Netherlands 2010]
Fattener	Slanted walls, metal bars, 0.18 m^2/ap	1.01 (0.99 – 1.02) ([2])	0.275 ([2])	17.9 ([2])	[194, Netherlands 2010]
	Slanted walls, metal bars, 0.27 m^2/ap	1.4 ([2])	0.275 ([2])	17.9 ([2])	[195, Netherlands 2010]
	Slanted walls 0.18 m^2/ap	1.2			[186, BE Flanders 2010]

([1]) Values derived by expert judgement based on conclusions by analogy.
([2]) Measured data.

~~The manure channel is sized for a maximum 0.10 m² area per piglet place. In fatteners pens, the manure channel has a width of at least 1.10 metres, and the manure surface in the channel is dimensioned between 0.11 m² and 0.27 0.18 m² per pig place~~ **Reported under description**.

The flushing system requires a mechanism ~~an extra operating installation~~ to separate the liquid from the slurry manure before it can be used as the flushing fluid. The depth of the gutters should not exceed 4 cm, to prevent sediments from accumulating on the bottom and from drying, leading to a difficult cleaning that in turn might result in problems of flies. [261, France 2010].

Applicability

This technique was reported to be in use for rearing weaners, growers and fattening pigs.

Retrofitting the system with two channels into existing houses is difficult and costly (see economic section). The entire ground plate of the manure pit has to be removed in order to construct the discharge system for emptying the slurry and water, and possibly, digging operations have to be performed near the load bearing walls.

Building sloped walls and flush gutters is relatively easy ~~in existing houses, the applicability depends on the design of the existing manure pit. This system is easily applicable~~ in pens with a central convex or a partly-slatted floor, with a sloped concrete floor. To implement these features ~~this system~~ only a few alterations are needed. ~~Side walls on a slope can be applied in existing channels, with few alterations.~~

A minimum length of 2.75 m is reported as necessary for retrofitting pens for weaners. [273, BE Flanders 2010]

Economics

The basic investment for the two channels and sewage system (or vacuum system) implies an extra investment per pig place compared with the fully-slatted floor system of EUR 2.85 for piglets and EUR 3.00 for fatteners, and extra annual operational costs of EUR 0.35 per piglet place and EUR 0.50 per fattener place. Such figures This means that a with a 60 % reduction of ammonia emission from (i.e. 3.0 to 1.2 kg NH_3) of ammonia per fattening pig place costs are about EUR 1.65 per kg NH_3 abated. [IRPP BREF 2003]

Data on extra-investment costs for the implementation of the technique, related to weaned piglets and fattening pigs as compared to a standard housing, are reported from the Netherlands and presented in Table 4.80.

Table 4.80: Extra investment costs for the implementation of slatted pens with convex floor and separated manure and water channels, from the Netherlands

Animal category	Floor type/animal places	Investment costs (1)	Annual costs (1)	Source
		EUR/ap	EUR/ap/yr	
Fattening pigs	Partly-slatted floor, 4 200 ap	39	5	[194, Netherlands 2010] [195, Netherlands 2010]
Weaners	Partly-slatted floor; pen with sloped walls in the manure channels and large group, 2 016 ap	13	2	[176, Netherlands 2010]
Weaners	Fully-slatted floor with sloped walls and triangular slats, 2 016 ap	21	2	[589, Netherlands 2010]
(1) Baseline: partly-slatted floor with 60 % solid floor; available total surface: 0.8 m^2 per fattening pig and 0.4 m^2 per weaned piglet; 0.8 m manure channels.				

The needed investments for the version with sloped walls is around EUR 13 per weaning pig place (annualised to EUR 2 per year). [176, Netherlands 2010]
The extra investment cost for the version with a flushed gutter in weaners is EUR 25 per place. This means that with a 65 % reduction (0.60 to 0.21 kg NH_3), costs are EUR 64.10 per kg NH_3 abated. The extra annual operational costs are EUR 4.15 per pig place. This means EUR 10.64 per kg NH_3 is abated. [IRPP BREF 2003]

Building fattening pens with For the iron bars requires an extra investment costs of are EUR 39 23 per pig place **Reported in the table above**

In Belgium-Flanders, the investment costs for implementing this technique (manure pit with water and manure channels, with slanted side walls) to an existing housing system for 880 animal places (operating with fully-slatted floor with deep pit) is reported at EUR 344 per animal place, for partly-slatted floors, or EUR 168 per animal place for fully-slatted floors [273, BE Flanders 2010] [274, BE Flanders 2010]. For newly built houses, the reported extra cost for implementing the above variation of the technique is in the range of EUR 86 – 109 per animal place, for fully-slatted floor. [265, BE Flanders 2005]

Retrofitting a house for weaners, with a system having a manure pit with a combination of a water and manure channels, equipped with slanted side walls, is reported to cost about EUR 45 per animal place.[273, BE Flanders 2010]

Driving force for implementation
These systems are effective in reducing ammonia emissions.
Partly-slatted floors are considered to improve animal welfare.

Example plants

In the Netherlands these system appear rather popular as about 75 000 weaned piglet places are equipped with the flushed version and about 250 000 weaner places have been equipped with this sewerage version system. Sloped walls are being implemented in most new Dutch buildings and alterations, both for weaning and growing/fattening pigs.

In the Netherlands, this system has been implemented in most new buildings and modifications of existing houses. [176, Netherlands 2010]

Reference literature
[42, Netherlands 1999] [22, Bodemkundige Dienst 1999] [176, Netherlands 2010] [186, BE Flanders 2010 V-1.5, V-4.7] [194, Netherlands 2010] [195, Netherlands 2010] [265, BE Flanders 2010, V-4.7].

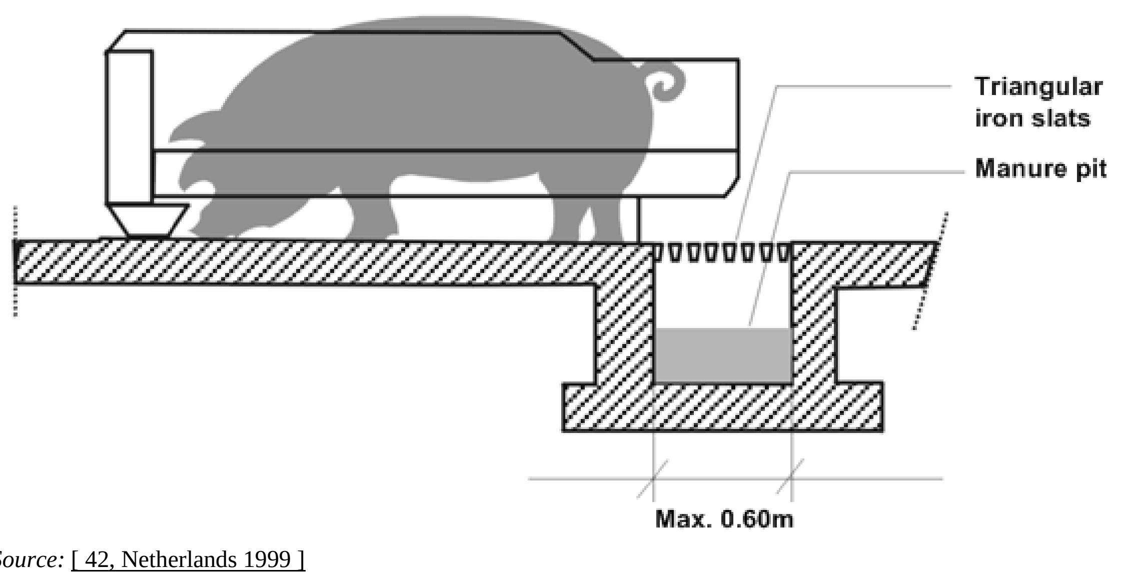
4.7.1.7 Partly-slatted floor with a reduced (in width) manure pit

Description
Ammonia emissions can be reduced by applying the principle of reducing the manure surface area, in particular by applying a small manure pit with an maximum approximate width of 0.60 m. The manure pit is equipped with triangular iron metal slats or concrete slats.

Substantial reductions of the channel width are possible because the sows are individually housed. In the narrow pit, Urine and faeces fall at the back of the stall in the narrow pit. As a consequence, the cleanliness and the welfare security for animals and workers are improved. Gilts houses need an increased width of the pit. [261, France 2010]

In the UK, farrowing crate slats are usually made of cast iron, but some manual mucking out is sometimes necessary. [173, UK 2010] In Austria, plastic slatted floors are used to cover one third of the sow area. [159, Austria 2010]

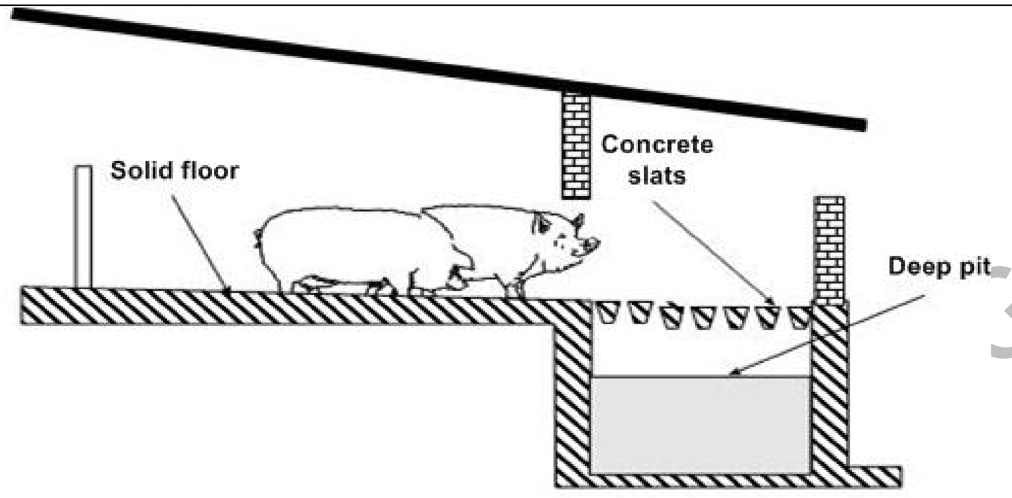
The channels are cleaned after each farrowing when the farrowing crates are disinfected, i.e. at intervals of about 4 – 5 weeks. The slurry is usually removed via a central sewer system by opening a valve and using constructing an inclination of the manure pipe. Some systems are equipped with scrapers (see Section 4.7.1.5).



Source: [42, Netherlands 1999]

Figure 4.36: Individual housing with a small manure pit

In Italy a loose-housing design was reported to be ~~is~~ in use, where the inside of the house is all solid flooring and outdoors is all slatted flooring, making a corridor or alley adjacent the external walls and over a deep pit (see Figure 4.37). Hatched openings allow the animals to move in and out the stable. The environmental performances and operating conditions are comparable to the normal partly-slatted floors and reduced pit, but costs may be different.



Source: [292, Italy 2001]

Figure 4.37: Solid concrete floor and fully-slatted external alley with storage pit underneath

Achieved environmental benefits

The reduction of emitting surfaces, obtained by a ~~combination of the~~ reduction of ~~the~~ manure pits and slurry surfaces in combination with ~~and~~ the fast discharge of the manure, ~~by using triangular slats~~ reduces the NH_3 emissions by 20 to 40 %.

The efficiency of the technique, when farrowing sows are individually housed, depends on the cleaning of the slats, otherwise there will be no positive effect.

Cross-media effects

~~These Houses can be naturally or mechanically ventilated, but generally, the climate control (temperature, airflowrate) is difficult (see Section 2.3.2.2). [261, France 2010]~~ In Denmark, mechanical ventilation is applied and dimensioned for an output of a maximum of 100 m^3 per hour per sow place. In areas with low outdoor temperatures, these units can also be equipped with auxiliary heating. Energy input is unchanged.

In the case of the external slurry pit, a reduced emission will not benefit the internal environment, which can be considered as one of the advantages of the reduced pit inside.

In Italy, energy savings are possible because artificial ventilation is not required. [292, Italy 2001]

For animal welfare reasons a solid floor is better than a slatted floor, however, in farrowing crates, the benefits are only for ~~the~~ piglets and not for the sows [291, IRPP TWG 2002]. Additionally, water consumption always increases when a conversion ~~substitution~~ is made from slatted floor to solid floor, due to the increased cleaning needs of the solid floor. [261, France 2010]

A slight increase of water consumption is associated with a reduction of the slatted-floored area, due to higher cleaning needs of the solid floor. [500, IRPP TWG 2011][261 , France, 2010]

Operational data
Reported emission ~~values~~ data, concerning ammonia and methane, are summarised in Table 4.81.

Table 4.81: Reported emissions (kg per animal place per year) from different production pigs housed with a reduced manure pit

Animal category	NH_3 emission kg/ap/yr	CH_4 emission kg/ap/yr	Source
Gestating sows, group, solid concrete floor and fully-slatted external alley with storage pit underneath	2.96		IRPP BREF 2003
Gestating sow, individual with reduced manure pit (maximum width of 0.60)	1.23 – 2.40		IRPP BREF 2003
	0 – 2.272 ([1])	18.2 (1.5–55.5) ([1])	[164, Spain 2010]
Fattening pig ([2]) (with a maximum width of 0.60 m)	0.89–1.69 ([1])	0.9–1.82 ([1])	[196, Spain 2010].

([1]) Measured data in forced ventilated houses.
([2]) 2/3 of slatted floor area, manure removal at the end of the cycle.

From Spain, 49 % of ammonia reduction was measured for individual housing of gestating sows [164, Spain 2010] and 42 % for group housing of fattening pigs [196, Spain 2010]. In Denmark, it is reported that systems for farrowing sows with partly-slatted floors and a reduced manure pit have about half the emissions, compared to fully-slatted floors.

This housing type is fitted with mechanical ventilation either in the form of negative pressure or balanced pressure plants. Ventilation for farrowing houses is dimensioned for a maximum output of 250 m^3 per hour per farrowing crate. ~~Its operation is described in Chapter 2.~~

Applicability
In existing houses, the applicability depends on the design of the existing manure pit, but it is mostly difficult if not impossible to apply. For existing housings with an internal concrete solid floor an extension with an external alley with a storage pit might be possible. [292, Italy 2001] The application of a maximum width of 0.60 m may require more pit depth or more frequent removal and then outside manure storage. If a minimum pit size is imposed then consequently ~~by relation~~, a reduction will not be applicable, (e.g. Ireland: > 0.90 m).

This technique is widely practised in Denmark for farrowing houses. ~~It is assumed that in existing houses the applicability will depend on the design of the existing manure pit, but that it is generally difficult if not impossible to apply.~~

From 1 January 2013, individual housing is no longer permitted for gestating sows, during a period starting from four weeks after the service to one week before the expected time of farrowing. The system may be applied for farrowing sows only and for temporary accommodations like service rooms and transits before slaughter.

In France, this system is used outdoors with wider channels (about 1.2 m). It is used for specific programs against trichinellosis, with individual control before departure for slaughter. It is reported to entail risks for workers.

Economics
Updated costs have been calculated in Spain for this technique as extra costs for refurbishing existing housings compared to the FSF systems. Results are given in Table 4.82 ~~for~~ to describe the various productions and are referred to obtainable productions and to environmental

benefits. Hence values are given per animal place per year, per produced pig and per kg of abated ammonia, given a range of expected efficiency (% reduction). Additional emissions reductions that are obtainable with increased removal frequency are not taken into account. [379, Spain 2006]

Table 4.82: Extra costs for fitting partly-slatted flooring with a reduced manure pit in existing housings, in Spain

Production	(%) Reduction)	Extra cost (EUR/place per year)	Extra cost (EUR/kg pork produced)	Extra cost (EUR/kg NH_3 reduced)	Additional reduction for frequent removal
Gestating Sows	20 – 50	5.69 – 6.83	0.0021 – 0.0030	4.21 – 12.65	25 %
Piglets (6–20 kg)	25 – 35	0.88 – 2.25	0.0010 – 0.0026 ~~0.0039~~	3.49 – 12.50	25 %
Growers/finishers (20–100 kg)	30 – 35	3.61 – 4.33	0.0123 – 0.0147	4.57 – 3.26	30–60 %
Source: [379, Spain 2006]					

In Belgium-Flanders, in individual housing for mating and gestating sows, the reported extra costs (including all construction works inside the pit, as well as the cost for the additional demand for storage capacity) ~~are calculated as a difference of costs~~ ~~building~~ for the housing construction, compared to houses with ~~to~~ fully-slatted floors and deep pit of 1.2 m depth, ~~conventional barns that are common in that region. Extra costs, related to individual housings for mating/gestating sows~~ are equivalent to EUR 450 per animal place, in the case of new houses, and EUR 671 per animal place for rebuilding existing housing. In group-housed sows extra investment costs are reported equivalent to EUR 292 per animal place in the case of new houses, and EUR 472 per animal place for retrofitting existing houses. [274, BE Flanders 2010]. [273, BE Flanders 2010]

In the UK, the investment cost for a new installation for farrowing sows is reported around EUR 2 500 per farrowing crate, including building costs, not labour.

Driving force for implementation
Partly-slatted floors are considered to improve animal welfare.

Example plants
~~This is a very common housing system for mating and gestating sows in many European Member States.~~ In Italy 40 % of the growers and/finishers are kept in these kinds of installations. [292, Italy 2001] ~~Applied~~ In Denmark, Austria and in the UK this system is commonly applied to farrowing houses.

In Belgium-Flanders, there are 108 farms (including farms below and above the threshold production capacity set by Directive 2010/75/EU) ~~permits have been released~~ ~~installations~~ for rearing sows with this system.

Reference literature
[42, Netherlands 1999] [391, Italy 1999] [397, Denmark 2000] [292, Italy 2001] [159, Austria 2002] [164, Spain 2010] [173, UK 2010] [196, Spain 2010].

4.7.1.8 PSF with slurry cooling channels

Description

A cooling system is installed under the manure pit or the manure channel floor~~ing~~ of a housing system, equipped with vacuum cleaning or with scrapers. Low-density polyethylene (PE-LD) pipes for the refrigerating liquid are cast in the concrete floor with a distance of 35 – 40 cm between each pipe loop (see Figure 4.38). Alternatively, cooling pipes can be installed above concrete, at the bottom of the manure pits. Pipes are connected to a heat ~~exchange~~ exchanging device (pump or plate) to recover energy from the process that might be used for heating other parts of the farm (house for weaned piglets, farrowing pens ~~animal houses~~, private farmhouse, or greenhouses, etc.). In the cooling circuit glycol or other types of antifreeze can be added in order to allow the slurry to be cooled to temperatures even below 0 ºC. However, extreme cooling reduces the heat pump efficiency. Usually, it is recommended that the system is designed to cool down to a temperature of +5 ºC. [499, AgroTech 2008]

Figure 4.38: Example of PE pipes ready to be cast in concrete

Achieved environmental benefits

A reduction of slurry temperature is induced to reduce ammonia emissions. At a lower slurry temperature, less ammonium is turned into ~~evaporating~~ gaseous ammonia, hence emissions are reduced.

Cooling systems in the Netherlands showed a reduction of 25 % of odour ~~for dropping~~ by decreasing the temperature ~~by~~ of 3° C.

Cooling manure is expected to reduce also greenhouse gas emissions (primarily CH_4) but the performance has not been verified. [197, Denmark, 2010]

~~Tests have shown that emission can be reduced by 10 % for every 10 watt (W) per m^2 of applied cooling effect~~.

Cross-media effects

Electrical power is needed to run the pumps (heat pump and circulation pump). If the recovered heat is utilised in other parts of the installation, then the indirect greenhouse gas emissions, associated with the production of electricity, will be mitigated.

Due to the cooling effect, the application of this technique may result in lower ventilation rate compared to standard ventilation. In this case, it is important to control that the health and safety requirements, in particular the exposure to dust, ammonia and other gases (e.g. hydrogen sulphide) are met. [499, AgroTech 2008]

It is reported that the technique may present problems related to ice formation.

Operational data

Depending on the animal type, pen floor and system design, large variations in energy consumption may be observed. Examples of the energy requirements to reach a given cooling effect are explained in Table 4.83 which refers to varied different combinations of slatted-to-solid floor ratios. It is reported that energy requirements for fattening pigs range between 21 and 63 kWh per animal place per year and for sows in the range of 151 – 452 kWh per animal place per year, based on the cooling program.

Table 4.83: Expected electricity consumption energy use for electricity when a target cooling effect of 10, 20 or 30 W/m^2 is used applied

Animal type	Pen design	Cooling area per pig place	10 W/m^2	20 W/m^2	30W/m^2
		m^2	kWh/ap/yr		
Fattening pigs	25 – 49 % solid floor	0.47	21	42	63
Fattening pigs	50 – 75 % solid floor	0.23	11	21	32
Waiting sows	Group rearing, partly-slatted floor	1.75	151	302	452
Source: [197, Denmark 2010]					

Channels need to be scraped daily or flushed on a daily or frequent basis. If not, large volumes of slurry cannot be cooled by the relatively small exchanging surface.

Ammonia emission reductions mostly depend on the type of pen floor design, but mostly, on the cooling effect per square metre. In Table 4.84, ammonia emission values achieved by the manure cooling system for different animal types, housing systems and cooling effect levels are presented. Danish tests have shown that ammonia emissions are reduced by a factor of 10 % for every 10 W/m^2 of added cooling effect. Differently expressed, it is also reported that evaporation is reduced by 5 – 10 % for every degree the temperature is lowered [499, AgroTech 2008]. Based on the experimental results, the emission reductions (compared to non-cooled manure) can be estimated by the following formulae that refer to different manure collection and removal in the channels, combined with manure cooling:

- mechanical scraping and frequent removal: reduction (%) = $-0.008\ x^2 + 1.5\ x$
- traditional manure pit and a maximum depth of 40 cm: reduction (%) = $-0.004\ x^2 + x$.

Where x = cooling effect per surface, W/m^2.

Cooling programmes are often chosen as a result of the possibility to reuse the heat. Emission values of 1.16 and 1.52 kg NH_3 per animal place per year correspond to the options presented in Table 4.83 for fattening pig housing systems, with a ratio of solid floor of 25 – 49 % and 50 – 75 % respectively. [268, Denmark 2010]

In Denmark, in fattening pig houses with partly-slatted floors and scrapers in manure channels, the assessed maximum ammonia emissions reduction reported is 40 %, when compared to a conventional house with fully-slatted floor, and 30 % compared to a partly-slatted floor. In gestating sows houses with pens and partly-slatted floor, the maximum reduction is reported equivalent to 30 %, compared to a corresponding housing system without cooling. [499, AgroTech 2008]

Table 4.84: Ammonia emission values achieved by manure cooling applied for different animal types, housing systems and cooling effect levels

Animal type	Housing system	Cooling effect	Ammonia emissions
		(W/m^2)	(kg NH_3/ap/yr)
Fattening pigs	25 – 49 % solid floor, frequent removal by vacuum, no bedding	10	1.16
Fattening pigs	50 – 75 % solid floor, frequent removal by vacuum, no bedding	10	1.52
Fattening pigs	Partly-slatted floor, manure scraper, straw addition	50	2.2
Fattening pigs	Partly-slatted floor, manure scraper, straw addition	10	2.6
Waiting sows	Partly-slatted floor, manure scraper, straw addition	50	6
Waiting sows	Partly-slatted floor, manure scraper, straw addition	10	8
Source: [160, Denmark 2010] [268, Denmark, 2010]			

From a farm for fattening pigs, in Finland, where the technique of slurry cooling is implemented, but also additives that may have an influence on emissions are used in the slurry, it is reported that ammonia and odour emissions are reduced by approximately 25 %, compared with the system without the applied measures. Fuel savings are reported in the range of 70 – 80 %, due to heat recovery; approximately 90 % of the energy used for heating the housing system was obtained by recovered heat from slurry cooling. The annual fuel consumption is reported equivalent to 10 kWh per animal place per year, which roughly corresponds to 1 litre of oil per animal place per year. On the other hand, electricity requirements are reported at 60 kWh/ap/yr (the effect of energy saving fans is also included in the value). [276, Finland 2010]

In a Danish study, in which cooling pipes were cast into the manure channels and the manure was scraped out daily, no reduction of odour emissions was observed. [499, AgroTech 2008]

A heat exchange pump has a typical operating life ~~durabilty~~ of at least 15 years.

From Denmark, it is reported that the height of slurry in pit should not be more than 40 cm.

Applicability

The system is known to be in use for fattening pigs and waiting sows. Retrofitting is only possible in manure pits with a vacuum or flushing system ~~or flushing~~ where the cooling pipes are placed above concrete.

Manure cooling is not effective in large slurry volume; therefore, it can be implemented in new systems where ~~manure~~ slurry is ~~can be~~ frequently removed (i.e. daily scrapers or vacuum removal) ~~as with liquid manure systems (a vacuum system with a pull and plug). It is widespread in systems with scrapers.~~

In housing with a mixed slatted and straw bedded ~~housing~~ system, cooling can only be applied to the parts of the pen equipped with slats (eating/defecating area). ~~In these cases, manure and urine are mixed with slurry in the storage tank.~~

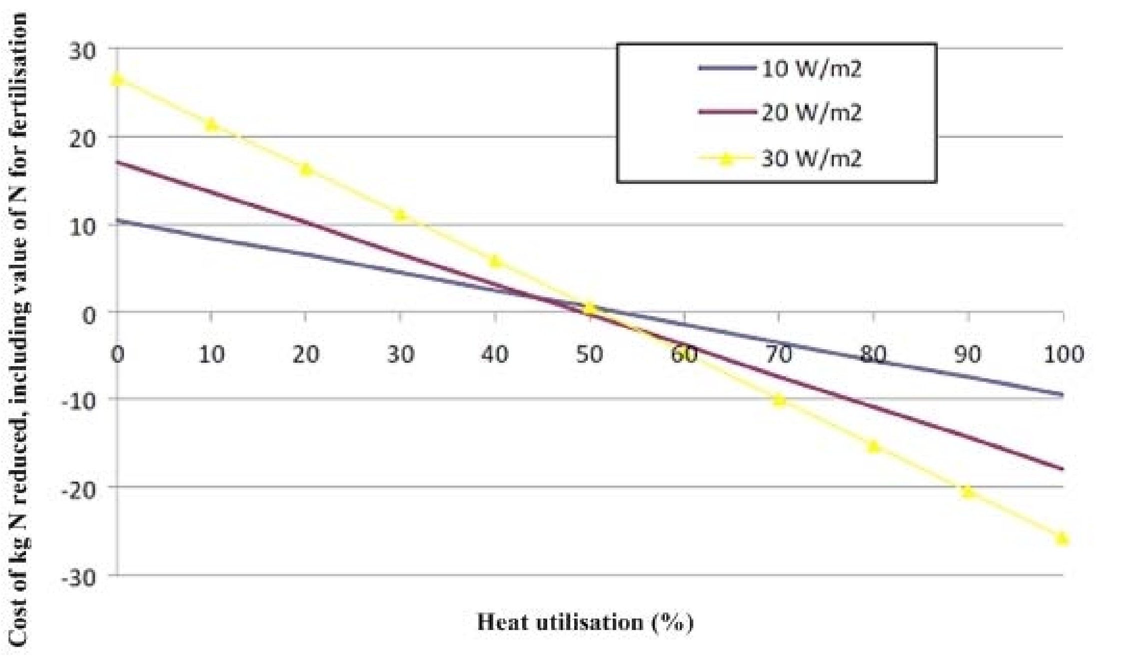
Economics

From Denmark, it is reported that this system has lower maintenance costs, compared with other cooling systems (i.e. floating cooling fins), for maintenance are lower. ~~Investment and running costs have not been provided.~~

From a farm with 3000 fattening pigs, in Finland, the reported extra investment costs are equivalent to 100 EUR/ap/yr, including the cost of energy saving fans.

From Denmark, the extra costs for the implementation of the technique in a fattening pigs house operating with a vacuum system, are reported to vary in the range of EUR 0 – 6.8 per animal place per year, or from EUR -0.4 to 1.7 per produced pig meaning that there will be a surplus if all heat is reused elsewhere in the production).

The extra costs for the implementation of the technique in a waiting sows house operating with a scraper system is reported from Denmark to vary between EUR -8 to 38 per animal place per year. This means that a benefit of EUR 8 will be generated when 100 % of the recovered heat is used on-farm to replace conventional fuels; while, the cost of 38 EUR/ap/yr corresponds to the situation when no heat is utilised and a cooling effect of 30 (W/m^2) is applied. In the Figure Figure 4.39, the effect on costs of heat utilisation for different levels of slurry cooling (temperature reductions) applied to a housing system for fattening pigs, with 50 – 75 % of solid floor, is illustrated. Figure 4.39 shows that slurry cooling for the abatement of ammonia emissions is profitable when the system converts more than 50 – 60 % of the recovered energy from slurry pits into heating energy for other purposes.



Source: [197, Denmark 2010]

Figure 4.39: Effect on costs of heat utilisation for different levels of slurry cooling

In Denmark, this technique is reported having lower maintenance costs, compared with ~~the~~ other cooling systems (floating cooling fins).

Driving force for implementation
The system can be used on any farm, but it is most convenient on integrated farms where farrowing sows and weaners use the recovered heat from the cooled manure in other sections.

Apart from the environmental benefit of reducing ammonia emissions, the technique may offer a significant energy saving, e.g. reduction of electric energy consumption by a factor of three.

Example plants
More than 300 installations exist in Denmark. The solution with the heat exchanger is in operation in Finland since 2004.

Reference literature
[160, Denmark 2010] [197, Denmark 2010] [268, Denmark 2010] [276, Finland 2010] [499, AgroTech 2008]

THIS TECHNIQUE IS NOW INTEGRATED WITH THE PREVIOUS TECHNIQUE 'SLURRY COOLING''

4.7.1.8.1 Cooling manure by heat exchanger

Description
As a simpler variation of the previous system, by the use of a heat exchanger, a cooling effect can be obtained which is sufficient for farm needs in the coldest climates, as is the case of this example of rearing fattening pigs that was reported from Finland.

A heat exchanger is used to recover heat from the slurry produced in a well insulated shed where fattening pigs are reared in partly-slatted pens (30/70 ratio of slatted to solid floor). The slurry removal is done by vacuum system, and automatic ventilation system is used to control the indoor environment (3 – 15 m^3 of air per animal in the cold season, and 40 – 100 m^3 in the warmer season).

Achieved environmental benefits
By the use of the slurry cooling system and slurry additives, ammonia and odour emissions are reduced as well as the use of external energy, in comparison with the conventional system.

Cross-media effects
Around 1 litre of fuel and 60 kWh of electricity are still necessary per animal place per year.

Operational data
Ammonia and odour emissions are estimated to be reduced by 25 % compared to the systems without the applied measures. Energy savings are possible in the range of 70 – 80 %, due to the heat recovery. Approximately 90 % of the recovered energy is used for heating.

A little straw is added over the solid floor, and a bedding additive is used.

Applicability
The system is known to be in use for fattening pigs. The installation of the slurry heat recovery system is not feasible in old houses.

Economics
Investments required are around EUR 500 per animal place, meaning an extra cost of EUR 100 due to the heat pump and energy saving fans.

Human labour needs are estimated at 1 hour per animal per year.

Driving force for implementation
In the Nordic climatic conditions, fully insulated animal houses and reliable heating systems are needed. Better average daily weight gains were reported.

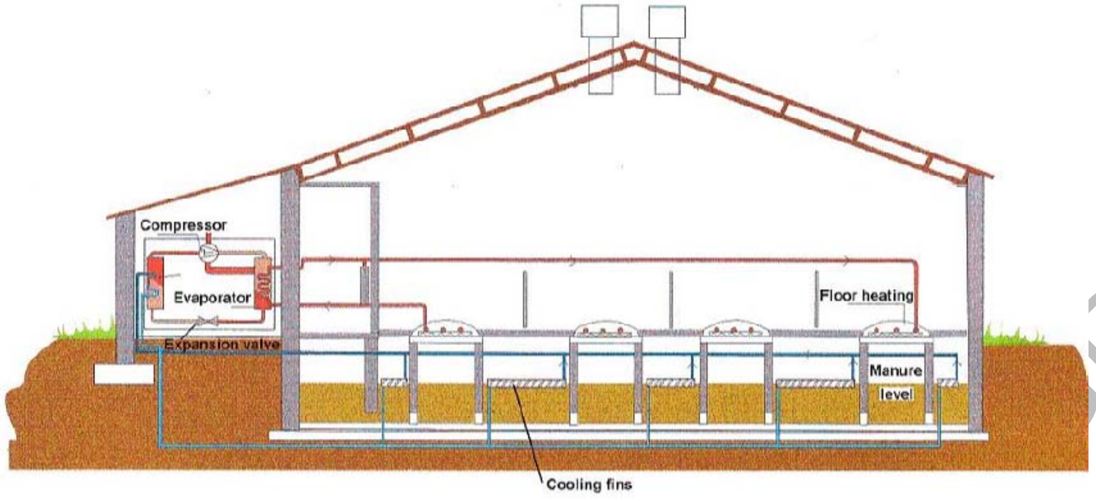
Example plants
The described data were recorded in a fattening farm that has been in operation since 2004.

Reference literature
[276, Finland 2010].

4.7.1.9 FSF or PSF with manure surface cooling fins

Description
Floating fins on the manure will cool the surface of the manure, A number of fins are installed in the manure pit. These fins are filled with water and float on the manure.
A number of plastic fins are placed in the pit to float over the manure. In each manure channel, fins They are connected to one another in a series and, in parallel between manure channels

(Tichelmann system), for a uniform cooling effect in all cooling elements over the whole slurry surface (see Figure 4.40).



Source: [546, TWG ILF 2002]

Figure 4.40: Manure surface cooling fins

Groundwater is circulating through floating fins and used as a coolant. ~~The total surface of the fins has to be at least 200 % of and compared to the manure surface.~~ By the use of a heat pump exchanger, ~~is used as a coolant. the~~ heat can be obtained ~~can be used~~ for ~~a~~ floor heating ~~system~~. The temperature of the top layer of the manure should ~~does~~ not exceed ~~be no higher than~~ 15 °C; hence, coolant water temperature needs to be lower than 12 °C.

Fully-slatted floor combinations have been reported for weaners and farrowing sows. Fattening pigs and waiting/mating/gestating sows are mostly reared on partly-slatted pens equipped with concrete, plastic or metal elements.

Achieved environmental benefits
Ammonia emissions are reduced. ~~can be obtained.~~ Where a heat exchanger is used, the obtained heat can be used for a floor heating system to reduce energy consumption.

In combination with a heat pump there will be a reduction in fuel consumption for heating of buildings (e.g. heating floors in the piglets' area).

Cooling manure is supposed to reduce also greenhouse gas emissions but the performances are unknown.

In a Dutch study in which cooling hoses floated on the surface of the slurry, a reduction of odour emissions of 20 – 25 % was measured. [499, AgroTech 2008]

Cross-media effects
Increased energy consumption for pumping water; however, ~~the use of~~ the heat recovered ~~obtained~~ by a heat exchanger can be used for other purposes. [169, Netherlands 2010]. Moreover, water consumption can be a limiting factor, especially in countries where access to ~~subterranean~~ underground water is limited. [261, France 2010]

Operational data
~~From the achieved reduction~~ It seems that ~~the~~ surface temperature is one of the most important factors determining the NH_3 emission. ~~It is recommended~~ The rule to follow is to keep the housing as cool as possible without affecting ~~with respect to the~~ animal welfare and production.

~~The achieved~~ Ammonia emissions have been measured ~~are is~~ at 2.2 kg NH_3 per sow place per year. ~~Compared to a fully-slatted floor the ammonia emission is reduced by about 50 % (individually housed sows).~~ To achieve this performance, for individual housing, the manure surface under the slatted floors must be adjusted to ~~have~~ at least 1.0 m^2 per sow place and the ratio of the fins' cooling surface to the manure surface ~~must be adjusted to have at least 1.0 m^2 per sow place,~~ should be at least 115 %. For group housing the corresponding values are 1.1 m^2 per sow place, and 135 % the ratio of cooling fins' surface to manure surface. ~~ratio are needed~~. Dust and odour emission per sow ~~animal~~ place and year are estimated at 0.22 kg and 18.7 ou_E respectively. [168, Netherlands 2010] [169, Netherlands 2010]

The technique does not require a frequent slurry removal. It is applied in deep pit systems with a reported frequency of slurry removal in the range of 3 – 12 months.

The increased energy consumption is estimated at 19 kWh per gestating sow place per year, 73 kWh per farrowing sow place per year, 10 kWh per fattening pig place per year and 3 kWh per weaned piglet place per year, for partly-slatted floors, and 7 kWh per weaned piglet place per year for fully-slatted. [589, Netherlands 2010].

Applicability

The technique is used either for individual and group gestating sow housing and can also fit pens equipped with electronic sow feeders. The system can theoretically be used for fattening pigs and weaners. Application is also possible in pens with a convex floor~~. The convex floor separates both with two channels. Slats are made of concrete, metal or plastic. [186, DK/NL, 2002]~~

The experience in the Netherlands is positive, in both new and existing houses, since the design and the size of the pen are not critical for the applicability of the system. However, other Member States do not share the opinion and consider that this technique is not easy to operate or to apply. In particular, issues concerning the fins buoyancy, with the continuous production of slurry from the pigs over the slatted floor, and the maintenance of the system are raised and potential solutions are reported to be difficult and expensive. [291, IRPP TWG 2002] [500, IRPP TWG 2011].

Economics

~~There is no information as to the durability of the cooling fins and consequently the cost of the maintenance of this system.~~

Table 4.85 shows the reported extra-investment and annual costs (including depreciation, interest, maintenance and all other operating costs, such as energy, etc.) from the Netherlands, together with the ~~calculated economic data for each animal category concerning~~ expected achievable ammonia emissions reduction (compared to an FSF system). ~~Investment costs and operational costs are also related to each kg of abated ammonia.~~

EXISTING TABLE 4.54 (DRAFT 1) HAS BEEN MODIFIED (see new table 4.85), BY ADDING MORE RECENT COST DATA; THEREFORE, SOME SET OF DATA PREVIOUSLY INCLUDED ARE NO LONGER VALID AND HAVE BEEN ELIMINATED (extra-cost per kg abated NH_3)

Table 4.85: Costs for the implementation of cooling fins for different animal categories ~~and equipment~~ and expected ammonia emissions reduction, in the Netherlands

Animal category	NH_3 emissions reduction		Extra investment cost (3)	Annual operational costs (3)
	(%) (1)	kg/ap/yr	EUR/ap	EUR/ap/yr
Gestating sow	50	2.2 (2) (3)	110	20
Farrowing sow	70	2.4 (3)	240	40
Weaning piglet – fully-slatted floor	75	0.15 (3)	19	3
Weaning piglet – partly-slatted floor	75	0.15 (3)	14	2
Fattening pig – concrete slats	50	1.4 (3)	27	5
Fattening pig – metal slats	60	1.4 (3)	35	6
(1) *Source*: IRPP BREF 2003 (2) *Source*: [168, Netherlands 2010] [169, Netherlands 2010] (3) *Source*: [589, Netherlands 2010]				

Driving force for implementation
Implementation is easy both for new buildings and for retrofitting existing houses.

Example plants
In the Netherlands, the system is ~~being~~ implemented in many rebuild situations and in some new buildings, where it is applied for fattening pigs, mating and gestating sows, farrowing sows and piglets.

~~About 3 000 mating and gestating sow places, about 10 000 farrowing pens and about 20 000 rearing pig places were mentioned to be are equipped with this system around the year 2 000.~~

Reference literature
[168, Netherlands 2007] [169, Netherlands 2007] [42, Netherlands 1999] [22, Bodemkundige Dienst 1999] [546, TWG ILF 2002]

This technique is the result of the grouping of former Sections 4.7.1.10 and 4.7.1.11 (Fully-slatted floor with flush gatters or flush tubes + permanent slurry layer)

4.7.1.10 Housing techniques with frequent slurry removal by flushing

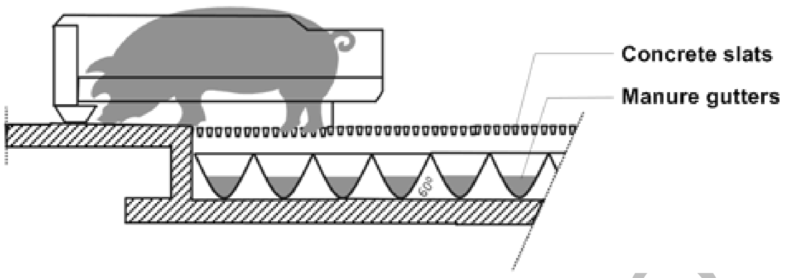
Description
Slurry removal is performed once or twice a day by flushing the channels with the liquid fraction of the slurry after mechanical separation. The liquid fraction of slurry can also be aerated before pumping or flushing. The objective of the technique is to reduce emissions by a frequent removal of the slurry with a dilute recirculated liquid. The flushing technique is used in combination with specific individual variations of the bottoms of channels or pits, as described below:

Gutters. Small plastic or metal gutters of a maximum of 4 cm in height and 60 degrees of slope are placed over the surface of the manure channels under fully-slatted or partly-slatted floors. The oval shape is intended to reduce the surface of manure exposed to the air and to naturally drain the urine (see Figure 4.41).

Tubes. PVC tubes are incorporated into the concrete under each slat (see Figure 4.42). Alternatively, the bottom of the pit is organised in channels by the construction of low walls in the blockwork. [261, France 2010]

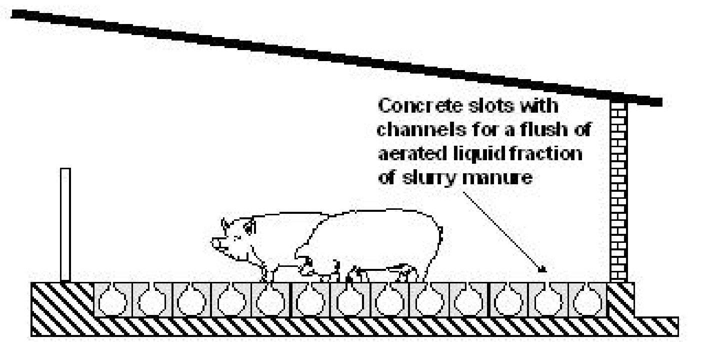
Permanent slurry layer. Channels underneath the slatted floor are filled with a 10 cm layer of slurry manure (see Figure 4.43). This technique is also used in Italy for the slurry management in external channels that run adjacent to the external walls (see Section 4.7.1.7).

A common feature of all variations is the slightly sloped bottom (around 0.5 %) that facilitates the slurry flushing and allows for the natural draining of the urine where it can be separated (gutters and tubes).



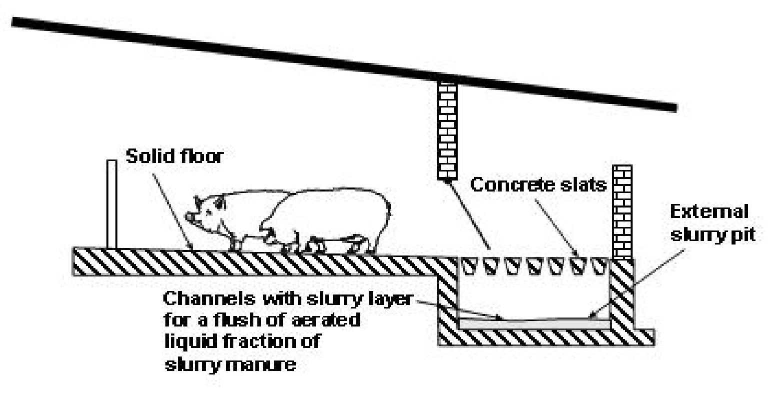
Source: [42, Netherlands 1999]

Figure 4.41: Partly -slatted floor with flushing gutters in individual farrowing sow housing



Source: [391, Italy 1999]

Figure 4.42: Fully-slatted floor with flushing tubes



Source: [292, Italy 2001]

Figure 4.43: Partly-slatted floor and external alley with the flushing of a permanent slurry layer in channels underneath

Achieved environmental benefits

The reduction of the slurry surface (gutters and/or partly-slatted floors), the frequent removal of the slurry and the continuous draining of the urine, all contribute to reduce NH_3 emissions. No difference is reported on ammonia emissions between using tubes and gutters

A study carried out in France, showed that the system with fully-slatted floor and flush gutters or flush tubes allows to reduce the ammonia emissions, compared to the reference system, only at the beginning of fattening period. The levels of emissions are equivalent or even higher at the second half of the fattening period (in finishing)[261 , France, 2010]

It is also reported that the largest reduction in emissions is achieved where the slurry is discharged from the gutters prior to flushing, resulting in a decrease in NH_3 emissions of about 70 % less than those from a fully-slatted system with deep pit. [439, Sommer et al. 2006].

Aerosols may also be reduced by frequent flushing.

Cross-media effects

The energy requirements for these systems show large variations especially in combination with the aeration of the slurry. Energy consumption depends on the distance of the building from the treated slurry store.

Odour peaks due to flushing may cause a nuisance when there are residential areas near the farm. The peaks are higher if flushing is done without aerated slurry. It is reported from France that when using slurry for flushing which underwent only a simple separation, sanitary risks from the flushing liquid exist in an integrated farm (e.g. young pigs and sows cannot be flushed with liquid coming from fattening pigs).

Slurry aeration, as a technique for treating manure is associated with potential negative effects (see Section 4.12.3.1).

Operational data

The mechanically separated liquid fraction of the slurry that is used to flush the channels has a low dry matter content; it may be aerated before being used for flushing. (see Section 4.12.2)

Performance levels for the reduction of ammonia emissions, associated with the systems based on frequent slurry removal by flushing, are presented in Table 4.86.

Table 4.86: Ammonia emission reductions from housing techniques with frequent slurry removal by flushing (compared with a fully-slatted floor system with deep pit)

Animal category	Variant	Floor	NH_3 emission reduction	
			Non-aerated slurry (%)	Aerated slurry (%)
Gestating~~s~~ sows	Gutters/tubes	PSF	60	70
	Permanent slurry layer	FSF	30	55
	Permanent slurry layer	PSF	50	60
Farrowing sows	Gutters/tubes	PSF/FSF	62	62
Weaners	Gutters/tubes	FSF	40	50
Fatteners	Gutters/tubes	FSF	40	55
	Gutters/tubes	PSF concrete slats	60	70
	Gutters/tubes	PSF metal slats	67	
	Permanent slurry layer	FSF	30	50
	Permanent slurry layer	PSF	50	60

N.B.: Comparison with a system with FSF and deep pit.
Source: Elboration based on data from IRPP BREF 2003.

The quality of the flushing liquid influences the efficiency of the system, meaning that ammonia volatilisation is facilitated by the transfer of urea during the flushing. [261, France 2010]

The depth of the gutters should not exceed 4 cm, in order to limit the accumulation of solid residues in the bottom. The frequent flushing prevents the dehydration of slurry in the bottom of gutters, which would affect the cleaning of the pit bottom and cause the appearance of flies in the house, particularly in the hot season. [261, France 2010]

Energy consumption levels for operating the flushing systems, separating the slurry and for aeration are reported in Table 4.87, for different categories of pigs.

Table 4.87 Energy requirements for flushing systems with fast and frequent recirculation of slurry fractions

Type of animal	Flooring	Type of slurry	Energy requirement by operation (kWh/ap/yr)		
			Flushing	Liquid separation	Aeration
Gestating sows	FSF		3.9 – 8.2	14.6	13.9 – 17.5
	PSF		2.4 – 3.4	12.0 – 18.3	15.6 – 16.8
Farrowing sows	FSF/PSF		8.5		
Weaned piglets	FSF	Non-aerated	1.9		
		Aerated	3.1		
Fattening pigs	FSF	Non-aerated	18.5		
		Aerated	21.7 – 32.4		40.3
	PSF	Non-aerated	14.4		
		Aerated	22.8 – 30.0		38.5

NB: An extra energy consumption of 0.5 kWh per sow place is required for extra pumping when flushing is done twice a day.
Source: IRPP BREF 2003

With this system, the ventilation can be made only by over-floor extraction. [261, France, 2010]

The frequent flushing prevents the bottoms from dehydrating that would in turn affect the cleaning of the pit bottom and cause the infestation of flies, particularly in the hot season. [261, France 2010]

Applicability
Construction adaptations are only minor if the housing system is already equipped with a manure channel with a sloped floor. In case the existing house consists of a fully-slatted floor with deep pit, major construction adaptations are required.

The implementation in existing houses may be possible but not affordable for gutters, not practicable for tubes and possible with little construction adaptations for the channels with a permanent layer of slurry.

The use of aerated slurry for flushing is possible only for farms already equipped for this type of slurry treatment. It is reported that in Belgium-Flanders, the possibility of using the effluent from on-farm biological treatment of the liquid fraction of separated pig slurry is being explored.

An optimal solution for these systems is the combination with a biogas installation. The fermented slurry from the biogas installation is odourless and free of solid components and, therefore, optimal to be used as a flushing liquid.

Economic constraints and increased management demand limit substantially the widespread use of these systems.

Economics
Most Italian farms equipped with these systems are also fitted with natural ventilation that makes the investments and the global economy of the farm interesting. In comparison to houses with deep pits, these systems are also advantageous for the reduced building needs of digging the shallow pits that are required. As a consequence of these preconditions, the investment costs that were calculated in the past sometimes gave negative results, meaning that economic benefits resulted.

At present, only enlargements of farms with these systems already in place are known to be implemented. No updated economic values have been provided.

In the case of existing houses, the costs for modification of the ventilation system should be considered when the buildings are equipped with under-floor extraction. [261, France 2010].

The cost of an additional external slurry store should also be taken into account.

Driving force for implementation
The indoor air quality significantly improves and the animal health improves as a consequence. This results in less diseases and less use of antibiotics.

Example plants
Some farms in Italy, are still equipped with these systems. Several fams in the Netherlands (350 farms in 2007 and 84 in the Province of Noord-Brabant alone in 2012) are equipped with the gutters systems and operate with non-aerated slurry. In France, the system is little developed and is only applied for fattening pigs.

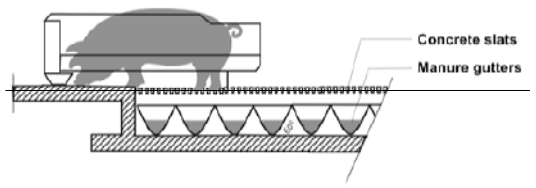
Reference literature
[292, Italy 2001] [42, Netherlands 1999] [391, Italy 1999] [412, Italy 2001] [261, France 2010].

THIS TECHNIQUE IS NOW GROUPED IN NEW SECTION 4.7.1.10

~~4.7.1.10 FSF and PSF with flush gutters or flush tubes~~

~~**Description**~~
~~Small plastic or metal gutters are placed over the surface of the manure channels under a fully-slatted or partly-slatted floors. Urine continuously drains due to a slight fall (decline slope) in these gutters. Slurry is removed once or twice a day by flushing with the liquid fraction of slurry manure (see Figure 4.31). Urine drains continuously into a drain towards the slurry storage.~~

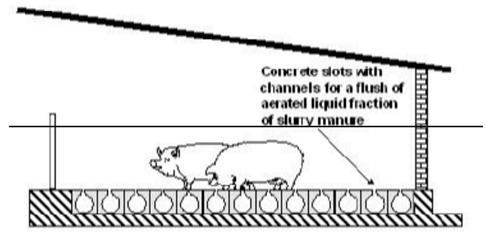
~~The slats are made of concrete. The gutter sides should have a slope of 60 degrees. The gutters should be flushed twice a day. The flushing will be done by the fresh or aerated liquid fraction of the manure (after separation) and the dry matter content should not be higher than 5 %.~~



~~*Source:* [42, Netherlands 1999]~~
~~Figure 4.31: Partly- slatted floor with flushing gutters in individual housing~~

~~An alternative system consists of pens with fully-slatted floors with PVC tubes incorporated into the concrete under each slat, (see Figure 4.32). A slope allows the urine to drain continuously. Once a day or~~

even more frequently, a recirculation of separated and aerated slurry is made in order to remove the manure and clean the tubes.



Source: [391, Italy 1999]

Figure 4.32: Fully-slatted floor with flushing tubes

An alternative can be the construction of low walls in the blockwork making it possible to organise the bottom of the pit in channels. This installation is possible if pits have a sufficient height under the floor to apply a slope of 0.5 % allowing for the draining of the slurry. [261, France 2010]

The application of these systems is possible in individual stalls and in group-housing systems, in which case. For group housing the same description applies as that given in Section 4.6.1.3. The pictures are only different in the sense that the concrete floor surface is larger and the slatted part with the slurry gutters/tubes underneath it is smaller. The manure surface should not be larger than 1.10 m^2 per sow.

Application is possible in farrowing sow crates pens with a partly- or fully-slatted floor, in which case. The manure is removed frequently by a flushing system. the slats are made of triangular iron metal slats are used. The gutter sides should have a slope of 60 degrees. The gutters should be flushed twice a day. The flushing will be done by the liquid fraction of the manure (after separation), where the dry matter content should not be higher than 5 %.

Achieved environmental benefits

Reduction of the slurry surface, frequent removal of the slurry and continuous draining of the urine all help to reduce NH_3 emissions. Less water is needed to clean the fully-slatted floor compared to the partly-slatted or the solid concrete floors. [261, France 2010]

Cross-media effects

The energy requirements for these systems show unexpectedly large variations. Energy consumption levels are reported in Table 4.55.

Table 4.55: Energy requirements (kW/h) for flushing systems in each category of reared pigs

Operation	Gestating sows		Farrowing sows FSF/PSF	Weaning pigs		Fattening pigs			
				FSF		FSF		PSF	
	FSF	PSF		Non-aerated	Aerated	Non-aerated	Aerated	Non-aerated	Aerated
Flushing	3.9	2.4	8.5	1.9	3.1	18.5	32.4	14.4	30.0
Liquid separation	14.6	12.0							
Aeration	13.9	15.6							
Source: IRPP BREF 2003									

These levels vary slightly from those reported in Figure. The pumping energy varies with the distance to the flushing liquid storage. An extra energy consumption of 0.5 kWh per sow place is required for extra pumping when flushing twice a day. Also, in the case of sow manure, it was commented that the flushing fluid could be run back to a receiving tank by gravity. Settling of the low dry matter in the sow manure (5 %) would allow pumping of the clean fluid from the top of the tank and would therefore not require mechanical separation. After some time, a layer will have settled on the bottom of the tank and this may have to be pumped out for further handling.

Where artificial ventilation is not applied in this system, e.g. in Italy, the total energy used is less than with the fully-slatted floor with artificial ventilation. In France, about 80 % of the gestating sows and more than 90 % of the farrowing sows are reared in systems equipped with dynamic ventilation. Hence, the implementation of this system will generate extra costs related to energy consumption.

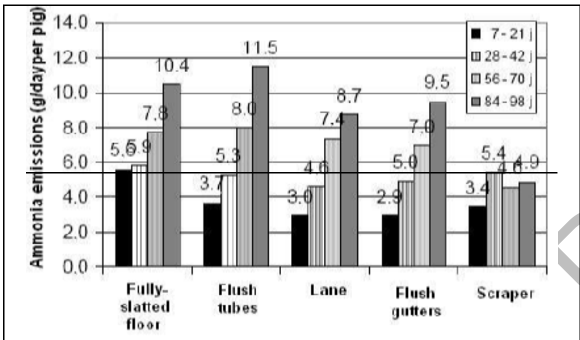
Aerosols may also be reduced by the frequent flushing.

Odour peaks due to flushing may cause a nuisance when receptors are living near the farm. The peaks are higher if flushing is done without aeration rather than if it is done with aeration. On a case by case basis it has to be decided whether an overall load (thus applying a non-flushing system) or peak values are more important. [291, IRPP TWG 2002]

The quality of the flushing liquid influences the efficiency of the system, meaning that ammonia volatilisation is facilitated by the transfer of urea during the flushing. [261, France 2010]

Operational data

Ammonia emissions only are available. The performances of this system are best at the beginning of the fattening cycle, whereas at the end of cycle, emission levels are at least the same as in fully-slatted floors, as can be seen in Figure 4.33.



Source: [261, France 2010]

Figure 4.33: Evolution of ammonia emission during the fattening cycle in relation with the type of systems

Gestating sow houses with fully-slatted floor will reduce emissions by 40 % when flushing with fresh slurry, and 55 % when flushing with aerated slurry. No difference is reported between using tubes and gutters.

From gestating sows on partly-slatted floor, the emissions is reduced in individual housing on concrete slats to 2.50 kg NH_3 per sow place per year due to from a reduced manure surface and a from flushing in gutters or tubes (NL, B).

The effect of using fresh non-aerated slurry or aerated slurry is clearly visible in Figure that reports emissions arising from these systems in the various pig categories. When emissions were not available, reductions were displayed as a result of the comparison with FSF with deep pit.

Table 4.56: Ammonia emissions (kg NH_3/animal place per year) from flush gutters and flush tubes by pig category and variant of used system.

Animal category	Floor	Type of slurry	NH_3 emission	NH_3 reduction
Gestating sow, individual rearing	FSF	Non-aerated		40 %
	FSF	Aerated		55 %
Gestating sow groups, grouped rearing	PSF	Non-aerated	1.48	
	PSF	Aerated	1.11	
Farrowing sows	PSF/FSF		3.3	
Weaners	FSF	Non-aerated	0.36	
	FSF	Aerated	0.30	
Fatteners	FSF	Non-aerated		40 %
	FSF	Aerated		55 %
	PSF concrete slats	Aerated	0.90	
	PSF concrete slats	Non-aerated	1.20	
	PSF metal slats	Non-aerated	1.00	
Source: IRPP BREF 2003 Type of data = *.				

The depth of the gutters is intended not to exceed 4 cm to limit the accumulation of solid dejections in the bottom. The dehydration of slurry in the bottom of the gutters affects the cleaning of the pit bottom and causes the infestation of flies, particularly in the hot season. [261, France 2010]

Applicability

In Italy, gutters and tubes are applied for gestating sows and an increasing number of farms are adopting the tube system for finishers.

Only a few alterations are needed to implement this system in a manure pit with a sufficient depth. The liquid fraction after slurry separation is used for aeration, hence a separator is necessary before pumping the liquid back for flushing. Application of this system needs an installation (tank) to separate the liquid fraction from the slurry before it can be used or further treated, in the case of aeration, and then pumped back for flushing.

Economics

Gestating sows FSF. Application in new housing ranges from an extra cost of EUR 0.56 per sow place per year (gutters) to a negative extra costs of (i.e. a benefit) EUR 5.54 per sow place per year (tubes). In flushing without aeration, the negative extra costs (i.e. benefits) are EUR 2.44 – 8.54 per sow place per year. The annual extra operational costs show a benefit of EUR 1.22 – 4.27 per sow place without aeration, and with aeration this ranges from an extra cost of EUR 0.28 to a benefit of EUR 2.77 [184, TWG ILF, 2002]. Costs are slightly higher than for the flush canal system, given the lower benefit data. Gutters with aeration have a net cost compared with the canal system.

Gestating sows PSF. The implementation costs of the system for individual housing, as reported by the Netherlands, are significant. With a remaining ammonia emission of 2.5 kg NH_3 per sow place per year the extra investment costs (for the system with aeration) are EUR 161.80 per sow place. This is equal to EUR 95.20 per kg NH_3 abated. The extra costs per year are EUR 57.40 per pig place. This means EUR 34.05 per kg NH_3. For the system without aeration the extra investment costs are EUR 59 per sow place, and extra annual costs of EUR 9.45 per sow place. Italy reported much lower cost figures, although these were related to growers and finishers, for the group housing system which is of course cheaper per pig place. These cost figures are in the same range as reported in Section 4.6.1.3 for the fully slatted floor system. [185, Italy, 2001]

Farrowing sows. The extra investment costs are EUR 535 per sow place. This means with a 60 % reduction, i.e. 8.3 to 3.3 kg NH_3, costs are EUR 107 per kg NH_3 abated. The extra operational costs per year are EUR 86.00 per pig place. This means EUR 17.20 per kg NH_3.

Weaners. For the system without aeration, the extra investment costs are EUR 25 per pig place and the extra annual operational costs are EUR 4.15 per pig place. The system with aeration is considered to be very expensive [184, TWG ILF, 2002].

Investment costs that have been calculated sometime give negative results, that is to say that economical benefits may result, and a summary is given in Table. Costs are slightly higher than for the flush canal system (Section 0), given the lower benefit data. Gutters with aeration have a net cost compared with the canal system.

Additional running costs would include the additional working time related to the operations and the cost of the additional external slurry storage. [261, France 2010]

Table 4.57: Extra costs (referring to FSF and deep pit) for flush gutters and flush tube variations by pig production category

Animal	Floor type	Investment costs in EUR	Operational costs in EUR	Cost per abated NH_3 kg in EUR
Gestating sows and fattening pigs gutter/tubes NOT Aerated	FSF	-8.54 – -2.44	-4.27 – -1.22	
Gestating sows and fattening pigs gutter/tubes AERATED	FSF	-5.54 – 0.56	-2.77 – 0.28	
Gestating sows and fattening pigs gutter/tubes NOT Aerated	PSF	59	9.45	
Gestating sows and fattening pigs gutter/tubes AERATED	PSF	161.8	57.4	95.2 (investment)([1]) 34.05 (operation)
Farrowing sows	FSF	535	86	107 (investment)([1]) 17.20

				(operation)
Weaned piglets NOT Aerated	PSF	25	4.15	
([1]) For a remaining emission of 2.5 kg/ap per year. *Source*: IRPP BREF 2003.				

Driving force for implementation
To reduce indoor odours and gases for improved quality of air.

Example plants
In Italy, about 5000 sows (Bertacchini farm, where a variant on the PSF is also found) are kept on an FSF with gutters and 7000 sows on an FSF with tubes. Examples are found in Italy, e.g. Bertacchini farm. In the Netherlands 2000 pig places are equipped with this system under partly-slatted floor.

In the Netherlands, about 500 farrowing sow places are equipped with this system.

Reference literature
[292, Italy 2001] [42, Netherlands 1999] [391, Italy 1999] [412, Italy 2001] [37, Bodemkundige Dienst, 1999] [261, France 2010].

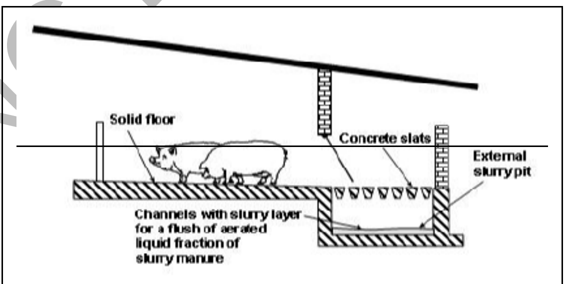
THIS TECHNIQUE IS NOW GROUPED IN NEW SECTION 4.7.1.10

4.7.1.11 FSF or PSF with flushing of a permanent slurry layer in channels underneath

Description
A fully-slatted floor with Canals Channels underneath the slatted floor are filled with a 10 cm layer of slurry manure. The canals channels are flushed with the fresh or aerated liquid fraction of slurry at least once a day (see Figure 4.34). The aerated liquid contains 5 % of dry matter. The channels canals have a slight inclination to enhance the removal of the slurry and the flushing liquid is pumped from one side of the unit or house to the other side, where it is collected in a channel to be removed to an external slurry storage.

Please TWG provide a description on the slurry aeration system
This technique is known in place for mating and gestating sows and for growing and finishing pigs.

A variation of this system is in use in Italy with an external alley as it is described in Section 4.7.1.7 (see Figure 4.34). The same considerations on the ratio of solid to slatted floors and on performances can be drawn.



Source: [292, Italy 2001]

Figure 4.34 Partly-slatted floor and external alley with the flushing of a permanent slurry layer in channels canals underneath

Achieved environmental benefits
The effect of emissions reduction is due to the combined effect of the reduced manure surface and of the slurry removal by flushing and by the manure aeration, if used.

Cross-media effects
The total energy consumption is less than or equal to the reference system because Artificial ventilation is not required. The energy required for operating this system depends on the distance from the pit to the treated slurry storage. Average flushing needs extra energy, which is estimated to be as reported in Table 4.58.

Table 4.58: Energy requirements for operations with flushing in permanent slurry channels (kWh per animal place per year)

Operation	Mating and gestating sows		Growing and fattening pigs	
	FSF	PSF	FSF	PSF
Flushing	8.2	3.4	21.7	22.8
Liquid separation	14.6	18.3		
Aeration	17.5	16.8	40.3	38.5
Source: [292, Italy 2001]				

Aerosols may also be reduced by the frequent flushing.

Odour peaks due to flushing may cause a nuisance if there are residential areas when receptors are living near the farm. The peaks are higher if flushing is done without aeration rather than if it is done with aeration. On a case-by-case basis it has to be decided whether an overall load (thus applying a non-flushing system) or peak values are more important. [291, IRPP TWG 2002]

Operational data
Ammonia emissions only are available. The effects of this technique on ammonia emissions are summarised in Table 4.59..

Table 4.59: Ammonia emissions and reductions in systems with flushing of a permanent slurry layer in channels underneath

Animal category	Flooring	Slurry treatment	NH_3 reduction([1])	NH_3 emission([2])
Gestating sows	FSF	Non-aerated Aerated	30 % 55 %	
	PSF	Non-aerated Aerated		1.85 1.48
Fattening pigs	FSF	Non-aerated Aerated	30 % 50 %	
	PSF	Non-aerated Aerated	50 % 60 %	

([1]) Comparison with an FSF with deep pit.
([2]) kg of NH_3 per animal place per year
Source: IRPP BREF 2003.

No artificial ventilation is applied in these houses, on the assumption that sufficient ventilation is achieved from natural ventilation and from the frequent flushing of the slurry.
Applicability
Application of this system needs an installation to separate the liquid fraction from the slurry before, in the case of aeration, it can be treated and pumped back for flushing. Where the liquid fraction of the slurry is used for flushing, a system is needed to separate the liquid from the solid fractions and to air-treat it and pump it back for flushing.

The design (e.g. depth) of the existing manure pit may allow for application in existing houses. Examples exist of applications on existing solid concrete floors, where gutters can be placed on the existing floor, but sufficient height must be available.

Economics
The Its application of the fully-slatted version of this system in new housing has a negative extra cost (i.e. a benefit) of EUR 4.82 per sow place per year. In flushing without aeration, the negative extra costs (i.e. benefits) are EUR 12.16 per sow place per year. In existing houses, costs are variable and depend on the design of the existing building, see the introduction to Section 4.6.1.

In relation to the partly slatted version, there are no data on capital costs, but operational costs are estimated as a negative extra cost (i.e. a benefit) of EUR 6.07 per animal place when no aeration is applied, or EUR 2.89 (also a benefit) when aeration is applied and when applied to new housing. [291, IRPP TWG 2002]

Driving force for implementation

~~Existing building reconversions only require little construction adaptations.~~

~~**Example plants**~~
~~This system is increasingly applied in housing for gestating sows (and finishers), e.g. Borgo del Sole farm, Parma.~~
~~An increasing number of farmers adopted are adopting this technique in new buildings for gestating sows in individual stalls (and for growers/finishers).~~

~~**Reference literature**~~
~~[292, Italy 2001]~~.

4.7.1.11 Kennel or hut housing on partly-slatted floors

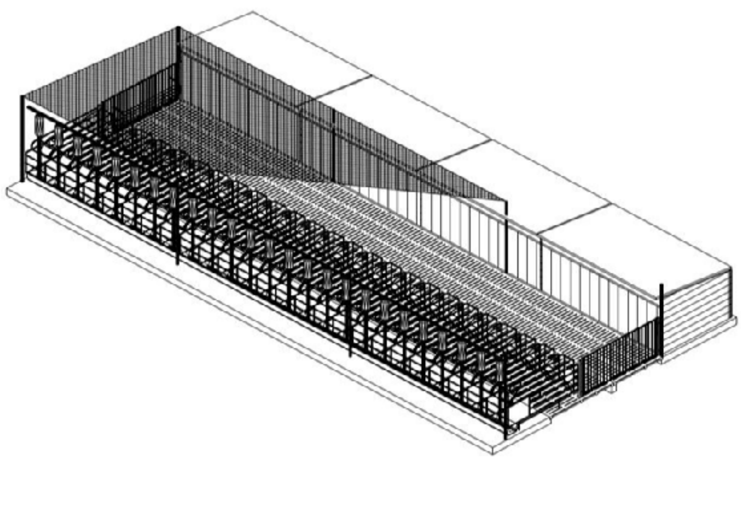
Description
The building is open, non-insulated (only the ceiling can be insulated) with free (natural) ventilation system and separate ~~Different~~ functional areas ~~having different types of flooring are~~ organised in the pen. The lying area consists of a levelled insulated concrete floor with covered, ~~is made of~~ insulated boxes (huts or kennels) ~~solid concrete and can be enriched~~. The ~~walking/~~activity and feeding ~~eating~~ area lie on a perforated or slatted floor. ~~Under the slatted floors, dung is managed both as solid manure and, preferably for piglets, slurry~~. The system is equipped with automated feeding and drinkers. Fattening pigs are kept in large groups of up to 60 animals per pen, weaned piglets up to 100, and gestating/mating sows in groups of at least 40 animals.

Slurry removal for sows and weaners is reported to be frequent (vacuum system); whereas, for fattening pigs slurry is reported to be removed at the end of the cycle (overflow channel).

Kennel for weaners can be heated with warm water piping.

Sow feeders are in individual stalls on full or partially perforated flooring.

A variant of the technique reported for sows and weaned piglets ~~this system is~~ has ~~with~~ freestanding temperature-insulated lying huts with an activity and feeding area on the solid ~~concrete~~ floor, which can be littered with a small amount of straw for enrichment; therefore, solid manure is produced (see Figure 4.44 and Figure 4.45). For weaned piglets, it is reported that an amount of 80 g of straw per animal place and day could be added.



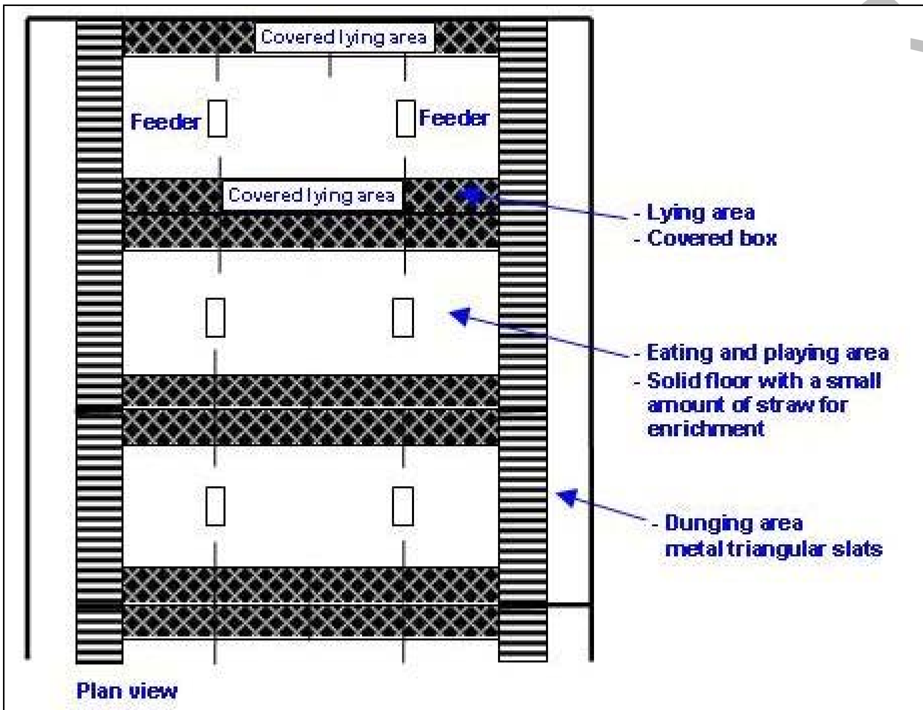
Source: [155, Germany 2010]

Figure 4.44: Kennel housing for mating and gestating sow (version with separate huts)

Along the width of the pen, covered kennels are placed side by side, ~~that are built~~ over level concrete, whilst the defecating ~~dunging~~ areas are situated on the short sides of the pen. The solid floor covers about 50 – 60 % of the total space.

~~Emitting surfaces of the metal triangular slats are around 0.09 m^2, 0.14 m^2 and 0.29 m^2 per each weaner, grower (up to 50 kg) and fattening pig.~~

Due to the sheltering effect of covered lying boxes, the room temperature can be lower than ~~as~~ normal. Kennels are kept warm by the animals in winter and do not require heating. So, the system is well applicable in naturally ventilated houses. ~~, where straw can bed the solid floor areas, typically with 80 grams per weaning pig place per day.~~ **Moved above**



Source: [547, IMAG-DLO 2001] ~~[187, IMAG-DLO, 2001]~~

Figure 4.45: Kennel housing system for weaners

Achieved environmental benefits

The working principle is that ammonia reduction is pursued by means of ~~compared to the reference is brought about due to the~~ a small emitting manure pit. ~~Providing some~~ The straw on the solid concrete floor is used to ~~in the middle will~~ prevent the floor from getting dirty and, therefore, reduce air emissions. ~~and to further reduce emissions.~~ Emissions are also reduced due to the lower room temperature achieved in the naturally-ventilated house and the separation of functional areas.

From Germany a reduction of 25 % of ammonia emissions is reported [155, Germany 2010] [183, Germany 2010] for weaners and sows; while, from the Netherlands, a reduction of 36 % is reported, compared to the fully-slatted floor system [547, IMAG-DLO 2001]. For fattening pigs, it is reported that the potential for ammonia emissions is approximately 35 % lower in naturally-ventilated houses than in closed forced-ventilated houses with fully-slatted floors. [575 , UBA , 2012]

This system has a low energy demand ~~input~~ due to the low room temperature. Quite low energy demands have been reported for growing pigs (see Table 4.88).

The high air exchange rates during most of the time provide low indoor contamination.

Cross-media effects

Water consumption always slightly increases after reducing the slatted-floored area, due to the cleaning needs of the solid floor. The control of housing climate of this system (temperature, air flowrate, etc.) is difficult to manage, and an overall increased resources for operation is are required [261, France 2010]. Increased labour requirements for operations, such as cleaning of the concrete floor area in the lying kennel, are necessary. It is also reported that the system may cause a deterioration of the farmer's working conditions.

Operational data

In Table 4.88, displays the achievable emission levels are reported for three animal categories; while, in Table 4.89 other characteristics data concerning energy consumption and labour requirements are presented.

Table 4.88: Emissions levels associated with the use of kennel or hut housing systems, reported from Germany

Animal category	Emissions				
	NH_3	CH_4	N_2O	PM_{10}	Odour (1)
	kg/ap/yr	kg/ap/yr	kg/ap/yr	kg/ap/yr	ou_E/s/ap
Gestating sows	3.75 (2)			0.16 (2)	8 (2)
Weaners	0.38 (2) (0.2 – 0.7) (3)			0.08 (2)	2.25 (2)
Fatteners	2.4 (2) (1-6) (3)	1 – 4 (3)	0.11 – 0.15 (3)	0.24 (2)	7 (2)

(1) Values have been calculated from odour emission factors and average weights for each animal category as follows:
Sows (with piglets up to 10 kg), 200 kg and 20 ou_{Ee}/s per LU
Weaners (up to 25 kg), 15 kg and 75 ou_E/s per LU
Fatteners (from 25 to 115 kg), 70 kg and 50 ou_E/s per LU.
(2) Values derived by expert judgement based on conclusions by analogy.
(3) Measured data.
Source: [155, Germany 2010] [183, Germany 2010] [190, Germany 2010]

Table 4.89: Consumptions and labour requitrements for kennel housing systems

Animal categories	Bedding	Electric power	Fuel	Cleaning Water	Labour
	kg/ap/yr	kWh/ap/yr	kWh/ap/yr	l//ap/yr	h/ap/yr
Gestating sows	140 (1)	16	0	250	1
Weaners	26 (1)	2 – 3 (2)	80	150	1.37
Fatteners	0	2.5	0	75	1

(1) When the hut housing system is used.
(2) This value can be achieved when a kennel of 20 piglet , from 3 – 5 weeks of age, is fitted with automatically controlled natural ventilation and when 1 kW heating is provided by under-floor heating elements. [356, Carbon Trust 2005]
Source: [155, Germany 2010] [183, Germany 2010] [190, Germany 2010]

The reported available space per animal, applied in Germany, is 2.9 m^2/sow, 0.41 m^2/weaned piglet and 1.1 m^2/fattening pig.

Under extreme climate conditions, the reliability of the ventilation system in weaner houses must be assured.

Gestating sows are held in groups of at least 40 animals, hence automatic feeders can be installed to allow for individual feeding. With the use of phytase and a mucking out frequency of 2 – 8 weeks, it is estimated that odour emission of 20 ou_E per LU (livestock unit = 500 kg of animal live weight) per second will ~~to~~ arise from the ~~waiting~~ gestating/mating houses. Reported emission levels are displayed in Table 4.88.

Applicability
The technique is applied for fattening pigs, weaners, mating and gestating sows; it is not applied for farrowing sows. The option of natural ventilation is only suitable for new buildings. [575 , UBA , 2012]

~~No limitations for applying the technique in both new or existing sow houses were reported, except in the case of weaners buiding where retrofitting seems not possible~~.
The benefits of a natural ventilation are achieved when ~~Good stall climates are achieved by having~~ the building orientation is at a ~~be at right~~ proper angle to the main wind direction and the ~~stall alingment~~ crates are aligned along the longitudinal axis of the animal house.

In France, this technique is considered as an outdoor system for the implementation of Commission Regulation 2075/2005/EC on trichinellosis and leptospirosis.

Economics
Pig fattening in naturally-ventilated houses requires greater investments and, therefore, this causes higher fixed expenses compared with forced-ventilated fully-slatted floor houses [575 UBA]. Additionally, the system requires more surface area per animal. The reported ~~the relatively large space requirements,~~ investments needed per newly built pig place are ~~around~~ EUR 249 for weaners (1 m^2 per animal ~~head~~) and EUR 470 per fatteners (1.1 m^2 per animal). In addition, more labour is needed, e.g. for the cleaning of the lying kennels. The additional expenses caused by these factors, however, are compensated for by energy cost savings in the unheated naturally-ventilated house. The corresponding total annualised costs are EUR 28 and EUR 51 per animal place per year for weaners and fattening pigs, respectively.

It is reported from Germany that the total additional costs of the technique in fattening pigs housings, in comparison with a closed, forced-ventilated fully-slatted floor house are EUR 11 per animal place per year, which is equivalent to EUR 9.18 per kg of NH_3 removed, in comparison with forced-ventilated fully-slatted floor houses.

Driving force for implementation
The main motivation for the construction of a naturally-ventilated house is generally the animal-friendly housing and the securing of a good health status. In addition, ~~The~~ animal welfare is enhanced ~~by the open climate and the structure of the pens with functional areas. The system suits the animal needs due~~ by a greater freedom of motion. ~~and allowing for a stimulating climate.~~

Exemple plants
The technique is available and is very frequently used in southern Germany. ~~but not very frequently put in place.~~

Reference literature
[547, IMAG-DLO 2001] [155, Germany 2010] [183, Germany 2010] [190, Germany 2010] [575, UBA 2011].

This technique is now in Section 4.7.2, dedicated to mating and gestating sows
~~4.7.1.13 Solid concrete floor and full litter for mating/gestating sows~~

~~Description~~
~~Groups of sows are kept in pens on a fully concrete floor that is almost completely covered with a layer of straw or other lignocellulosic materials that to absorb urine and incorporate faeces (see **Error! Reference source not found.**). Solid manure is obtained, which has to be frequently removed in order to avoid prevent the litter from becoming too moist.~~

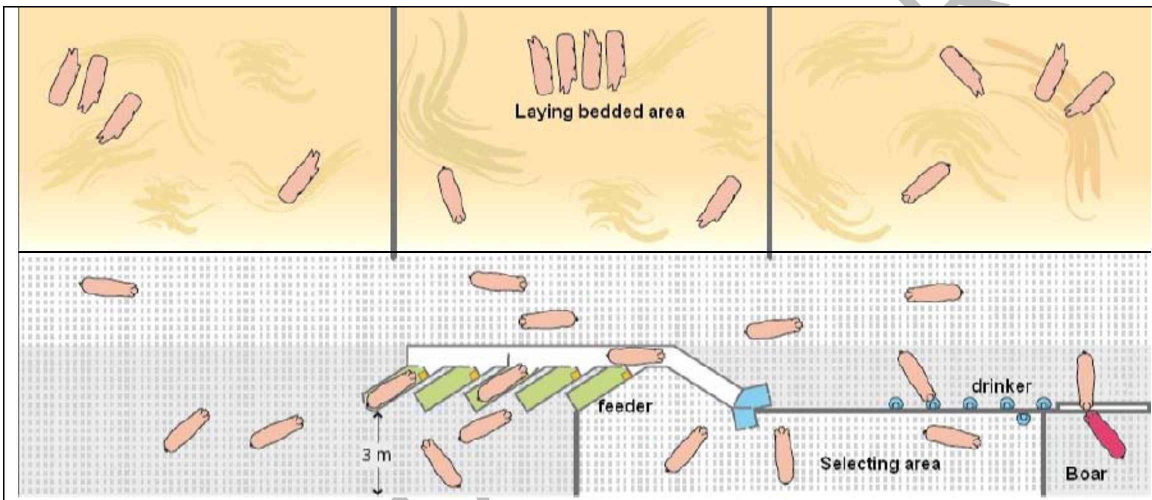
Two main litter management systems exist:

- scraped litter: the manure is frequently evacuated (1 – 3 times per week) and straw is replaced for the same amount;
- accumulated litter: the manure (straw or sawdust) is removed after the removal of the pigs, or after several successive production cycles. [261, France 2010]

Buildings can be naturally ventilated and in these cases one side is fitted with open boards. Separate functional areas can also be organised, with deep littered walking areas, raised and levelled concrete eating areas and lockable insemination stalls. [161, Germany 2010]

Pens can be organised with the installation of the electronic sow feeders (ESF, see Figure 4.46). In this case, the units consist of a bedding area, a central manure area and a feeding area with ESFs electronic sow feeders. The defecating dunging area consists of a concrete solid floor. A tractor-mounted scraper is used to daily remove the manure from the solid floor area daily. The litter in the deep straw littered lying area is removed only 1 – 2 times per year.

In open, non-insulated buildings, separate functional areas can be organised, complete with an external yard. The living (walking and lying) area is on an insulated solid concrete floor (1.4 m^2 per head), the feeding area can be on a slatted raised floor and the external yard is on a straw bedded concrete level (1 m^2 per head). [157, Germany 2010]



Source: [262, France 2010, Ramonet (2009) Loger les truies en groupes au DAC]

Figure 4.46: Solid concrete floor system with straw and electronic sow feeders

Achieved environmental benefits
Energy savings are permitted by the improved climate. Litter and manure management are mechanised. Animals benefit from the group association life, the improved climate and the large motion area.

Ammonia emissions are lowered by reducing the emitting manure surface by steering the defecating behaviour of the sows and by altering the manure composition. This is achieved through a specific housing design aimed at encouraging the natural behaviour of the sows and application of specific 'manure and straw management' technique. [186, BE Flanders 2010]

Cross-media effects
Bedding material requirements have been reported at 300 to 400 kg per animal place per year up to 640 kg of straw. Other requirements to keep the housing running are 15 kWh of energy and 220 litres of water per animal place. The energy use is very low, because this system does not require need a heating system since it and is normally equipped with a natural ventilation system.
The emission of nitrous oxide is negligible. The emission of methane is 39 grams per day per sow., but further research is needed to establish how this compares to the reference system.

Operational data
No limitations on group size are reported. once a week, new bedding is added. Litter and manure removal is done by tractor. The litter in the living area and in the yard are removed twice a year. Where a shallow pit exists, the dung is removed daily.

Controlled ventilation is dimensioned for a maximum output of 100 m^3 per hour per sow place. Although the sows are capable of compensating for low temperatures by hiding in the deep litter mat, auxiliary heating is applied in colder parts of Europe to reduce humidity during reduced ventilation.
The benefit of applying this system depends on the animal behaviour, which is influenced by the pen design. The available lying area per sow is at least 1.3 m^2 per sow and must be easily accessible, especially for young gilts, by making the passages between the lying and dunging areas wide (min. 2 metres, max. 4 metres). The distance from the entrance of the lying area to the farthest (separation) wall should be no longer than 16 metres. The emitting dunging area should be no higher than 1.1 m^2 per sow. The manure pit under the slatted floor is provided with a vacuum system.
Ammonia emissions on straw-based deep litter vary between 2.5 and 5.6 kg per sow per year, as reported in Table 4.90.

Table 4.90: Reported emissions for mating and gestating sows housed in deep littered systems.

All with ESF	NH_3 emissions kg/ap per year	PM_{10} kg per animal place per year	Odour OU_E/s
With ESF	2.5–5.6 D (2) 2.6 * (1) 2.6 E (3) 3.7 * (1)		
With or without yard	5.0 A (4) 5.2 * (1)	0.8	20

Source:
(1) IRPP BREF 2003.
(2) [261, France 2010].
(3) [186, BE Flanders 2010].
(4) [161, Germany 2010]

The effect of straw on the manure is controversial: on the one hand, it can increase methane emissions due to a high dry matter content. On the other hand, it can limit CH_4 production through an aeration effect of the manure. Raised dust levels can be expected. The existence of aerobic and anaerobic zones in the litter leads to nitrogen protoxide emissions from sows in the range of 0.03 – 10 g/day. High NO and N_2O emissions are reported for fattening the pigs and in pig production in the references listed below [188, Finland, 2001].

Applicability
This system is very good functions very well when applied to in new houses and to in some of the existing houses. Limitations for applying the technique were reported only for the electronic sow feeders in existing houses, for which the applicability depends on the design of existing manure pits, but it is usually difficult to apply.

Economics
The costs for this system are not higher than the reference FSF system. However, there are no costs calculated for extra labour and these costs are therefore unknown. Extra costs referred to FSF system are shown in **Error! Reference source not found.**. Due to the frequent litter refreshing and tractor dung removal, increased management requirements are needed, that are quantifiable in 1.5 – 2.6 h per animal place per year. [161, Germany 2010]

The production of solid manure instead of slurry manure is considered an advantage from the agronomical point of view. Organic matter incorporated into the fields improves the physical characteristics of the soil; reducing run-off and the leaching of nutrients to water bodies.

Driving force for implementation
According to EU legislation, farms are obliged to keep sows in groups. This system may receive more attention in the future in view of developments in European legislation on animal welfare.

The availability of useful manure might be interesting for farms with arable areas.

Example plants

This system can be found in several Member States. In the Netherlands more than 50 % of new buildings apply this system, and this system is also implemented in retrofit situations. In Belgium-Flanders, 27 farms have received authorisation for having this system. [300, Belgium-Flanders 2010]

Reference literature

[175, IMAG-DLO, 1999] [397, Denmark 2000] [412, Italy 2001] [157, Germany 2010] [161, Germany 2010].

On high NO and N_2O levels:

- Groenstein, Oosthoek, Faasen; 'Microbial processes in deep litter systems for fattening pigs and emissions of ammonia, nitrous oxide and nitric oxide', 1993
- Verstegen, Hartog, Kempen, Metz; 'Nitrogen flow in pig production and environmental consequences', EAAP publication number 69, 1993.

4.7.1.12 Solid concrete floor and with full litter for weaning, growing and fattening pigs with or without external features

THIS SECTION HAS BEEN RE-ARRANGED IN ORDER TO SEPARATE THOSE PARTS THAT APPLY ONLY TO WEANERS. SOME EXISTING TEXT IS NO LONGER AVAILABLE HERE, HAVING BEEN MOVED TO THE MOST RELEVANT SECTIONS

Description

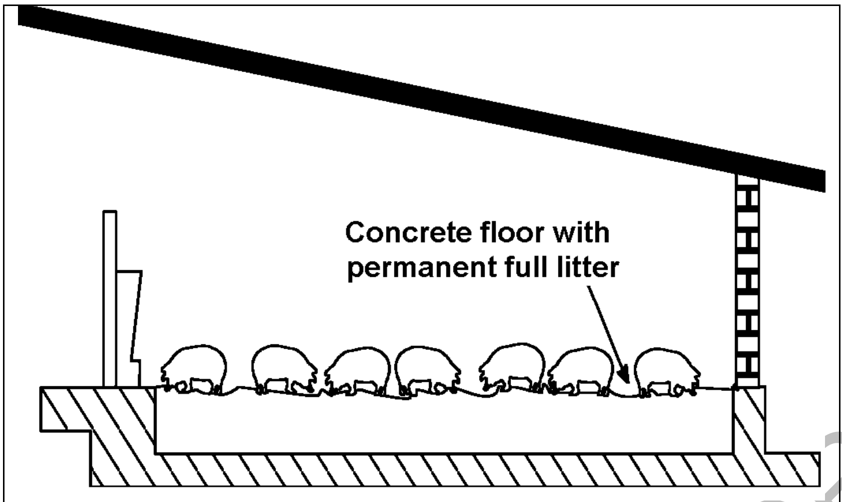
Pigs are kept in one large pen or two smaller ones at both sides of the house, with a central alley in between used for feeding and control. The solid floor is covered by an organic layer usually made of straw or lignocellulose materials (e.g. sawdust). The organic layer absorbs urine, incorporates faeces and provides the animals with the opportunity to express their natural exploratory behaviour. Two basic systems are typically used for solid concrete floor houses: 'deep litter' and 'littered floor' (see Section 2.3.1), depending on the amount of bedding material and the way it is managed, as well as on the manure removal frequency.

Littered-floor systems may be enriched with outdoor yards; this configuration is mandatory in Germany in ecological farming.

In Italy, straw is used in a system that combines indoor solid unbedded floors and a littered external alley. The system is described in Section 4.7.5.1.

In the deep litter system, bedding is spread every week and manure is removed at the end of the fattening period or is also used for more cycles. In the littered-floor system, litter spreading and removal is carried out weekly for the indoor area and twice per week for the yard. Generally, the main objective in the technique is to maintain the bedding dry and clean.

The abundance of bedding provides protection against low temperatures. A schematic representation of a housing system with solid concrete floor with litter is given in Figure 4.47.



Source: [548, TWG ILF 2002] [189, Italy/UK, 2002]

Figure 4.47: Pens with solid concrete straw-bedded floor and natural ventilation

Solid manure (mixed with straw/bedding) is removed as dry manure by front-end loaders after each growing cycle.

Littered-floor or deep litter floor houses for fatteners have has an open front and are mostly is fully naturally ventilated. An exception is reported for deep litter systems, where a thin sawdust layer is used as bedding; in this case closed buildings with forced ventilation are normally used [420, Ramonet 2003].

In the pen with the deep litter system, the feeding area can be placed on a raised level in relation with the defecating or bedded areas.

In both types of littered systems (deep litter and littered-floor), automatic feeding and drinking systems are used. In general, 20 – 40 animals per pen are housed; the space provided per animal for the deep litter configuration is 1.1 m^2 and for the littered-floor with outdoor yard is 1.5 m^2/animal (0.5 m^2 in the yard and 1 m^2 in the house).

Achieved environmental benefits
The system is recommended in particular for animal welfare reasons.

Odour emissions are reduced compared to slurry-based housing systems, if the system is managed according to the best agricultural practices (e.g. supply of enough bedding material).

Energy requirements are reduced because straw, in conjunction with naturally-ventilated housing systems, allows the animals to self-regulate their temperature with less ventilation and heating.

The production of solid manure instead of liquid manure (slurry) is considered an advantage due to organic matter content of the litter. from the agronomical point of view. Organic matter incorporated in the fields improves the physical characteristics of the soils, reducing run-off and the leaching of nutrients to water bodies.

Environmental effects, ammonia emissions included, are debated.

According to some authors [289, MLC 2005] [530, Nicks et al. 2003], NH_3 emissions arising from accumulated litters deep-litter systems and from slatted floors are identical.

Cross-media effects

Increased dust emissions are reported. In general, in the case of poor management of the litter, ammonia, odour and nitrous oxide emissions are expected to be higher than from housing systems based on slurry. The composting process that may take place in the litter is associated with higher NH_3 and N_2O emissions (up to 1.5 – 3 times higher compared to slurry based systems) [261, France 2010].

It is also reported that sawdust deep litter with sawdust produces lower NH_3 and CH_4 emissions than straw-litter, but higher N_2O emissions. [530, Nicks et al. 2003]

Management requirements for the littered-floor system are increased, since regular littering and cleaning of the yard are necessary.

A more difficult control of sanitary risks and bad working conditions are also reported.

Methane emissions are considered to be low, unless anaerobic conditions prevail in the bedding material. Methane emissions are reduced if, in a deep litter system, the litter is used only for one batch. [530, Nicks et al. 2003]

Animal growth performances are is generally affected. The average daily feed intake is reduced by 8 % and, at the same time, the average daily gain is reduced by 3 % and the food conversion ratio rate is reduced by 7 %. Finally, the carcass quality is slightly affected: fat and lean thickness at loin eye depth (positions G2 and M2) are respectively increased by 1.3 mm and reduced by 2.8 mm, respectively [261, France 2010]. However, overall, the growth rate of animals is not significantly affected and the worst performance observed in littered-based farms, in comparison with slurry-based farms, is attributed partly to the specific type of productions (higher age and weight at slaughter) [329, CORPEN, 2003]. Other studies have found no significant differences in the performance and carcass quality of pigs housed in fully-slatted floors and straw-based houses. [289, MLC 2005]

Due to high nitrogen losses during storage and application of solid manures (by ammonia emissions and denitrification), there is a significant lack of fertiliser value compared to a slurry-based housing system; consequently, the use of chemical fertilisers may increase.

A set of factors that are or can be affected by this technique are listed in Table 4.62.
EXISTING TABLE 4.62 (Schematic overview of the environmental and management parameters) HAS BEEN DELETED. ALL VALUABLE INFORMATION HAS BEEN DISTRIBUTED IN THE MOST PROPER SECTIONS

Operational data

It is expected that the use of straw will allow pigs the weaners to control the temperatures themselves in systems where insulated kennels or creeps are not used, thus requiring no additional energy for heating. The system is spacious but needs clear requires cleared concrete areas in summer at feeding places for the pigs to cool down. In regions with hot climates, full litter is normally not applied. If a possible covered lying area is present, the litter quantity needs to be adjusted to the temperature and the cover must be removed at high temperatures.

The amount of straw or other bedding material varies for different animal categories. For deep litter floors, the amounts of applied straw are approximately 1 – 1.2 kg per fattening pig per day, or 275 to 400 kg/animal place per year. For littered-floors, the amount of straw is in the range of 250 – 300 kg/animal place per year (see summary of resources demand in Table 4.92).

Bedding that is topped-up upon necessity (around 1 kg/day) to reach a thickness of up to around 80 cm at the end of the production, is also called ‘accumulated straw’.

Sawdust bedding should be replaced at least every two successive batches, in order to reduce ammonia emissions. [530, Nicks et al. 2003]. The substitution of straw with other types of litter is done for similar amounts of dry matter. [531, Ramonet et al. 2002] [532, Nicks et al. 2002]

Emissions from fattening pig houses have been measured ~~in Germany~~ under various ~~different~~ conditions of bedding material and management of the litter and are summarised in Table 4.91. ~~Higher~~ Emissions due to the external yard ~~are presumed, but~~ have not been estimated. [181, Germany 2010]

Table 4.91: Emission levels from housing systems with littered floors for the rearing of fattening pigs

Type of litter	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	kg/ap/yr				ou_E/s/ap	
Deep litter with straw, natural ventilation	4.2 (1) (1.0 – 6.0) (2)	1.6 – 18.0 (2)	0.6 – 3.7 (2)	0.32 (1)	3.9 (3) (1)	[193, Germany 2010] [474, VDI 2011]
Deep litter with straw, forced ventilation Removal of litter after three consecutive batches, addition according to cleanliness (4)	5.12 (2)	2.78 (2)	0.01 (2)	NA	NA	[530, Nicks et al. 2003]
Deep litter with straw, forced ventilation. Removal of litter after 3 consecutive batches, addition according to cleanliness (4)	4.58(2)	1.87(2)	0.79(2)	NA	NA	[530, Nicks et al. 2003]
Deep litter with straw, removal at the end of cycle	4.56(2)	NA	NA	NA	NA	[375, Philippe et al. 2007]
Littered floor with straw, weekly removal	2.43 (1) (1.0 – 5.0) (2)	0.8 – 2.8 (2)	NA	0.32 (1)	6.9 (6) (1)	[191, Germany 2010] [474, VDI 2011]
Deep litter floor with sawdust or soft wood particles, mechanically ventilated. Removal at the end of cycle (7)	5.65-7.53 (2)	NA	NA	NA	NA	[531, Ramonet et al. 2002]

NA= Not available.
(1) Values derived by expert judgement based on conclusions by analogy.
(2) Measured data.
(3) Value calculated from an emission of 30 ou_E/s/LU and an average weight for fattening pigs of 65 kg.
(4) Calculations were made from measured data reported in g/head per day, for a 120 days rearing and 3.14 cycles a year.
(5) Calculations were made from measured data reported in g/head per day, for monthly periods with rearing from 30 to 110 kg in 120 days and 3.14 cycles a year.
(6) Value calculated from an emission of 50 ou_E/s/LU for an average weight for fattening pigs of 65 kg.
(7) Calculations were made from measured data reported per animal place and 3.14 cycles a year.

Resource requirements as reported from Germany, for the two variants of the variants of the technique, a summary is presented in Table 4.92.

Table 4.92: Resource requirements associated with deep litter and littered-floors applied to fattening pigs housing systems ([1])

System	Electricity	Bedding material	Water	Fuel	Source
	kWh/ap/yr	kg/ap/yr	l/ap/yr	kg/ap/yr	
Deep litter	8 ([2])	350 from 275 to 400	120 from 100 to 180	NA	[193, Germany 2010]
Littered floor combined with yard	3 from 2.5 to 4	275 from 250 to 300	115 from 90 to 140	0	[191, Germany 2010]

NA not available.
([1]) Data refer to open, non-insulated buildings, naturally ventilated, with solid concrete floors for fattening pig housing (28 – 118 kg).
([2]) Energy breakdown (kWh/ap/yr): feeding:1, manure removal/cleaning: 4.8, lightning: 2.

From France, it is reported that in deep litter systems when a thick sawdust bedding (from 60 to 80 cm) is used, the average requirement for sawdust is about 60 kg per fattening pig, when only the surface layer is removed and, consequently, the deep layer can be used for several fattening periods. In thin sawdust bedding, the thickness of the litter is reduced to approximately 20 cm, and then the average requirement will be 30 kg per animal. When straw is used, the average requirement per pig is 70 kg for the deep litter system and 45 kg for the littered-floor system [29, CORPEN, 2010].

In Table 4.93, average characteristics of the solid manure, produced with the use of straw and sawdust as bedding material, are presented, based on experimental data sets gathered in France for fattening pigs in deep litter.

Table 4.93: Average characteristics of solid manure produced by deep litter housing systems for fattening pigs, in France

	Unit	Straw	Sawdust
Type of Bedding			
Quantity of bedding used	kg/pig	62.2 ± 15.4 (mixed) 54.4 ± 14.2 (dry)	58.1 ± 21.8 (mixed) 40.5 ± 11.7 (dry)
Quantity of produced manure	kg/pig	202 ± 52 (mixed) 61 ± 14 (dry)	141 ± 44 (mixed) 53 ± 18 (dry)
Manure Composition			
Dry matter	%	30.5 ± 8	37.5 ± 6.3
Total N	g/kg of manure	9.7 ± 1.9	7.7 ± 2.5
N ammoniacal	g/kg of manure	1.4 ± 0.7	1.2 ± 0.7
P	g/kg of manure	3.6 ± 1.5	4.2 ± 1.6
K	g/kg of manure	11.6 ± 3.9	11 ± 3.9

Source: [329 , CORPEN , 2010]

Applicability

The system can be applied in all new housing. For existing housing, this technique ~~it~~ may be applicable in buildings with concrete solid floors. Design details will vary. To benefit from the outdoor climate, houses are situated according to the main wind direction. [181, Germany 2010] In regions with hot climates, deep litter is normally not applied.

The use of litter on the solid floor inside the house is not recommended for the Italian heavy pigs because they are normally fed with liquid feed, and the litter becomes too moist in a very short time. Using litter only in the external alley prevent ~~avoids~~ this negative effect and at the same time maintains the solid manure production. The solid manure is applied to land as fertiliser where it has a positive effect on soil structure.

The scarcity of bedding materials in some geographical areas may be a limitation to the use of these systems.

Economics

~~Capital costs for weaning pig houses are expected to be in the same range as with the reference technique. The annual operational costs are expected to be higher [291, IRPP TWG 2002]. Compared with the reference, the additional operational costs are about EUR 8 per pig place per year, but this depends on the price of litter. The capital investment for the fattener housing is much less than the reference system about EUR 454. Operating costs for the solution of an external alley range from an extra cost of EUR 6.00 per pig per year to a benefit of EUR 1.09 per pig per year compared to the reference. [291, IRPP TWG 2002]~~

Investment costs are reported from Germany at EUR 400 per animal place for the deep litter system, which corresponds to an annualised investment cost of 40 EUR/ap/yr, and EUR 454 per animal place for the littered -floor with yard.

Straw prices and bedding availability vary considerably from area to area inducing different economic results. Examples of extra costs, in comparison with fully-slatted floor systems, as reported from Spain are shown in Table 4.94.

Table 4.94: Extra costs for implementation of straw littered housing systems for fattening pigs

Type of litter	Type of house	Total extra costs (EUR/ap/yr)	Total extra costs (EUR/tonne of produced pig)
Littered system with weekly replacement of bedding	New houses	36.51 – 42.07	124.2 – 143.1
	Existing houses	20.16 – 25.72	68.6 – 87.5
Source [379, Spain 2006]			

From UK, the extra cost of production in a straw-based housing system, in comparison with a fully-slatted floor, was measured at approximately EUR 34 per tonne of produced pig meat (EUR 1 = 0.88 GBP), due to increased labour input and the requirement for bedding material. [289, MLC 2005]

From Denmark, it is reported that, even though this system is less expensive than a traditionally insulated house operating with slurry, other economic factors do not favour the implementation of littered housing systems, such as extra running cost for purchasing straw, poorer growth performance, extra labour requirements and a reduced utilisation of nitrogen (lower fertiliser value). Concerning these aspects, it is reported also from Denmark that when using solid pig manure for field fertilisation, and compared to the use of slurry, the need of 1.1 kg of additional nitrogen from chemical fertilisers to compensate for the loss of 1 kg of nitrogen from the manure, would add an extra cost of EUR 10 per produced pig.

Driving force for implementation

Improved animal welfare due to comfort provided by the straw and due to more space available per animal.

Lower energy requirements in the case of natural ventilation.

Example plants

~~Sartori farm (Parma) in Italy. About 4 % of the weaning pigs in Italy are kept on fully bedded systems. In the UK, kennels and creeps (with heat) in association with a fully bedded system are common, with group sizes of around 100 pigs of from 7 kg (weaning) up to 15 or 20 kg.~~

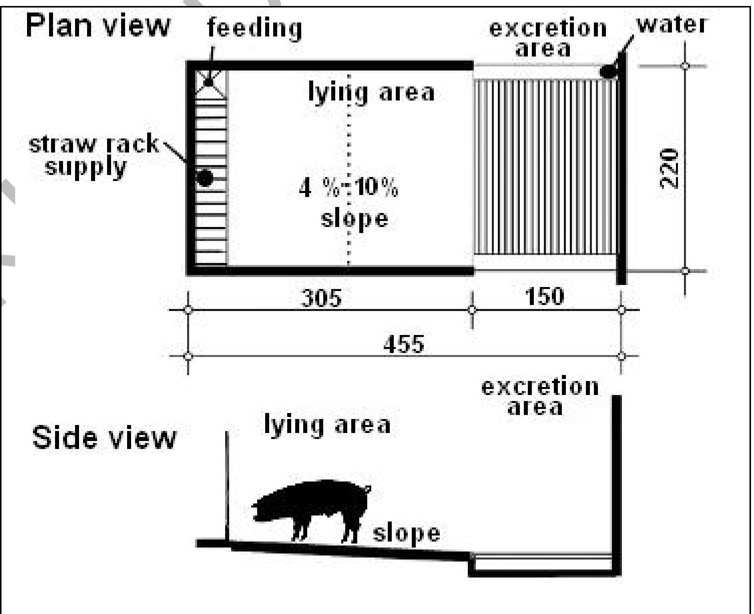
Applied in some farms in e.g. UK and Germany. Not widely applied yet, but might get more attention because of animal welfare considerations.

According to a survey in 2008 on livestock buildings (SCEES Survey of 2008), 6.9 % of all post-weaning places in France are equally divided between littered and fully-slatted floor systems. According to the same survey,
In France, 5.2 % of the fattening places were using littered housing systems, in 2008. Furthermore the use of the variations of deep litter systems with straw (accumulated straw) and littered-floor (thin litter) with sawdust bedding, is increasing against the systems of littered-floor with straw incregained favour in place of (scraped straw) and deep litter system with sawdust bedding options. [261, France 2010]

Reference literature
[291, IRPP TWG 2002] [292, Italy 2001] [39, Germany 2001] [191, Germany 2010] [157, Germany 2010] [181, Germany 2010] [185, Germany 2010] [193, Germany 2010] [289, MLC 2005] [375, Philippe et al. 2007] [420, Ramonet 2003] [519, Amon et al. 2007] [530, Nicks et al. 2003] [531, Ramonet et al. 2002] [532, Nicks et al. 2002]

4.7.1.13 Straw flow housing system

Description
Pigs are reared on pens with solid floors, where a sloped concrete lying area and an excretion area are clearly defined. Straw is provided to the animals daily, from a supply rack at the top of a sloped pen or from bales manually dropped in the pen. Pigs activity pushes and distributes the litter down the pen's slope (4 – 10 %) to the manure collection aisle (see Figure 4.48). In the so-called straw flow system, only a small part of the pen is soiled with excreta because the pigs only excrete in the rear of the pen and keep the lying area dry and clean. The excretion area is operated as a straw-based system where farmyard manure is produced. The solid fraction can be removed frequently (daily) with a scraper; whereas, there is a drainage for the effluent which is removed at the end of each batch. Alternatively, the excretion area can be fitted with slatted floor to operate the system as a slurry-based system, since only low amounts of straw are added. The adjacent excretion areas can be fitted with scrapers for frequent dung removal.



Elaboration from [519, Amon et al. 2007]

Figure 4.48: Design of the straw flow system for fattening pigs

The daily use of straw absorbs urine, avoiding wet open surface areas; manure is removed daily from the dung channels with a scraper.

The ventilation is frequently natural (e.g. in UK), with systems frequently placed in houses with open fronts or with curtains or vertical wooden planks not butted together. From UK, it is also reported that the technique can be combined with kennels made of boards, curtain or bales of straw, in naturally ventilated houses with daily manure removal and with long straw addition. [535, UK 2011]

Achieved environmental benefits
The absorption of urine on the straw, which reduces the emitting surface, and the frequent removal of manure from the dung channel, result in lower ammonia emissions.

From Austria, reduced levels of NH_3, N_2O and CH_4 emissions have been reported in comparison with the reference values given for forced-ventilated fully-slatted floor systems.

However, in another study in Belgium-Wallonia, higher ammonia emissions were associated with the system, in comparison with a deep litter system using straw and, in addition, much higher compared to a conventional slurry system with slats, presumably due to fast degradation of urea.

Buildings are kept cool, with plenty of straw to absorb urine, thus minimising the formation of wet surfaces.

Cross-media effects
The frequent scraping of the manure, which is removed outside, may require covering the manure store, in order to prevent ammonia and greenhouse gas emissions from storage. [519, Amon et al. 2007] [535, UK 2011]

Operational data
The length-to-width ratio of the pens is around 1.5:1 and the lying-to-excretion area ratio are around 2:1, to induce pigs to dung in the rear of the pen. Sprinklers are installed in the excretion area, in order to avoid excretion on the lying area due to thermal stress in hot months. [375, Philippe et al. 2007]

Reported straw consumption ranges from around 650 g/day per pig to as low as 50 g/day per pig, which is sufficient for ensuring animal welfare. With such small amounts of fibres, the excretion area can be fitted with slats or scrapers for the separation of the liquid fraction. Straw is normally provided in long stems.

Reported emissions from straw-flow systems are presented in Table 4.95.

Table 4.95: Emission levels (kg per animal place per year) from straw flow systems

Type of production	NH_3	CH_4	N_2O	Source
	kg/ap/yr			
Weaners	0.21 ([1])	NA	NA	[535, UK 2011]
Fattening pigs, frequent manure removal with a scraper (twice a day)	1.9 ([2])	0.54 ([2])	0.0245 ([2])	[519, Amon et al. 2007]
Fattening pigs, infrequent manure removal without a scraper in the dung channel	2.1 ([2])	1.24 ([2])	0.0399 ([2])	[519, Amon et al. 2007]
Fattening pigs, removal every month	4.46 ([3])	NA	NA	[375, Philippe et al. 2007]

([1]) Modelled values (e.g. results based on N balance).
([2]) Measured values.
([3]) Value calculated from a reported measurement of 13.3 g/head per day, for a rearing period of 53 days and 6.33 cycles per year.

Applicability
See Section 4.7.1.12.

Driving force for implementation
Improved animal welfare by supplying straw as activity material, which allows the animals to express their natural exploratory behaviour.

Economics
Labour requirements are quite low. From UK, it has been reported that the total cost for a new installation is around EUR 160 per animal place (1 GBP=0.88 EUR) [535, UK 2011]

Buildings are simple, and easy to clean and maintain; hence, a long lifespan is expected.

Example plants
The production system, also named "straw-flow welfare system" is applied in many different Member States, in particular in UK, Belgium-Wallonia and Austria.

Reference literature
[519, Amon et al. 2007] [375, Philippe et al. 2007] [535, UK 2011]

FORMER SECTION 4.7.1.15 (Floating balls in manure channel) HAS BEEN MOVED TO SECTION 4.8.5

4.7.2 System-integrated housing techniques for waiting, mating and gestating sows

IN THE FOLLOWING SECTIONS, SOME EXISTING TEXT (NO LONGER UP-TO-DATE) HAS BEEN REMOVED; OTHER TEXT HAS BEEN RELOCATED IN THE MOST SUITABLE SECTION/PARAGRAPH

All the techniques that are in use to rear waiting, mating, and gestating sows have been described in Section 4.7.1. The performances associated with the techniques are summarised in Table 4.96.

~~Currently,~~ Mating and gestating sows can be housed either individually or in groups. However, EU legislation on pig welfare (Directive 2008/120/EC) provides minimum standards for the protection of pigs and ~~will~~ requires that Member States must ensure that sows and gilts ~~to be~~ are kept in groups, during a period starting from 4 weeks after ~~mating~~ service to 1 week before the expected time of farrowing. ~~, for new or rebuilt houses from 1 January 2003, and from 1 January 2013 for existing housing~~.

In the same EU legislation on pig welfare as mentioned above (Directive 2008/120/EC), requirements for flooring surfaces are included. In particular, for gilts after service and pregnant sows when gilts and/or sows are kept in groups, the total unobstructed floor area available to each gilt and to each sow should be at least 1.64 m^2 and 2.25 m^2, respectively. When these animals are kept in groups of fewer than six individuals, the unobstructed floor area should be increased by 10 %. When these animals are kept in groups of 40 or more individuals the unobstructed floor area may be decreased by 10 %. In addition, a part of the above available area equal to at least 0.95 m^2 per gilt and at least 1.3 m^2 per sow, should be of continuous solid floor, of which a maximum of 15 % is reserved for drainage openings. Finally, when concrete slatted floors are used for sows kept in groups, the maximum width of the openings should be 20 mm for gilts after service and sows, and the minimum slat width should be 80 mm.

Table 4.96: Emission levels of system-integrated housing techniques for waiting, mating and gestating sows

Section	Housing system	Variant	NH_3 reduction %	NH_3 kg/ap/yr	CH_4 kg/ap/yr	Dust kg/ap/yr	Odour ou_E/s/ap	Source
4.7.1.2	Fully – slatted floor with a vacuum system			5 (1)	NA	NA	6.6(2)	IRPP BREF 2003 [156, Germany 2010]
4.7.1.3	Partly-slatted floor with a vacuum system	Metal slats		2.40	NA	0.16	NA	IRPP BREF 2003
		Concrete slats		2.77	NA	NA	NA	IRPP BREF 2003
4.7.1.4	Partly-slatted floor with slanted walls in the manure channel	Concrete		2.50 (3) 2.60 (3)	NA	0.22	18.7	[165, Netherlands 2010] [186, BE Flanders 2010]
		Metal		2.15 (3) 2. 30 (3)	NA	0.22	18.7	[166, Netherlands 2010] [186, BE Flanders 2010]
4.7.1.5	Partly-slatted floor or fully-slatted flat decks with a scraper	Metal slats		1.85	NA	NA	NA	IRPP BREF 2003
		Concrete slats		2.22 – 3.12	NA	NA	NA	IRPP BREF 2003
4.7.1.7	Partly-slatted floor with a reduced (in width) manure pit, solid concrete floor and fully-slatted external alley with storage pit underneath	Grouped		2.96	NA	NA	NA	IRPP BREF 2003
4.7.1.7	Partly-slatted floor with a reduced (in width) manure pit	Individual	20 – 40	1.23	18.2	NA	NA	IRPP BREF 2003
			49	0 – 2.272 (3)	18.2	NA	NA	[164, Spain 2010]
				2.40	18.2	NA	NA	IRPP BREF 2003
4.7.1.8	PSF with slurry cooling channels		10 – 50		15	NA	NA	[160, Denmark 2010]
4.7.1.9	FSF or PSF with manure surface cooling fins	Individual or group		2.2 (1)	18.2	NA	NA	[169, Netherlands 2007]
4.7.1.10	Housing techniques with frequent slurry removal by flushing	FSF	30 – 55	2.94 – 1.40	18.2	NA	NA	IRPP BREF 2003
		PSF	50 – 70	1.85 – 1.11	NA	NA	NA	IRPP BREF 2003
4.7.1.11	Kennel or hut housing on partly-slatted floors	PSF		3.75 (3)	NA	0.22	8	[155, Germany 2010]

Section	Housing system	Variant	NH_3 reduction	NH_3	CH_4	Dust	Odour	Source
			%	kg/ap/yr	kg/ap/yr	kg/ap/yr	ou_E/s/ap	
4.7.2.1	Solid concrete floor and full litter for mating/gestating sows		0 – 67	2.5 – 5.6	NA	NA	NA	[261, France 2010]
				2.6				[186, BE Flanders 2010]
				3.7-5.2				IRPP BREF 2003
				4.8 (1) (4)	NA	0.8(1)	6.6 (1) (2)	[161, Germany 2010],
				4.8 (1) (4)	NA	0.8(1)	6.6 (1) (2)	[157, Germany 2010]
	Litter based housing with feeding/lying boxes on a solid floor		22	1 (3)	NA	NA		[186, BE Flanders 2010]

NA= Not available.
(1) Values derived by expert judgement based on conclusions by analogy.
(2) Measured values.
(3) Values calculated from an emission 42 ou_E/s per LU and an average weight of 150 kg for early-pregnant or non-pregnant sow.
(4) In the case there is a yard, additional emissions are likely.

4.7.2.1 Solid concrete floor and full litter for mating/gestating sows

Description

Groups of sows are kept in pens on a fully concrete floor that is almost completely covered with a layer of straw or other lignocellulosic materials that ~~to~~ absorb urine and incorporate faeces (see Figure 2.14). Solid manure is obtained, which has to be frequently removed in order to ~~avoid~~ prevent the litter from becoming too moist.

Two main litter management systems exist:

- scraped litter (littered floor): the manure is frequently removed ~~evacuated~~ (1 – 3 times per week or more frequently) and straw is replaced in the same amount; A tractor-mounted scraper is used to ~~daily~~ remove the manure from the solid floor area; ~~daily~~
- accumulated litter (deep litter): the manure (straw or sawdust) is removed at the end of the rearing period after the removal of the pigs, or after several successive production cycles (1 – 2 times per year). [261, France 2010]

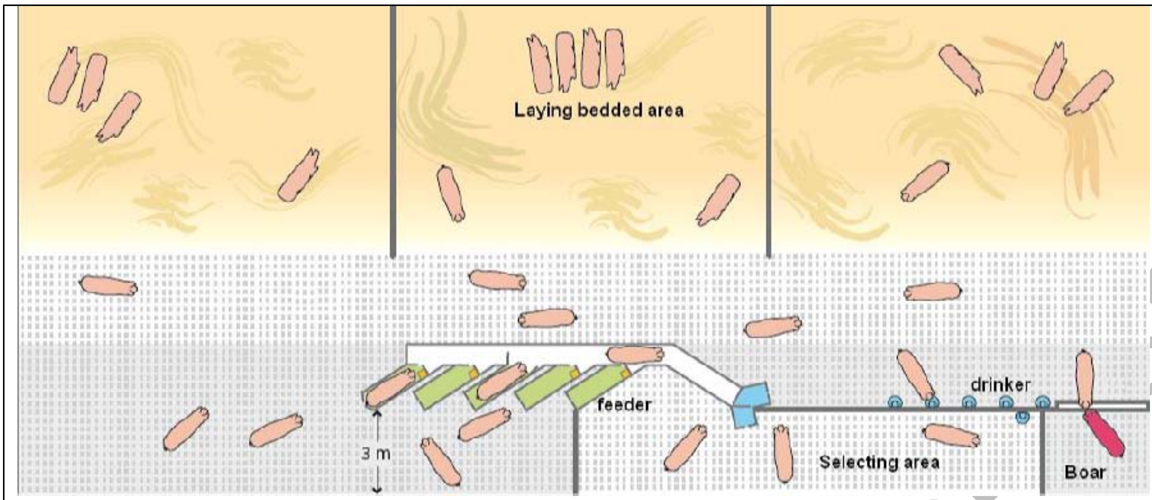
The available space in the housing system is subdivided into a lying area and an activity area. For each group of sows a clear division between the two areas should be provided. The lying area is fully littered and used by the sows as resting area, and only a limited amount of manure spots should be present. From Belgium-Flanders it is reported that the lying area commonly covers 1.3 – 1.5 m^2/animal place. The bedding has a height of at least 0.15 m and 0.40 m at the most. The activity area consists of the following functional areas: passage corridor, waiting area, feeding area and drinking area. ~~Pens can be organised with the installation of the~~ In the feeding area, electronic sow feeders (ESF) can be installed. Sows defecate in the activity area; the emitting manure surface is reported to be at a maximum 1.1 m^2 per animal place [186, BE Flanders 2010]

A schematic representation of a solid concrete floor system with straw and electronic feeders is shown in Figure 4.49.

~~The defecating dunging area consists of a concrete solid floor A tractor-mounted scraper is used to daily remove the manure from the solid floor area daily. The litter in the deep straw littered lying area is removed only 1 – 2 times per year.~~

Buildings can be naturally ventilated; ~~and~~ in this ~~these~~ case, one side is fitted with open boards. Separate functional areas can also be organised, with deep littered walking areas, raised and levelled concrete feeding ~~eating~~ areas and lockable insemination stalls; feeding and drinking systems are automatic [161, Germany 2010]. In Germany, group sizes are reported to be larger than 40 sows and the space per animal is 3.75 m^2 [161, Germany, 2010]. In Belgium-Flanders, the total available pen area per sow is reported at max. 2.5 m^2.

In a variant of the technique for waiting sows, reported from Germany for naturally-ventilated, ~~In open~~, non-insulated buildings, separate functional areas are ~~can be~~ organised on a plane floor system, combined ~~complete~~ with an external yard. The living (walking and lying) area is on an insulated solid concrete floor covered with straw (about 1.4 m^2 per head), the feeding area can be on a raised, slatted floor (producing slurry) and the external yard is on ~~bedded~~ a concrete level (about 1 m^2 per head), fully littered with straw. Feeding and drinking systems are automatic [157, Germany 2010].



Source: [262, France 2010, Ramonet (2009) Loger les truies en groupes au DAC]

Figure 4.49: Solid concrete floor system with straw and electronic sow feeders

Achieved environmental benefits
Energy savings are ~~permitted~~ ~~by~~ achieved due to the improved climate. The energy use is very low because this system does not require ~~need a~~ heating, since it ~~and~~ is normally equipped with a natural ventilation system.

Ammonia emissions are lowered by reducing the emitting manure surface by steering the defecating behaviour of the sows and, in the cases when slatted floor is also present, by altering the manure composition. This is achieved through a specific housing design aimed at encouraging the natural behaviour of the sows and the application of specific management of manure and straw. [186, BE Flanders 2010]

Cross-media effects
The system requires increased management for handling of litter and manure removal.

It is generally considered that a poor bedding management may lead to formation of nitrogen monoxide emissions.

Operational data
~~No limitations on group size are reported~~. Indicatively, in deep litter systems new bedding is added once a week, and the frequency of addition is adjusted according to the cleanliness of the litter and the season. Litter and manure removal is done by tractor. The litter in the living area and in the yard are removed twice a year. Where a shallow pit exists, the dung is removed daily.

Controlled ventilation is dimensioned for a maximum output of 100 m^3 per hour per sow place. Although the sows are capable of compensating for low temperatures by hiding in the deep litter mat, auxiliary heating is applied in colder parts of Europe to reduce humidity during reduced ventilation. From Germany, the ventilation requirements are reported at 16 m^3/ap/yr for the cold season and 220 m^3/ap/yr for the warm season.

An increase in N_2O emissions is generally expected due to the existence of aerobic and anaerobic zones in the litter, as well as higher dust emissions; reported emissions vary in the range of 0.03 – 10 g/day [506, TWG ILF BREF 2001]. Higher dust emissions are also expected. **Text moved (and amended) from former Section 4.7.1.14**

The effect of straw on ~~the manure~~ methane emissions is controversial. On the one hand, ~~it can increase~~ methane emissions may increase due to high dry matter content of manure; on the other hand, aerobic conditions in the manure ~~it~~ can limit CH_4 production through an aeration effect of the straw ~~manure~~.

Comparative measurements with fully-slatted floor systems and deep pit for gestating sows in Spain, resulted in a reduction of ammonia and methane emissions of 14 % and 66 % ,respectively, and in an increase of N_2O emissions of 178 %. [379, Spain 2006].

In Table 4.97, ammonia emissions on straw-based deep litter housing systems are reported.

Table 4.97: Reported emissions for mating and gestating sows housed in deep littered systems.

All systems with electronic sow feeders	NH_3 emissions	PM_{10}	Odour	Source
	kg/ap/yr	kg/ap/yr	ou_E/s/ap	
Without yard	2.5–5.6 ([1]) 2.6 ([1])	NA	NA	[261,France201] [186, BE Flanders2010]
With or without yard	4.8 ([2]) ([3])	0.8	6.6 ([4])	[161, Germany 2010] [474, VDI 2011]

NA= Not available.
([1]) Measured data.
([2]) Values derived by expert judgement based on conclusions by analogy.
([3]) Additional emissions are likely due to emitting surfaces in the yard.
([4]) Value calculated from an emission of 22 ou_E/s/LU, and an average weight of 150 kg per for early-pregnant or non-pregnant sow.

Resources requirements, as reported from Germany for two alternatives of the system, are presented in Table 4.98.

Table 4.98: Resources demand associated with solid floor housing systems covered with litter, for waiting/mating/gestating sows, in Germany

System	Labour	Energy	Bedding material	Cleaning water	Source
	h/ap/yr	kWh/ap/yr	kg/ap/yr	l/ap/yr	
Deep litter for group housed mating/gestating sows	2.6	60	640	NA	[161, Germany 2010]
Deep litter for group housed waiting sows with a yard and a slatted feeding area	1.8	15	300 – 450	220	[157, Germany 2010]

NA= Not available.

From France, it is reported that the quantity of straw required daily for gestating sows is 2.4 kg/sow for the deep litter housing system (weekly straw input and manure removal every 2 – 3 weeks, up to one month) and 1.7 kg/sow for the littered-floor housing system (scraping manure and adding straw 1 to 2 times per week) [262, France 2010].

Due to the frequent litter refreshing and tractor dung removal, increased management requirements are needed, that are quantifiable as 1.5 – 2.6 h per animal place per year. [161, Germany 2010]

Applicability
This system ~~is very good~~ functions very well when applied to ~~in~~ new houses and to ~~in~~ some existing houses. Limitations for applying the technique were reported only for the electronic sow feeders in existing houses, for which ~~the~~ applicability depends on the design of existing manure pits~~, but it is usually difficult to apply~~.

Economics

~~The costs for this system are not higher than the reference FSF system. However, there are no costs calculated for extra labour and these costs are therefore unknown.~~ Extra costs, as reported from Spain, in comparison with fully-slatted floor systems, are shown in Table 4.99.

Table 4.99: Extra costs for implementation of straw-littered solid floors with weekly replacement of bedding, in Spain

Production	Type of house	Extra costs	
		EUR/ap/yr	EUR/tonne of produced pig
Gestating sows	New houses	72.71 – 80.45	27.3 – 30.2
	Existing houses	47.61 – 55.35	17.9 – 20.8
Source: [379, Spain 2006]			

~~The production of solid manure instead of slurry manure is considered an advantage from the agronomical point of view. Organic matter incorporated into the fields improves the physical characteristics of the soil; reducing run-off and the leaching of nutrients to water bodies.~~ **Already stated in the general part of Section 4.7**

Driving force for implementation

According to EU legislation (Directive 2008/120/EC), all farms (new, rebuilt or existing) are obliged to keep sows in groups. This system may receive more attention in the future because it favours group housing. ~~in view of developments in European legislation on animal welfare.~~

The technique improves animal welfare conditions as sows ~~animals~~ benefit from the group ~~association~~ life, the comfortable lying area, the improved climate and the large available space for movement ~~motion area~~. Straw is a good occupational/investigation material for the animals.

~~The availability of useful manure might be interesting for farms with arable areas.~~

Example plants

This system can be found in several Member States. In the Netherlands more than 50 % of new buildings apply this system, which is also implemented in retrofitted existing houses. ~~situations~~. In Belgium-Flanders, 27 farms have received authorisation for this system. [300, Belgium-Flanders 2010]

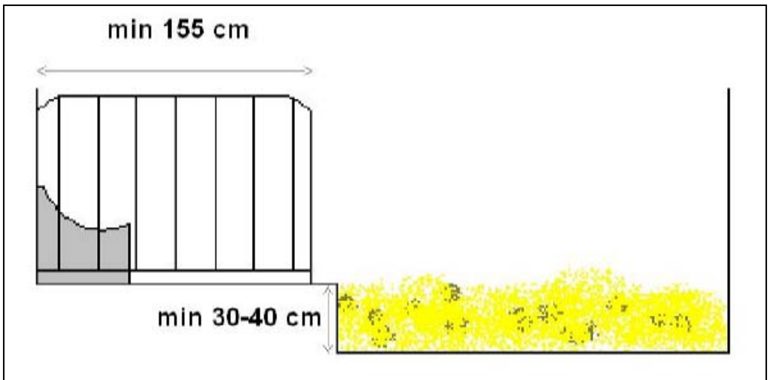
Reference literature

[549, IMAG-DLO 1999] [397, Denmark 2000] [412, Italy 2001] [157, Germany 2010] [161, Germany 2010] [186, BE Flanders 2010]

4.7.2.2 Litter based housing with feeding/lying boxes on a solid floor

Description

Sows are housed in pens of 6 to 12 animals. Each pen is divided into two functional areas: the feeding/lying cubicles and the littered (straw) bedding area. One cubicle with a solid floor is provided for each sow. The cubicles are 0.50 to 0.65 metres wide and the length of the solid floor of the cubicle is at least 1.55 metres (see Figure 4.50).



Source: [435, Van Gansbeke et al. 2011]

Figure 4.50: Scheme of the floor levels in bedded pens with feeding/lying boxes

The bedding area is situated behind the feeding/lying cubicle at 0.30 to 0.40 m below the floor level; a minimal littered surface of 1.5 m² is provided for each animal place.

Achieved environmental benefits
Lower ammonia emissions are achieved by keeping the bedding clean and dry, with regular supply and replacement of the straw.

Cross-media effects
It is generally considered that inefficient management of the bedding may lead to increased greenhouse gas emissions.

Operational data
At the beginning of each production cycle, the bedding area is littered with 30 – 40 cm of straw and, in any case, in sufficient quantity to ensure that the difference in height between the bedding area and the cubicles level is not more than 10 cm.

Topping-up of straw is done at least three times per week, so that no wet manure spots emerge in the bedding area. The bedding material is replaced every five weeks or when it reaches the maximum height of 50 cm. The total consumption of straw is estimated at around 2 kg per sow per day.

A reported ammonia emissions factor for this housing system is 1 kg NH_3 per animal place per year (indicative measurements). [186, BE Flanders 2010]

Applicability
The system can be applied in all new housing and may be applicable in existing buildings with concrete solid floors.

Economics
No data is available

Driving force for implementation
Directive 2008/120/EC requires keeping sows and gilts in groups; this provision entered into force for all pig farms starting from 1 January 2013.

Example plants
In Belgium-Flanders, the system is applied in 18 farms (including farms above and below the capacity threshold set by Directive 2010/75/EU, Annex I).

Reference literature
[435, Van Gansbeke et al. 2011], System V-3.7

4.7.3 System-integrated housing techniques for farrowing sows

In Europe, farrowing sows are generally housed in crates with steel or plastic slatted floors and a deep manure pit underneath. In the majority of houses, sows are confined while piglets are free to walk around. All houses have controlled ventilation and often a heated area for the piglets during their first few days after birth. The difference between fully and partly-slatted floors is not as distinct for farrowing sows as for growers because the sow is confined and excretion generally takes place in the slatted area. Reduction techniques therefore focus on alterations in the manure pit. [508, TFRN 2012]

The performances of the techniques that are used to rear farrowing sows are summarised in Table 4.100, along with the reference and a note for each figure. ~~as they are described at the end of Section 4.7.~~

Many techniques have been described in Section 4.7.1 and are not repeated here. Only techniques will be described that have a specific suitability for this animal category or that have characteristics strictly related to this category.

Table 4.100: Emission levels of system-integrated housing techniques for farrowing sows

Section number	Housing system	NH_3	Dust	Odour	Source
		kg/ap/yr		OU_E/s/ap	
4.7.1.1	Fully-slatted floor (FSF) with deep pit	8.3–8.7 9.0 (1)	NA	NA	IRPP BREF 2003. [261, France 2010]
4.7.1.4	Partly-slatted floor with slanted walls in the manure channel	3.2 (1)	NA	NA	[186, BE Flanders 2010]
4.7.1.5	Partly-slatted floor or fully-slatted flat decks with a scraper	4 – 5.65	NA	NA	IRPP BREF 2003.
4.7.1.9	FSF or PSF with manure surface cooling fins	2.4	NA	NA	IRPP BREF 2003.
4.7.1.10	Housing techniques with frequent slurry removal by flushing	3.3	NA	NA	IRPP BREF 2003.
4.7.3.1	Stall-housing with fully-slatted floor	8.3 (2)	0.16	8.0 (3)	[171, Germany 2010] [474, VDI 2011]
4.7.3.1	Stall-housing with partly-slatted floor	8.6 (2)	NA	NA	[159, Austria 2010]
4.7.3.2	Crates with fully-slatted flooring and a combination of a water and manure channel	4	NA	NA	IRPP BREF 2003.
4.7.3.3	Crates with fully or partly-slatted flooring and manure pan	2.9 (1)	NA	NA	[186, BE Flanders 2010]
4.7.3.4	Littered pens with or without a yard	8.3 (2)	0.16	8.0 (3)	[172, Germany 2010] [474, VDI 2011]

(1) Measured data.
(2) Values derived by expert judgement based on conclusions by analogy.
(3) Values calculated from an odour emission of 20 ou_E/s per LU, and animal mass= 0.4 LU.

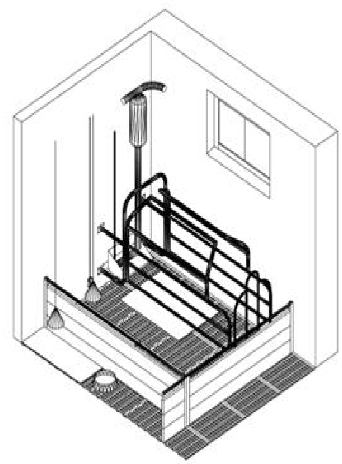
4.7.3.1 Stall-housing with partly-slatted floor ~~Crates with fully-slatted floor and fixation of sows~~

Description

In a closed insulated building, individual farrowing pens ~~of around 4.3 m^2 have~~ are equipped with stalls which allow for the ~~permanent or~~ temporary confinement ~~fixation~~ of sows. The floor in the farrowing crate is partly-slatted; whereas, the laying area ~~may~~ has ~~be~~ a partially continuous solid floor. Slats are made of plastic, metal or concrete. Piglets are provided with a levelled and heated nest. Feeding and drinking systems can be automatically controlled, whereas ventilation can be forced or natural (with fan assistance in hot weather). A scheme of the system is presented in Figure 4.51.

From UK, a variation of the fixed crate is reported, which consists of a lifting farrowing crate ~~are also manufactured~~ where the floor ~~crate~~ mechanically rises as the sow lies down, to allow piglets to ‘fall away’ in order not to be ~~layed~~ laid on by the mother. This system is installed in insulated, mechanically ~~fully~~ ventilated housings, where ventilation is controlled with real time monitoring, with the air inlet next to the sow’s snout, cooling pipes installed under the sow and an air-cooling system with a heat exchanger in place. The solid part of the floor can raise its temperature by 5 °C. Slurry is frequently removed with a vacuum system (every 2 – 4 weeks). Suckling piglets do not have access to a nest. [174, UK 2010]

~~The slurry vacuum system frequently (daily) removes dung. Forced ventilation is applied.~~



Source: [171, Germany 2010]

Figure 4.51: Stall housing for farrowing sows

Achieved environmental benefits

Fuel savings are reported, and a consequent reduction of indirect emissions from fossil fuel combustion.

Cross-media effects

None reported.

Operational data

In Germany, emissions are evaluated at 8.3 ~~7 kg~~/ap/yr for NH_3, ~~and~~ 0.16 kg/ap/yr of PM_{10} ~~dust~~ and odour emissions at 8 ou_E/s/ap (value derived from the reported emission factor of 20 ou_E/s/LU, for an average weight of sow with the piglets of 200 kg) [474, VDI 2011]. At the same time, ventilation is applied at rates of 22 – 27 m^3 per animal per hour in the cold season and at 125 – 127 m^3 per animal per hour in the hot season.

Consumptions have been estimated in Germany per animal place per year at 60 kWh for electricity energy, 850 litres of cleaning water, and 680 kWh for piglet nest heating and 180 kWh for room heating. Human labour needs are estimated at 3.9 hours per animal place per year. [171, Germany 2010]

For the lifting farrowing crate (welfare friendly farrowing crate), a higher weaning weight of 1 kg is reported because of a higher feed intake. In addition, fuel savings of 40 % are reported for the system. [174, UK, 2010]

Applicability
The solution may not meet future welfare standards of consumer preference, as sows are restrained during the farrowing period.

Economics
Costs for newly built houses are reported between EUR 2500 2 800 and EUR 2 900 per animal place, from Germany for 180 farrowing pens, and are calculated equivalent to EUR 2 877 per animal place in Belgium-Flanders for a new installation with 95 farrowing pens [265, BE Flanders 2005].

For the lifting farrowing crate system, an extra cost of at least 35 % is reported from UK. [174, UK 2010]

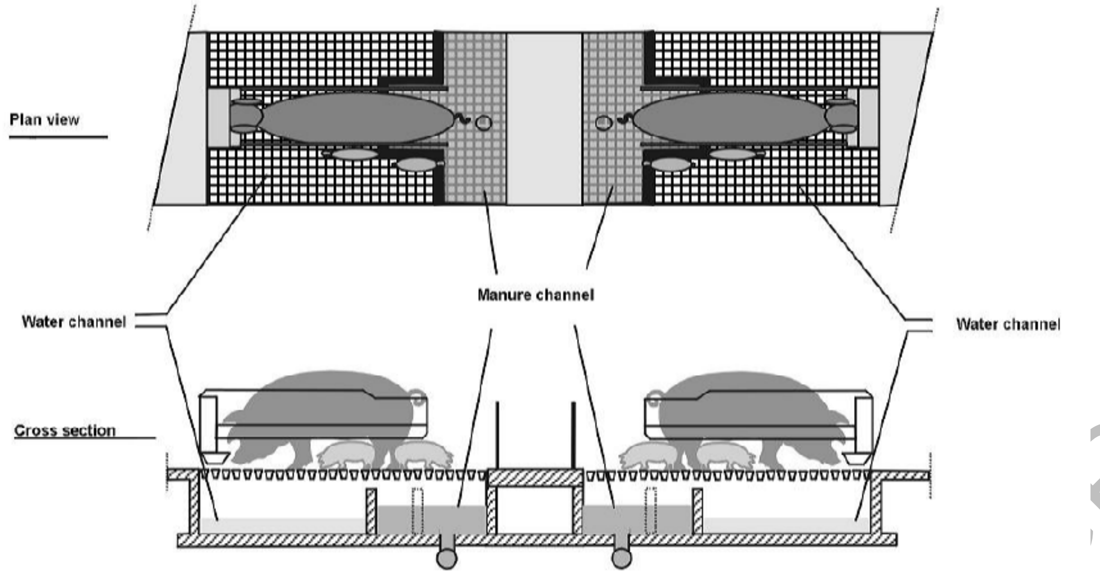
Driving force for implementation
To improve For the lifting farrowing crate, pig health is improved and increased weaning weights and lower mortality are achieved. rates. The system

Example plants
This system is one of the The technique is the standard systems in Germany.

Reference literature
[171, Germany 2010] [174, UK 2010] [173, UK 2010]

4.7.3.2 Crates with fully-slatted flooring and a combination of a water and manure channel

Description
The sow has a fixed place and as a result it is clear where the defecating dunging area is clearly identified will be. The manure pit is split up into a wide water channel at the front and a small manure channel at the back (see Figure 4.52 and Figure 4.53). In this way, the manure surface is greatly reduced, which in turn reduces the ammonia emissions. The front channel is partly filled with water. The slats are made of iron metal or plastic.



Source: [42, Netherlands 1999]

Figure 4.52: Combination of a water and manure channel

Source: [265, BE Flanders 2010]

Figure 4.53: Shallow slurry pits separating manure and water channels during construction

Achieved environmental benefits

Reduceda mmonia emissions due to the ~~It~~ limited ~~the~~ emitting manure surface and ~~has~~ frequent slurry removal ~~of the slurry~~ by a discharge ~~sewerage~~ system.

Cross-media effects

The frequent removal of the slurry may require extra energy. Water is needed to fill the front pit.

It is anticipated that future consumer standards will not favour techniques that limit farrowing sows' freedom of movement, due to animal welfare considerations.

Operational data

An ammonia emission level of ~~A reduction of 52 % (~~4.0 kg NH_3 per sow place per year (NL, BE) can be achieved, which is more than 50 % lower, in comparison with the typical emission levels of 8.3 – 8.6 kg NH_3 per sow place per year reported for stall-housing system with partly-slatted floor with deep pit.

Supposedly the two pits are emptied into the same slurry sewerage system towards the slurry store ~~storage~~. Water is changed after each round (approximately every 4 weeks). The front section is drained completely, cleaned, disinfected and then filled up again with fresh water.

Applicability
~~This system is easy to implement in the reconstructions of~~ For retrofitting this system into existing buildings equipped with fully-slatted floors, ~~an FSF~~ ~~the reference technique, as~~ the design of the pen is not critical in itself but the implementation depends on the conditions of the pit. ~~for the applicability of the system.~~ ~~Very simply, all that would be needed would be the separation of the two pits.~~ Openings to a discharge system (e.g. tubing) are required to be placed underneath each crate. This means that the entire existing manure pit has to be removed and rebuilt in order to construct the discharge system and the openings. Proper support has to be considered when digging operations need to be performed near the load-bearing walls.

In cases where the existing house has crates with partly-slatted floors, new crates have to be installed, as the existing crates (fixed on the previous portion of partial solid floor) can no longer be used.

Economics
~~The extra investment costs are EUR 60 per pig place. This means for a 52 % reduction about EUR 13.85 per kg NH_3 abated. The extra annual operational costs are EUR 1.00 per pig place or EUR 0.25 per kg NH_3.~~

~~In Belgium-Flanders, the extra cost compared to buildings and techniques that are conventional for the territory, is EUR 432 per crate for building new housings and EUR 2434 per crate for retrofitting an existing house. [265, BE Flanders 2010]~~ **See below**

Investment cost data for a fully-slatted floor housing system with water and manure channels in the slurry pit, as reported from Belgium-Flanders, are presented in the Table 4.101. Calculations are based on a compartment with 95 farrowing pens. Investment costs are 15 % higher than for a system with fully-slatted floor and deep pit; extra investment costs are equivalent to EUR 433 per farrowing pen in new installations. Included in this extra cost, is the cost for an additional storage volume consisting of a concrete storage tank of 300 m^3 is also included, to compensate for the reduced slurry storage volume underneath the slats. Without the additional storage, the extra costs would be equivalent to EUR 316 per farrowing place.

Table 4.101: Investment costs reported for a fully-slatted floor housing system with shallow slurry pit with water, in comparison with fully-slatted floor with deep pit

Parameter	**Building costs**	**Additional costs**	**Total**
	EUR/sow place		
Deep pit (Conventional system)	1354	1523	2877
Deep pit with water and manure channels	1354	1956	3310
Extra-cost			433
Source: [265, BE Flanders 2010]			

From Belgium-Flanders, also cost data for the implementation of the technique in existing houses are reported which amount to EUR 2434 per sow place for fully-slatted floors and EUR 4565 per sow place for partly-slatted floors. [274, BE Flanders 2010]

~~Spanish~~ Extra costs reported from Spain are calculated considering payback time (10 years), running costs, interest rate (5 %) and maintenance rate (2 %), and are given per place per year in comparison to crates with fully-slatted floors. Figures are given in Table 4.102. [379, Spain 2006]

Table 4.102: Extra costs for fitting partly-slatted flooring with a combination of water manure channels compared to an FSF

Production	Reduction	Extra costs		
	%	EUR/ap/yr	EUR/tonne pig produced	EUR/kg NH_3 reduced
New house	52	16.74 – 20.09	~~0.0021 – 0.0025~~ 2.1 – 2.5	8.63 – 10.36
Retrofitting existing house	52	3.29 – 3.95	~~0.0004 – 0.0005~~ 0.4 – 0.5	1.70 – 2.04
Source: [379, Spain 2006]				

Driving force for implementation
The technique is relatively easy to implement in existing buildings.

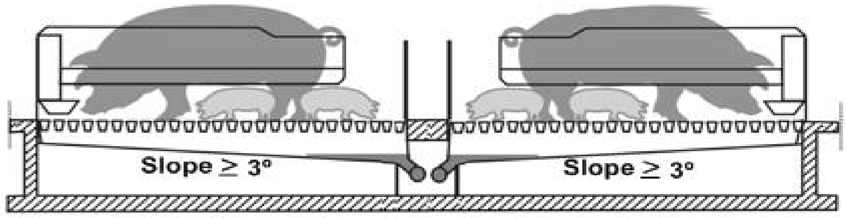
Example plants
~~In the Netherlands, 5000 sow places are equipped with this system.~~ In Belgium-Flanders, 157 farms equipped with this system (including farms above and below the capacity threshold set by Directive 2010/75/EU) have been authorised ~~that are~~ [300, Belgium-Flanders 2010]. In the Netherlands, in the province of Noord-Brabant only, 126 farms with farrowing sows are equipped with the system.

Reference literature
[42, Netherlands 1999] [22, Bodemkundige Dienst 1999] [500, IRPP TWG 2011]

4.7.3.3 Crates with fully or partly-slatted flooring and manure pan

Description
A ~~prefabricated~~ pan is placed under the slatted floor and is ~~can be~~ adapted to the dimensions of the pen, needing to encompass the entire slatted floor area (see Figure 4.54). The manure pan consists of a shallow recipient ~~The pan is deepest at one end of the pen and the pan has~~ with a slope of at least 3° towards a central slurry channel~~. The pan~~ connected to ~~with~~ a sewerage system. ~~Every three days the manure should be removed by the sewerage system.~~ The slurry ~~manure~~ is discharged before its level reaches 12 cm. A reachable and clearly visible overflow drain assures the level is kept. The pan can be subdivided into a water and a manure channel. ~~a water section and a manure section where a water channel exists.~~ Manure pans can be prefabricated and are made of smooth, corrosion resistant, non-adherent to manure, and easy to clean material.

~~The Slats are made of iron or plastic.~~



Source: [42, Netherlands 1999]

Figure 4.54: Fully-slatted floor with manure pan

Achieved environmental benefits

Ammonia emissions are lowered by reducing the emitting manure surface to a maximum of 0.8 m² per animal place and by providing a manure pan with a water and manure channel underneath the crate. ~~Limiting the manure surface and~~ Frequent removal of the slurry by a sewerage system contributes also to a reduction of ammonia emissions. Overall, a reduction of ~~achieves a~~ 65 % ~~reduction~~ in ~~of~~ NH_3 emissions is achieved, in comparison with the emission of 8.3 kg NH_3/ap/yr associated with the technique of stall-housing with slatted floor and deep pit.

~~An increased reduction of 50 % compared with the sloped board construction is achieved, although both designs seem to be very similar. A lower emitting surface and a more frequent removal of the slurry is considered to be the most important factors determining the difference.~~

Cross-media effects

This solution is typically associated with the development of flies.

The housing systems where sows are restrained during the farrowing period may not meet future standards for animal welfare.

Operational data

Ammonia emissions of 2.9 kg NH_3 per sow place per year were reported from the Netherlands and Belgium-Flanders. From trials carried out in Spain, the measured ammonia emissions reduction is reported equivalent to 32 %, which is associated with an average value of 0.468 kg NH_3/ap/yr. However, ~~in Spain~~ peaks as high as 21.25 kg NH_3/ap per year of ammonia are reported from Spain. Ventilation ~~air~~ requirements have been reported from Spain at 325 m^3/h/ap for the warm season, with a maximum of 465 m^3/h/ap.

The inner diameter of the discharge openings should be at least 90 mm and the diameter of the discharge tube ~~must be~~ should be at least 110 mm. Where a dedicated water channel is in place, the level of the water needs to be maintained at least at 5 cm at all times. In addition, at the end of each production cycle the water and manure channel have to be discharged, after which the crate can be cleaned.

Applicability

The application does not depend on the pen design (e.g. crates placed either straight or diagonal), or on whether it is with a fully or a partly-slatted floor. This system is easy to implement in reconstructions of existing buildings, as well as in new buildings. ~~The design of the pen is not critical for the applicability of the system.~~

Economics

The extra costs ~~investment costs are EUR 280 per pig place. This means with a 65 % reduction, i.e. 8.3 to 2.9 kg NH_3, costs are EUR 53.85 per kg NH_3 abated. The extra operational costs per year are EUR 45.85 per pig place. This means EUR 8.80 per kg NH_3.~~ have been calculated in Spain and are reported in Table 4.103. Costs are referred ~~also refer~~ to units of production, as well as and to reductions of ammonia emissions for the range of abatement of 32 to 65 %. [170, Spain 2007]

Table 4.103: Extra costs for partly-slatted floor with manure pan, in comparison to fully-slatted floor

Production	Ammonia emissions reduction (1)	Extra costs		
	(%)	(EUR/ap/yr)	(EUR/tonne pig produced)	(EUR/kg NH_3 reduced)
New to build house	32 – 65	17.52 – 21.02	~~0.0022 – 0.0026~~ 2.2 – 2.6	7.22 – 17.66
Retrofitting existing house		30.98 – 37.17	~~0.0039 – 0.0046~~ 3.9 – 4.6	12.80 – 31.23

(1) Comparison made between an experimental design where pens with a manure pan were tested against control pens with fully-slatted floors
Source: [170, Spain 2007]

In the Netherlands, the reported extra-investment costs to standard housing are EUR 270 per animal place, and the annual costs are equivalent to 40 EUR/ap/yr (including depreciation, interest, maintenance and all other operating costs, such as energy, etc.). In the case of a manure pan with a water and manure channels, extra-investment costs are reported at EUR 295 per animal place, and annual costs at 40 EUR/ap/yr. [589, Netherlands 2010]

Driving force for implementation
The technique is relatively easy to implement in existing buildings.

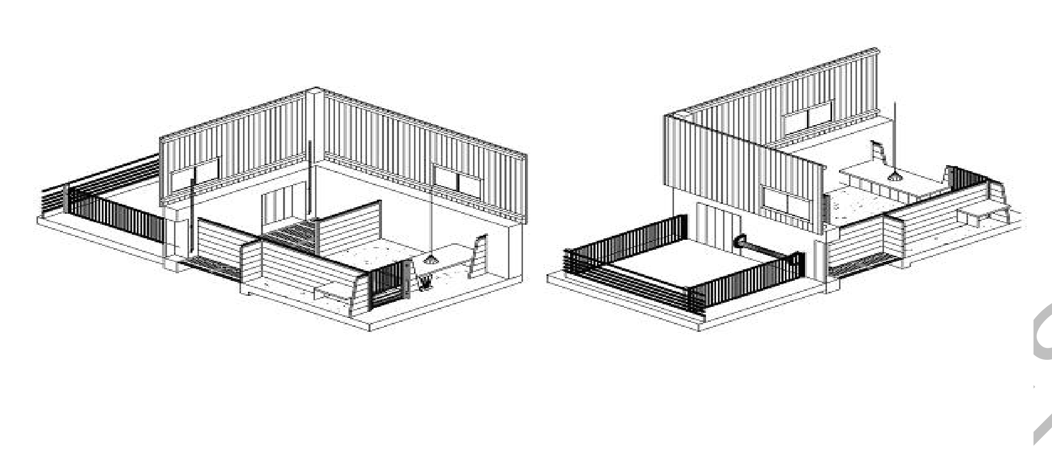
Example plants
In the Netherlands, ~~about 10000 sow places are equipped with this system. This system has only recently been developed (~~starting in 1998,~~). Currently~~ this system has been ~~is being~~ implemented in many reconstructions, as well as in new buildings. In the province of Noord-Brabant alone, 126 farms with farrowing sows are equipped with this system.

Reference literature
[42, Netherlands 1999] [170, Spain 2007] [186, BE Flanders 2010 V-2.6]

4.7.3.4 Littered pens with or without a yard

Description
In closed, non-insulated buildings, pens are equipped with separate functional areas for the sow: the lying area is bedded, the walking and dung areas have slatted or perforated floors and the feeding ~~eating~~ area is on solid flooring. Piglets are provided with a littered and covered nest and an optional non-littered yard. Under the slatted floor, the slurry is frequently mucked out, and from the solid floor areas, the solid manure is manually removed daily.

A schematic representation of a housing system with littered pens with a yard is presented in Figure 4.55.



Source: [172, Germany 2010]

Figure 4.55: Littered farrowing pens with yard

Achieved environmental benefits
Please TWG provide information.

Cross-media effects
Please TWG provide information.

Operational data
In Germany, emissions are assumed to be 8.3 ~~7 kg~~ of ammonia per animal place per year, ~~and~~ 0.16 kg of PM_{10} dust per animal place per year and 8 ou_E/s per sow (value derived from the reported emission factor of 20 ou_E/s/LU and an average weight of a sow with piglets of 200 kg) [474, VDI 2011]. For the same system, ~~the same time,~~ ventilation ~~per animal per hour~~ is applied at rates of 22 – 27 m^3/h/animal in the cold season and of 125 – ~~127~~ 187 m^3 in the hot season. From Finland, ~~higher~~ the reported ventilation rates ~~have been reported,~~ are at least ~~of~~ 35 and 250 m^3 per animal place per hour in the cold season and in the warm season, respectively. [229, Finland 2010]

It is necessary to provide around 180 kg of bedding each year to the 7 m^2 of space per sow.

Applicability
Please TWG provide information.

Economics
The technique entails additional costs for daily mucking out.

Driving force for implementation
The bedded housing improves animal welfare. The yard is mandatory in ecological farming.

Example plants
This system is the standard for organic farming in Germany.

Reference literature
[172, Germany 2010].

4.7.4 System-integrated housing techniques for weaned piglets

Ammonia performances of the techniques that are used to rear weaned piglets are summarised in Table 4.104. along with the reference and a note for each figure as they are described at the end of Section 4.7. Data concerning emissions of methane, nitrous oxide, dust and odour are also presented, when available.

Some techniques have been described in Section 4.7.1; and therefore, and are not repeated in the following sections. Only techniques will be described that have a specific suitability for this animal category or that have characteristics strictly related to the rearing of weaning pigs.

Table 4.104: Emission levels of system-integrated housing techniques for-weaned piglets

Section number	Housing system	NH_3 emission	CH_4	PM_{10}	Odour	Source
		kg/ap/yr	kg/ap/yr	kg/ap/yr	ou_E/s/ap	
4.7.1.1	Pens or flat decks with fully-slatted floor (FSF) with deep pit	0.6 – 0.8	NA	NA	NA	IRPP BREF 2003 [261, France 2010]
4.7.1.2	Pens or flat decks with fully-slatted floor and vacuum system	0.5 (8-28 kg) (1) 0.06–0.40 (6-25 kg) (2)	2.81–5.86	0.08	3	[182, Germany 2010] [180, Spain 2010]
4.7.1.3	Pens or flat decks with partly-slatted floor and vacuum system	0.39-0.60	NA	NA	NA	IRPP BREF 2003
4.7.1.5	Partly-slatted floor with a scraper	0.18 – 0.36	NA	NA	Na	IRPP BREF 2003
4.7.1.6	Partly-slatted pens with convex floor and separated manure and water channels	0.26 (discharge) 0.21(flushing) 0.14–0.22 (slanted walls) (2)	NA	0.132 (slanted walls)	5.4 (slanted walls)	IRPP BREF 2003 ([186, BE Flanders 2010] [176, Netherlands 2010])
4.7.1.9	Fully stalled floor or partly-slatted floor, with manure surface cooling fins	0.15	NA	NA	NA	IRPP BREF 2003
4.7.1.10	Housing techniques with frequent slurry removal by flushing, with: - non aerated flush - aerated flush	0.36 (non aerated flush) 0.30 (aerated flush)	NA	NA	NA	IRPP BREF 2003 IRPP BREF 2003
4.7.1.11	Kennel or hut housing on partly-slatted floor	0.38 (1)	NA	0.08	2.25	[183, Germany 2010]
4.7.4.4	Solid concrete floor and full litter for weaning pigs (forced or natural ventilation)	0.5 (1)	NA	0.08	3	[181, Germany 2010]
4.7.4.1	Pens for weaning pigs, with partly-slatted floor	0.53	NA		NA	IRPP BREF 2003
		0.5 (1)	NA	0.08	2.25	[184, Germany 2010]
4.7.4.2	Pens or flat decks with fully-slatted floor and slanted manure pit walls	0.029 – 0.324 (2)	1.8-5.98	NA	NA	[179, Spain 2010]
4.7.4.3	Manure collection in water	0.12 – 0.16 (2)	NA	0.132	5.4	[177, Netherlands 2010]

NA= Not available.
(1) Values derived by expert judgement based on conclusions by analogy.
(2) Measured values.

4.7.4.1 Pens for weaning pigs with partly-slatted floor

Description

The principle of reducing ~~limiting~~ the emitting manure surface is used by applying a partly concrete solid floor. Pens may be fitted with a sloped floor to one slatted section, or with a convex floor and ~~with~~ slats at both sides, with two manure channels (see Figure 4.56).

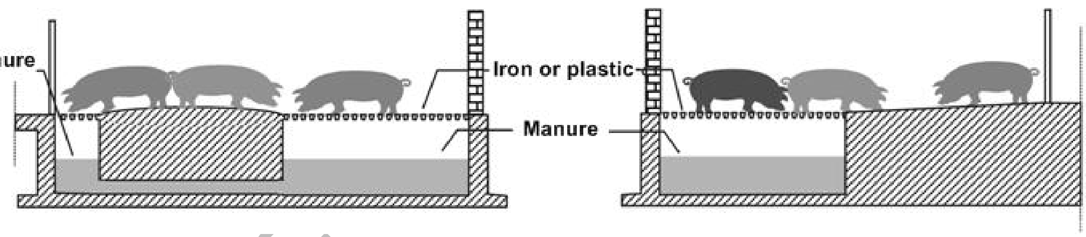
The slats can be ~~iron~~ metal, or plastic; concrete slats can also be used. In general, the buildings (walls and roof) are insulated.

Manure is handled as ~~a~~ slurry and it is ~~often~~ drained through a pipe discharge system ~~where the individual sections of the manure channels are drained~~ via plugs or ~~via~~ gates. ~~in the discharge pipes. The channels can also be emptied~~. The channels are usually drained after the removal of each group of pigs, ~~often~~ in connection with disinfecting the pens, i.e. at intervals of 6 - 8 weeks.

This housing type is normally equipped with mechanical ventilation, either in the form of negative-pressure or balanced-pressure ventilation. The ventilation is dimensioned for a maximum output of around 40 – 50 m^3 per hour per place. Auxiliary heating is available in the form of either electric fan heaters (room heating) or a central heating plant with heating pipes (floor heating). ~~In Denmark this solution is named the 'two climate system'.~~ Naturally-ventilated designs are also applied.

In Denmark, houses with partly-slatted floors are called 'two-climate system': the floor below the covered laying area is heated with hot water pipes during the first couple of weeks, and then it is turned off since the heat production of the pigs is sufficient for keeping them warm.

Windows are installed in the housing to allow the pigs to be easily checked.



Source: [42, Netherlands 1999]

Figure 4.56: Partly-slatted floor with ~~iron~~ metal or plastic slats and convex or sloped concrete floor

Achieved environmental benefits

Limiting the manure surface in the manure channel achieves ammonia emission ~~a~~ reductions. ~~of 43 % (0.34 kg NH~~$_3$ ~~per pig place per year). The reduction can in fact only be achieved by changing the design of the pen. This design is similar to the previous design, although a higher~~ The highest reduction is achieved with the use of ~~which is attributed to~~ the convex or sloped flooring.

Cross-media effects

The naturally-ventilated design uses less energy compared to the reference system [291, IRPP TWG 2002]. Water consumption is higher for higher slatted to solid floor ratios. [261, France 2010]

A partly-slatted floor may entail increased requirements in temperature control and general management, as solid floors can get soiled, in particular at high temperatures (see general remarks in Section 4.7). Dirty floors have implications on pig hygiene and health and on odour emissions.

Operational data

A reduction in ammonia emissions by 34 % (0.53 kg NH_3 per pig place per year) is achieved when applying this technique. This technique has been applied in Denmark and its performance is therefore compared with the emission level of the reference obtained in Denmark (0.8 kg NH_3 per pig place per year).

The proportion of slatted-to-solid floor is frequently around one-to-one. The average ammonia emissions are estimated at 0.5 kg of NH_3 per animal place and year, with since a measured range of 0.2 – 0.7 kg was measured. Dust emissions are also considered to be on average 0.08 kg PM_{10} per animal place and year. [184, Germany 2010]

Odour emissions are reported from Germany equivalent to 75 ou_E/s per Live Unit (LU). Odour emission factors vary depending on the growth stage of the animals, as displayed in Table 4.105.

Table 4.105: Odour emission factors for weaned piglets, in Germany

Variable	Unit	Stage of growth		
Live weight	kg	up to 10	up to 25	up to 30
Live mass	LU/animal	0.02	0.03	0.04
Emission factor	ou_E/s/ap	1.5	2.25	3.0
Source: [474, VDI 2011]				

The "two climate" system applied in Denmark is reported to have ammonia emissions 40 % lower than those from a fully-slatted system.

Applicability

The system with partly-slatted floor or a convex floor can be applied in new houses. In existing houses, the applicability depends on the design of the existing manure pit.

An adaptation of existing slatted-floor pens would be possible by clogging part of the slatted floor (without changing the total surface of the pit).

Dutch legislation does not allow this system in new buildings.

Economics

Extra investment is not needed if this technique is alternative could be applied instead of a fully-slatted floor. Annual costs are also similar.

Extra costs related to the retrofitting of this technique in existing buildings with fully-slatted floors are shown in Table 4.106.

Table 4.106: Extra costs associated to the retrofitting of partly-slatted floors in existing fully-slatted floored pens for weaned piglets, in Spain

System	Reduction ([1])	Extra costs		
	%	EUR/ap/yr	EUR/tonne pig produced	EUR/kg NH_3 reduced
Pens with partly-slatted floor retrofitted in existing houses (piglets from 6 to 20 kg)	25 – 35	0.88 – 2.25	1 – 2.6	3.49 – 12.50
([1]) Data refer to a comparison made against fully-slatted floored pens. *Source*: [500, IRPP TWG 2011]				

Driving force for implementation
Please TWG provide information

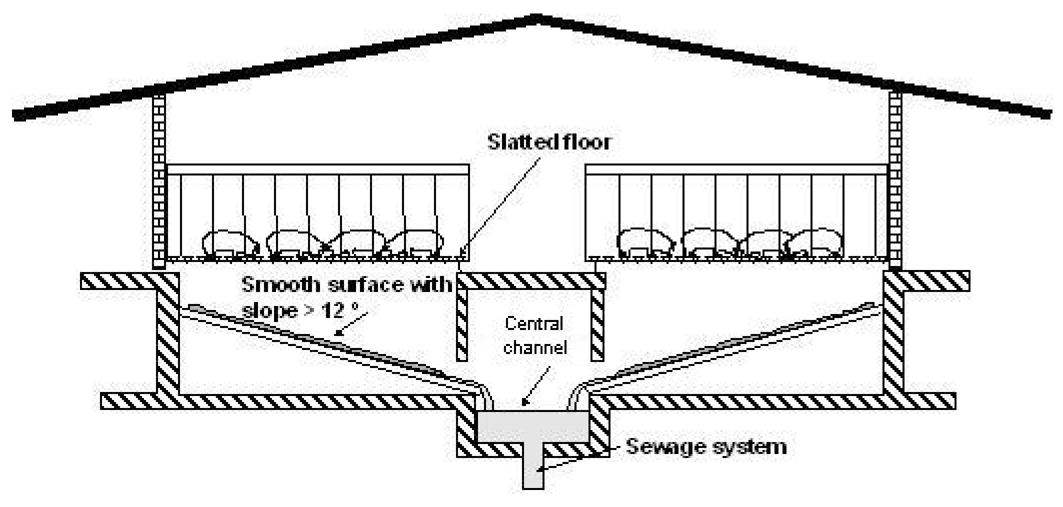
Example plants
In Denmark, at the time of writing (2013), only housing systems with partly-slatted floored pens are built; it is estimated that at least 80 % of all weaned piglets are housed in the 'two climate' systems. The system is also applied in the Netherlands and Germany.

Reference literature
[42, Netherlands 1999] [397, Denmark 2000] [184, Germany 2010]

~~4.7.4.2~~ Pens or flat decks with fully-slatted flooring and a manure pit with sloped walls ~~concrete sloped underground floor to separate faeces and urine~~

Description
~~The principle is described in Section 4.6.2.1.~~
The very smooth sloped surface that is placed under the slatted floors allows the urine to drain continuously and the slurry to move towards the central pit. Frequent or continuous emptying of the central slurry channel is possible, to further reduce manure emissions (Figure 4.57).

At the end of the weaning period, dry faeces are easily removed by water jets.



Source: [391, Italy 1999]

Figure 4.57: Flat decks or pens with concrete sloping ~~sloped~~ underground ~~floor~~ ~~underneath~~ to separate faeces from ~~and~~ urine

Achieved environmental benefits
The immediate removal of manure to the central channel and the immediate draining of urine achieve~~s~~ a reduction of 30 % of ammonia emissions, since (~~0.42 kg NH_3 per pig place per year (I)~~) emissions predominantly come from the slurry remaining on the slopes.

Cross-media effects
Flies can be a serious problem, especially when the manure sticks to the slope. [261, France 2010]

Operational data

In Spain, with a continuous removal system, ammonia and methane emissions have been recorded; in particular, NH_3 emissions have been measured from 0.029 to 0.324 kg/ap/yr, of ammonia corresponding to approximately a 50 % emission reduction, and CH_4 emissions have been measured from 1.08 to 5.98 kg/ap/yr, of methane per animal place per year corresponding to about 65 % emission reduction, in comparison with a deep pit system.

No additional energy consumption is required.

Applicability

With a manure pit of sufficient depth, this technique can be easily be applied to in existing housing, but only if a discharge system is located in a central position of the pen for emptying the manure channel. If this is not the case, the entire floor plate of the manure pit has to be removed to install the discharge/sewage system, which is only possible at significant extra costs.

Economics

Investment costs are estimated to be less than the reference, if the benefits are included in costs calculation. Extra costs compared to the system with the deep pit have been calculated and refer both to the animal place and the final production. They are displayed in Table 4.107. [179, Spain 2010]

Table 4.107: Extra costs for partly-slatted floors with manure pan, compared to fully-slatted floors with deep pit

Production	Reduction	Extra costs ([1])		
	%	EUR/ap/yr	EUR/tonne pig produced	EUR/kg NH_3 reduced
New to build house	30 – 60	0.00 – 0.23	0 – 0.4	0.00 – 1.16
Retrofitting existing house		1.27 – 2.67	2.2 – 4.6	2.94 – 12.36

([1]) Extra costs are reported in comparison to a reference system of a fully-slatted floor with deep pit, emptied at the end of the cycle.
Source: [179, Spain, 2010]

Driving force for implementation

Please TWG provide information.

Example plants

A few applications are known in Italy. The system is also applied in Spain.

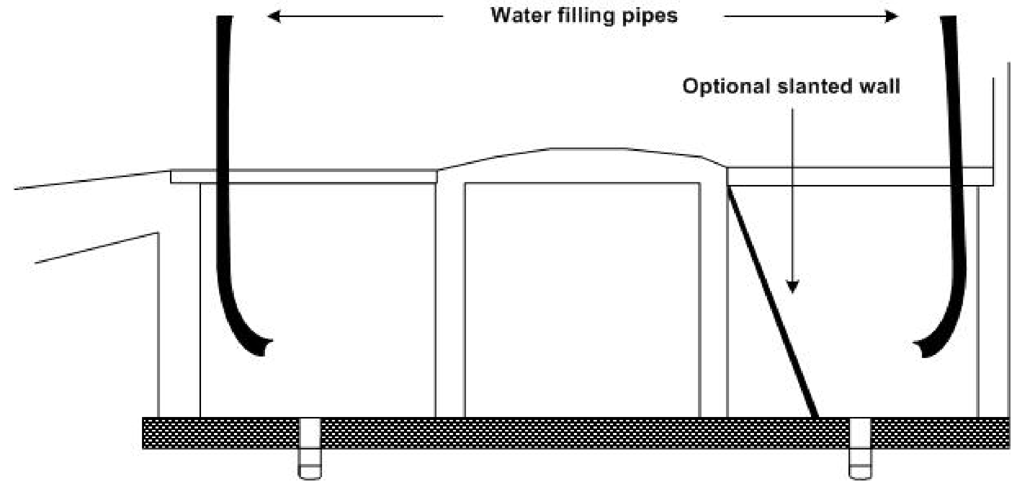
Reference literature

[391, Italy 1999] [292, Italy 2001] [179, Spain 2010].

4.7.4.3 Manure collection in water

Description

The manure is collected in the cleaning water that is kept in the channel after cleaning. After each breeding cycle round, and before the pens are cleaned, the manure channel is emptied, then the pens are cleaned. Cleaning water is kept in the channels which and is automatically refilled until a level of 120 –150 mm is reached (see Figure 4.58). Slurry collection is done through pipes of 200 mm diameter.



Source:[178, Netherlands 2010]

Figure 4.58: Cross-section of a variation of a system for rearing weaners with manure collection in water

If the system complements a fully-slatted floor, slats are made of triangular iron/metal elements, except for slats around the feeding trough that are made of plastic. In partly-slatted floors ~~solutions~~, slats can be at one side of a sloped solid pavement, or at both sides of a central convex solid floor. In this latter case, the feeding equipment is placed over the solid floor.

The minimum depth of the channel is 500 mm. Slanted channel walls are optional variations for the further reduction of the ammonia emitting surface. In the Netherlands, one slanted wall is permitted.

Achieved environmental benefits
A ~~strong~~ high reduction of ammonia emissions is possible. ~~Slanted walls in the channel can further limit the emission surface.~~

Cross-media effects
Water is used in abundance. Dilute slurry is disadvantageous to storage and subsequent field application; furthermore, it is not suitable for biogas production.

Operational data
Pens of approximately 16 by 3 metres (divided into areas for 8 weaners each) host 80 weaners at a minimum required solid surface of 0.12 m^2 per animal.

In the Netherlands, measured ammonia emissions are reported in the range of 0.12 – 0.13 kg per animal place per year, if the density is kept at 0.3 m^2 per animal ~~head~~, and ~~or it is~~ 0.16 kg of ammonia per animal place per year, at a density of 0.4 m^2 per animal. In addition, dust and odour emissions have been measured in the Netherlands at 0.132 kg PM_{10}/ap/yr and 5.4 ou_E/s/ap, ~~each year~~.respectively.

~~Each animal is considered to also cause/ 0.132 kg of PM_{10} dust and 5.4 OU_e each year.~~

Economics
~~Investments are around~~ Extra investment costs are reported from the Netherlands equivalent to EUR 21 ~~13~~ per animal place ~~(annualised to EUR 2 per year)~~, with annual costs equivalent to 2 EUR/ap/yr (including depreciation, interest, maintenance and all other operating costs) for a fully-slatted floor system. [589, Netherlands 2010]

Applicability
The technique is difficult to implement in existing buildings.

Driving force for implementation
This system is relatively inexpensive for new buildings.

Example plants
In the Netherlands, this system was very popular in new housing systems for the reduction of ammonia emissions, before air cleaning systems (wet scrubbers) became widespread.

Reference literature.
[177, Netherlands 2010] [608, Netherlands 2010]

4.7.4.4 Pens with a solid concrete floor with litter

THIS SECTION CONTAINS PARTS FROM SECTION 4.6.3.12 (IRPP BREF 2003) AND TEXT RELATED TO WEANED PIGLETS FROM CURRENT SECTION 4.7.1.12

Description
The concrete solid floor is almost completely bedded with a layer of straw or other ligno-cellulose materials (e.g. sawdust) to absorb urine and to incorporate faeces. Solid manure is obtained, which has to be frequently removed in order to avoid the litter becoming too wet. In cooler climatic regions, the floor area may be divided such that a fully insulated kennel or creep (heated) provides a lying area for the weaned pigs with access to a fully bedded dunging area. Some straw is provided in the kennel or creep. A schematic representation of the housing system with pens on solid concrete floor with full litter (deep litter) is given in Figure 4.47, in Section 4.7.1.12.

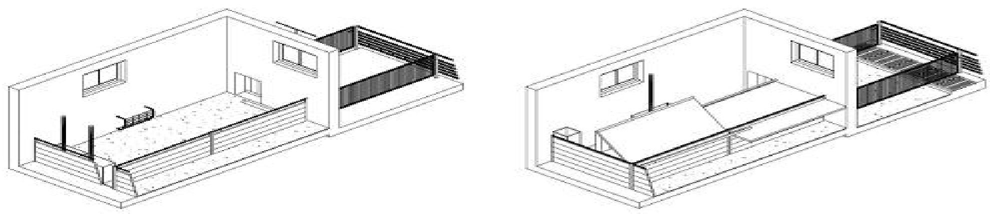
Post-weaning rearing houses are mainly based on a manure management system with deep litter [329, CORPEN 2003]. The technique operates typically in open-climate, naturally-ventilated houses. The technique can also be applied in closed, insulated, mechanically-ventilated houses, in a variation that uses a smaller quantity of bedding for the littered floor at the beginning of the rearing period and a regular addition during the cycle [185, Germany 2010]. In both cases, automatic feeding and drinking systems are used, the group size is up to 100 animal places and a space of 0.35 – 0.4 m^2 per animal is provided. In the deep litter system, bedding is spread every week and manure is removed at the end of the rearing period.

~~Lying areas can be covered and an external yard with solid bedding can be added, this being required~~ The plane littered-floor variation can be combined with a fully-bedded yard with a concrete floor, which is a requirement for ecological farming. In a variation of this technique, a covered lying area is present.

In Figure 4.59, a plane littered-floor system with a bedded yard (with and without a covered lying area) is illustrated.

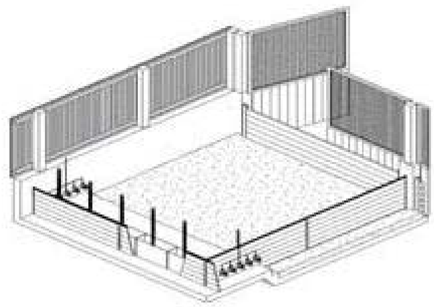
A schematic representation of an outdoor climate house with deep litter is given in Figure 4.60. A raised-plan concrete feeding ~~eating~~ area may be ~~is~~ constructed~~,~~ to lead piglets ~~are led~~ to prepare themselves a defecating area where sufficient space is available. [185, Germany 2010] [420, Ramonet 2003]

Buildings are kept cool, with plenty of straw to absorb urine, preventing wet surfaces. They are washed/cleaned and dried completely between batches. [535, UK 2011]



Source: [185, Germany 2010]

Figure 4.59: Housing system with littered floor with yard (with or without covered laying area) for weaned piglets



Source: [181, Germany 2010]

Figure 4.60: Housing system with deep litter for weaned piglets

Achieved environmental benefits

See also Section 4.7.1.12.

If the dunging area is cleaned regularly or an adequate quantity of straw is added in order to absorb urine to avoid wet open surface areas, ammonia emissions are low.

For naturally-ventilated systems, low energy consumption is achieved. No additional energy for heating is required.

Cross-media effects

Poorly maintained litters (inadequate quantity of straw and insufficient frequency of addition) can lead to emissions of odours and ammonia higher than those measured with fully-slatted floor. [261, France, 2010]. Emission of greenhouse gases is also possible.

In the closed system of littered-floor, the straw bed might warm up in the summer. The functional reliability of the system, under extreme climatic conditions, is not always guaranteed.

Management requirements are higher, due to the necessary regular littering of the floor and possible need for dung removal.

Operational data

It is expected that the use of straw will allow ~~pigs~~ ~~the~~ weaners to control the temperature themselves in systems where insulated kennels or creeps are not used, thus requiring no additional energy for heating. The system ~~is spacious but needs clear~~ requires cleared concrete areas in summer at feeding places for the pigs to cool down. If a ~~possible~~ covered lying area is present, the litter quantity needs to be adjusted to the temperature and the cover must be removed at high temperatures. Manual dung removal from the covered lying area may also be necessary.

In order to maximise their exposure to wind, naturally-ventilated houses should be situated at right angles to the main wind direction. [181, Germany 2010]. The ventilation rate for the mechanically-ventilated configuration is reported at 3.5 – 7 m^3/h/ap for the cold season and 20 – 50 m^3/h/ap for the warm season [185, Germany 2010].

In one ~~the~~ whole cycle of weaned piglets on deep litter, a quantity of approximately 15 kg of sawdust or 6 kg of straw are used per piglet per cycle (having about the same amount of dry matter), which results in ~~means~~ a production of about 17 kg of 'composted' manure containing ~~of~~ sawdust or straw at the end of rearing cycle [261, France 2010]. On a yearly basis, the used straw is approximately 30 to 60 kg per animal place.

In France, in deep litter systems for rearing weaned piglets, the required straw quantity is 10 – 15 kg per piglet per cycle [329, CORPEN, 2010]

Resources demand, as reported from Germany for two variations of the technique, are presented in Table 4.108.

Table 4.108: Resources demand for two different variations of solid concrete floor housing systems with litter for weaned piglets (8-28 kg)

System	Electricity	Bedding material	Cleaning water	Fuel	Source
	kWh/ap/yr	kg/ap/yr	l/ap/yr	kg/ap/yr	
Deep litter, open climate, with natural ventilation	2	53 (1) from 40 to 60	150	NA	[181, Germany 2010]
Littered-floor combined with yard; closed house with forced ventilation	12	35	150	170	[185, Germany 2010]
NA= Not available. (1) 150 g/animal per day.					

Reported emissions from weaned piglets ~~fattening pig~~ houses have been measured ~~in Germany~~ under different conditions and are summarised in Table 4.109. Tests carried out in France showed that rearing weaned piglets on deep litter system with sawdust produced 4 times less ammonia than rearing them on the same system with straw; while, the quantity of manure produced per piglet was identical. Higher emissions due to the external yard are presumed, but have not been estimated. [181, Germany 2010]

Table 4.109: Emission levels associated with straw-littered systems for rearing of weaned piglets

System	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
	kg/ap/yr				ou_E/s/ap	
Littered-floor with straw and forced ventilation	0.5 (0.2 – 0.7)	NA	NA	0.08	3 ([1])	[181, Germany 2010]
Deep litter with straw and natural ventilation	0.5 (0.2 – 0.7)	NA	NA	0.08	3 ([1])	[185, Germany 2010]
Deep litter with straw ([2]) and forced ventilation, removal of litter after 5 consecutive batches, regular addition of straw	0.43	0.60	0.16	NA	NA	[532, Nicks et al. 2002]
Sawdust litter ([2]) and forced ventilation, not regular addition of sawdust, manual scatter of manure every 10 days	0.11	0.29	0.57	NA	NA	[532, Nicks et al. 2002]

NA= Not available.
([1]) Values have been calculated from an emission factor of 75 ou_E/s/LU (weaned piglets up to 30 kg (average weight 20 kg).([2]) Values calculated from measured data reported in g/head per day, for 53 days breeding time and 6.33 cycles a year.

Applicability
The system can be applied in all new housing. For existing housing, this technique ~~it~~ may be applicable in buildings with concrete solid floors.

The scarcity of bedding materials in some geographical areas may be a limitation to the use of such a system.

In regions with hot climates, full litter is normally not ~~applied~~ applicable.

Economics
~~Capital costs for weaning pig houses are expected to be in the same range as with the reference technique.~~ The annual operational costs are expected to be higher than for reference systems. [291, IRPP TWG 2002]. The cost of straw is reported to be increasing.

Driving force for implementation
Improved animal welfare.

Example plants
The technique is applied in Germany. According to a survey carried out in 2008 on livestock buildings (SCEES Survey of 2008), in France, 6.9 % of post-weaning places were using littered systems. About 4 % of the weaning pigs in Italy are kept on fully bedded systems. In the UK, kennels and creeps (with heat) in association with a fully bedded system are common, with group sizes of around 100 pigs of ~~from~~ 7 kg (weaning) up to 15 or 20 kg.

Reference literature
[181, Germany 2010] [185, Germany 2010] [261, France 2010]

4.7.5 System-integrated housing techniques for growing and finishing fattening pigs

In Table 4.110, performances of housing techniques for fattening pigs concerning NH_3, CH_4, N_2O, dust and odour are summarised. Some of these techniques have been described in Section 4.7.1 and are not repeated here.

Table 4.110: Emission levels of system-integrated housing techniques for fattening pigs

Section number	Housing system	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
		kg/ap/yr				ou_E/s/ap	
4.7.1.1	Fully-slatted floor with deep pit	2.39 – 3.0					IRPP BREF 2003
	• Removal every 2 months	4.6 (1)					[266, Austria 2010]
	• Removal at the end of cycle	3.6 (1) (2.0 – 7.0) (2)	1.0 – 6.0 (2)	0.02 – 0.15 (2)		6.5 (2)	[189, Germany 2010] [474, VDI 2011]
		2.91 (1.37 – 3.95) (2)	2.1 (2)	0.035 (2)		1.2 (2)	[269, France 2010] [270, France 2010]
	Partly-slatted floor • Removal 2 – 3 times per cycle	2.63 (2)	2.42 (2)	0.0432 (2)			[271, France 2010]
	• Removal twice per cycle	3.6 (2 – 7) (2)	4 – 30 (2)	0.02 – 0.15 (2)	0.24 (1)	7 (1)	[192, Germany, 2010]
		3.6 (2)				68 (2)	[272, France 2010]
4.7.1.2	Fully-slatted floor with a vacuum system	2.25					[292, Italy 2001]
		0.54 – 1.85 (2)	0.42 – 2.35 (2)				[187, Spain 2010]
		3.64 (1)	1 – 6 (1)		0.24 (1)	7 (1)	[474, VDI 2011]
4.7.1.3	Partly-slatted floor with a vacuum system • with metal slats	1.55 – 1.95					IRPP BREF 2003
	• with concrete slats	1.8 – 2.25					IRPP BREF 2003
4.7.1.4	Partly-slatted floor with slanted walls in the manure channel	1.23 – 1.61 (2)	0.59 – 1.46 (2)				[188, Spain 2010]
		1.0 – 1.2					[589, Netherlands 2010]
4.7.1.5	Partly-slatted floor with a scraper and concrete slats	1.2–1.5					IRPP BREF 2003
		1.4–1.8					IRPP BREF 2003
4.7.1.6	Partly-slatted pens with convex floor • Slanted walls, metal bars, 0.18 m^2/ap	1.01 (0.99 – 1.02) (2)			0.275 (2)	17.9 (2)	[194, Netherlands 2010]
	• Slanted walls, metal bars, 0.27 m^2/ap	1.4 (2)			0.275 (2)	17.9 (2)	[195, Netherlands 2010]
	• Slanted walls 0.18 m^2/ap	1.2					[186, BE Flanders 2010]
4.7.1.7	Partly-slatted floor with a reduced (in width) manure pit	0.89 – 1.69	0.9 – 1.82 (2)				[196, Spain 2010]
4.7.1.8	Partly-slatted floor with slurry cooling channels • 25 – 49 % solid floor, frequent removal by vacuum, no bedding and 10 W/m^2 cooling effect	1.16 (3)					[268, Denmark, 2010]

Section number	Housing system	NH_3	CH_4	N_2O	PM_{10}	Odour	Source
		kg/ap/yr				ou_E/s/ap	
	• 50 – 75 % solid floor, frequent removal by vacuum, no bedding and 10 W/m^2 cooling effect	1.52 (3)					[268, Denmark, 2010]
	Partly-slatted floor, manure scraper, straw addition • 50 W/m^2 cooling effect	2.2 (3)					[268, Denmark, 2010]
	• 10 W/m^2 cooling effect	2.6 (3)					[268, Denmark, 2010]
4.7.1.9	FSF or PSF with manure surface cooling fins • concrete slats	1.4					IRPP BREF 2003
	• metal slats	1.2					IRPP BREF 2003
4.7.1.10	Frequent slurry removal by flushing • PSF, concrete slats, aerated	0.90					IRPP BREF 2003
	• PSF, concrete slats, non-aerated	1.20					IRPP BREF 2003
	• FSF, permanent slurry layer, non-aerated	2.1					[292, Italy 2001]
	• FSF, permanent slurry layer, aerated	1.35					[292, Italy 2001]
4.7.1.11	Kennel or hut housing on partly-slatted floors	2.4 (1) (1.0 – 6.0) (2)	1 – 4 (2)	0.11 – 0.15 (2)	0.24 (1)	7 (1)	[190, Germany 2010]
4.7.1.12	Deep litter floor system with straw	4.2 (1) (1 – 6) (2)	1.6– 18 (2)	0.6 – 3.7 (2)	0.32 (1)	3.9 (1)	[193, Germany 2010] [474, VDI 2011]
	Deep litter floor with sawdust or soft wood particles (removal at the end of cycle)	5.65 – 7.53 (2)					[531, Ramonet et al. 2002]
	Littered floor with removal once a week	2.43 (1) (1.0 – 5.0) (2)	0.8 – 2.8 (2)		0.32 (1)	6.9 (1)	[191, Germany 2010] [474, VDI 2011]
4.7.5.1	Solid concrete floor with littered external alley	1.6					IRPP BREF 2003
4.7.5.2	PSF with slurry V-shaped manure belts	1.05 – 1.20 (2)	0.94 (2)	0.11 (2)		5.9 (2)	[198, Netherlands 2010]

(1)Values derived by expert judgement based on conclusions by analogy.
(2) Measured values.
(3) Modelled values (e.g. results based on N balance).

4.7.5.1 Solid concrete floor with littered external alley

Description

A small door allows the pigs to go out to defecate dung in an external alley with a concrete floor that is covered with straw (0.3 kg straw per pig per day) and that has a slight slope (4 %) that ends in a manure alley with a scraper (see Figure 2.25). By moving around in the external alley, the animals push the straw with the manure into the lateral channel. All the manure falls into the channel and is scraped one step down, and once a day it is scraped on to a manure belt. The lateral channel is fenced off, allowing space for the sludge to pass.

A scraper removes the sludge (3 – 7 kg solid per pig per day) to a solid manure heap. The sludge is moved along a channel that has a perforated area just before where the sludge is dragged upwards towards the manure heap and this allows most of the fluid to be drained. The manure heap itself is also drained, and the liquid is collected (approximately 0.5 – 2 litres of liquid per pig per day) in a suitable basin underneath the storage.

Achieved environmental benefits

A reduction in ammonia emissions of 20 to 30 % is achieved compared to the fully-slatted system.

Cross-media effects

The energy use of the system is about 6 kWh, operating 0.5 hours per day in a housing unit for 450 pigs.

The use of litter on the solid floor inside the house is not recommended for the Italian heavy pigs because they are normally fed with liquid feed, and the litter becomes too moist in a very short time. Using litter only in the external alley prevents avoids this negative effect and at the same time maintains the solid manure production. The solid manure is applied to land as fertiliser where it has a positive effect on soil structure.

Odour might be a problem if not enough straw is used [291, IRPP TWG 2002].

Operational data

Ventilation is natural and operated manually. Automatic (phase) feeding and watering is applied. Heating is not required.

Applicability

Systems with an external alley are not applicable in cold climate areas. In France, this system is used for specific programmes against trichinellosis, with individual control before departure for slaughter. It is reported though to degrade working conditions.

Economics

The costs for implementing and running this system are not expected to differ significantly from those given in Section 4.7.1.12 for 'Solid concrete floor and with full litter for weaning, growing and fattening pigs' and as shown in Table 4.94.

Reference literature

[292, Italy 2001]

4.7.5.2 PSF with slurry V-shaped manure belts

Description

V-shaped manure belts roll inside the manure channels of partly-slatted pens, covering the whole channel surface, so that all faeces and urine are dropped on them. Belts are made of plastic, PP (polypropylene) or PE (polyethylene) and operate are run frequently (at least twice a day) to discharge separately ~~carry~~ urine and faeces from the animal house to closed manure storage.

Manure belts can fit channels in pens with one channel and sloped solid flooring (4.5 degrees), or pens with convex flooring dividing two channels (of the two, the front channel is much smaller than the back channel). The system is generally designed to provide a surface area in the pen in the range of 0.75 – 1 m^2 per animal place, of which at least 0.30 m^2 ~~of solid flooring~~ per animal should be solid ~~is provided~~. The solid floor can be plastic covered or partly galvanised metal covered. Slats are preferably triangular in shape and made of iron, alternating 15 mm of bars with 15 mm of open space. Alternatively, slats over the wider channel can be 80 mm bars in concrete with 12 mm of open space, alternating.

The technique can be used with two possible variations of partly-slatted floors:

- at the front of the pen there is an inclined solid floor and at the back, a slatted floor above the manure channel;
- the partly-slatted floor is combined with a convex solid floor; at the front and the back of the pen, there is a slatted floor above the manure channels.

In farms using this technique, one or two floors are possible in the stable. Proper operation is monitored by the twister frequency of the manure belts.

Achieved environmental benefits

The system ~~has been designed for more sustainable pig production, allowing~~ allows a notable reduction of ammonia and odour emissions,. ~~while having a negligible effect on nitrous oxide emissions~~ due to the daily separate removal of urine and solid manure, by means of the V-shaped belt, compared to a conventional house.

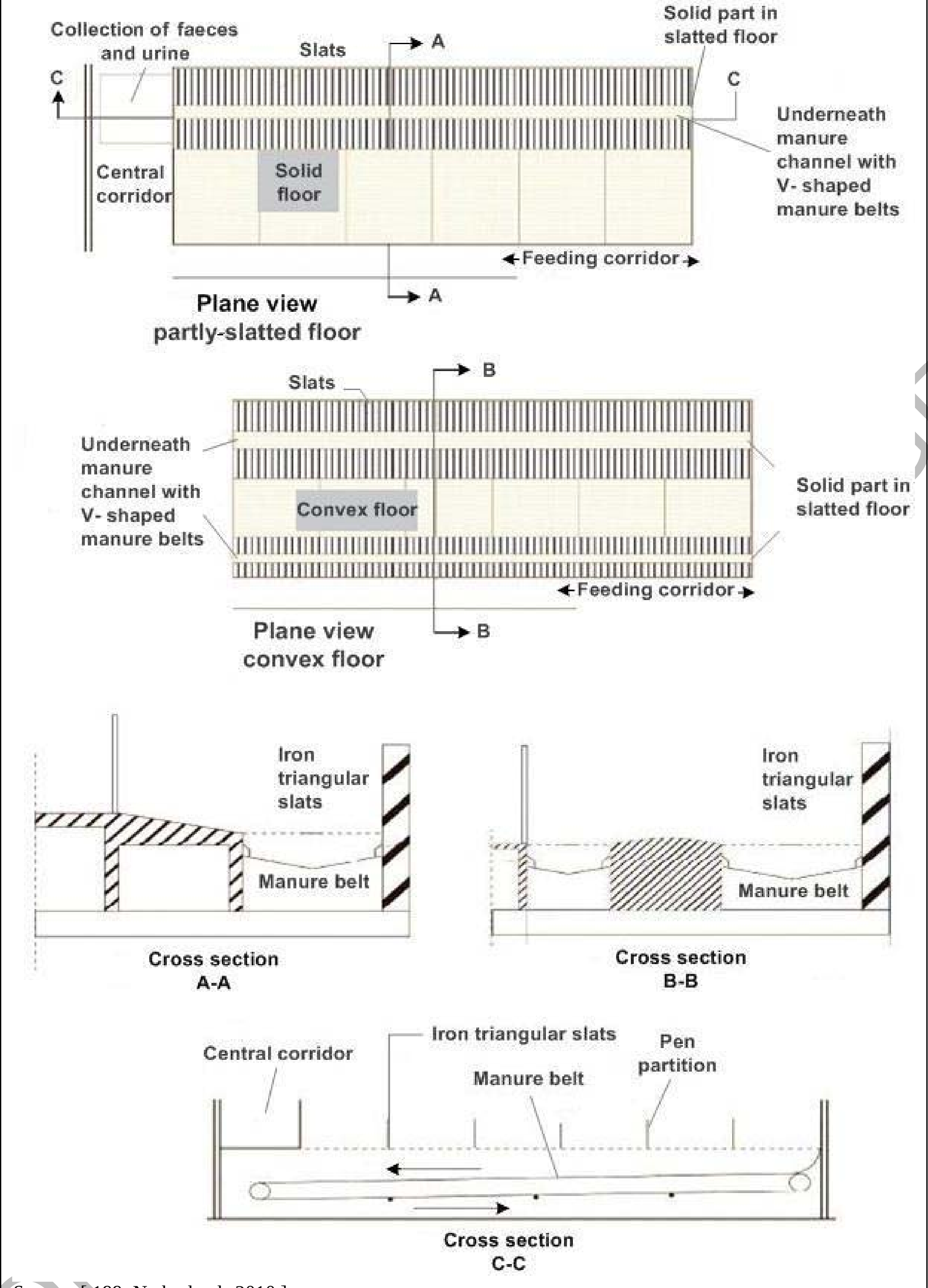
Cross-media effects

The system requires a slightly increased energy consumption, to operate the manure belts.

Cleaning of the belts is needed after each production round. A maintenance contract is also reported as necessary, for a complete check of the belts and the whole equipment, at least once a year.

Operational data

The V-shape is given by an inclination of 40 mm inwards of the two sides of the belt. Belts are inclined length-wise by 1 mm per metre (see Figure 4.61), are suspended with plastic or steel rollers to prevent them from hanging, and are kept clean by means of terminal scrapers.



Source: [199, Netherlands 2010]

Figure 4.61: Schematic plans and sections of housings equipped with V-shaped belts

Depending on the surface of the slatted area, the emitting manure surface is determined; hence, emissions vary as shown in Table 4.111.

Table 4.111: Emissions associated with the use of the V-shaped belt system depending on the provided surface per head

Total animal space per head	Ammonia	Methane	N_2O	~~PM_{10}~~	Odour
	kg/ap/yr	kg/ap/yr	kg/ap/yr		ou_E/s/ap
0.8 m^2	1.05	0.94	0.11	~~0.11~~	5.9
1 m^2	1.20	0.94	0.11	~~0.11~~	5.9
Source: [198, Netherlands 2010] [200, Netherlands 2010]					

With this technique, ammonia emissions measured in the Netherlands are 58 – 70 % (depending on the area per pig) lower than from a conventional housing system with a deep pit below the slatted floor; while, odour emissions are 74 % lower in comparison with the standard emission factor used in the Netherlands for growing-fattening pig houses (23 ou_E/s/ap).

No effects on methane and nitrous oxide emissions are reported.

An efficient separation of faeces and urine is achieved, resulting in very low phosphorus content of the urine and high dry matter content of the manure.

Applicability
Applicable to both fattening pigs and sow farms. Only suitable for new buildings. ~~It is not reported whether retrofitting is possible.~~

Economics
The cost benefit of the technique has been calculated in comparison with a conventional housing system for growing/finishing pigs; the results show an annual cost benefit equivalent to EUR 8.07 per animal place for a stable with one floor, and EUR 9.98 for a stable with two floors [198, Netherlands 2010]. The factors influencing costs are the following:

- In the Netherlands, separated urine has lower disposal costs than slurry. It is assumed an average slurry production of 1.1 m^3 per animal place per year.
- The lower investment costs reported for the system, in comparison with a conventional house, are due to the higher share of steel among the materials for construction of the system and are based on early 2007 prices. If steel prices rise by 25 %, then an additional cost of EUR 0.8 per animal place for the single floor barn and EUR 1.35 per animal place for the double floor barn have to be considered.
- In the stable with two floors, energy costs are lower, because the heat from the bottom floor partly heats up the top floor.

Detailed investment and annual costs reported from the Netherlands, in comparison with a conventional system for growing/fattening pigs are presented in Table 4.111, including also the case of a barn with a double floor.

Table 4.112: Investment and operational costs for partly-slatted floors with V-shaped manure belts, compared to conventional houses, in the Netherlands

	PSF with slurry V-shaped manure belts (one floor)	Conventional house		PSF with slurry V-shaped manure belts (two floors)	Conventional house
Animal places	2 160	2 160		4 320	4 320
Investment costs, VAT included (EUR/ap)	436	501		423	467
Annualised investment cost ([1]) (EUR/ap/yr)	50.26	55.91		48.02	52.19
Electricity and gas costs (EUR/average present pig)	6.9	6.9		3.5	6.9
Manure disposal costs (EUR/average present pig)	14.08	16.5		14.08	16.05
Total costs	71.24	79.31		65.6	75.9

([1]) Costs include buildings plus devices.
Source: [609, Wageningen 2007]

Driving force for implementation
The direct separation of urine and the solid part of the manure is an advantage.

This system has been conceived in the Netherlands, where the pressure on the environment from livestock rearing is considered excessive, hence the system is seen as a new concept in housing systems to improve the sustainability of pig rearing.

Example plants
At the time of writing (2013), this system is in use in two Dutch farms.

Reference literature
[198, Netherlands 2010] [199, Netherlands 2010] [200, Netherlands 2010] [609, Wageningen 2007]

4.8 Techniques for the reduction of ~~aerial~~ emissions to air within ~~livestock~~ poultry and pigs housing

4.8.1 Introduction

From the animals, bedding and manures that are kept inside the livestock houses, emissions to air ~~of aerial substances~~ arise. Techniques are in use to improve the indoor air quality and remove from the air these substances before they are ~~expelled~~ released from the housing. The basic reason to apply these techniques is to improve the animals' living environment and workers' conditions by removing excessive heat, dust and odour essentially.

These techniques are kept separate from the 'End-of-pipe' techniques that treat the air ~~just~~ before ~~expelling~~ releasing it into the environment (~~and that are~~ described in Section 4.9). Hence in ~~Section 4.8.5~~, the following sections describe techniques ~~are included~~ that are usually applied before end-of pipe systems even though the treated air has already left the animal houses.

Techniques presented in this Section 4.8 do not include those concerning the housing systems or techniques that achieve emission abatement by changing the properties of manure and, in this way, having an effect on the whole chain of manure management e.g. slurry acidification. Techniques presented in the next sections are mostly 'secondary' measures, being additional processes that do not change the fundamental operation of the core process and, in general, are characterised by a low level of complexity.

4.8.2 Ionisation

Description
An electrostatic field is created in the house ~~stable~~ to produce negative ions. Circulating airborne dust particles are charged by free negative ions and increase in weight. Under the gravitational force and the attraction ~~potential of the gradient~~ of the electrostatic field, the charged particles are ~~attracted~~ collected to the floor and room surfaces.

Achieved environmental benefits
Dust reduction in the range of 10 – 49 %. ~~At least a 25 % reduction of fine dust is achievable~~ **(MOVED BELOW)**. No effect can be expected on ammonia or odour emissions.

Cross-media effects
Increased energy use is necessary to supply high voltage power.

Operational data
It is reported that fine dust emissions are reduced by at least 25 % for PM_{10} and 10 % for $PM_{2.5}$ fraction during the whole broiler growing period [137, Netherlands 2010]; with average concentrations of 1.01 mg/m^3 and 0.07 mg/m^3 for PM_{10} and $PM_{2.5}$ respectively. [569, Report 215 Wageningen 2009].

Rows of negative DC ionisation units running are placed along the length of the house to generate electrons by means of their electrodes. Discharge electrodes are connected to a high voltage power supply to create a high density electron array (-30 kV DC), limited to a current of below 2.0 mA to ensure safety.

The minimum current from the voltage power supply is 1.3 mA. At least 0.45 m of discharge electrodes should be placed per square metre of living area. The minimum height of the discharge electrodes is 2.5 m above the floor. The minimum distance to grounded surfaces is 0.2 m. The roof and equipment in the housing should be grounded to prevent the accumulation of electrostatic voltage. Emitters cannot be installed under fans or ventilation channels.

Adequate safety measures need to be applied. The installation needs to be made to the highest professional standards and checked by an expert before connecting to the power source. Weekly control is needed to maintain a correct functioning.

Emissions have been measured in the framework of the Dutch official determination of reduction in poultry houses. Reported values per broiler place per year are 0.0117–0.0201 kg for PM_{10} and 0.00058 – 0.00142 kg for $PM_{2.5}$. [137, Netherlands 2010]

Applicability
The technique is generally applicable in new houses.

Economics
Investment costs for the acquisition of ~~a set of relevant devices~~ the necessary equipment (source of ionising radiation and 200 m of wire with emitters), for treating a surface of approximately 450 – 600 m^2 in a fattening pig house, is reported at approximately EUR 2 000. The corresponding annual running costs, including higher energy consumption, were reported at approximately EUR 8 per animal place. [154, Czech Republic 2010]

For broilers, in the case of a Dutch farm with 90 000 bird places, the extra investment costs per animal place are reported at EUR 0.65; while, the annual ~~operational~~ operating costs are EUR 0.01 per animal place. After amortisation (7 years) of the extra-investement costs, the total annual extra cost is calculated at about EUR 0.1 per animal place. [503, Vermeij 2011] ~~joined with energy consumption are approximately EUR 8 per animal place. [154, Czech Republic 2010]~~

Driving force for implementation
Workers and animals can enjoy better conditions because of the lower dust concentration. The abatement of dust concentration producs a reduced transportation of airborne transferable diseases.

Example plants
The technique is in use on two Dutch farms for broilers production, where measurements for determining the effective reduction of dust emissions are in progress.~~ in common use in the Netherlands~~

Reference literature
[569, Report 215 Wageningen 2009] [137, Netherlands 2010] [154, Czech Republic 2010]
~~ASG-Rapport 215: Measures to reduce fine dust emission from poultry houses: reduction from broiler houses by ionisation BWL2009.18.~~
~~Dolejs, Toufar: Air ionization in the stables of rearing pigs. Annual report of project NAZV QF1340.~~

4.8.3 Fogging

Description
Water is sprayed by nozzles at a high pressure (70 – 100 bar, or 1 000 psi) to produce fine droplets of up to around 10 microns. These droplets absorb the heat present in the atmosphere and evaporate, becoming water vapour or gas. Evaporation takes place very quickly so that walls or animals are not moistened.

The operation of these systems at a lower pressure (100 – 250 psi) produces droplets of around 200 microns in size and is called 'misting'. Water droplets are heavier and fall to the floor, moistening dust and other particles that become heavy enough to drop as well.

Fogging is also applied to reduce the indoor temperature in hotter climatic conditions.

Achieved environmental benefits
Dust emission reductions are achieved. Odour and ammonia emission reductions are possible by limiting the dispersion of dust, on which particles odorous compounds are attached.

Cross-media effects
Water and power consumption depends on climatic conditions, in the case the technique is also used for cooling the indoor housing environment. In experimental conditions, consumptions of 264 kWh of electricity and 17 m^3 of the water were recorded for a period of 90 days in a gestating sow house for 100 places for 90 days, where a compressor of 1.1 kW was used for spraying around 18 hours a day in a cycle of maximum length of 30 seconds.

For fattening pigs, the consumption of water is slightly under 1 litre per day per pig. That is compensated by a reduction of drinking water of about 0.5 litres per pig and day. [360, Boulestreau 2006]

Operational data
Concentration Abatement of pollution in indoor air of fattening pig houses is obtainable achievable in the range of at 22 – 30 % for ammonia, 14 – 46 % for dust and 12–23 % for odours. [261, France 2010]

Animals feel a thermal decrease during fogging. Therefore, for the use of the technique, caution must be given to sensitive stages of animal's life and to the climate conditions.

Applicability
There are no technical or zootechnical limitations for the application of the technique that is generally applicable to new and existing houses, for both pigs and poultry production.

Economics
Investment costs to equip fattener housings are as low as EUR 3.8 to 6 per animal, while costs per sow reach EUR 10 per animal place.

Economic consideration for the poultry sector are summarised in Table 4.113 and Table 4.114.

Table 4.113 compares fogging to other water spraying techniques that are in use for the only purpose of refreshing the indoor environment.

Table 4.113: Parameters and performances of fogging in poultry rearing as compared to water spraying techniques

Systems	Investment EUR/m^2	Pressure Bar	Advantages	Disadvantages
Water spray of incoming air	1.5 – 2	3 – 5	Low costs	Little effect, large waste. Used only with dynamic ventilation. Not for temperatures above 35 °C
Medium-pressure water fogging	2.5 – 3	20 – 70	Good cost/efficiency rate	Risk of moistening the litter, medium cooling
High-pressure fogging	5 – 8	> 70	Highest effectiveness	Sensitive to water quality
Source: [261, France 2010]				

In Table 4.114, the estimated costs for the application of a fogging system to a standard broiler house of 1 000 m^2 are presented.

Table 4.114: Estimation of the annual operating costs for a fogging system in a standard broiler house of 1 000 m^2 in France

Cost factor	Consumption of resources	Costs (EUR)
Water consumption	100 m^3 (EUR 0.76/m^3)	76
Maintenance	1 maintenance visit	150
Replacement parts	1 filter per year, oil for pump circuit, nozzles maintenance, pump replacement parts every three years	150
Electric consumption	5 CV pump working 10 hours a day for 30 days (EUR 0.05 /kWh)	55
Source: [354, ITAVI 2004]		

For an amortisation over 5 years, the total annual costs (investment: EUR 8/m^2, annualised investment cost: EUR 1.6/m^2, annual running cost: EUR 0.43/m^2) would range from EUR 0.078 to 0.156 per broiler place (animal density from 13 to 16 birds/m^2).

Driving force for implementation
The reduction of mortality, especially in poultry, and the improvement of fertility parameters in sows are the most significant improvements achievable for animal productivity.

~~Due to the refreshment effect, a decrease in poultry mortality is achievable by~~ In hot summers, animal mortality due to heat strokes causes economic losses of about 12 % in chicken and 6.5 % in turkey ~~meaning~~ rearing. A reduction of these losses of about 90 % for broilers and 80 % for turkeys ~~respectively~~ can be achieved with fogging. ~~compared to normal mortality~~. [354, ITAVI 2004]

Example installations
Fogging has also been reported to be used at latitudes as high as Finland. [144, Finland 2010]

Reference literature
[261, France 2010] [354, ITAVI 2004] [368, France 2010]

4.8.3.1 Atomisation of capturing and reacting agents (brumisation)

Description
Active chemical compounds are produced to be used with high pressure systems. The stereo chemical structure allows these compounds to capture odorant molecules, to inactivate them and eventually to transform them in their stable and non-odorant form; in this way, the process of odorous pollutants biodegradation is accelerated.

Different from the oil spraying technique described in Section 4.8.4, this family of products are hydrosoluble, so they are better dispersed when implemented in mist, through diffusion devices operating at high pressure, in order to maximise ~~to be dispersed in the very fine dimension that increases~~ the contact/reaction surface with the odorous substances to eliminate, and their transfer from the gaseous phase to the liquid phase.

Chemicals may have patented formulations. These products are formulated from active ingredients of plant origin and, from a chemical standpoint, the active substances are derivatives of carboxylic acids.

In general, chemical substances need to be registered and produced complying with the REACH regulation (Regulation 2006/1907 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals). Producers are requested to certify the absence of counter-effects on health and the environment.

Achieved environmental benefits

Odours are eliminated by the same equipment that can be used for the simple ~~refreshment~~ cooling of the livestock.

Cross-media effects

Water and chemical substances are the only reported consumptions. Documentation on the absence of environmental consequences or effects on animal or human health was not provided for the draft of this document.

Operational data

For atomisation, the equipment in use for fogging is run at high pressure and equipped with proper nozzles.

The application rates are adapted to the breeding conditions, temperature and humidity. The application in pig sheds ~~requires dilution of~~ can be done e.g. with diluted products by 1 % that are sprayed through nozzles ~~of~~ with a capacity of 4 ~~of~~ l/h, in treatments of 14 seconds at 6 minute intervals. For poultry, ~~the~~ one example of dilution is of 0.8 % ~~and the~~ with spraying intervals ~~are~~ of 30 seconds each 10 minutes.

Reduction efficiency achieved for the indoor ammonia concentration is reported to be at 79 % for a fattening pig house and 90 % for a broiler installation, with final NH_3 concentrations of around 2 ppm. Lack of perceptible odours by expert judgement is reported to be in the range of 200 – 300 m around the buildings [279, Fefana 2010].

~~At these application rates, the achievable abatement efficiencies~~ Achieved abatement efficiencies for a group of substances, monitored on the basis of their nature and odour in laboratory trials, are reported in Table 4.115. A complete olfactory measurement was not provided.

Table 4.115: Odour abatement efficiencies achieved by brumisation in laboratory trials ~~by nature of odour particles~~

Compound type	Formula	Olfactive threshold mg/m^3	Abatement %	Type of odour
Ammonia	NH_3	20	91.4	Pungent, irritant
Hydrogen sulphide	H_2S	$1 – 5\times10^{-3}$	54.0	Bad egg
Trimethilamine	$(CH_3)_3$-N	0.5×10^{-3}	89.2	Bad fish
Butyraldehyde	C_3H_7-COH	$20 – 50\times10^{-3}$	50.2	Apple
Butyric acid	C_3H_7-COOH	$4 – 50\times10^{-3}$	89.6	Rancid butter
Source: [279, Fefana 2010]				

Applicability

There are no technical limitations for the application of the technique that is considered generally applicable.

Economics

Costs per produced animal have been reported, depending on the needed amount of atomised product per capita**.** Average costs are shown in Table 4.116.

Table 4.116: Estimates of average costs for the atomisation of patented odour-abating chemicals by animal produced

Production	Product consumption	Average running cost (EUR per animal produced)	n. of cycles	Average running cost (EUR/ap/yr)
Fattening pigs	1 (0.25 – 1.5) g/day per pig	1.70	3.14	0.541
Broilers ~~Chicken~~	29.8 mg/day per broiler (25 kg per 30 000 broilers) in the final 4 weeks of rearing	0.014	6	0.002
Turkeys	66.2 mg/day per turkey (50 kg per 12 000 turkeys) in the final 9 weeks of rearing	~~0.024~~ 0.071	2.5	0.028
Ducks	29.8 mg/day per duck (25 kg per 18 000 ducks) in the final 10 weeks of rearing	~~0.071~~ 0.024	8.6	0.003
Source: [278, Fefana 2010]				

~~On average,~~ The installation costs are substantially the same as for the fogging technique described in Section 4.8.3 (on average, around EUR 15 000), and running costs are shown in Table 4.116. ~~one year of brumisation in a building would cost around EUR 10 000~~. [384, Fefana 2011]

Driving force for implementation
With odorous compounds, also toxic and sub-toxic substances are removed, such as ammonia. The improvement of animal respiratory comfort ~~ends up~~ results in an improved feed utilisation and growth rateof the animal. ~~No odours are perceptible within a radius of 300 m around the building.~~

Example plants
Studies on atomisation of the patented products have extensively been realised on poultry and pig farms. Less than ~~around~~ 10 installations for weaned pigs are reported to already use this technique. [384, Fefana 2011]

Reference literature
[278, Fefana 2010] [279, Fefana 2010] [384, Fefana 2011]

4.8.4 Oil spraying

Description
Pure rapeseed oil is sprayed by nozzles inside the house. Circulating dust particles are bound to the oil drops, and are collected in the bedding or litter; also, a thin layer of rapeseed oil is applied on the bedding, thus preventing dust becoming airborne.

Achieved environmental benefits
Reduction of fine dust emissions is an achieved benefit. No difference in ammonia emissions, nor in odour emissions are obtained.

Cross-media effects
~~No counter-effect has been reported.~~ Questions concerning contamination from oil particles are not solved. Oil residues may cause slippery floors or even fire hazards. Safety of animals and workers has to be demonstrated and the medium-long term potential for wall dirtiness is unknown. The application of an oil film results in a slightly less loose bedding. [582, Wageningen NL 2009]

Operational data

Less then 1 % of the oil droplets should be smaller then 10 micrometer.

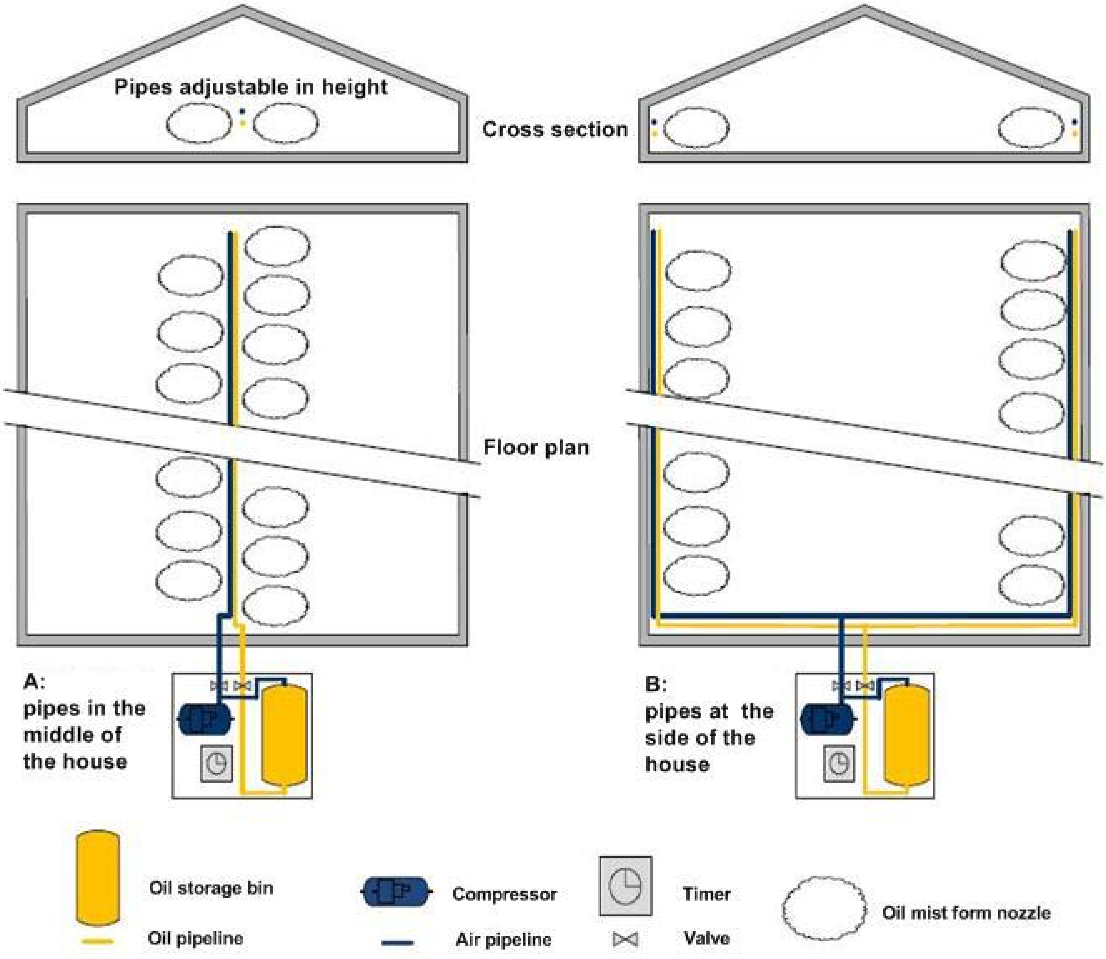
Dust reductions of ~~50~~ 54 % are obtained at least for PM_{10} fraction and 75 % for $PM_{2.5}$ fraction.

Oil and air are sprayed simultaneously into the nozzles. Pipes and nozzles can be placed in the middle of the house or along the side walls (see Figure 4.62). There should be one nozzle per 28 m^2 of living area.

A minimum of 12 ml of oil per square metre should be spread once per day. Operators must keep out of the house during application.

Applicability

The technique is suitable to birds of at least 21 days of age. The system can be easily fitted in new and in existing houses. Oil spraying is better suited for broilers than for layers, because less equipment is present in the shed that can be contaminated.



Source: [140, Netherlands 2010]

Figure 4.62: Schematic view of an oil spraying system

Economics

Additional work is required to clean the oil residues from the walls and to clean the system itself. The system durability is around 10 – 15 years. It is reported that the extra time required for cleaning after treatment is approximately equivalent to one-fourth of the time needed for cleaning when no treatment is applied. [582, Wageningen NL 2009]

Extra-costs were estimated in the Netherlands for common broiler and turkey housings and are presented in Table 4.117.

Table 4.117: Extra-costs related to the technique of oil spraying in poultry housings

Type of animal	Extra investment (EUR/ap)	Annualised extra investment (EUR/ap)	Annual operating extra-cost (EUR/ap)	Total annual extra-cost (EUR/ap)	Total annual extra-cost (EUR/produced animal)
Broiler, housing for 90 000 birds	0.5	0.09	0.09	0.18	0.026
Turkey, housing for 20 000 birds	2.2	0.39	0.93	1.32	0.46
Source: [503, Vermeij 2011]					

Driving force for implementation
Better working conditions ~~are created because of the~~ due to lower dust concentration. Along with the increased productivity, possibly lower investments and structural flexibility can derive. The application of an oil film reduces personal dust exposure by 75 to 95 %., which is an important advantage in comparison with the use of end-of-pipe techniques for cleaning the air, such as wet scrubbers. [582, Wageningen NL 2009]

This technique can be used as an instant reaction at the occurrence of dust peaks.

Example plants
The system is in use on two farms in the Netherlands to conduct measurements for determining the official emission reduction factor.

Reference literature
ASG-Rapport 204: Measures to reduce fine dust emission from poultry: optimisation of an oil spraying system for broilers.
ASG-Report 154: Reduction of dust emission from broilers by application of an oil film
ASG-Report 229: Measures to reduce fine dust emission from poultry houses.
[138, Netherlands 2010] [582, Wageningen NL 2009]

This technique was moved in this section from section 4.7.1.15

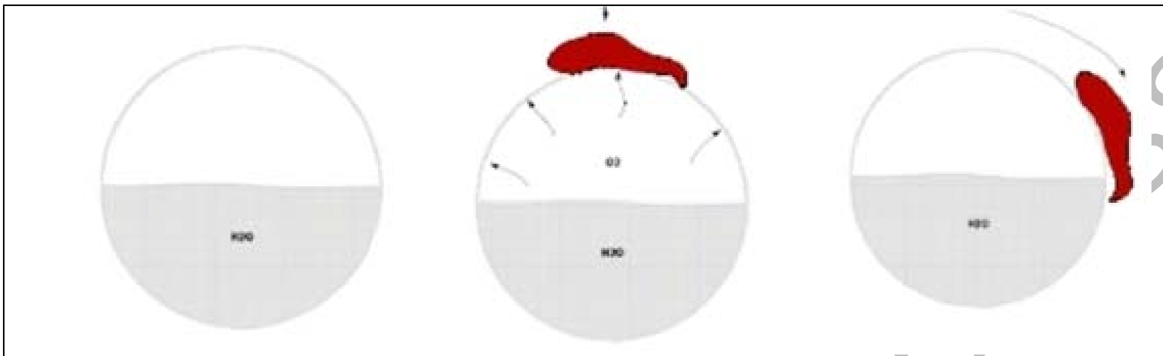
4.8.5 Floating balls in manure channels

Description
High-density polyethylene (HDPE) balls are left to float on the surface of manure channels below slatted floors. Balls are filled only way half with water and therefore are only half sunk. The ball axis changes when faeces are dropped on it and the ball tilts to drop the dung into the slurry contained in the channel.

This system fits every pig production type, but at the moment has been applied and verified only for fattening pigs and gilts.

The ~~additional~~ effect of floating balls has been studied in the Netherlands, ~~the~~ in combination with ~~of~~ the use of 1 % of benzoic acid in the feed formulation, since the target for ammonia emission reduction could not be achieved by applying only one technique. ~~has also been studied~~. The working mechanism of benzoic acid is based on shifting the equilibrium in urine and manure from the volatile ammonia to the ionised and non-volatile ammonium, by lowering the pH of the urine. Benzoic acid is currently authorised as zootechnical additive for piglets and fattening pigs (see Section 4.3.6.1).

A schematic represention of the functioning principle of the technique is shown in Figure 4.63.



Source**:** [583, Netherlands 2010]

Figure 4.63: Schematic representation of the functioning principle of floating balls

Achieved environmental benefits

The emitting surface in the slurry channels is notably decreased ~~being~~ as most of the surface ~~being occupied~~ is covered by balls, hence emissions are reduced. A comparison of emissions ~~are~~ is made with the same housing system without floating balls.

Cross-media effects

Balls ~~must~~ have to be disposed of at the end of their useful life. Additional workload is needed for cleaning the balls when necessary, after each breeding cycle.

Operational data

A ball diameter is 225 millimetre. The maximum potential reduction of the emitting surface is 70 % and it is achieved with 18 balls per m^2, which is the maximum number of balls fitting a m^2 of manure emitting surface. ~~that is 18 balls per m^2~~. The manure level in the pit ~~cannot~~ should not be kept too high in order to allow free mobility to the balls that need to tilt when faeces are dropped on them. Similarly, at the manure removal, a sufficient level of slurry has to be left to allow balls to continue to float.

Tests carried out in the Netherlands, ~~Official Dutch tests (TacRav, Report 193, November 2009)~~ credit this system with an average ~~mean~~ ammonia emissions reduction of 28 %, compared to the same housing system without floating balls. ~~and an ammonia emission factor of 2.3 kg per animal place per year~~. Measured ammonia emissions for the application of the technique in mating and gestating sows housing systems are reported to be equivalent to 2.3 kg NH_3/ap/yr.

In the case of a combination of the floating balls with the addition of ~~The use of a maximum of~~ 1 % ~~of~~ benzoic acid, the ammonia emissions reduction is increased ~~by~~ to 42 %.

The maintenance of the floating balls is minimal (no real costs), although it is recommended to regularly check manure adherence. Balls are cleaned after each breeding round, if needed. At delivery, the supplier should release a certificate with at least the number and type of balls installed.

Applicability

This system is generally applicable and is simple in use ~~very promising and economic~~. It fits in existing houses equipped with pits (having vertical walls) that do not have slanted walls. No particular specification of floor is needed. The technique is not compatible with channel flushing.

Economics

Investment costs depend on the surface of the manure pit, and on average are around EUR 31 (taxes excluded) per fattening animal place (around 1 m^2). No information was found on the extra cost associated with the workload needed for the cleaning operation of the ball nor on the expected lifetime of the balls.

Driving force for implementation

~~Because in the Netherlands the addition of 1 % benzoic acid will not alone reach the value to be recognised as a low emitting system, the product is tested in combination with other low emitting housing systems as is this system of floating balls.~~
The technique of floating balls, as it is in the Netherlands, can be used in combination with other ammonia reducing measures, e.g. benzoic acid addition, in order to apply a recognised "low emitting integrated system".

Example plants

At the time of ~~drafting~~ writing (2013) approximately 10 housing systems are equipped with the floating balls rearing around 4 000 fattening pigs.

Reference literature

[213, Netherlands 2010] [582, Wageningen NL 2009] [584, NL 2010]

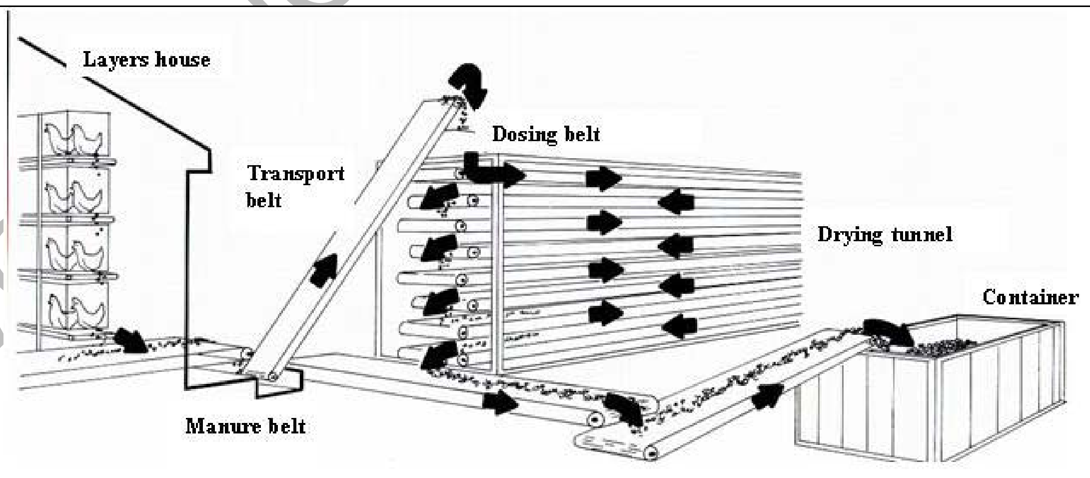
4.8.6 Techniques for the reduction of ~~aerial~~ emissions to air in poultry housing

4.8.6.1 External drying tunnel with perforated manure belts

Description

The manure that is extracted daily by belts from the laying hen house is run over a series of overlapping belts that form the tunnel. Warm air that is blown through the belts dries the manure in around three days time.

The newly incoming manure is sent to the top of the tiered belt ~~upper belt of a drying tunnel. the several tiers of punched belts~~ as pictured in Figure 4.64. The manure is carried along each ~~the~~ belt from one end to the other and then drops ~~downloaded~~ to the lower belt that rolls in the opposite ~~reverse~~ direction. The tunnel is ventilated with the air that is extracted from the hen house.



Source: [44, Netherlands 2000]

Figure 4.64: Principle of external drying tunnel with perforated manure belts

Achieved environmental benefits

The high dry matter contents that are achievable with this technique allow reductions of ammonia emission both from houses, manure storage and treatment, and from land application, in comparison to what is produced by wet manures. ~~It is reported that no effect on odour is obtained.~~ A reduction of odour emissions is also achievable with this technique, in comparison to systems with lower dry matter content in the manure.

~~The reported emission from the housing is 0.067 kg NH_3 per bird place per year, but it is not clear whether this represents the emission of the total system, i.e. including the emission from the drying tunnel.~~

Cross-media effects

Only limited extra energy ~~(electricity) is needed to ventilate this system, because the fans for the drying tunnel are the same as those used for the ventilation of the hen house. Although at the same time more belts have to be operated, so extra energy~~ is required to operate the additional ~~extra~~ belts, since no extra air heating is applied other than for the indoor climate conditioning. The ventilation system needs 20–30 % more power to overcome the resistance due to the additional room where the drying system is hosted. [150, CRPA 2008]~~The odour levels in the cage house are likely to be lower than where manure is dried within the house.~~

Should the process not be fast or complete enough to dry the droppings (e.g 80 % in 72 h), an inverse effect may occur where NH_3 is formed and extracted to the air by the blowing air that initially was meant to extract humidity.

Operational data

The tunnel is usually built at the side of the hen house. At the end of the run on the lower belt, the process ends with the manure having a ~~has a 65 – 75 %~~ dry matter content that usually depends on the season, since no additional heating is performed. In Italy the dry matter content of the manure leaving the hen house, varies by season from 26 to 47 % and is dried in the tunnel to a moist content from 55 to 90 %.

After drying, the manure ~~and~~ is discharged to a covered storage or to a container, therefore emissions during storage and landspreading compared to wet droppings are reduced by up to 65 % or 90 % with respect to ammonia and total nitrogen losses. In particular, ammonia emissions from the total applied nitrogen to land in the cases of spreading of the dried manure compared to the undried droppings have been calculated. Percentages of losses in summer of 1.1 % and of 0.5 % in autumn were recorded for the dried manure in comparison with the 15.2 % and 7.7 % for the untreated manure. [150, CRPA 2008]
~~It is possible to get a very low dry matter content manure in a short time. If regular container transport cannot be operated, a separate storage facility will be necessary for the dried manure~~

Over the whole year, average emissions of ammonia and some greenhouse gases ~~GHG emissions~~ out of the laying hen house and out of the drying tunnel are those reported in Table 4.118.

Table 4.118: Average ammonia, methane and nitrous oxide ~~and GHG~~ emissions from laying hen house and drying tunnel

Emission	Layers House		Drying Tunnel	
	Yearly average	Min – max	Yearly average	Min – max
	kg/ap/yr	kg/ap/yr	kg/ap/yr	kg/ap/yr
NH_3	0.152	0.044 – 0.290	0.167	0.126 – 0.210
N_2O	0.002	0.000 – 0.017	0.001	0.000 – 0.003
CH_4	0.094	0.000 – 0.354	0.010	0.003 – 0.028
Source: [141, Italy 2010]				

In France, manure drying is sometimes coupled with a system for pelletising the droppings. [368, France, 2010]

Applicability
This system is currently in use at laying hens houses only. It can be applied to new houses, but it is particularly suitable for existing houses because it hardly interferes with the existing structures. It just requires a means of extracting warm air to supply the drying tunnel.

Economics
Cost data relate to its application in Italy. Although investment costs have not been reported, the extra investment costs for the tunnel may be offset by the fact that the cost for the external manure storage is lower. The extra costs for energy are limited, equal to only EUR 0.03 per bird place per year. The total extra running cost (including capital + running costs) is EUR 0.06 per bird place per year. This means that with a 70 % NH_3 reduction, the cost is EUR 0.37 per kg NH_3 abated.

Driving force for implementation
After the manure is very dry, very low levels of emissions of ammonia and odour occur in the storage period. This technique could offer an advantage where odour is a local social constraint.

Example plants
It has been reported that the system has gained interest among Italian poultry farmers. ~~A few applications in Italy have been reported.~~

Reference literature
[44, Netherlands 2000], [141, Italy 2010] [150, CRPA 2008]

4.8.6.2 Dry filters

Description
The air that is extracted from the shed is blown against a screen made of multi-layered ~~tightly folded~~ plastic, placed in a plenum chamber in front of the exhaust fan, which forces the air ~~where it~~ ~~is forced~~ to sudden~~ly~~ changes of direction. The centrifugal force separates the dust particles from the airflow that are consequently congregated and collected in V-shaped filter pockets. ~~chambers~~.

Achieved environmental benefits
Reduction of dust emissions.

Cross-media effects
The filters need to be regularly cleaned, and the collected dust can be distributed on land with the manure.

Operational data
Manufacturers claim 70 % total dust abatement. Average abatement efficiencies of 41 % ± 4 for $PM_{2.5}$ and of 64 % ± 6 for PM_{10} particle fractions have been scientifically proved. Bacteria and fungi concentrations are reduced by 1 % and 20 % (on logarithmic scale) respectively.

Applicability
In principle the system can be retrofitted to any building with gable end fans, hence it is generally applicable.

Economics
~~The~~ Investment, ~~the~~ operating and maintenance costs are significantly reduced compared to wet scrubbing systems used for air treatment ~~systems~~. The capital cost for the installation of a dry filter is estimated to be about EUR 1.14 (1 GBP = 0.88 EUR) per 30 m^3.of air change, to be

compared with the same cost of about EUR 1.14 for treating 3 – 4 m^3 of air change with a wet scrubbing system.

Driving force for implementation
Local regulations imposing limit values for dust emissions.

Example plants
One commercial filter is fitted in a farm in the UK composed of four houses of 38 250 broilers.

Reference literature
[136, UK 2009]

4.8.6.3 Water trap

Description
The exhaust air from inside the shed is directed by the ventilation fans down onto a water bath (15 cm deep pit containing water) to soak up dust particles, and is then redirected 180 degrees upward to disperse any pollutants further (see Figure 4.65).

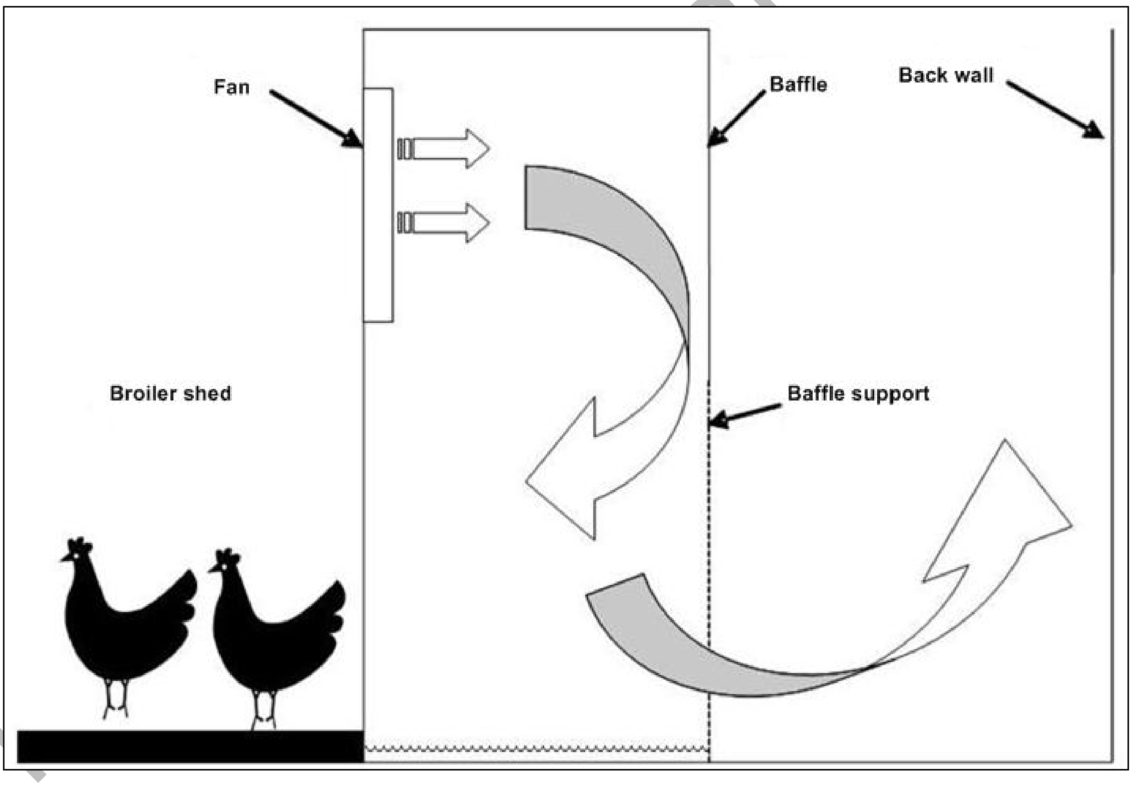


Figure 4.65: Scheme of the water trap

Achieved environmental benefits
Reduction of dust emissions.

Cross-media effects
No counter-effect is found. Dusted water can be spread on land.

Operational data
Abatement of emissions has been reported for $PM_{2.5}$, PM_{10}, ~~bacteria and fungi~~ of 19 %, 22 % respectively. Abatement of bacteria and fungi has also been reported equivalent to 16 % and 4 % respectively, on a logarithmic scale.

The water bath needs to be filled regularly due to evaporation.

Applicability
In principle the system can be retrofitted to any building with gable end fans.

Economics
Please TWG provide information.

Driving force for implementation
Local regulations may impose limit values to dust emissions.

Example plants
One example has been reported from a farm in the UK that rears more than 30 000 ~~thousand~~ broilers.

Reference literature
[136, UK 2009]

4.8.6.4 Biological additives in poultry litter

Description
Biological additives are used to improve the quality of beddings. Additives consist of complexes of microorganisms containing lactobacillus and bacillus, mixture of bacteria and mushrooms. The process of organic matter degradation is modified and a fast humification process starts after addition, which improves the physical conditions and the performance of the litter (drier, low emitting litter).

Achieved environmental benefits
Less ammonia is emitted in the air; the quality of indoor environment improves. [368, France 2010]

Cross-media effects
No cross-media effects have been reported.

Operational data
The bedding inoculation is done at the beginning of the breeding cycle and no later than the 10th day of life of chicks.

The selected strains of microbes (*Bacillus subtilis*) included in the additive have a positive influence on the litter properties, according to their defined metabolic criteria. The physical status of the litter is improved and more nitrogen is bound in the humified form.

Experimental tests were carried out, on the basis of mass balances, comparing treated to untreated litters. Litters treated with biological additives always showed a higher overall nitrogen content; whereas, the portion of ammoniacal nitrogen was not increased (same or less ratio NH_3-N/Ntotal). This means that nitrogen is better linked and conserved in an organic form in the treated litter. The C/N ratio, which reflects the degree of degradation of the organic matter, gets as low as 10 – 15 in comparison with the level of 20 – 40 observed for untreated litter. Experimental data concerning the characteristics of treated and untreated litter are presented in Table 4.119. [502, Guinebert et al. 2005]

Table 4.119 Composition of treated and untreated turkey manure, expressed as (%) of the dry matter content

Parameters	Type of litter			
	Straw bedding		Shavings bedding	
	Untreated	Treated	Untreated	Treated
Organic matter (% of DM)	40 – 50	60 – 72	50 – 60	60 – 75
Total N (% of DM)	2 – 2.5	5 – 6	2 – 3	3.5 – 4.5
NH_3 (% of DM)	0.5 – 0.8	0.5 – 0.8	0.6 – 0.8	0.1 – 0.3
C/N	20 – 40	8 – 15	20 – 40	2 – 10
Source: [502, Guinebert et al. 2005]				

The reduction in ammonia emissions, as a consequence of the litter treatment, is reported to be 36 % as an average [501, Aubert et al. 2011].

The competition of the added bacteria with harmful microorganisms inside the litter, enables a drastic reduction of the population of microorganisms such as enterobacteria and coliforms, with a consequent reduction of the risk for birds contamination. [502, Guinebert et al. 2005]. A reduced animal mortality of about 27 % (from 4.3 to 3.1 %) has been recorded. [501, Aubert et al. 2011]

Applicability
These products are especially used for broiler and turkey rearing, spread or pulverised over the bedding.

Driving force for implementation
Litters are richer in nitrogen that can be used efficiently at landspreading. Animal mortality may be reduced. [501, Aubert et al. 2011]

Example plants
In France, the use of this technique is increasing in meat poultry production; one French farm have been using this technique since 1996.

Reference literature
[501, Aubert et al. 2011] [502, Guinebert et al. 2005] [368, France 2010]

4.9 End-of-pipe measures for the reduction of ~~air~~ emissions to air from housing ~~s of pigs~~

4.9.1 Introduction

The treatment of the ~~waste~~ exhaust air coming from animal houses is a practice that has lately gained importance since intensive farming needs to comply with stricter regulations and emission limits. ~~Systems that are in use are mostly wet scrubbers, which offer the possibility to remove ammonia, odour and particulate matter at the same time, even though they have originally been designed for ammonia removal only.~~ In general, these techniques are used for ammonia, odour and dust removal from the exhaust air of animal housing, on the basis of different physical, biological and/or chemical removal principles of the air cleaning systems. The~~ir~~ principles of the two main types of air cleaning systems: wet scrubbers (acid scrubber, water scrubber, bio trickling filter) and biofilters are briefly described in Section 2.4.

In Table 4.120, the different air cleaning systems and their combinations in use are presented together with an indication of the applicability to the various animal categories and the removal performances.

Table 4.120: Types of exhaust air cleaning systems from animal housing, ~~with~~ their ~~suitability~~ applicability and removal performance~~, according to present knowledge~~

Type of air cleaning system	Applicability		Removal performance		
	Animal category	Manure removal system	Odour	NH_3	Dust
Biofilter	Pigs, cattle	liquid manure system (no bedding)	++	n.s.	+
Biotrickling filter	Pigs, cattle	liquid manure system (no bedding)	+	+	+
Acid scrubber	Pigs, cattle, dry dung store	liquid manure system (no bedding)	n.s.	++	+
MULTI-STAGE AIR CLEANING SYSTEMS					
Two stages					
Water scrubber + acid scrubber	All kinds of animal	Liquid and solid manure system	0/+	++	++
Water scrubber + biofilter	All kinds of animal	Liquid and solid manure system	++	0/+	++
Acid scrubber + biofilter	All kinds of animal	Liquid and solid manure system	++	++	++
Acid scrubber + biotrickling filter	All kinds of animal	Liquid and solid manure system	+	++	++
Three stages					
Water scrubber + water scrubber + acid scrubber	All kinds of animal	Liquid and solid manure system	++	+	+++
Water scrubber + acid scrubber + biofilter	All kinds of animal	Liquid and solid manure system	+++	+++	+++

NB: n.s.= not suitable; 0 = conditionally suitable; + = suitable ++ = good; +++ = very good
Source: [424, VERA 2010]

Information from Section 2.4 has been included in this section

Wet scrubbers are required in some Member States in order to comply with ~~maximum air emissions~~ acceptable emission levels for ammonia, PM_{10} and odour; in densely populated areas and vulnerable natural protected areas (e.g. Natura 2 000 sites), but they are still considered costly installations.

Specific emission reduction effects (factors) are usually associated with each type of air cleaning system ~~scrubber~~. Therefore, on individual farms, scrubbers are dimensioned to treat the volumes of air so as to let the air rest in the filter for 0.5 – 1 second. Hence, filter packs are generally dimensioned as 1 cubic metre for each 7 200 – 3 600 m^3/h of ~~that are hourly~~ ventilated air, and can achieve the emissions reduction for which they are certified.

General achieved environmental benefits
The average ammonia removal efficiency that can be achieved with the different systems ranges from 70 to over 90 %. ~~of acid scrubbers is higher than 90 % and is between 50 % and 90 % for biotrickling filters~~. In Germany, the required minimum removal efficiency of air cleaning systems for ammonia and total dust is 70 %. Ammonia separation is assessed with the aid of a nitrogen balance covering the entire production system. Dust removal efficiencies from 80 % up to more than 95 % are reported as achievable. [514, KTBL 2008].

Odour removal is on average 30 % for acid scrubbers and 45 % for biotrickling filters, although wide ranges are reported ~~ranges~~ for individual measurements ~~are wide~~, since the efficiency of odour reduction highly depends on the raw gas concentration. The minimum requirement for odour reduction of air cleaning systems applied in Germany is defined as an odour concentration in the clean gas not exceeding 300 ou_E/m^3 (European odour units per cubic metre); this means that no typical process odours (animal house odour) may be perceptible in the clean gas. [514, KTBL 2008]

General information on applicability
~~The highest odour removal efficiency of air scrubber cleaning systems is achieved by adjustment of design and operational strategy. Another used approach is that of multi-stage scrubbing systems where each stage aims to remove one type of compound.~~ **Moved under operational data**

Investment and operational costs for scrubbing systems for livestock operations are generally high and this limits the widespreaded take up of the system across the EU. The fixed costs are related to the scrubber size. Costs for energy use are notable to run water pumps and to overcome the increased resistance to the mechanical ventilation due to the presence of the filters.

Another essential constraint for the implementation of air cleaners is the centralisation of air extraction which is not always practicable in existing buildings. Additionally, air cleaning systems significantly increase the flow resistance of the forced ventilation system. Therefore, the ventilation system of the housing must be planned and designed efficiently which is relatively easy in newly planned houses. The adaptation of existing houses will be difficult and expensive in most cases. In existing houses, the ventilation system is rarely adequate to support a scrubber since multiple air outlets may be present and flows might not be channelled to a single outlet point where the air could enter the scrubber. In addition, the design and capacity of the installed fans might not meet the increased capacity required to overcome the extra flow resistance that inevitably is introduced by the presence of a scrubber. Not only the costs for the installation of air cleaning systems in existing houses are normally significantly higher than those for the implementation of the same techniques on new installations, also the operating costs are expected to be higher (compared to new housing) because of the difficult optimisation of the existing ventilation system.

In Germany, the Netherlands and Denmark, the air cleaning ~~scrubbing~~ systems are officially tested before their commercialisation, and are certified for the removal of ammonia, odour and dust ~~removal~~ with reduction factors for each animal category that is reared. In order to harmonise the testing procedures and facilitate acceptance of the results in different countries, a joint initiative of parties from the above mentioned Member States developed a standardised protocol for testing and verifying different air cleaning systems: 'Test Protocol for Air Cleaning Technologies'. [424, VERA 2010] Hence it is possible to fit a housing unit ~~stable~~ with a system that ensures the desired combination of performance and cost. By applying the test protocol, the

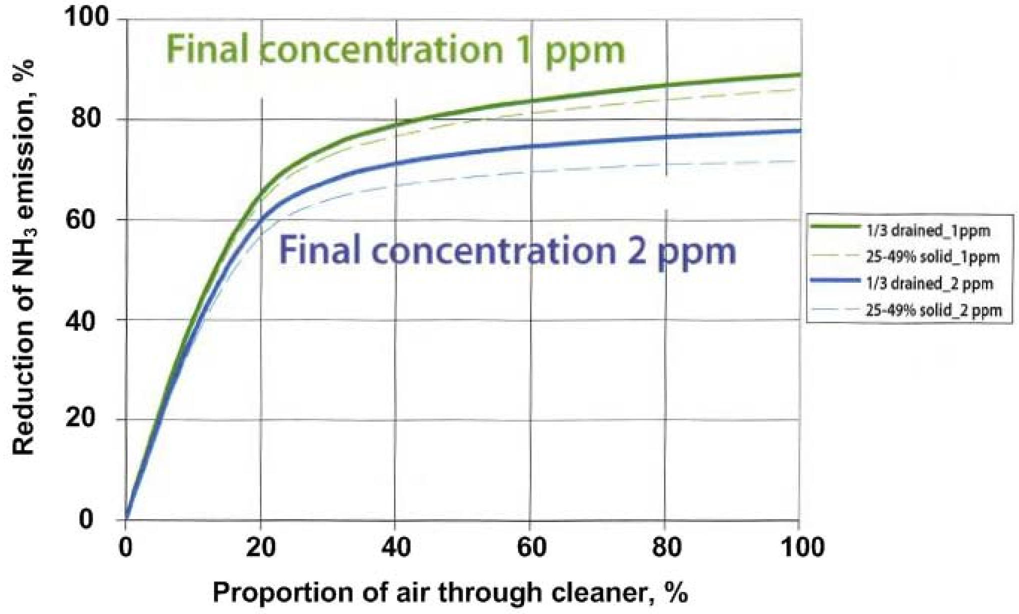
final ammonia, odour and dust emission abatements associated with the treated air are ~~*a priori*~~ calculated beforehand for the combination of animal production and housing system.
~~The Dutch Ammonia and Livestock Farming Regulation distinguishes between three types of low-ammonia-emission air treatment systems:~~

1. ~~acid air scrubbers; assigned ammonia emission reduction is either 70 %, 90 %, or 95 %;~~
2. ~~biological air scrubbers (or bioscrubber or biotrickling filter); assigned ammonia emission reduction is 70 %;~~
3. ~~multi-stage air scrubbers (or combi-scrubber); assigned ammonia emission reduction is either 70 %, or 85 %. [153, Netherlands 2010]~~

An example of the locally widespread application of air cleaning techniques, in Germany in only three districts: Cloppenburg, Vechta and Emsland of Lower Saxony, a number between 370 and 400 of pig farms (around 17 % of all pig farms) have installed air abatement techniques (as of 2010). Two out of three newly built houses are fitted with air cleaning systems of which, 75 % are bioscrubbers and multi-stage devices and 25 % are biofilters. [504, Grimm E. 2010]

General information on operational data
Ventilation systems only operate at full capacity in warmer seasons and the average air flowrate over the course of the year may vary depending on different factors including the climatic zone. As an example, a yearly average air flow around 50 % of the maximum capacity is reported for Germany. In Northern European coastal climates, for about half of the year the ventilation is applied at about 25 % of the capacity. Many tests investigated the removal efficacy of air treatment systems at reduced ventilation capacity; the results showed that the efficiency of air cleaning systems, expressed as average ammonia reduction over a year, depends on the proportion of air that is treated [55, Denmark 2010] in a way that, as an example, a reduced scrubber operating at 50 % of the maximum capacity still enables 80 – 90 % of ammonia removal, with 10 – 20 % of the total ammonia emissions to be vented untreated (see Figure 4.66). This strategy reduces investment and operational costs but hardly affects the average emission levels. [13, Melse 2009]

For the climatic zones as for the example given in Figure 4.66, it is possible to comply with a given annual emission limit for ammonia by reducing the volumes of treated air. This implies that when the housing ventilation is at maximum levels, only a portion of the air is treated while the exceeding flow is left untreated to exit into the external environment.



Effect of a reduction of the ammonia emission of a proportion of air through an air cleaner with a final concentration of 1 and 2 ppm respectively.
Source: Grøn Viden (Green Knowledge) no. 47: Partial cleaning of ammonia in livestock house air. Faculty of Agricultural Science.

Source: [55, Denmark 2010]

Figure 4.66: Ammonia removal ~~Theoretical~~ efficiency as a function of the proportion of ~~in~~ air cleaning capacity ~~treatment~~

~~Electronic~~ Monitoring of the operating parameters is necessary both for proper operation and for authority control. Some of the ~~following~~ parameters listed in Table 4.121 may be ~~are normally~~ stored in electronic operation logs, depending on the equipment used.

Table 4.121: Parameters to be recorded in the operations logbook

Parameter	Biofilter	Trickle bed reactor (bioscrubber)	Acid scrubbers and multi-stage scrubbers
Pressure loss in the exhaust air treatment system	x	x	x
Air flowrate	x	x	x
Pump running times (separate for the circulation pumps and the elutriation pumps)		x	x
Sprinkling intervals	x	x	x
Total water consumption of the exhaust air treatment system	x	x	x
Proof of acid consumption (with receipts)		m	m
Elutriated water quantity and its discharge		x	m
pH regulation		x	x
Water pressure	x	x	x
~~Crude~~ Raw gas temperature	x	x	x
Clean gas temperature		x	x
Calibration of the pH sensor		m	m
System control – sprinkling pattern	m	m	m
Maintenance and repair times (including the kind of work)	m	m	m
Change of filter material	m		

NB ‘x’= electronic recording; ‘m’= manual recording.
Source: [514, KTBL 2008]

In the Netherlands, Continuous monitoring of electrical conductivity EC, pH, discharge volume, electricity consumption and pressure drop are considered to allow a sufficient estimation of the system functionality.

The highest odour removal efficiency of air scrubber cleaning systems is achieved by adjustment of design and operational strategy. Another used approach is that of multi-stage scrubbing systems where each stage aims to remove one type of compound.

The generation of aerosols from these air cleaning systems may raise concerns about the potential presence of *Legionella*.

The two main air cleaning techniques (wet scrubbers and biofilters), applied alone or in combination within the sector for the intensive rearing of poultry and pigs, are presented in the next sections.

4.9.2 Water scrubber (former Section 4.9.1.1)

Description
The exhaust air from the housing is blown through a packed filter medium by transverse flow. Water is continuously sprayed on the packing material. The dust is removed in the water and settles down in the water tank that is emptied when it is filled before refilling.

Achieved environmental benefits
Reduction of fine dust.

Cross-media effects
The dust collected needs to be disposed of. Water is removed with dust when the tank is emptied, but no flush of waste water occurs. Other requirements are the fresh water replacement for the evaporating part and the energy for running pumps.

Operational data
For a filter surface load of 4 300 m^3/m^2 per hour, and a thickness of the contact bed packing of 0.6 m, the reduction of fine dust (PM_{10}) is reported to be approximately 30 %. is achievable. The reported average flowrate over the course of the year in percentage of the maximum flowrate is equivalent to 33 %. [124, Netherlands 2010]

Every week the packing material should be controlled for congestion by dust, as should the circulating water be sprayed on the column. The packing material should be cleaned once a year.

Applicability
The system is very currently only fitted on poultry housing. It is easy to implement as an addition to new buildings that apply artificial ventilation under a negative air pressure with only one outlet point, and to existing farms with the same central ventilation of sufficient capacity and where ventilation is controlled by fans placed in one end of the house. Where the ventilation system has multiple fans or multiple outlet points, the implementation is hardly practicable.

Economics
The extra-costs associated with the implementation of water scrubbers, estimated in the Netherlands for common poultry housings, are reported in Table 4.122.

Table 4.122: Extra-costs related to water scrubbers in poultry housing

Type of animal	Housing capacity in animal places (ap)	Extra investment costs EUR/ap	Annualised extra investment costs EUR/ap	Operating annual extra costs EUR/ap	Total annual extra costs EUR/ap	Total annual extra costs EUR per produced animal
Pullets	50 000	2.32	0.32	0.33	0.66	0.25
Laying hens (aviary)	40 000	2.97	0.41	0.45	0.86	0.98
Broiler grand parents	33 000	3.34	0.47	0.48	0.94	0.46
Broiler parents	19 000	6.26	0.87	0.92	1.79	1.75
Broilers	90 000	3.26	0.46	0.46	0.92	0.134
Turkeys	20 000	22.36	3.15	3.19	6.34	2.19
Ducks	40 000	4.84	0.68	0.70	1.38	0.21
Source: [503, Vermeij 2011]						

Driving force for implementation
~~Poultry housings only are known for being equipped with this system~~ (**moved to Applicability**)

In the Netherlands, the incorporation of the system in new or existing farms makes it possible to grant an environmental permit in situations where this would otherwise not be possible under the local legislation, due to exceeding the maximum permissible values for fine dust concentrations.

Example plants
This system is applied in the Netherlands since 2009, where several farms use this technique. Emission measurements were performed in a 145 000 head pullets farm.

Reference literature
[124, Netherlands 2010]

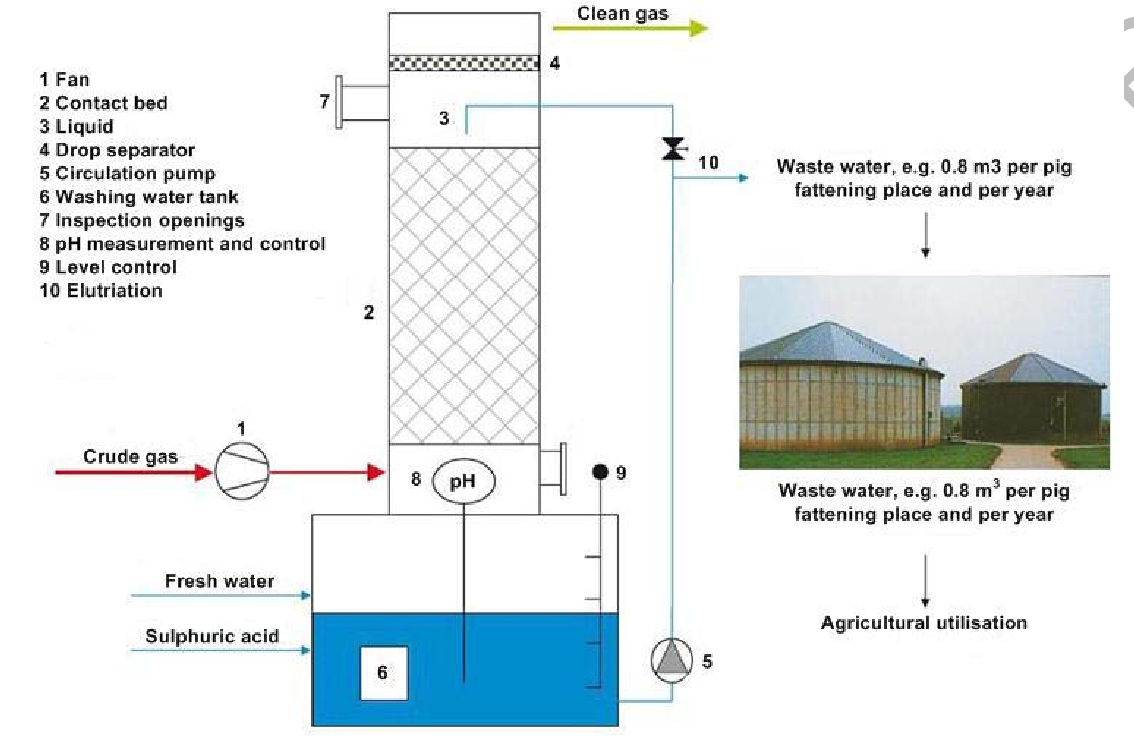
4.9.3 Bioscrubber (former Section 4.9.1.2)

Description
~~In this systems all the ventilation air of the pen is fed through a biofilter unit. As described in~~ Both the wording 'bioscrubber' and (bio)trickling filter are used as equivalent for describing a packed tower filter with inert packing material that is normally maintained continuously wet. Contaminated air is generally passed upwards (counter-current) over the filter elements that are continuously sprinkled with water. Due to an intensive contact between air and water, dust, ammonia and odour contained in the contaminated air are absorbed in the liquid phase and subsequently degraded by microorganisms settling on the filter elements as a bio film (see section 2.4)~~, a biolayer that is formed on the surfaces of the packed material absorbs and reduces;~~. The effluent is collected in a storage tank before being recycled back to the scrubber. In this way, the biomass in the system grows partly as a film on the packing material of the filter and is partly suspended in the water that is recirculated. [13, Melse 2009]

The typical workflow of a bioscrubber is shown in Figure 4.67.

Ammonia is degraded by bacterial conversion into nitrites and nitrates (nitrification), while odorous compounds are oxidised by bacteria to CO_2, H_2O and by-products. ~~that in turn is reduced by microbes~~. Water circulation keeps the biolayer moist and provides the nutrients ~~available~~ for the microorganisms; the accumulated nitrite and especially nitrate (which may be toxic to the microorganisms) is discharged with the scrubbing water so that the pH remains in a favourable range (between 6.5 and 7.5) for microorganisms.

The bioscrubber can be preceded by a simpler filtering stage to reduce dust and odour as a first step, which often is done by the 'water curtain', where a simple flush of water and air are flowing in the same direction (not the usual 90 ° cross flow).



Source: [121, Germany 2010]

Figure 4.67: Bioscrubber workflow

Achieved environmental benefits

Ammonia, odour and dust emissions are simultaneously reduced. The odour reduction is effective for ~~limited to~~ neutral and acid compounds as well as for odorous substances attached to dust particles. **Cross-media effects**

The energy and water consumption, ~~is increased by about 1 m^3 per pig place per year and in accordance with this an extra effluent is produced that has to be discharged.~~ in addition to the requirement to discharge waters, may limit the application of this system. ~~This system has a higher energy consumption (extra 35 kWh per pig place). For weaners, the extra energy input was reported to be lower, i.e. at about 8 kWh per pig place.~~ A discharge of water ~~consumption of~~ up to 10 times higher than with a chemical scrubber may result.

The waste water is usually stored with the slurry and applied to land taking into account the additional supply of nitrogen. It might also be treated in a subsequent denitrification process, where in a separate reactor the nitrogen compounds are transformed into gaseous N_2, allowing for a reuse of the process water and its final discharge at lower costs.

If conditions in the bed media are not properly controlled, transient aerobic/anaerobic zones might form causing a risk of N_2O emissions formation. Filter beds made of peat imply high indirect GHG emissions due to peat digging.

Operational data

Ammonia emission reductions around 70 % – ~~and up to~~ 85 % have been reported ~~for of the content in the treated air.~~ Removal efficiencies higher than 90 % have been measured only at high elutriation rates or pH regulation and conductivity controlled elutriation rate. [121, Germany 2010][129, Netherlands 2010], [127, Netherlands 2010], [135, Netherlands 2010], [51, BE Flanders 2010].

The odour reduction strongly depends on raw gas concentration and varies between 28 % and 75 %. In Germany, for bioscrubbers that are properly operated an odour concentration in the clean gas < 300 ou_E/m^3 is considered achievable and no raw gas odour to be perceptible in the clean gas.

A removal of total dust of at least ~~around~~ ~~60 %~~ 70 % can be usually obtained, while the reduction of the PM_{10} fraction is reported to reach at least 70 % and can be raised to 95 %, especially with the use of a dedusting filtering stage.

In Table 4.123 a summary of the emission reductions achieved by applying bioscrubbing in the pig production is shown as reported by different Member States.

Table 4.123 Emission reductions achieved by the application of bioscrubbers in pig production

Achieved emission reductions (%)				
Ammonia	**Odour**	**Dust**	**PM_{10}**	**Reference**
50 – 85	28 ([1]) – 54	95	-	[53, Denmark 2010]
70 – 95 90 (average)	50 – 90 70 ([2])	70 – 95	80	[121, Germany 2010]
50 – 90 70 (average)	-	-	-	[42, Netherlands 1999]
70	45	-	60	[135, Netherlands 2010]
84 – 93 85 (average)	40 – 72	94 – 96	80	[129, Netherlands 2010]
87 – 98	75	94 – 96	80	[127, Netherlands 2010]

([1]) The level refers to a removal efficiency observed during summer.
([2]) Minimum requirement in Germany for odour concentration in the clean gas is < 300 ou_E/m^3, which is comparable to a reduction efficiency of about 70 %.

In Table 4.124, specific emission levels achieved with the application of bioscrubbers are presented as reported by Denmark and the Netherlands.

Table 4.124: Reported emission levels achieved with the application of bioscrubbers

	Animal category	Ammonia	Odour	PM_{10}	Reference
		kg/ap/yr	ou_E/s/ap	g/ap/yr	

Installation A	Fattening pigs	0.44 (100 % air cleaned) 0.56 (60 % air cleaned) 0.88 (20 % air cleaned) ([1])	-	-	[53, Denmark 2010]
Installation B	Weaners	0.09 – 0.11	1.4 – 2.0	26	[129, Netherlands 2010]
	Farrowing sows	1.25	7.0	42	
	Mating/gestating sows	0.63	4.7	44	
	Fattening pigs	0.38 – 0.53	4.5 – 5.8	55	

Energy is required to operate water pumps and to supply fans with the additional power required by the ~~Systems for waste air cleaning can significantly~~ increased ~~the~~ flow resistance of the forced ventilation systems. Air flowrates related to these systems are typically ~~around 30 000~~ from 10 000 to 100 000 m^3/h; volumes up to 255 000 m^3/h are reported for installations with a capacity of 3 000 pigs. ~~have been reported up to 84 500~~ m^3/h.

Electricity consumption can be associated to modules of 1 000 m^3/h of the installed capacity of the scrubbing system (around 11.8 pig places covered at a flowrate of 85 m^3/animal place per hour). On a yearly basis, the electricity consumption ~~The energy~~ consumptions ~~for each 1000 m^3 of the filter's ventilation capacity is measurable from~~ is around ~~150 to 180~~ 12.7–15.3 kWh/animal place for what concerns the system's requirements (pumps, control, etc.) and ~~from 130 to 235~~ 11 – 20 kWh/animal place to compensate for the additional pressure drop required to the ventilation system (up to 150 Pa for biotrickling beds) [121, Germany 2010].
~~Recently, by the optimisation of the humidification system and the reduction of the pressure drop drastic reduction in energy needs are claimed as low as 11kWh per animal place (9kW for running fans and 2kW for running pumps [NL]. In order to ensure the requisite air rates, particularly in the summer, higher-capacity fans with a higher specific power requirement may be necessary. In addition, power is~~
~~required to operate the pumps for water circulation in bioscrubbers and for humidifying operations in biofilters.~~

~~The water consumption has been reported in the range from 1.9 to 6.5 m^3/d. [127, Netherlands 2010] or as low as~~ In Denmark, the total water consumption ~~0.25 m^3~~ per produced pig is estimated around 0.25 m^3. [53, Denmark 2010]. In Germany, water consumption is reported in the range of 1.6 – 2.4 m^3/pig place per year for modern systems, with pH-control (in order not to exceed a set pH value above which ammonia is released from the scrubbing water into the exhaust air), and elutriation based on water conductivity; otherwise the consumed volumes may be much higher.

The process water that is not evaporated ~~taken with the outgoing air flow~~ can be spreaded on land or ~~is~~ discharged. Waste water volumes are reported of around 0.02 m^3 per produced pig [DK], or from 170 to 800 litres per fattening pig place per year ~~or~~ and around 25 litres per weaner place per year [NL]. [13, Melse 2009] ~~From a system capacity of 255 000 m^3, some 1300~~ In Germany, around 0.3–0.4 m^3 of waste water per fattening pig place and year are ~~produced~~ reported for systems equipped with pH control and elutriation based on water conductivity. [121, Germany 2010]
Data concerning total water consumption and the amount of water discharged from the scrubbing system are presented in Table 4.125 for different installations applying bioscrubbers for air treatment.

Table 4.125: Examples of water consumption and water discharges for fattening pigs installations applying bioscrubbers

Location	Total water consumption (m^3/ap/yr)	Water discharged from the air cleaning system (m^3/ap/yr)	Remarks
Denmark	1	0.08	The values have been calculated with the assumption of 4 fattening pigs produced per year per animal place (values reported: 0.25 and 0.02 m^3/produced pig, respectively)
Germany	1.6 – 2.4	0.42 or 0.3 – 0.4	Calculated values from 4 800 – 7 200 m^3/yr reported for fresh water requirements and 1 300 m^3/yr water discharge (with pH control, elutriation according to water conductivity) for a capacity of 255 000 m^3/h and for 85 m^3/fattening pig/yr of airflow capacity)
The Netherlands	0.9 – 3.1	1 – 4	With water curtain. Values are calculated from the reported data: 1.9 m^3/day for winter and 6.5 m^3/day for summer, for a farm of 520 fattening pigs and 240 weaners
The Netherlands	0.8 – 1.8	0. 17 – 0.68	With water curtain. Values are calculated from the reported data: 2.27 m^3/day for winter and 5.25 m^3/day for summer, for a farm of 1 080 fattening pigs. This unit is reported to have a relatively low amount of flushing water due to an optimized flushing water management.

Source: [53, Denmark 2010] [121, Germany 2010] [135, Netherlands 2010] [127, Netherlands 2010] [129, Netherlands 2010]

OLD TABLE 4.25, ALREADY DELETED IN DRAFT 1, HAS BEEN ELIMINATED

Applicability

In principle, this system is very easy to implement both as an in addition to new buildings and in to refurbishing reconstructions of existing buildings already applying artificial ventilation under a negative air pressure. In practice, the installation of a scrubber in an existing house requires in most cases a redesign of the ventilation system and the installation of new, more powerful, fans. Where the ventilation system has multiple fans or multiple outlet points, the implementation is hardly practicable.

The design and the size of the pens are not critical for the applicability of the system.. There are no adaptations needed inside the building, but this system cannot be applied in naturally ventilated pig houses, without channelling the airflow in the building., and typically applies to housing with forced ventilation (under a negative air pressure). A dust filter may be necessary where dust levels are higher (straw systems), which will increase pressure in the system and also raise energy use.

Bioscrubbers are proven and certified only for slurry based systems, not for litter housing; hence, the technique is more suitable for pig production. The application in poultry houses is quite limited because of the high dust and feather load of the ventilation air which increases the risk of blockage of the packing bed, with consequent increase of the pressure drop and energy use. In addition, Since the biolayer needs continuity in the provision of contaminated air; this requirement cannot be maintained this system is less suitable for those productions where the entire house is emptied at once, as it happens with the rearing of poultry.

Economics

Reference costs related to the application of bioscrubbers applied in the Netherland are reported in Table 4.126.

Table 4.126: Average costs in EUR for biological scrubbers in the Netherlands by type of production

Type of scrubber	Investment costs (EUR/ap)				Annual running costs (EUR/ap)			
	Weaner	Farrowing sow	Gestating sow	Fattening pig	Weaner	Farrowing sow	Gestating sow	Fattening pig
System without water curtain	15	170	90	40	30	30	20	10
System with water curtain	16	170	100	50	4	35	23	12

In Table 4.127 examples of investment, operational and total costs are presented for different housing capacities in pig production.

Table 4.127: Cost ranges associated with the use of bioscrubbers for exhaust air treatment in pig production

Housing capacity	Associated costs (1)							
	Investment costs		Annualised investment costs		Operational costs		Total costs	
	EUR/ap		EUR/ap/yr		EUR/ap/yr		EUR/ap/yr	
	from	to	from	to	from	to	from	to
460 – 700 animal places (39 000 – 60 000 m^3/h)	62	70	7.1	8.2	10.0	11.1	17.1	19.3
1 060 – 1 180 animal places (90 000 – 100 000 m^3/h)	47	54	5.2	6.0	8.1	9.1	13.3	15.1
1 700 – 1 850 animal places (150 000 – 157 000m^3/h)	39	46	4.4	4.9	7.7	8.6	12.1	13.5
Housing capacity	Investment costs		Annualised investment costs		Operational costs		Total costs	
	EUR per 1 000 m^3/h	EUR/ap	EUR/yr	EUR ap/yr	EU/yr	EUR ap/yr	EUR per 1 000 m^3/h	EUR ap/yr
400 fattening pigs (40 000 m^3/h)	678	-	68	-	-	-	-	12
3 000 fattening pigs (255 000 m^3/h)	600 (from 470 to 720)	40 – 61	65 (from 50 to 80)	4 – 7	100 (from 90 to 1 100	7.5–9.5	165 (from 140 to 190)	12 – 16

(1) All cost data are given without VAT
Source:[514, KTBL 2008] [53, Denmark 2010] [121, Germany 2010]

An example of costs for a biotrickling filter applied to a pig house, broken down for each cost factor, is given in Table 4.128.

Table 4.128: Investment and operational annual costs for a biotrickling filter applied to a newly built facility for pig production

	EUR/ap/yr
Investment costs (1)	43.5
Operational costs	
Annualised investment cost (10 %)	3.4
Maintenance (3 %)	1.8
Interest (6 %)	1.0
Electricity use (EUR 0.11/kWh)	3.8
Water use (EUR 1.0/m^3)	1.7
Chemical use (EUR 0.6/litre H_2SO_4, 98 %)	Not applicable
Water discharge (2)	2.5
Total annual operational costs	10.8
Total annual costs	*14.3*

(1) The investment costs are based on a maximum ventilation capacity of 60 m^3/ap/h.
(2) Water disposal costs are assumed equivalent to 2 EUR/m^3 for discharge from biotrickling scrubbing.
Source:[568, Melse et al. 2010]

In general, for applications to pig housings, an investment of EUR 470 to EUR 720 is necessary for each 1 000 m^3/hour of capacity. At the condition of standard ventilation of 85 m^3/h per animal place, , ~~which can be annualised~~ (10 years amortisation for the installation of the air cleaning system, 20 years for the construction, at 4 % interest rate) ~~at EUR 50 to EUR 80 per year. The~~ the annualised investments are around EUR 4 – 7 per animal place per year and the annual running costs ~~seems to~~ vary between EUR 7.5 and EUR 9.5 per animal place per year. ~~EUR 90 to EUR 110~~. [121, Germany 2010] This system's durability is expected to be around 10 years.

Cost data for the application of bioscrubbers in poultry housings are presented in Table 4.129.

Table 4.129: Extra costs related to the application of bioscrubbers in poultry housing

Type of animal	Size of housing in animal places (ap)	Extra investment (EUR/ap)	Annualised extra investment (EUR/ap)	Operating annual extra cost (EUR/ap)	Total annual extra cost (EUR/ap)	Total annual extra cost (EUR per produced animal)
Pullets	50 000	2.93	0.41	0.59	1.00	0.40
Laying hens (aviary)	40 000	3.41	0.50	0.63	1.13	1.29
Growing pullets of broiler breeders	33 000	4.24	0.60	0.86	1.46	0.70
Broiler parents	19 000	8.26	1.15	1.76	2.90	2.83
Broilers	90 000	3.71	0.55	0.64	1.19	0.173
Turkeys	20 000	25.83	3.57	4.71	8.28	2.86
Ducks	40 000	5.75	0.78	1.15	1.93	0.30
Source: [503, Vermeij 2011]						

In general, for applications to pig housings, an investment of EUR 470 to EUR 720 is necessary for each 1 000 m^3/hour of capacity. At the condition of standard ventilation of 85 m^3/h per animal place, , ~~which can be annualised~~ (10 years amortisation for the installation of the air cleaning system, 20 years for the construction, at 4 % interest rate) ~~at EUR 50 to EUR 80 per year. The~~ the annualised investments are around EUR 4–7 per animal place per year and the annual running cost ~~seems to~~ vary between EUR 7.5 and EUR 9.5 per animal place per year. The total costs are reported to be in the range of 12 and 16 EUR/ap/yr. ~~EUR 90 to EUR 110~~. [121, Germany 2010] [53, Denmark 2010]. The durability of these systems ~~durability~~ is expected to be around 10 years.

Driving force for implementation

Local regulations on odour or ammonia emissions can prescribe maximum emission loads. In some northern Member States, ~~Denmark and the Netherlands~~ air treatment systems are frequently required by environmental permits in situations where it would otherwise not be possible to comply with maximum ammonia or odour emissions.

Example plants

This system is commonly used. ~~run.~~ ~~was developed just a few years ago in the Netherlands. It is now being implemented in some reconstruction situations.~~ In the Flemish part of Belgium, 190 ~~IPPC authorised~~ farms are provided with such installations. At least 243 German farms are using this technique. [505, Hahne J. 2011]. In the Netherlands, the installed capacity of bioscrubbers for ammonia removal in 2008 is reported to be 14 million m^3/hour for 90 farms. [568, Melse et al. 2010]

Reference literature

[42, Netherlands 1999] [51, BE Flanders 2010] [53, Denmark 2010] [121, Germany 2010] [135, Netherlands 2010] [127, Netherlands 2010] [129, Netherlands 2010] [568, Melse et al. 2010]

4.9.4 Wet chemical acid scrubber (former Section 4.9.1.3)

Description
All The ventilation air of an animal house the pen is fed through a filter chemical scrubbing unit. where an acid scrubbing liquid is trickled. The scheme of a wet acid scrubber does not differ substantially from the general design presented in Figure 2.32 (see Section 2.4). pumped around this unit. When the ventilated air is brought into contact with the scrubbing liquid, ammonia is absorbed and the clean air leaves the system. Diluted. Filters can be packed walls or made of lamellae of synthetic polymer fibres or plastic pads.

Sulphuric acid is mostly used in this system and is automatically added to keep the circulating liquid within a proper range of pH, generally below 5. Hydrochloric acid may also be used.
Working principle: Ammonium absorption: $2\ NH_3 + H_2SO_4 \rightarrow 2\ NH_4^+ + SO_4^{2-}$. (For picture see Figure 4.15)

Achieved environmental benefits
See Table 4.26. Significant ammonia reductions can be obtained. Also dust can be removed. Acid scrubbers are less effective in reducing odorous compounds due to the low pH value that inhibits microbial odorant degradation. Odour reduction efficacy is limited to those compounds of alkaline nature that can be diluted in an acid solution as well as odorous substances that can be attached to dust particles.

Cross-media effects
The effluent from the scrubber contains increased levels of sulphate or chloride, depending on the type of acid used. The effluent must be discharged and this may limit application. This system has a higher energy consumption compared with the previous air cleaning system. Again, levels vary with the pig category. Where sulphuric acid is used, the effluent contains has a load of ammonium sulphate that can directly be used for fertilisation taking into account the possible need of correcting the acidity of the effluent (liming). With the use of different acids, sludges might have to be are disposed of.

Air cleaning systems results in increased energy use for ventilation due to counter pressure in the filter material and ducting plus power for water and acid pumps.

Under optimal conditions, it is reported that approximately 40 litres of scrubbing water to be drained are produced per fattening place, per year in litterless pig housing The fresh water requirements to compensate for evaporation losses amount to 5 – 7 l/1 000 m^3 exhaust air [514, KTBL 2008].

In Table 4.130, data from Denmark concerning the additional energy consumption in relation with the portion of air flow of maximum ventilation rate that is treated are presented.

Table 4.130: Additional energy consumption associated with air cleaning by acid scrubber applied in pig farms in Denmark

Animal type	Partial air cleaning capacity of maximum ventilation rate (%)	Additional energy consumption (KWh/animal produced)
Fattening pigs (30-100 kg)	31	2 – 4 (1)
Weaners (30 kg)	100	6.8
Weaners (30 kg)	34	1.3
Gilts	100	24

(1) These values correspond to 8 – 16 kWh/ap/yr
Source: [55, Denmark 2010]

Specific safety measures are required for the storage and handling of acids and chemical substances, according to national or local regulations. These may include constructional requirements which may pose some limits to the possible implementation of the technique.

Operational data
Ammonia reductions of at least 70 ~~85 %~~ and up to 99 % of the content in the treated air are reported. [130, Netherlands 2010], [132, Netherlands 2010], [134, Netherlands 2010], [133, Netherlands 2010], [131, Netherlands 2010], [54, Denmark 2010] [125, Netherlands 2010].

The odour reduction efficacy varies between 30 % and 40 % and raw gas odours can still be perceived in the clean gas. As a result, acid scrubbers are not generally considered suitable for odour elimination as a single step process.

A removal of fine dust (PM_{10}) of around 60 % can be usually obtained. If combined with a dedusting neutral stage, the removal efficiency of the system is expected to improve. (see Section 4.9.4). ~~If a dedusting neutral stage is applied, odour and dust abatement of reach about 70 % and 94 96 % (winter and summer) respectively have been reported. [125, Netherlands 2010]~~ **Moved to Section 4.9.4**

Data concerning the removal efficiency of chemical scrubbers applied in different animal housing are reported in Table 4.131.

Table 4.131 Examples of removal efficiencies of chemical scrubbers applied in pig and broiler housings

Type of animal	Source	Emissions reduction (%)			
		Ammonia	Odour	Dust	PM_{10}
Pigs	[514, KTBL 2008]	70 – 95	-	>70	
Pigs	[54, Denmark 2010]	90 – 99	-		
Pigs	[130, Netherlands 2010] [132, Netherlands 2010] [133, Netherlands 2010] [134, Netherlands 2010]	95 – 99 70 (1)	30	-	60
Broilers	[131, Netherlands 2010]	90	40	-	30
Broilers	[374, DK 2010]	80 – 90	-	-	-

(1) Lower removal efficiency (about 70 %) is achieved when the filter is operated at higher filter surface area, consequently at lower costs.

As already reported in Section 2.4, an acid scrubber needs approximately 90 litres of water and 3 litres of sulphuric acid to remove 1 kg of ammonia from the air [55, Denmark 2010].

The pH at which each system operates is different: generally, when the liquid reaches pH 4, acid is added to the circulating liquid to obtain pH values of 3, 1.5 or as low as 0.5. The concentration of ammonium sulphate should not exceed 2.1 mol/l to prevent the risk of crystallisation. On average, 90 litres of water and 3 litres of 96 % sulphuric acid are needed to remove 1 kg of ammonia from treated air [55, Denmark 2010]. The replacement of the circulating liquid is automatic and can be done after a number of times that the pH has been corrected to the needed value (e.g. 5 times correction to 0.5 pH [134, Netherlands 2010], [130, Netherlands 2010]. Hence the system management can be controlled upon request by ~~reading~~ using electronic devices to control operating parameters.

Filters and components need frequent maintenance and control.

At an NH_3 removal efficiency of 95 %, the waste water production is about 0.2 m^3/kg of NH_3 removed per year, which equals a yearly amount of 70 litres per growing/finishing pig place or 2 litres per broiler place [13, Melse 2009].

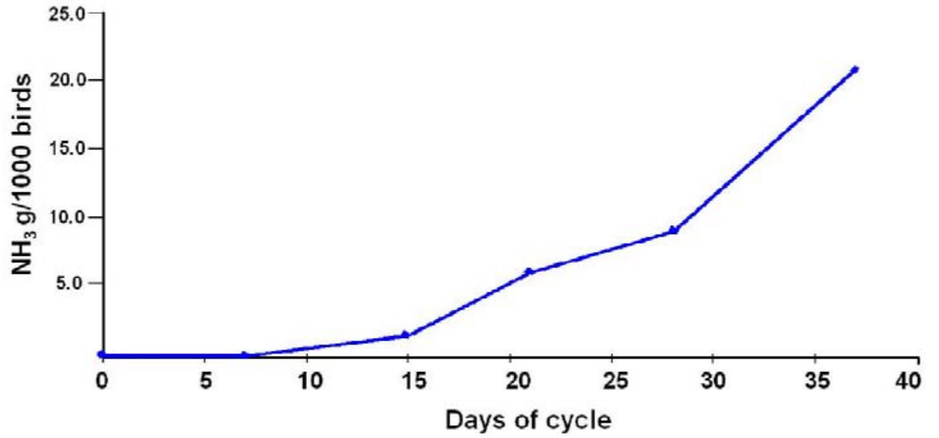
OLD TABLE 4.26 AND PART OF THE TEXT UNDER "APPLICABILITY", ALREADY DELETED IN DRAFT 1, HAVE BEEN ELIMINATED

Applicability

This system can be implemented in new and existing housing applying ~~artificial~~ forced ventilation. High dust levels in the exhaust air from the housing can affect the scrubbing performance; hence it is less suitable in dry climates.

The system can be easily turned on and off, making it suitable to the poultry farms that apply all-in, all-out animal management.

In broiler houses, the microbiological degradation of the accumulating manure increases the ammonia emissions over time. Emissions before day 15 are very low and hardly reach 5 grams of NH_3 per thousand chickens per day. Therefore, emissions are only relevant from day 20 onwards, and only at this time, cleaning of waste air becomes justifiable (see Figure 4.68).



Source: [374, DK 2010] Hansen J. M 2008. Agroteh Kemisk luftrensning ved slagtekyllingestald

Figure 4.68: Ammonia emissions from a ~~poultry~~ broiler house (measurements in September-October)

Economics

Average costs have been calculated in the Netherlands and are reported in Table 4.132. Different costs are evaluated depending on the assigned emission reduction category (see Section 4.9.1) and on the reared animal.

Table 4.132: Average costs for acid scrubbers in the Netherlands by category of associated reduction and type of production

Emission reduction	Investment costs (EUR/ap)				Total annual costs (EUR/ap/yr)			
	Weaners	Farrowing sows	Gestating sows	Fattening pigs	Weaner	Farrowing sows	Gestating sows	Fattening pigs
70 %	10	105	60	30	2	20	15	8
95 %	12	120	70	35	3.50	30	20	11
Source: [132, Netherlands 2010] [133, Netherlands 2010]								

Emission reduction	Investment costs (EUR/ap)			Annualised investment costs (EUR/ap/yr)			Total annual costs (EUR/ap/yr)		
	Broilers	Broiler breeders	Laying hens	Broilers	Broiler breeders	Laying hens	Broilers	Broiler breeders	Laying hens
90 %	2.70	8.55	3.95	0.38	1.37	0.62	0.63	2.37	1.09
Source: [131, Netherlands 2010] [589, Netherlands 2010]									

An example of investments and annual costs for an acid scrubber applied to a newly built facility for pig production, broken down for each cost factor, is given in Table 4.133 with separate values for each cost factor.

Table 4.133: Investment and operational annual costs for an acid scrubber applied to a newly built facility for pig production

	EUR/animal place/yr
Investment costs ([1])	32.8
Operational costs	
Annualised investment cost (10 %)	2.6
Maintenance (3 %)	1.5
Interest (6 %)	0.8
Electricity use (EUR 0.11/kWh)	3.3
Water use (EUR 1.0/m^3)	0.6
Chemical use (EUR 0.6/litre H_2SO_4, 98 %)	1.4
Water discharge ([2])	0.6
Total annual operational costs	8.2
Total annual costs	*10.8*
([1]) The investment costs are based on a maximum ventilation capacity of 60 m^3/ap/h. ([2]) Water disposal costs are assumed equivalent to 10 EUR/m^3 for discharge from acid scrubbing *Source:*[568, Melse et al. 2010]	

Depending on the farm size, extra-cost data are in the range of 0.5 – 5 EUR/ap/yr. [54, Denmark 2010]. Reported extra-costs based on the share of maximum ventilation rate treated by the chemical scrubber range from 2 to 2.4 EUR per pig produced when the partial air cleaning capacity of the maximum ventilation rate is equivalent to 100 %; while, extra-costs between 0.1 and 1.2 EUR per pig produced are reported for 20 % partial air cleaning capacity, with the low value corresponding to a large farm with approximately 8 000 fattening places. [55, Denmark 2010]

Examples of extra-cost data, for different animal categories and size of housing in the rearing of poultry, are presented in Table 4.134

Table 4.134: Extra costs related to the application of acid scrubbers in poultry housing

Type of animal	Size of housing animal places (ap)	Extra investment (EUR/ap)	Annualised extra investment (EUR/ap)	Operating annual extra cost (EUR/ap)	Total annual extra cost (EUR/ap)	Total annual extra cost (EUR per produced animal)
Pullets	50 000	2.77	0.37	0.50	0.87	0.34
Laying hens (aviary)	40 000	3.44	0.46	0.63	1.10	1.25
Growing pullets of broiler breeders	33 000	3.95	0.52	0.71	1.23	0.60
Broiler breeders	19 000	7.59	1.00	1.40	2.40	2.35
Broilers	90 000	3.69	0.50	0.62	1.12	0.163
Turkeys	20 000	24.7	3.39	4.37	7.76	2.68
Ducks	40 000	5.65	0.76	0.93	1.69	0.26
Source: [503, Vermeij 2011]						

Example plants
This system is commonly used in the Netherlands and Denmark. ~~was developed just a few years ago. It is now being implemented in some reconstruction situations~~.

In 2009, about 25 – 30 pig farms were reported applying acid scrubbers in Denmark. [54, Denmark 2010]; whereas, one broiler farm was reported for the poultry sector.[374, DK 2010]

In the Netherlands, the installed capacity of acid scrubbers for ammonia removal, referred to the year 2008, was reported at 64 million m^3/h installed on a total of 790 farms. [568, Melse et al. 2010]

In the Flemish part of Belgium, 145 ~~IPPC authorised~~ farms are provided with chemical wet scrubbers.

Reference literature
[42, Netherlands 1999] [54, Denmark 2010] [131, Netherlands 2010] [133, Netherlands 2010] [132, Netherlands 2010] [134, Netherlands 2010,] [130, Netherlands 2010] [568, Melse et al. 2010] [514, KTBL 2008]

4.9.5 Biofilter (former Section 4.9.7)

Description
The exhaust air of animal housings is led through a filter bed of organic material, such as root wood or wood chips, coarse bark, compost or peat. [52, BE Flanders 2010] [514, KTBL 2008]. Fine grained filter materials have a relatively large specific surface that facilitates mass transfer but, on the other hand, cause higher pressure losses. The filter material is always kept moist, so that microorganism populations may live on it forming a film. This is achieved by humidifying the filter material by intermittent sprinkling of the surface. Gaseous compounds are absorbed by the wet film and are oxidised or degraded by micro-organisms living on the moisturised bedding material.

Achieved environmental benefits
Biofilters are mainly used to eliminate odours arising from housings with non-bedded slurry systems, but can also be used in litterless housing for dust separation if coarsely structured filter material (which does not tend to clog) is used at least on the crude gas side.

Ammonia is also degraded in biofilters but the possible counter-effects need to be taken into account (See 'cross-media effects'). This aspect, together with a not known retention of the performance over time, makes the ammonia removal efficiency of biofilters controversial. ~~The system is not suitable for ammonia reduction to the formation of secondary trace gases, such as nitrous oxides and dinitrogen monoxide.~~

Cross-media effects

The system ~~provides~~ involves an extra pressure drop of roughly 30 – 150~~200~~ Pa [514, KTBL 2008], which depends on the filter surface load, the type and height of the filter material and its age, ~~that~~ Ventilating fans ~~in use~~ must be able to overcome the added resistance;~~.~~ Therefore, additional energy consumption is required for running the fans. The water consumed for moistening the substrate is reported to be in the range of 5 – 7 litres per 1 000 m^3 of exhaust air.

The system is not suitable as a sole process for ammonia reduction from exhaust air from livestock houses presenting a high load of ammonia. Due to the separation of ammonia, the microbial activity is influenced, the pH value is significantly lowered (no adjustments are possible) while the formed salts cannot be removed. Finally, ~~due to the formation of~~ secondary trace gases are formed, such as nitrous oxides and dinitrogen monoxide and the functionality of the whole system would be impaired.

If bed scrubber filter material consists of peat, a significant emission of greenhouse gases (GHG) would be associated with the peat mining process; while, GHG emissions from the farm system itself may become significant due to the potential formation of N_2O.

Operational data

~~Air flows can be treated in the range of 14 to 85 m³ per animal place per hour.~~

A capacity of 440 m^3/h of exhaust air per m^2 of filter surface has been reported. Based on this figure and knowing the air flowrate that has to be treated, the dimensions for a filter module can be estimated. The thickness of the active filter layer is normally between 0.3 – 1.4 m, depending on the material, whereas the contact time ranges from 4 – 20 seconds depending on the filter height and surface load. Upscaling or downscaling of the treatment capacity, due to the modular design, is possible.

The sprinkling of the filter with fresh water (approximately 5 to 7 ~~5.5~~ litres of water/1 000 m³ of outgoing air; with 60–70 % material moisture) is automatically controlled on the basis of the air flow volume. The filter is sprinkled from the surface by two nozzles per filter module.

Each year, about 21 kWh /animal place per year ~~63 400 kWh~~ of energy is needed for pressure compensation (220 – 280 kWh per 1 000 m^3/h capacity), and 1.5 m^3/animal place per year ~~4600~~ of fresh water are necessary.

As for all air cleaning systems, the removal efficiency of ~~the~~ odour ~~reduction~~ depends on the crude gas concentration and is reported from 84 to 97 %. In Germany, for biofilters that are properly operated, an odour concentration in the clean gas of <300 OU_E/m^3 is considered achievable, and no raw gas odour to be perceptible in the clean gas.

Dust abatement efficiency is ~~possible~~ reported from 80 % to 100 %. [120, Germany 2010] Measurements on the finest dust fraction $PM_{2.5}$ indicate an abatement efficiency of 63 %. [515, UR Wageningen 2010]

Used biofilter materials are applied to land. Other material (nets, plastics and steel) are usually collected by dealers for following recycling or disposal. No additional waste water is produced.

Applicability

As reported above, typical modules provided by manufacturers ~~provide modules~~ are designed for treating 440 m^3/h exhaust air per m^2 of filter surface ~~and hour~~, which means ~~(~~about 1 936 m^3/h per module ~~and hour or~~ equivalent to about 20 – 24 fattening pig places.

As the filter area requirement is approximately 0.2 – 0.25 m^2 per animal place, sufficient area outside the facilities must exist to accommodate the filter packages.

The implementation in existing houses must be planned with the adaptation of exhaust air ducts and with significant additional requirements for ventilation.

In order not to undermine the removal capacity of the bed, a replacement of the biofilter packing at regular intervals is necessary. Pre-treating the air in order to remove the main part of the ammonia load before entering the biofilter, minimises the formation of nitrite/nitrate salts and allows a much longer packing life span, and thus reduces refilling costs [568, Melse et al. 2010].

In Germany, the application of biofilter for ammonia reduction is not recommended. At the same time, it is supported that a biofilter can be also operated as an ammonia abatement technique under certain conditions (e.g. in combination with a water curtain) and if carefully operated (comparable to the requirements for bioscrubbers) [500, IRPP TWG 2011]. Ammonia abatement efficiency is reported over 70 % [516, TÜV 2009] and up to 89 % but it is not clear whether the removal efficiency can stay high over time due to the secondary effects previously described (see cross-media effects). [515, UR Wageningen 2010]

Economics

Figures are given for a capacity of 255 000 m^3/h exhaust air volume ~~/year~~, equivalent to 3 000 fattening pig places. A total annual cost between EUR 11.60 and EUR 13.10/ap results from the annualisation (20 years construction and 4 % interest rate) of the investment requirements (EUR 59 – 64/ap, annualised investment costs from 6.5 to 6.8 EUR/ap). ~~The annual running costs are in the range of 59 – 64 and~~ summed to annual running costs of 5.10 – 6.30 EUR per animal place.

The resource demand needed for operating a biofilter with a capacity of 255 000 m³/h exhaust air volume is reported in Table 4.135.

Table 4.135: Resource demand of for the operation of a biofilter

Resource	Unit	Consumption (per 1 000 m^3/h capacity)
Energy – Air treatment system	kWh	3.3
Energy – Ventilation (additional consumption)	kWh	220-280
Fresh water requirements	l	14 000 – 22 500
	m^3/ap/yr	1.53
Labour	h	0.35 – 0.4
Source: [120, Germany 2010]		

Driving force for implementation

Local high immission loads or insufficient spatial distances from odour-sensitive receptors ~~objects. In Germany, minimum requirement are set requiring less than 300 OU_e per m^3 released and no crude odour perceptible in the clean gas.~~ **Moved to another part of this section**

Example plants

~~Several farms in Germany are equipped with this system.~~ At least 267 German farms are using this technique. [505, Hahne J. 2011]

Reference literature

[120, Germany 2010] [52, BE Flanders 2010] [500, IRPP TWG 2011] [514, KTBL 2008] [515, UR Wageningen 2010] [516, TÜV 2009] [568, Melse et al. 2010]

4.9.6 Multi-stage scrubber, or combi-scrubber (former Section 4.9.1.4)

Multi-stage scrubbers are a development of air scrubbers. Each stage aims at the removal of one type of compound, thus these systems combine in a series the concepts of acid scrubbing, bioscrubbing, water-curtains and biofiltration. As a consequence theoretically, there are many possible combinations. At least 438 German farms are using techniques of this type. [505, Hahne J. 2011]

4.9.6.1 Two-stage scrubber of combined ~~chemical~~ wet acid scrubber and bioscrubber (former Section 4.9.1.4.2)

Description
A chemical scrubber and water/biological scrubber are set in a series ~~and each stage is followed by a drop separator.~~ The chemical stage is operated as a single ~~chemical~~ wet acid scrubber (see Section 4.9.4). The second stage is a biologically active water scrubber. The plastic contact bed packing is permanently sprinkled with water in the direction of the air flow and against it. The scrubbing water flows back into the water tank, which is equipped with an additional submerged contact bed for the improvement of the biological degradation of residual compounds. For the separation of aerosols, a drip separator is installed immediately at the point where the clean air leaves the system.

A scheme of a two-stage system for air scrubbing is presented in Figure 4.69.

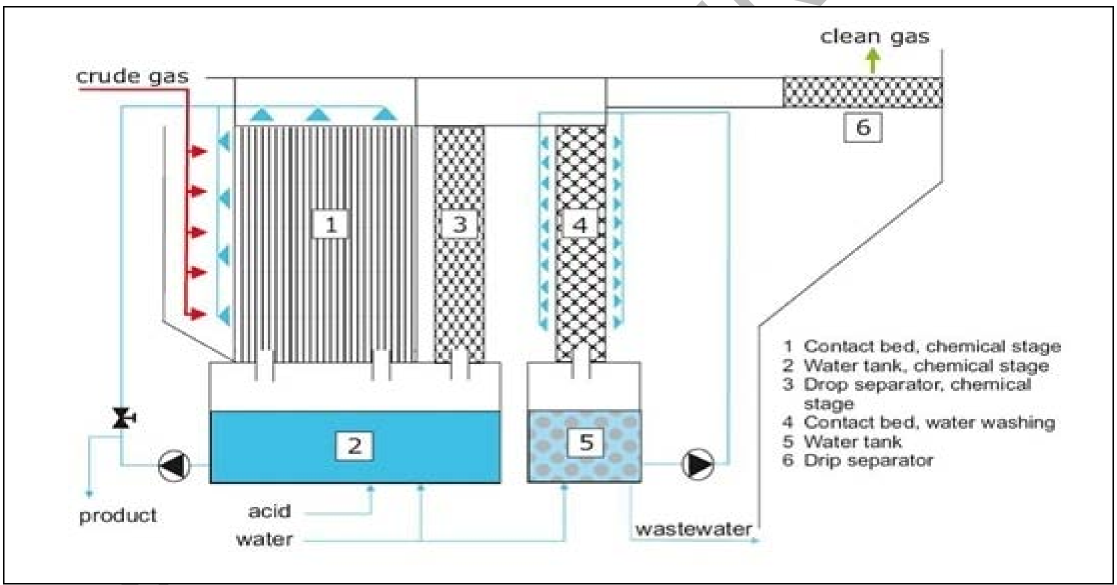


Figure 4.69 Two-stage air scrubber with combined acid scrubber and bioscrubber

Achieved environmental benefits
Reduction of emissions of odorants, ammonia, and dust.

Cross-media effects
The energy consumption is increased due to greater ventilation energy requirements that are needed to overcome a pressure of 150 – 200 Pa (total for house and air cleaner).
The scrubbing water in the chemical stage, which contains ammonium sulphate, must be stored in a separate storage tank, whereas the scrubbing water from the separate water stage can be pumped into the external slurry store. Nitrogen has to be taken into account for fertilizer planning. ~~Discharged waters can be applied to land, being rich in nitrogen and having no counter-effect.~~

Operational data

Air flowrates vary from 14 to 85 m³ per animal place per hour. Over the course of the year, the average flowrate is 48 % of the maximum air flowrate. Out of the chemical stage, one kg of ammonia is discharged in about 0.05 m^3 of water and out of the water stage 0.04 m^3 of water are discharged with the same amount of ammonia.

Ammonia reductions are obtainable in the range of 70 to 96 %, along with odour reduction from 60 to 77 % and total dust reduction from 85 to 98 %. Odours can be abated in order to obtain concentration in the clean gas <300 ou_E/m^3 and no raw gas odour in the clean gas is perceptible. On average, these results are equivalent to 70 % efficacy.

Ranges of for the resource demand related to a capacity of 1 000 m³/h are shown in Table 4.140.

The waste water of the chemical stage need to be stored separately. Its volume generally corresponds to 1.65 m^3 per 1 000 m^3/h (0.14 m^3/pig place per year) in the first stage and to 1.34 m^3 per 1 000 m^3/h (0.11 m^3/pig place per year) in the second stage.

In Table 4.136, data concerning the emission reductions achieved by applying two-stage scrubbers in pig production are presented.

Table 4.136 Emission reductions achieved by the application of two-stage scrubbers in pig production

Achieved emission reduction (%)				Reference
Ammonia	Odour	Dust	PM_{10}	
70 – 96 80 (average)	60 – 77 70 (average)	85 – 98 96 (average)		[122, Germany 2010]
84 – 93 85 (average)	40 – 72 70 (average)	94 – 96	80	[125, Netherlands 2010]

Applicability

The same objection for the single bioscrubber can be raised. Hence The system is applied in pig farms only; the high dust and feather load of the poultry production, having an effect on the discontinuity in feeding the bioscrubbers, would affect the efficiency of the whole system. (See Section 4.9.3, 'Applicability'). Otherwise, the system has the same limitations as any scrubber.

Two-stage air cleaners are not proven to be effective in littered housings.

The housing ventilation system requires proper planning (air inlet/outlet) and design (sufficient capacity of the fans for the increased pressure). In retrofitting existing installations, there are significant additional requirements for the adaptation of the air ventilation outlets and for the upgrading of the fans. Additionally, significant space must be available to host the various hardware.

Economics

Economic figures have been modelled in Germany for modules a of a capacity of 1 000 m³/h, equivalent to 11.8 pig places at a standard ventilation of 85 m^3/h per animal place, considering a. Investment are between EUR 720 and EUR 770, and annual running costs are between EUR 120 to EUR 140. The total annual costs (10 years amortisation for the installation, 20 years for the construction, and 4 % of interest rate) result in a range of EUR 200 to EUR 225. Results are given in Table 4.137. [122, Germany 2010]

Table 4.137: Costs related to the application of two-stage scrubbers with combined wet acid scrubber and bioscrubber, applied for fattening pig housing

	Associated costs for two-stage scrubbers	
Parameter	**EUR per animal place/year**	**EUR per animal place/year**
Investment costs	61–65	50
Annualised investment costs ([1])	6.8-7.2	-
Annual running costs	10–12	-
Total annual costs	17–19	12

([1]) Amortisation period: 10 years (installation), 20 years (construction); interest rate: 4 %; capacity: 255 000 m^3/h equivalent to 3 000 places.
Source: [122, Germany 2010] [125, Netherlands 2010] [514, KTBL 2008]

In Table 4.138, data related to investment, operational and total costs are reported for different system capacities in pig production.

Table 4.138: Cost ranges associated with the use of two-stage scrubber systems for exhaust air treatment in pig production

Housing capacity	Associated costs ([1])							
	Investment costs		Annualised investment costs		Operational costs		Total costs	
	EUR/ap		EUR/ap/yr		EUR/ap/yr		EUR/ap/yr	
	from	to	from	to	from	to	from	to
460 – 700 animal places (39 000 – 60 000 m^3/h)	70	75	9.1	9.5	9.9	10.8	19.0	20.3
1 060 – 1 180 animal places (90 000 – 100 000 m^3/h)	68	72	8.7	9.1	9.1	10.0	17.8	19.1
1 700 – 1 850 animal places (150 000 – 157 000 m^3/h)	63	68	8.0	8.4	8.7	9.6	16.7	18.0

([1]) All cost data are given without VAT
Source:[514, KTBL 2008]

Driving force for implementation
In densely populated areas (e.g. the Netherlands), air cleaning systems give farmers the only possibility to expand the activity complying with maximum allowed levels for ammonia, particulate matter or odour emissions.. It is an option for large scale livestock installations to remain in operation in areas closely located to residential areas and sensitive ecosystems.

Example plants
Several farms in Germany use this technique.

Reference literature
[122, Germany 2010] [125, Netherlands 2010] [514, KTBL 2008]

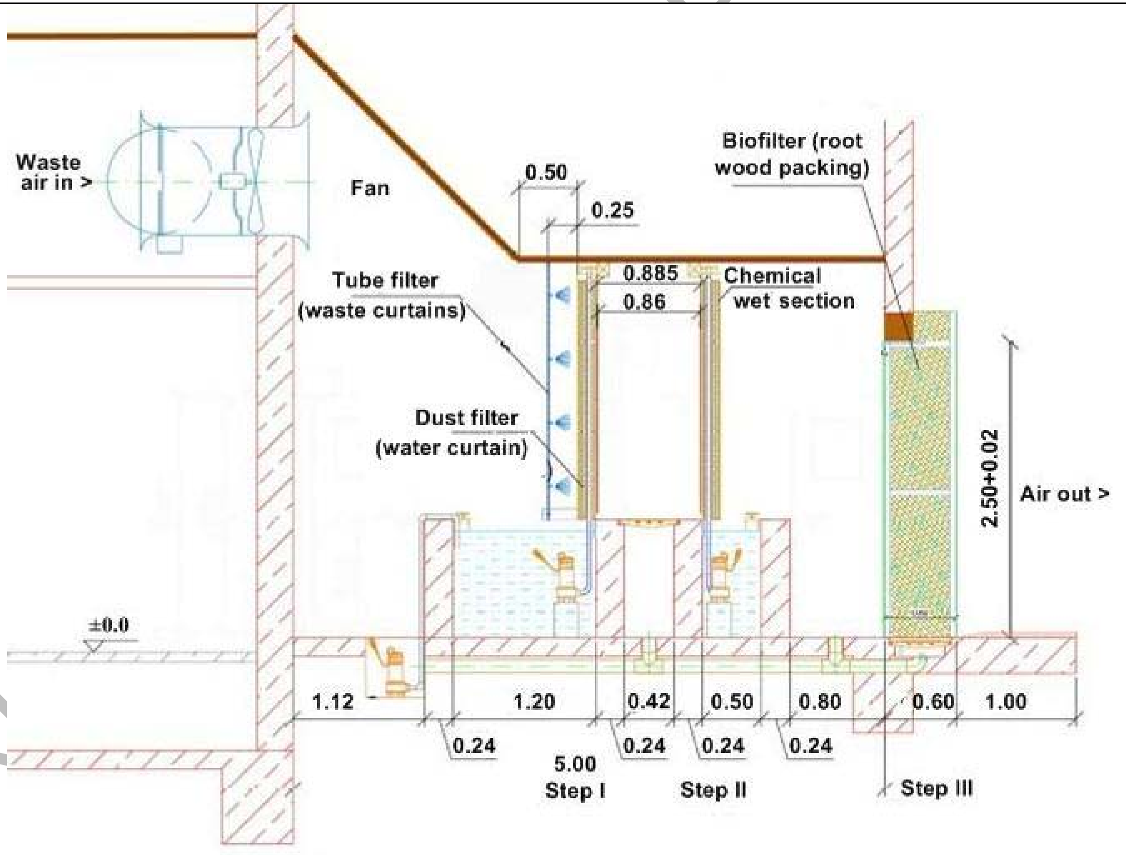
4.9.6.2 Three-stage scrubber of combined water scrubber, wet chemical ~~wet~~ scrubber and biofilter (former Section 4.9.1.4.1)

Description
This combination consists of three filter walls where the first and the second filter are a packed column (see Figure 4.70). The first filter is a continuous water scrubber that removes part of the fine dust and converts part of the ammonia into nitrate and nitrite by means of the microbial activity in the washing water. The second filter is continuously sprayed with sulphuric acid solution and removes part of the ammonia content and fine dust.

The third step is a biofilter (see Section 4.9.5) made of a column packed with root wood, which is frequently sprayed with water to keep it moist. The spraying frequency depends on the weather conditions.

In this third step, microbes that are present on the root wood substrate remove odour compounds and part of the ammonia left from the previous stages.

The flushing takes place every three months and coincides with the periodic~~al~~ cleaning of the installation. When flushing, the water reservoirs of the first two steps are totally replaced with fresh water.



Source: [139, Netherlands 2010]

Figure 4.70: Combined multi-stage scrubber: water scrubber, ~~chemical~~ wet acid scrubber and biofilter

Achieved environmental benefits
Air emissions of ammonia, odour and dust are reduced.

A reduced waste water volume is produced, in comparison with the application of a bioscrubber, as reported under 'operational data'.

Cross-media effects
Additional energy consumption is required to run fans and pumps in order to overcome the increased pressure drop (up to 80-100 Pa), with a resulting energy consumptions that may double. Notable water consumption is required due to evaporation and final compounds removal with water flushing. Waste water can be disposed of or reused as fertiliser e.g. with the slurry for land application (see section 'operational data'), in which case the related load of nitrogen has to be taken into account for a correct planning of the fertiliser. Water from the acid scrubbing stage must be stored separately.

Noise emissions can be associated with the intense work of the fans.

Operational data
Emission reductions have been measured in pig farms in the Netherlands under the Dutch Livestock Farming Regulation. Ranges for ammonia reduction were from 64 % to 84 % and for odour reduction ranges were from 64 % to 87.9 %. The achievable dust removal is from 94.8 % to 97.8 %, of which 80 % is related to PM_{10}.

In Table 4.139, the performance of three-stage systems applied on housing for pigs and sows is reported, expressed as removal efficiency for ammonia, odour and dust.

Table 4.139: Examples of removal efficiencies achieved with multi-stage combined scrubber systems (water scrubber –wet acid scrubber – biofilter)

Housing system characteristics	Removal efficiencies			
	Ammonia (%)	Odour (%)	Dust (%)	PM_{10} (%)
3 000 animal places for fattening pigs	70 – 95	50 – 90	70 – 95	
1 320 animal places for fattening pigs Filter surface load 3 020 $m^3/(m^2\ h)$	82.5 – 97.5 warm period 68.1-96 cold period 85 % reduction, based on Dutch ammonia and livestock farming regulation	79 – 87.9 warm period 71.1 – 82.3 cold period 75 % reduction based on Dutch odour nuisance and livestock farming regulation	94.8 – 97.8	80
600 animal places for sows Filter surface load 3 020 $m^3/(m^2\ h)$	70.1 – 79 70 % reduction, based on Dutch ammonia and livestock farming regulation	64 – 84 80 % reduction based on Dutch odour nuisance and livestock farming regulation	95	80
Source: [123, Germany 2010] [126, Netherlands 2010] [128, Netherlands 2010] [514, KTBL 2008]				

Acid consumption can be reduced considerably if the system is operated such as the nitrification provides biogenous acid formation at the first scrubbing stage and the scrubbing water is changed often. ~~by recycling in the acid stage the water that is used in the first step. If the water in the first step is replaced frequently enough, it outflows naturally acidified towards the second step to help neutralising the ammonia in the treated air~~. [123, Germany 2010].

Data for energy consumption and other ~~Ranges of~~ resources demand, ~~that are~~ related to a capacity of 1 000 m³/h that is equivalent to 11.8 pig places, are shown in Table 4.140.

Table 4.140: Resources demand related to a capacity of 1 000 m³/h

Operation	Unit	3 stage scrubber	2 stage scrubber
Energy – Air treatment system	kWh	100 – 150	190
Energy – Ventilation (additional consumption)	kWh	180 – 250	220 – 280
Fresh water requirements	l	16 500 – 25 000	14 900 – 25 500
Chemicals required	kg	20 – 34	100
Labour	h	0.3 – 0.4	0.4
Source: [123, Germany 2010]			

The waste water arising from the biological treatment, equivalent to about 1.8 m^3 per 1 000 m^3/h (0.15 m^3/pig place/yr) should can be stored (e.g. pumped into the slurry container) and reused taking into account the added nitrogen load. Waters from the chemical stage need a separate storage; their volumes are around of 0.7 m^3 per 1 000 m^3/h (0.06 m^3/pig place/yr).

A reduced amount of waste water is produced by a three-stage scrubber in comparison with a bioscrubber. While in the bioscrubber, good removal efficiency can only be guaranteed if at least 0.2 m^3/kg NH_3 input are elutriated, in three stage installations, whose removal efficiency is at least equal to bioscrubbers, only 0.055-0.083 m^3/kg NH_3 must be separated. The difference in the produced scrubbing waste water is presented in Table 4.141, for a housing system of 1 000 pigs located in Germany.

Table 4.141: Waste water volume produced in a 1 000 fattening pigs housing system

Treatment system	Elutriation rate (m^3/kg NH_3 input)	Quantity of waste water (m^3/year)
Bioscrubber (1)	0.2	730
Three-stage scrubber (1)	0.055 – 0.083	200 - 300
(1) Results are based on an emission factor of 3.64 kg NH_3/ap/yr (no crude protein adapted feed)		

Applicability
Several applications are known in pig farms but examples in poultry plants are not known reported, since the high dust and feather load having an effect on the discontinuity in feeding the bioscrubbers affects the efficiency of the whole system efficacy (see Section 4.9.3, 'Applicability'). Otherwise, these systems have the same limitations are as applicable as any scrubber especially for retrofitting existing houses. The housing ventilation system requires proper planning (air inlet/outlet) and design (sufficient capacity of the fans for the increased pressure). In retrofitting existing installations, there are significant additional requirements for the adaptation of the air ventilation outlets and for the upgrading of the fans. Additionally, significant space is needed to host the various hardware.

Economics
Economic figures have been modelled in Germany for modules of a capacity of 1 000 m³/h equivalent to 11.8 pig places at a standard ventilation of 85 m^3/h per animal place, considering a. Investment are between EUR 500 and EUR 615, and annual running costs are etween EUR 130 to EUR 160. The total annual costs (10 years amortisation for the installation, 20 years for the construction, and 4 % of interest rate. Results are given in Table 4.142.) result in a range of EUR 130 to EUR 160.

Table 4.142: Costs related to application of three-stage scrubbers with combined water scrubber, wet acid scrubber and biofilter

	Associated costs for three-stage scrubbers	
Parameter	**EUR per 1 000 m³/h installed**	**EUR per animal place/year**
Investment costs	500 – 615	43 – 52
Annualised investment costs (1)	50 – 60	4.2 – 5
Annual running costs	80–100	6.80–8.5
Total annual costs	130–160	11–13.5

(1) Amortisation period: 10 years (installation), 20 years (construction); interest rate: 4 %; capacity: 255 000 m³/h equivalent to 3 000 places.
Source: [123, Germany 2010] [514, KTBL 2008]

Investment and operational costs related to the application on a newly built facility of a three-stage system with a bioscrubber as third stage, in place of a biofilter, are reported in Table 4.143.

Table 4.143: Investment and operational annual costs for a three-stage scrubber (water and acid scrubber + biotrickling) applied to a newly built facility for pig production

	EUR/animal place/yr
Investment costs (1)	50.3
Operational costs	
Annualised investment cost (10 %)	4.2
Maintenance (3 %)	2.0
Interest (6 %)	1.2
Electricity use (EUR 0.11/kWh)	3.7
Water use (EUR 1.0/m³)	0.6
Chemical use (EUR 0.6/litre H_2SO_4, 98 %)	0.7
Water discharge (2)	1.0
Total annual operational costs	9.2
Total annual costs	*13.5*

(1) The investment costs are based on a maximum ventilation capacity of 60 m³/ap/h.
(2) Water disposal costs are assumed equivalent to 10 EUR/m³ for discharges from acid scrubbing and 2 EUR/m³ for discharges from biotrickling or water scrubbing. Discharge water from the biotrickling and water scrubbing stages is reused in the acid scrubbing stage.
Source:[568, Melse et al. 2010]

In Table 4.144, data related to investment, operational and total costs are reported for different system capacities in pig production.

Table 4.144: Cost ranges associated with the use of three-stage scrubber systems for exhaust air treatment in pig production

Housing capacity	Associated costs ([1])							
	Investment costs		Annualised investment costs		Operational costs		Total costs	
	EUR/ap		EUR/ap/yr		EUR/ap/yr		EUR/ap/yr	
	from	to	from	to	from	to	from	to
460 – 700 animal places (39 000 – 60 000 m^3/h)	65	75	7.7	8.6	10.6	11.6	18.3	20.2
1 060 – 1 180 animal places (90 000 – 100 000 m^3/h)	50	58	5.7	6.5	9.2	10.1	14.9	16.6
1 700 – 1 850 animal places (150 000 – 157 000 m^3/h)	45	53	5.0	5.8	8.4	9.4	13.4	15.1

([1]) All cost data are given without VAT
Source:[514, KTBL 2008]

Driving force for implementation
In individual cases of insufficient spatial distance from the nearest existing or planned residential buildings or other odour-sensitive constructions, as it happens in densely populated areas (e.g. the Netherlands), or from nitrogen-sensitive ecosystems (e.g. forests), air cleaning systems give farmers the only possibility to expand the activity complying with maximum allowed levels for ammonia, particulate matter or odour emissions.

Example plants
The system is in operation now in several pig farms in the Netherlands and Germany.

Reference literature
Ogink and Bosma, 2007; Arends et al., 2008;
[123, Germany 2010] [126, Netherlands 2010] [128, Netherlands 2010] [514, KTBL 2008] [568, Melse et al. 2010]

4.9.7 Partial air treatment in end-of-pipe air cleaning systems (former Section 4.9.1.5)

In mechanically ventilated pig houses, ventilation rates vary from 10 to 90 m^3 per fattening pig per hour depending on animal production stage and weather conditions. An average year-round ventilation rate at Dutch weather conditions is about 35 m^3 per fattening pig per hour. As a consequence, maximum (for summer) and average exhaust air flows are defined and, therefore, air cleaning systems are dimensioned accordingly.

Description
~~Air bypass systems are installed to allow the part of the exhaust air that exceeds a defined air flowrate to leave the housing untreated.~~ Where scrubbers are applied, it is possible to install an air bypass system. This ensures that ventilation needs are met for the welfare of the animals and that scrubbers are operated efficiently. A portion of the exhaust air is expelled from the housing through the bypass without being treated, whilst the remaining exhaust air passes through the scrubbing system. Hence scrubbers are operated at designated air flowrates, which are much lower than the maximum possible that varies upon necessity depending on climatic conditions.

Achieved environmental benefits
The ventilation rate and hence the benefits for animals remain unchanged, but the scrubber size is reduced, resulting in an increased efficiency of scrubber utilisation (kg of NH_3 removal per m^3 of scrubber volume). Achievable ammonia emission levels can be estimated for each given investment.

Cross-media effects

~~Both the investment and operational costs will be reduced, in comparison with full capacity scrubbers, as smaller scrubbers are built. The investment cost per m^3 will be only slightly higher due to the additional costs of the bypass itself.~~

The disadvantage of this technique is that peak emission management is not possible (e.g. summer heat, old animals, high ventilation). For ammonia emissions levels, which are generally set in terms of yearly average, this disadvantage may be irrelevant; however, for other pollutants such as dust and odour, for which peak emission levels are usually established, it may cause an above average nuisance to the neighbourhood.

Operational data

Non-sealed ventilation systems like those that allow bypasses are more difficult for inspectors to control and evaluate.

In Table 4.145, ammonia emission levels and the associated costs for implementing the cleaning system are presented. Data for a two-stage bioscrubber and for a two-stage chemical scrubber are reported for different percentages of exhaust air treated by the air cleaning system.

Table 4.145: Emission levels and cost data for different percentages of exhaust air treated by two-stage air cleaning systems

Type of cleaning system	Percentage of exhaust air treated	Ammonia emissions (kg NH_3/ap/yr) ([1])	Total costs (EUR/ap/yr) ([1])
Bioscrubber	100 %	0.44	12
Bioscrubber	60 %	0.56	7.6
Bioscrubber	40 %	-	2.8
Bioscrubber	20 %	0.88	-
Chemical Scrubber	100 %	0.40	-
Chemical Scrubber	60 %	0.56	-
Chemical Scrubber	20 %	1	-

([1]) Cost data are calculated on the basis of a production of 4 pigs per animal place per year.
Source: [53, Denmark 2010] [54, Denmark 2010]

Applicability

Bypasses may only be installed if local regulations allow for it (e.g. in the Netherlands, bypasses are not allowed).

The principle of the technique is independent of the animal species; therefore, it is applicable in pigs and poultry rearing.

Economics

The investment cost per m^3 of exhaust air to be treated will be only slightly higher due to the additional costs of the bypass itself. On the other hand, the costs for air cleaning are reduced as the investment and operating costs of scrubbers are related to their size.

Driving force for implementation

Predetermined emission levels may be achieved at reduced running costs of air cleaners.In this way, it is possible to design the ventilation/cleaning system on the basis of required reduction levels set for a specific location by competent authorities.

Example plants

This technique is commonly used in Denmark upon permit specification.

Reference literature

[13, Melse 2009] [514, KTBL 2008]

4.10 Techniques for the reduction of odour emissions

Odours are indigenous to all livestock production operations. Odour mainly originates from microbial conversion of feed (protein and fermentable carbohydrates) and by microbial conversion of urinary and faecal compounds in the manure under anaerobic conditions. Odour is a complex mixture of many different compounds such as sulphurous compounds, indolic and phenolic compounds volatile fatty acids, ammonia and volatile amines. [511, Le et al. 2007]

Odour is the principal concern that arises from local communities in relation to both pig and poultry farms. Odour arises from ~~pig manure and animals, therefore it can come from~~ animal housing as well as from manure transfer, ~~and~~ storage and ~~manure~~ spreading. The level of odour that arises from pig or poultry farms varies significantly and the degree of nuisance of a particular odour level varies according to location and context. [204, IMPEL 2009] Odour from broiler housing is reported to increase in offensiveness with the moisture content of the litter.

It is generally considered that most techniques described in the previous sections which are mostly intended for abating ammonia and dust emissions can have a reducing effect on odour emissions; although, this effect is not consistent throughout all animal categories, depending on the characteristics of their odour emissions. In some circumstances, such as housing systems for pigs with frequent removal of manure by flushing gutters underneath the slats, ammonia emissions can be significantly reduced, while odour emissions may be high, with levels during flushing events 3 to 3.5 times higher than those from other housing systems. Various other factors, like farm hygiene, type and feeding regime, and water/feed ratio, have a significant influence on odour emissions from livestock buildings and can conceal the emission reduction effects of the housing systems. [513, Mol and Ogink 2002]

4.10.1 General measures for odour prevention

~~Data suggest that low-protein diets influence the reduce emissions of both ammonia and odorous compounds.~~ **Moved below**
Odour can ~~also~~ be reduced in a number of other ways ~~also~~, including:

- by good housekeeping
- by storing the manure outside under a cover
- by avoiding an air stream passing over the manure.

For reasons of odour, application times and techniques have been developed for landspreading. Some additional techniques to reduce odour in the vicinity of the farm are applied on-farm to animal housing with forced ventilation. Local conditions may be decisive for the adoption of abatement techniques, as in the case of densely populated areas in the Netherlands. ~~However,~~ Applicability, cross-media effects and costs might generally limit the adoption of the ~~following~~ techniques given below or, alternatively, the positive effect on odour abatement in addition to the ammonia emission reduction, may suggest their implementation.

- Scrubber, see bioscrubber and chemical wet scrubber in Sections 4.9.3 – 4.9.6.
- Biodegradation – by leading the air from the housing through a biofilter of fibrous plant material, odourous elements are broken down by bacteria. The effectiveness depends on moisture content, composition, airflow per square metre of filter bed, and filter height. In particular, dust can be a problem, creating high air resistances (see Section 4.9.5).
- Horizontal air outlet channel – this does not mean a reduction of odour, but diverting the emission point of air from the housing to a different side of the farm, so as to reduce the potential impact for odour-sensitive objects (residential areas).
- Dilution of the concentration, which is explained below and is based on proper design of the housing and dimensioning of the ventilation.

Dietary effects
Data suggest that low-protein diets influence the ~~reduce~~ emissions of both ammonia and odorous compounds.

Dietary protein is precursor for odour production in the intestines of animals and in manure; thus, it is expected that odour emissions will be reduced as dietary crude protein level decreases.

Some experimental results reported a decrease in odour concentration and emission from pig manure, when dietary crude protein is reduced (by nearly 80 % by reducing crude protein from 18 % to 12 % and supplementing essential aminoacids [511, Le et al. 2007]). This reduction was relevant for specific odorous substances (idolic, phenolic and sulphurous compounds). Other results support that the composition and the quality of odour are influenced by the protein level supplied in the diet; while, odour concentration hardly reacts. [512, Andree et al. 2003]

Also fermentable NSP (non-starch polysaccarides) are important dietary components that determine the concentration of volatile fatty acids in the manure and, consequently, have an influence on odour emissions. [513, Mol and Ogink 2002]

On the other hand, it is also reported that there is no significant influence of feeding strategies on the odour emissions; whereas, the odour quality may change. [513, Mol and Ogink 2002]

Odour strength and offensiveness are measured by olfactometry and results are not always clear. [512, Andree et al. 2003] This might explain the difference in reported effects of dietary modifications on odour emissions.

Dilution of odorants.
The odorant concentration at a sensitive site depends, essentially, on the degree of dilution of the odorants emitted during atmospheric transport in the air-stream. Important factors affecting pollutant concentration are:

- the odorant flowrate
- the distance from the source
- the effective source height.

In addition, atmospheric dilution increases with the degree of turbulence in the atmosphere and the air stream. Mechanical turbulences can be achieved through the effective placement of flow barriers (e.g. vegetation).

The distance of the source from the receptors is the most important factor for odour dilution, since the alternative measures described in this section may entail restrictions and disadvantages (e.g. outlet height, exhaust speed).

Discharge conditions
The principles of natural ventilation and forced ventilation result in different waste air discharge conditions. While the exit apertures for the housing air are limited to a narrow cross-section in the case of force-ventilated housings, with naturally ventilated housings, they are occasionally quite large. In those housings, the cross-sections through which air enters and exits are adjustable in accordance with the meteorological and local climatic conditions outside the housing, and with the livestock-specific ventilation requirements inside the housing. Common to both systems are thermal upcurrents in the housing caused by the heat output of the livestock and the possible presence of heating equipment.

Essentially, an unimpeded incoming and outgoing flow of outside air must be ensured in the immediate vicinity of the housings (approximately 3 to 5 times the building height). With forced ventilation, the use of the area in the immediate vicinity of the housing determines the discharge conditions to be selected, e.g. side wall ventilation leading into the yard, or high discharge stacks above the ridge. In the case of naturally ventilated housings, a local odour may be regarded as acceptable, where the emphasis is predominantly on the effect of the housing emissions further afield.

Forced ventilation

As a rule, with force-ventilated housings the focus in terms of impact reduction is on achieving sufficient dilution of the waste air with the wind. In order to protect the local neighbourhood, it may be generally advisable to ensure that the emission air streams pass at a certain minimum height over ~~this area. In order to discharge over~~ and beyond local dwellings~~, the waste air must be transferred into an undisturbed external air stream~~ by raising the source height so that entrainment of the waste air plume in the wake zone of the building (downwash effect) can be kept to a minimum. This effect can be achieved by increasing the waste air exit velocity and/or raising the height of the waste air discharge stack.

The waste air should be discharged through sufficiently high stacks vertically upwards over the roof ridge and into the atmosphere without any flow-inhibiting hoods or covers. To this end, the local area and the site location should be examined to determine whether, for example, the waste air discharge stack could be raised to a higher level at the gable of e.g. a barn building where this barn towers over the livestock building.

The waste air plume can be given a further upward boost by imparting to it greater mechanical momentum by increasing the waste air discharge velocity. The waste air velocity can, for example, be increased upon necessity ~~throughout the year~~, e.g. by gang-switching multiple series of fans in a main central air duct ~~central waste air shaft~~.

The installation of an additional bypass fan is effective as an impact-reducing measure only in certain cases and for the local area, and tends usually to have no effect. Apart from the increase in investment outlay and energy consumption, the additional noise emissions also have to be taken into account.

When planning a waste air discharge system, it is important to consider the influences of livestock buildings and flow barriers in the immediate environment on both the windward and lee sides of the facility (e.g. the roof ridge of neighbouring buildings, and trees). Livestock buildings and flow barriers give rise to a plume downwash effect.

In the case of a single livestock building, the downwash effect depends on the relationship between the effective source height and the building height. The downwash effect describes the influence of the building on the waste air plume and the subsequent reduction in the effective source height. Undisturbed airflow is attained at a height which corresponds to twice the building height.

Side wall ventilation apertures may be regarded as desirable in individual cases if they are provided with a deflector cover which directs the waste air towards the ground, and if the air is dispersed at the housing side which faces away from the sensitive site requiring protection. When comparing the effects caused by side wall ventilation on the one hand and waste air discharge via the ridge on the other, the ambient air pollution encountered in locations further afield tends to be similar.

In the case of facilities with several livestock buildings, the position and height of the waste air sources play a subordinate role in relation to their impact in terms of ambient air pollution at remote locations. In such cases, the total area of the facility may be so large that the waste air plumes descend to ground level within the facility site, even if the original source heights are large. The overall facility is then considered to have the same effect as a single ground-level surface source.

With a different approach, forced ventilation has the advantage of allowing an easy implementation of air cleaning techniques.

Natural ventilation

In order to ensure sufficient functional efficiency with natural ventilation, certain requirements have to be met, for example the following:

- roof pitch angle of at least 20 ° for eaves-ridge ventilation in order to generate the necessary thermal upcurrent;
- mean height difference of at least 3 m between the inlet air apertures and the waste air apertures with shaft ventilation;
- dimensioning of the air inlet and waste air apertures ~~to be~~ in accordance with livestock occupancy and thermal upcurrent lift height;
- guaranteed disturbance-free flows of incoming fresh air and outgoing waste air into and from the housing;
- ridge axis aligned transverse to the prevailing wind direction.

If buildings are located upstream and/or downstream of an open housing system, it must be ensured that the livestock building is not located in zones with very low or significantly accelerated air movement. The distance from the housing to the neighbouring buildings should be at least 3 to 5 times the height of the neighbouring buildings.

In the case of pig and poultry housings, the installation of devices for changing the air inlet and waste-air aperture cross-sections has proven to be successful.

By aligning the livestock building in relation to the prevailing wind direction, a decisive influence can be exerted on both the internal environmental conditions of the housing and the emissions emanating from it. Different concentration and velocity fields occur, depending on whether the housing is subjected to transverse, diagonal or ridge-parallel through flow. With ridge-parallel flow patterns in particular, the degree of ventilation compared with cross-flow patterns is reduced by approximately 50 %. It is under these conditions that the highest odorant and ammonia concentrations arise in the housing.

In order to combat this effect, apertures in the gable wall can enhance the wind-induced volume flow. Apertures at the centre of the ridge additionally assist thermal upcurrent flow. With a slot aperture running along the entire ridge, higher throughput rates are achieved than with shafts. The ridge axis of the housing should therefore be aligned to the wind so that in the course of the year the prevailing direction of wind flow produces the best possible through-ventilation effect.
The air inlet and waste air apertures of housings with eaves-ridge ventilation have to be dimensioned so that in times of high outdoor temperatures there is still sufficient air circulation.
Otherwise, doors must be opened, which generally results in the emissions dispersing at the ground level and in an uncontrolled fashion.

~~According to the current state-of-the-art, housing systems of open design with large lateral cross-sections, ridge slots and gable-end apertures, located in a free-standing position, can be regarded as desirable in terms of the impact effects encountered further afield (e.g. box stalls with separate function areas).~~

THE TECHNIQUE ''BIOFILTER', PREVIOUSLY DESCRIBED IN SECTION 4.10.2, IS NOW IN SECTION 4.9.5, TOGETHER WITH OTHER END-OF-PIPE TECHNIQUES

4.11 Techniques for the reduction of emissions from manure storage

The Nitrates Directive (91/676/EEC) lays down minimum provisions on manure storage in general with the aim of providing all waters with a general level of protection against pollution, and additional provisions on storage in designated Nitrates Vulnerable Zones. ~~Some of the~~ Techniques for reducing emissions from manure storage are described in the sections below~~, but others mentioned in this Nitrates Directive are not addressed because of a lack of data~~.

4.11.1 Reduction of emissions from storage of solid manure

4.11.1.1 General practice

Solid manure may be stored and composted in heaps open to the surroundings or covered with plastic but not air tight and with openings between the manure and atmosphere or heaps that are tightly covered by e.g. plastic sheets, clay. [590, Batfarm 2013]

~~The~~ Storage of solid manure on a solid impermeable floor will prevent leakage to soil and groundwater. Equipping the storage with drains and connecting them ~~these~~ with a pit allows the collection of ~~the~~ liquid fractions and of any run-off caused by rainfall.

It is common practice ~~to build for farmers~~ to have storage facilities for solid manure~~, to hold~~ that hold sufficient capacity to store manure until further treatment or application is carried out, (see also Section 2.6), ~~The capacity depends on~~ considering that the local climate ~~, which~~ ~~usually~~ determines the periods in which the application to land is not possible or not allowed.

When manure is collected and carried immediately away from the farm, especially when further management is done by third parties, there is no need for intermediate manure storage on farm. For instance, daily collection from belts under laying hens or direct transport of broilers' manure at the end of cycle can be done directly from the farm to a third party.

Information already included in Section 2.6
~~In Belgium-Flanders, stores storages are required requested by law to allow the volume of storage for 3 months in case of farmyard manure and 9 months in the case of manure produced by animals that are kept indoor all the time (e.g. pig slurry, poultry manure). 6 months or 9 months depending on specific provisions. For a storage period of 9 months, the calculated volume is increased by half. Consistency factors are used to predeterminate storage volumes:~~

- ~~fattening pigs (10 weeks 100 kg): 0.8 m^3 per animal place (or 0.6 m^3 if water saving devices are used)~~
- ~~farrowing pens: 2.3 m^3/animal place~~
- ~~empty sows, pregnant sows, boars: 2.0 m^3/animal place~~
- ~~gilts: 1 m^3/animal place~~
- ~~piglets up to 10 weeks: 0.2 m^3/animal place~~
- ~~piglets of 11 15 weeks: 0.4 m^3/animal place~~
- ~~breeding chickens (wet manure): 10 m^3/1000 animal places~~
- ~~laying hens (wet manure): 30 m^3/1000 animal places~~
- ~~broilers: not applicable. [255, BE Flanders 2010]~~

To reduce odour, the location of the storage on the farm is important and should take into account the general wind direction.

~~The preferred position of the~~ Storage areas ~~locations~~, ~~far is~~ away from sensitive receptors ~~neighbohoods~~, are preferred ~~objects in the vicinity of the farm, also taking~~ and any advantage that can be taken from ~~of~~ natural barriers such as trees or height differences should ~~must~~ be capitalised. ~~Also,~~ Walls (wood, bricks or concrete) can also be erected to surround storage heaps. These can serve as windscreens, with the opening of the storage on the lee side of the prevailing wind direction.

The smaller the ratio between the surface and the volume of the storage is, the lower ammonia and odour emissions are since the exposed surface is reduced. In addition, self-heating (*passive composting)* is critical for ammonia emissions, which is determined by oxygen access to interior of the heap. Covering the heaps tightly will most probably stop air from being exchanged between the heaps and surrounding air and NH_3 emission from heaps may be assumed to be negligible. [590, Batfarm 2013] If the heaps are uncovered or not closed completely or compacted by increasing manure density to reduce air transfer, then composting (self-heating) will occur. [441, Webb et al. 2011] The air exchange in combination with the elevated heap temperature due to aerobic decomposition will promote losses of ammoniacal nitrogen (TAN) [517, Petersen et al. 2011]. Density and water content also affect air transport in the heap. A high density may be a consequence of high water content, of a low content of bedding material like straw or wood chips, or of a deliberate compaction of the animal manure. [441, Webb et al. 2011]

Compacting solid manure when stored is a practical management option, but the effect of compaction (i.e. lower ammonia emissions) will depend on manure composition. On the other hand, it is reported that nitrous oxide emissions may rise by increasing manure density, which is attributed to stimulation of nitrification and heterotrophic denitrification by an increased number and volume of sites with relatively low oxygen content [517, Petersen et al. 2011] [441, Webb et al. 2011]

Dry poultry droppings must be stored dry in a covered area. In enclosed sheds, condensation can be avoided by proper ventilation. Re-moistening of the droppings should be prevented as this will lead to a release of odorants. Droppings storage sheds should not be built so high as to allow pyrolysis to occur in the stored droppings.

Temporary stacks in the field should be located sufficient distances from watercourses. In Finland, for example, the stack must be at least 100 metres ~~away~~ from watercourses, main ditches or household wells and 5 metres from (small) ditches [26, Finland 2001]. In the UK, the applied distances are 10 metres from watercourses and 50 metres from springs, wells, boreholes or other sources intended for human consumption. [506, TWG ILF BREF 2001] ~~[190, BEIC, 2001]~~. In France, the minimum distance from watercourses is reported to be 100 m. [500, IRPP TWG 2011]

Temporary field stacks should be located in different places each year; this procedure is mandatory in some Member States, e.g. France. For field stacks that are made in the same place every year, or for stockpiles located on soils with high water tables, impermeable floors could also be applied to prevent leaching. Where clay soils prevail and stacks change location, no accumulation of harmful amounts of nutrients is expected and special measures do not need to be applied to the bottom of the stack. To prevent water from entering the manure heap, the accumulation of rainwater at the base of the stack needs to be avoided.

~~The covering of~~ Manure heaps can ~~is~~ also be covered ~~applied~~ to reduce run-off and evaporation of ammonia (and odour). Covers should be tight to the mass, since the application of simple roofs to broiler litter heaps (i.e. undercover storage) increase ammonia losses compared with conventional open-air storage by 45 – 60 %. This is thought to happen because the manure surface remains porous, allowing ammonia to diffuse out of the whole heap, whereas conventional heaps are exposed to rainfall and lead to the formation of a 'crust' that provides a physical barrier to ammonia loss. [207, ADAS 2004]

In any case, covering manure ~~storages~~ stores (or heaps) reduces the total ammonia emissions of the production process by a small amount, since emissions from housing and/or landspreading of manure are more significant. ~~has a much smaller impact than reducing emissions from housing or from spreading manures,~~ [205, ADAS 2000] however, ~~but~~ it is one of the easiest measures to monitor and control. Indeed, covers are important where stores are sited near residential areas or sensitive places to atmospheric N deposition. [337, Webb et al. 2005]

4.11.1.2 Application of a covering to solid manure stacks

Description

~~This technique mainly applies to broiler manure and dried layer droppings.~~ Covering materials are applied to solid manure heaps and stacks in the field. These can be peat, sawdust, wood chips or a tight UV-stabilised plastic cover. The purpose of the cover is to reduce evaporation of ammonia and to prevent the run-off of rainwater. Air exchange and aerobic decomposition in the manure heap decrease, resulting in a reduction of emissions.

The principle behind the application of peat was reported by Finland. [26, Finland 2001] The use of peat (as a 10 cm layer) is based on its ability to bind cations. Ammonia is absorbed into the peat in a chemical reaction in which the NH_3-molecule is transformed into a fixed NH_4-ion. The higher the acidicity of the peat, the more ammonia it can absorb.

If a cover is to be applied, stacks must be covered immediately after they are made, since most of the ammonia evaporates during the first few days.

Manure heaps are often covered with 500–1 000 gauge plastic sheeting (1 gauge = 0.0254 mm). [205, ADAS 2000] Geotextile covers let gases flow from the mass below while being water-proof, but on the other hand are rather expensive. Other types of covers on the market are those used for silage and weaved covering. [259, France 2010]

Achieved environmental benefits

Reduction of ammonia and odour emissions as well as prevention/reduction of leaching due to rainwater.

Cross-media effects

Dry peat and sawdust absorb rainwater. However, straw is not a good covering material because it does not absorb ammonia and also it prevents a natural crust from forming on the surface of the manure. A crust prevents the evaporation of ammonia from the fresh surface of the manure under it better than a covering of straw does.

It is clear that tight covers can be reused if properly applied, whereas other covering materials will need to be purchased for each new stack. These other covering materials, such as peat, will be incorporated and then treated (applied) as part of the manure. Peat will not create a hazard for grazing animals, but being ~~However, peat is~~ a non-renewable resource, whose extraction is associated with high CO_2 emissions, ~~which might be grounds for not using peat for the coverage of~~ the environmental benefits of its use for manure heaps is debated. [506, TWG ILF BREF 2001] ~~[190, BEIC, 2001]~~
~~It is not clear whether a plastic cover causes (anaerobic) reactions in the stack that may lead to a reduction in the quality of the manure or that may affect emissions during application.~~

Operational data

~~The amount of emitted ammonia from poultry manure is quite low and around 80 % of this amount is emitted during the first 100 days of storage. Emissions partly depend on the type of manure and may be reduced by covers only if they remain intact, as reported in Table 4.146. Covers also reduce leachate in volume and content (N, P, K), [205, ADAS 2000] but do not effect nitrous oxide emissions. [250, IGER 2004]~~ **Part of the text is now reported below**

In UK, experimental studies have shown a wide range in reduction efficiency of this technique (from 14 to 89 %), with an average value of 65 % ammonia emissions reduction. The reported values are associated to conditions where the manure heap is created, sheeted and left undisturbed. This condition might apply to broiler farms, where the sheds are cleared and the manure is stored and left undisturbed until the end of the next crop cycle, or to laying hen farms where manure from deep pit housing is cleared from the shed and stored. Where frequent additions to the heap are performed, for instance at farms with a weekly manure removal by belts, and the sheeting has to be removed and replaced, the evidence suggests that there is no significant reduction of ammonia emissions when compared to a conventional manure heap without cover. The same effect also is reported where polyethylene covers were damaged by high winds and even though they were replaced within 24 hours, there was no difference in ammonia losses from covered and uncovered stores. These cases should therefore be treated as an uncovered store. [500, IRPP TWG 2011]

Comparing different types of poultry manure, experimental results showed that ammonia emissions were highest during the first 100 days of storage (uncovered or covered), while the heap covers reduced ammonia emissions by 33 % for broiler litter, 52 % for manure from laying hens on deep pit, and 74 % for manure from laying hens removed by belts. These differences in ammonia emissions reduction reflect the higher available ammoniacal nitrogen content and higher temperatures measured during storage of the broiler litter and laying hens manure from deep pit, compared with the laying hens manure removed by belts, which favour ammonia volatilisation during the early storage period. [205, ADAS 2000]

In Table 4.146, data concerning ammonia emissions from covered and uncovered poultry manure heaps are reported.

Table 4.146: Ammonia emissions from covered and uncovered poultry manure heaps

Parameters		Broiler litter	Manure from laying hens, with deep pit	Manure from laying hens, with removal belts
		Ammonia emissions ($g\ NH_3/m^2$ ground surface area)		
Losses during first 100 days of storage	Uncovered	169	110	116
	Covered (1)	113	53	30
	Reduction	*33 %*	*52 %*	*74 %*
Total losses for a 350 days storage period (2)	Uncovered	271	192	159
	Covered (1)	245	156	56
	Reduction	*10 %*	*19 %*	*65 %*

(1) Covered with 1 000 gauge polythene sheeting.
(2) Including emissions from heap disturbance.
Source: [205, ADAS 2000]

~~Type of storage~~	~~NH_3-N losses kg NH_3 (1)~~		~~NH_3-N % losses~~		~~Emission factor NH_3 g/m^2~~	
	~~Broiler(2)~~	~~Layer(3)~~	~~Broiler(2)~~	~~Layer(3)~~	~~Broiler(2)~~	~~Layer(3)~~
~~Uncovered~~	~~7.7~~	~~4.5~~	~~4~~	~~3~~	~~271~~	~~159~~
~~Covered~~	~~6.9~~	~~1.6~~	~~3~~	~~1~~	~~245~~	~~56~~

~~(1) Time of storage approximately 350 d.~~
~~(2) Broiler litter.~~
~~(3) Layer belt scraped litter.~~
~~*Source*: [205, ADAS 2000]~~

In Table 4.147, data concerning nitrogen losses as a percentage of total nitrogen content in solid manure (ex-housing), stored for more than 100 days, with or without cover, are presented. Values reported are the result of large-scale field experiments carried out under different climatic conditions in northern Europe.

Table 4.147: Nitrogen losses from covered and uncovered manure heaps

Manure type	Type of storage	Nitrogen losses as a percentage of total N (ex-housing)		
		$N-NH_3$ (%)	N-denitrification (%) ([1])	Total N losses (%)
Pigs solid manure (FYM or litter)	Uncovered	25	15	40
	Covered	13	15	28
Laying Hens (FYM or litter)	Uncovered	10	10	20
	Covered	5	10	15
Broilers, ducks and turkeys (litter)	Uncovered	15	10	25
	Covered	8	10	18

([1]) Estimated values.
Source: [442, Hansen et al. 2008]

Covers also reduce leachate in volume and content (N, P, K), [205, ADAS 2000] ~~but do not effect nitrous oxide emissions [250, IGER 2004]~~ Total N and NH_4-N leachate losses were equivalent to about 0.5 % and 0.25 % of total N and NH_4-N inputs to the uncovered heaps, and were less than 0.1 % of total N and NH_4-N inputs to the covered heaps, respectively. Total P and K losses were equivalent to 0.2 – 0.3 % and 2 – 3 % of total P and K inputs to the poultry manure heaps. At the same time, the covers were very effective in reducing leachate production, as the mean volume of leachate from the covered heaps was 85 % lower than from the uncovered heaps. No significant effect of heap covering on ammonia losses during land spreading was reported [205, ADAS 2000].

No significant effect on N_2O emissions is reported, when using plastic sheets to cover manure heaps. Nitrous oxide emissions from broiler litter range from 0.55 % to 0.70 % of the total N of manure stored in a sheeted heap; while, for the conventionally stored litter (uncovered), the value ranges from 0.17 % to 0.81 %. [250, IGER 2004]

Applicability

In many areas it is common practice for practical reasons to create temporary manure heaps in the field. Applying the covers is relatively easy as no complex equipment or machinery is involved. The peat littered manure of broilers is very suitable for depositing in stacks on the field, because liquid does not seep from it and nearly all rainwater is absorbed in the stack. Peat used as litter absorbs ammonia effectively.

The technique can be applied to all solid manures that are stored in heaps which are not added to on a frequent basis. Sheet covering may not be appropriate for management systems that involve regular addition of material to manure heaps (e.g. daily, twice weekly), where there would be a continual need for sheet removal and replacement.

Economics:

~~Costs are thought to be very low. Costs consist of purchasing the covering material and applying it on the heap (labour, energy).~~

Reported costs of covers (tax included) from France are [259, France 2010]:

- geotextile cover: 1.45 – 2.45 EUR/m^2
- weaved cover: 0.95 – 1.10 EUR/m^2
- cover for silage: 0.17 – 0.24 EUR/m^2.

Calculations have shown that the covering of solid manure heaps are economically profitable because the cost of covering material is lower than the value of the amount of nitrogen retained in the manure. However, there may be operating policy problems with the establishment and maintenance of a surplus of fixed manure stacks. [499, AgroTech 2008]

Driving force for implementation
This technique is a less expensive alternative to silos, to enable on-field storage in the cases where uncovered storage is not allowed for protection of ground or surface water from nutrients run-off or leaching.

Sheeting may have the additional benefit of minimising flies contamination.

Example plants
~~Applied in trials.The technique is commonly applied.~~
In France, the application of a covering to solid manure heaps is an obligation for poultry manure only. In the Netherlands, covering is mandatory for manure heaps situated in the filed for more than two weeks.

Reference literature
[26, Finland 2001] [205, ADAS 2000] [250, IGER 2004] [259, France 2010] [442, Hansen et al. 2008]

4.11.1.3 Storage of poultry manure in a barn

Description
Solid poultry manure is normally stored in a barn. It is transported ~~removed~~ from the animal housing by front-end loaders or by means of a belt and transported to the shed, where it can be stored for a longer period of time. The barn is usually a simple, straightforward closed construction with an impermeable floor and a roof. It is equipped with ventilation openings and an access door for transport.

Achieved environmental benefits
Drying poultry manure in the housing reduces the emissions to air of gaseous compounds (ammonia) from the housing. To keep emission of gaseous compounds low the relatively high dry matter percentage of solid manure has to be maintained. This is helped by keeping solid poultry manure protected against outdoor influences such as rain and sunlight.

Cross-media effects
Odour levels may be kept low, but aerobic and anaerobic conditions can affect this. It is important to have sufficient ventilation to avoid anaerobic conditions. A monitor of the internal temperature of the manure pile is necessary, to prevent litter overheating and spontaneous auto ignition (combustion).

If a new barn is planned, it is a potential source of odour, so thought should be given to its location with respect to sensitive objects in the vicinity of the farm.

Operational data
The manure is protected against the outdoor climate by the barn construction.

Applicability
If sufficient space on the farmyard is available there are no limits to the construction of a new barn for the storage of solid manure. Existing barns may be used, but attention must be paid to the impermeability of the floor.

Economics
Costs are for the construction and maintenance of a barn. For an existing barn, renovation of the flooring may be needed.

Driving force for implementation
In cases where poultry manure is already dry (e.g. from poultry housing), a barn with an impermeable floor and sufficient ventilation will keep the manure dry and prevent losses, in comparison with any further long term storage elsewhere.

With permanent storage structures, field heaps and, consequently, the associated pollution risks, are avoided or reduced.

Example plants
The storage of poultry manure ~~droppings~~ in barns is applied in nearly all Member States.

Reference literature
[24, LNV 1994], [26, Finland 2001]

4.11.1.4 Concrete silo for solid manure storage

Description
A foundation slab of water-impermeable concrete is built, having a 2 % inclination towards a front drain gutter or elevated edges. On three sides, upstanding or supporting sidewalls allow the manure to be stacked in a space-efficient way.

Over the base, support walls or other constructional means, e.g. a perimeter channel, are necessary to make sure that fluids (urine and/or seepage) can flow into the storage pit underneath and to prevent external liquids (run-off from surrounding areas) to enter the system. A liquid-tight pit is built of concrete underneath the dung platform. Roofing over the dung platform helps to decrease the volume requirement of the liquid manure pit underneath.

Achieved environmental benefits
Improved protection of soils, surface and ground waters, by a complete control of leakages.

Cross-media effects
The run-off collected in the pit has to be handled. In the case of pig manure, it is treated as slurry.

Operational data
In addition to proper planning and construction, in accordance with the relevant regulations, water protection is ensured by careful operation and, in particularly, maintenance of the facility. In Germany, the facility operator is required ~~careful operation and facility maintenance to manager that must~~ to run regular checks of the density of containers, pipes, and fittings as well as the operability of the control equipment. Density checks (e.g. pressure tests) of underground pipes should ~~must~~ be repeated approximately every 10 – 12 years. In areas under water protection, shorter intervals are required.

Applicability
~~Storages~~ Stores with ~~of~~ an area up to 2 000 m^2 can be built ~~with appropriate techniques~~, to stack manure up to 5 metres high.

~~As an example, a silo of 1 100 m^3 can be used for 2 000 pig places, on a surface of 520 m^2 and side walls of 2 m. The urine and seepage pit should have a volume of 1 000 m^3.~~ **Moved below**

Economics
The investment per cubic metre is in the range of EUR 65 – 77, including the liquid pit. Total annual costs are between EUR 5.8 and EUR 6.8.

In the Table 4.148, cost data related to the construction of a silo for the storage of solid pig manure are presented.

Table 4.148: Cost data of a silo for the storage of solid pig manure

Parameters	Value	Remarks
Silo characteristics		
Storage capacity	1100 m^3	For 2 000 pig places
Surface area	520 m^2	
Height of side walls	2 m	
Durability	30 years	
Manure density	0.8 – 0.9 t/m^3	
Cost data		
Investment costs	73 EUR/m^3 (from 65 to 77 EUR/m^3)	Additional pit with a volume of 1 000 m^3 for urine and seepage is included (3 EUR/m^3)
Total costs	6.4 EUR/m^3/yr (from 5.8 to 6.8 EUR/m^3/yr)	Including additional cost for a liquid manure pit for seepage/drainage collection (0.27 EUR/m^3/yr)
Source [212, Germany 2010]		

Driving force for implementation
This technique is used to efficiently store solid manure in the cases when a storage capacity during several months is legally required.

Manure management is easier; the volume of manure to be transported is reduced; the use of field heaps and associated pollution risks are avoided or reduced.

Example plants
This technique is reported in use in Belgium-Flanders, Germany and in the UK.

Reference literature
[212, Germany 2010]

4.11.2 Reduction of emissions from the storage of slurry

4.11.2.1 General aspects

It is common practice for farmers to have storage facilities for pig slurry~~, and to have~~ with sufficient capacity until further treatment or application is carried out, see also Section 2.6. The capacity is ~~depends on the climate, which~~ determined~~s~~ by the length of storage which is a consequence of the periods when ~~in which~~ the application to land is not possible or not allowed. For example, the capacity can differ from the manure that is produced on a farm over a 4 to 5 month period in a mediterranean climate, to that produced over a 7 to 8 month period in atlantic or continental conditions, and again to that produced over a 9 to 12 month period in boreal areas. [537, EC 1999] ~~[191, EC, 1999]~~. Specific examples, concerning procedures applied in different Member States, are presented in Section 2.6, Table 2.14.

Slurry stores can be constructed in such a way that the risk of leakage of the liquid fraction can be minimised, see also Section 2.6.4.1 and Section 4.11.2.6. They are built using the appropriate concrete mixtures, and in many cases, ~~applying~~ a lining to a concrete tank wall or ~~by applying~~ an impermeable layer to steel sheets is applied. Bags, lined or unlined earth-banked lagoons, glass fibre reinforced plastic (GRP) tanks are also used.

~~After emptying a slurry storage store, inspection and maintenance will prevent the a further risk of leakage. The application of double valves in pipes used for emptying the tank will minimise the risk of an unwanted discharge of slurry onto the farmyard and surrounding premises (surface~~

~~water). The use of block floodgates is an extra tool to limit leak risks. [259, France 2010]~~
Moved to Section 4.11.2.6

~~Reducing the surface area to volume (SA/V) ratio of the storage will reduce NH_3 emissions. For example, the SA/V of 1 000 m^3 slurry storage can be reduced e.g. by 1/3, if the height of the sides is increased by 2 m from 3 to 5 m. For rectangular storages, the proportion of height and surface area should be 1: 30–50. [337, Webb et al. 2005] On another hand, an excessive height of the slurry store above the soil surface represents an added safety risk.~~ **Moved below**

Ammonia emissions from liquid manure (slurry) mainly depend on the chemistry of liquid ammonia dissolved in the transfer mechanism of gaseous ammonia at the manure surface. The emission rate of ammonia from manure can be calculated. Various parameters have an influence on ammonia emissions from manure storage, among them: manure surface area, surface roughness and temperature, wind speed. [439 , Sommer et al , 2006]

Air emissions during the storage period can ~~also~~ be reduced by applying the measures given below. ~~via:~~

- ~~having a smaller container diameter and/or a reduced wind contact area at the liquid manure interface~~
- Reducing the surface area to volume (SA/V) ratio of the storage; this measure will reduce NH_3 emissions. For example, the SA/V of 1000 m^3 slurry store ~~storage~~ can be reduced, e.g. by 1/3, if the height of the sides is increased by 2 m, from 3 to 5 m. For rectangular storages, the proportion of height and surface area should be 1: 30–50. [337, Webb et al. 2005] On the other hand, an excessive height of the slurry store above the soil surface represents an added safety risk.
- ~~by~~ Operating a lower level of fill ~~(works due~~ to take advantage of the wind shielding effect created by the freeboard~~).~~
- Emptying the stores in spring, before the outset of the warm season, so that the least possible slurry quantity is stored during summer. Stored slurry temperature follows the air temperature and at higher temperatures gaseous emissions will increase. This procedure applies for above-ground silos in climatic regions where there is a significant temperature rise during summer.
- Frequent transfer of slurry from a housing facility to an outdoor store. Since the temperature of the slurry tends to match the ambient temperature, this technique represents a relevant ammonia mitigation option in cool and temperate regions; whereas, in warmer climates the effect may be limited or even negative. [517, Petersen et al. 2011]
- The discharge of liquid manure in open storage containers should be performed as close to the base of such containers as possible (infilling below the liquid surface level). Homogenisation and the circulation pumping of liquid manure should preferably be performed when the wind is blowing away from any sensitive sites requiring protection.
- To reduce air emissions from slurry storage, it is important to reduce the evaporation from the slurry surface. A low evaporation rate can be maintained if the stirring of slurry is kept to a minimum and is done only before emptying the slurry tank for the homogenisation of the suspended matter.

Apart from the above general measures, the main abatement technique to reduce ammonia losses and odour emissions from slurry stores ~~can be minimised by~~ consists in covering open stores, therefore increasing the transport resistance from the manure surface (source of emission) to the atmosphere. A distinction is made between covers as various types of covers, impermeable or permeable, natural or artificial, fixed (rigid), flexible or floating, can be ~~are~~ applied ~~to reduce the water losses and the emissions of ammonia and odorous components from slurry storage, see Sections 4.11.2.2, 4.11.2.3 and 4.11.2.4.~~

In particular, covers in the form of roofs of PVC, wood and similar materials that create an impermeable lid over the storage, will reduce emissions. Porous floating surface material has also been shown to reduce NH_3 emissions because it creates a stagnant air layer above the slurry, through which NH_3 has to be transported by the slow process of diffusion. This material may be porous textiles, natural surface crust formed by solids floating on the surface, a cover of straw, peat or floating expanded clay particles. The lowest reductions occur when the surface is covered by natural crust, air temperature is low or the cover on treated slurry has submerged. At low air temperatures NH_3 emissions from stored uncovered slurry are low and emissions from covered storage are therefore not much lower than those from the reference system. [590, Batfarm 2013]

In Table 4.149, an overview of the different type of covers applied in slurry storage is presented with the indication about the applicability to round containers and earth-bank lagoons.

Table 4.149: Overview of the different type of covers applied in slurry storage

General category	Type of cover	Applicability	
		Round container (concrete or steel)	Earth bank lagoon
Rigid covers	Concrete covers	X	˜
	Fibreglass panels	X	˜
Flexible covers	Tent roof (with central post, dome-shaped or flat)	X	˜
	Floating sheeting covers	X	X
	Swollen covers	X	˜
Floating covers	Natural crust	X	X
	Straw (crust)	X	X
	Peat	-	˜
	Light bulk material (e.g. LECA, perlite, zeolite)	X	X
	Plastic pellets (polystyrene balls)	X	˜
	Rapeseed oil	X	˜
	Plastic blankets and foil	X	X
	Geometrical plastic tiles (plastic bricks)	X	-

Care must be taken to prevent the temperature of the slurry from rising to a point at which biochemical reactions can occur, otherwise these may result in an unwanted odorant production and a degradation of the quality of the slurry, with the possibility of methane emissions. [443, Chadwick et al. 2011]

Closed, impermeable covers ~~also~~ prevent rainfall ~~contamination~~ to dilute the slurry, ~~and increase the slurry volume hence limiting the~~; so that, a reduced volume of slurry is achieved and an increased effective storage period is provided by the store. In moderate to high rainfall areas, these types of cover can be cost effective, limiting transportation ~~disadvantages~~ and ~~the~~ spreading costs [525, BPEX 2011] [259, France 2010].

Generally, the covering of slurry stores is effective, but may pose problems in application, operation and safety and is only effective when the cover is not damaged.
~~Surveys have been conducted to assess these problems, but they only concluded that more data was needed. Quantified data on environmental aspects (emissions, nutrient content) and on costs are also scarce and do not easily allow an evaluation of the alternatives.~~

Ammonia emissions from storage during 6 to 12 months have been measured or estimated in Denmark and are shown in Table 4.150.

Table 4.150: Ammonia emissions as a percentage of the total stored nitrogen in slurry containers in Denmark

Type of cover	Emission % of total N (ex-housing)
Untreated slurry	
Uncovered	9.0 %
Natural organic cover	2.0 %
Floating fabric cover	1.5 %
Tent	1.0 % ([1])
Concrete cover	1.0 %
Digested slurry	
Uncovered	21 %
Covered (chopped straw, plastic, natural crust, etc.)	4 %
Tent or concrete cover	2.0 %

([1]) Estimation.
Source: [210, Denmark 2010] [442, Hansen et al. 2008]

Covers reduce the oxygen exchange between manure and air and result in an increase of temperature of the effluents by approximately 2° C. Methane can be produced in the mass, and its recovery and use is possible but for an extra cost. [259, France 2010]

Slurry bags are reinforced fabric bags coated with PVC or polyester sitting within an earth structure. They are restrained at the sides, fitted with gas vents, and the cover forms part of the structural integrity of the store. [525, BPEX 2011] They are intended for users needing to store and spread slurry in scattered areas, without a vacuum tanker. This technique is suitable for small farms (e.g. <150 fattening pigs). Available bag sizes may limit the use on larger livestock farms. Ammonia emissions reduction is reported at 100 %. [508, TFRN 2011]

Previous Section 4.11.2.2 (Concrete silo for solid manure storage (see Section 4.11.1.4)

4.11.2.2 Application of a rigid cover to slurry storage ~~storages~~

Description
Rigid covers are typically tight concrete covers, ~~or~~ fibreglass panels or polyester sheets with a flat deck or conical shape (see Figure 4.71). They should be well sealed or “tight”, in order to minimise air exchange. They fully cover the slurry surface, preventing rain and snow from entering, so there is a more predictable storage capacity. Covering small slurry stores is in general more straightforward than covering larger ones. If the cover is made of a lighter material then the span can be larger than for concrete covers exceeding 25 m and with a central support.

Achieved environmental benefits
The covering of storage ~~store~~ surfaces is well documented and is know to significantly reduce odour and ammonia emissions. Purpose-built (rigid) covers are reported to give reductions of at least 80 – 90 % for ammonia and odour emissions associated with manure storage. ~~a 70 to 90 % reduction [142, ADAS, 2000].~~ A dilution of the ~~manure~~ slurry is avoided, as it can occur in uncovered manure pits due to rain lowering the solid matter and the nutrient~~s~~ contents.

For very dilute pig slurries of less than 1 % of dry matter, ammonia emissions are low enough that covering provides little environmental benefit and so for ~~. Where the DM~~ dry matter (DM) content is less than 1 % the store may not need to be covered. The criterion for this to be acceptable is a regular (e.g. annually) control of the slurry store to confirm that the DM remains below 1 %. Exceedance of this figure may mean that the store needs a cover to be installed. [507, UK EA2012]

Source: [204, IMPEL 2009]

Figure 4.71: Rigid cover for slurry storage, with conical shape

Cross-media effects

Development of toxic (e.g. H_2S) or explosive (methane) gases may occur ~~They may not have an immediate environmental relevance, but~~ which must be considered for safety reasons. Some small openings (which do not undermine the minimum sealing required), or a facility for venting, are needed to prevent the accumulation of such gases.

Operational data

A concrete cover allows reaching ammonia emission reductions of 90 %. [575, UBA 2011].

Gaseous emissions were measured during field experiments, for the relatively warm and cold conditions related to Austria. The experiment concerned the storage of slurry produced by a straw flow system, with the use of a solid cover in underground pilot stores, compared with uncovered stores. The observation periods were 50 and 200 days of storage in warm conditions and 50 days of storage in cold conditions. A summary of the results is given in Table 4.151. Ammonia and methane emissions are reduced in both climatic conditions. The rigid cover seems to have a positive effect on nitrous oxide emissions only in cold conditions.

Table 4.151 Reduction of gaseous emissions from storage of slurry with the use of rigid cover in underground pilot stores, compared to uncovered stores

Emission	Warm conditions (1) (2)	Cold conditions (1) (3)
	Reduction %	Reduction %
Ammonia (NH_3)	28 – 44	15
Methane (CH_4)	32 – 70	38
Nitrous oxide (N_2O)	-4 (4) – 30	50

(1) The results for warm conditions have been tested for 50 and 200 days of storage. For cold conditions, the observation period was equivalent to 50 days of storage.
(2) Average slurry temperature 17 °C (from 13.6 to 21.9 °C).
(3) Average slurry temperature 12 °C (from 8.1 to 16.6 °C).
(4) Increase of 4 %.
Source: [519, Amon et al. 2007]

Applicability

Rigid covers are usually installed at the same time as the ~~storage~~ store. A fixed cover may not be suitable for retrofitting in existing tanks as it requires the store to be structurally suitable and may involve additional reinforcing to withstand the extra loading. [525, BPEX 2011] [508, TFRN 2012]

~~Retrofitting a cover to an existing store is reported to be expensive. In the UK market, the cost of a covered storage is 50 % more expensive than an uncovered one, nor are existing storeags structurally sound to accommodate retrofitted covers. [175, Ecodyn 2010]~~ **Moved to economics**

For technical reasons, rigid covers cannot fit ~~typical French duck slurry storages, as they consist of shallow and~~ widely dimensioned earth-banked lagoons and geomembranes-lined stores ~~storages~~, such as the typical French slurry stores used for duck manure. [259, France 2010]).

Economics

~~Cost indications were reported in a survey carried out by the UK [142, ADAS, 2000]: for concrete stores with diameters of 15 – 30 m the cost range is EUR 150 – 225/m² (1999). For rigid covers made of glass fibre-reinforced plastic (GRP) costs range between EUR 145 and 185 per m². This cost is generally considered to be too high.~~

Retrofitting a cover to an existing store is reported to be expensive. In the UK market, the cost of a covered storage is 50 % more expensive than an uncovered one, ~~nor are existing storeags structurally sound to accommodate retrofitted covers.~~ [175, Ecodyn 2010] **Moved from applicability**

~~For a rigid resin polyester cover, without a central post, the cost (on-farm installation included) is approximately EUR 0.01/kg of pork produced (tax excluded), for a 550 fattening pig places house.~~

~~For a polyester cover, with central post, prices (installation and taxes excluded) are:~~

- ~~approximately EUR 0.005/kg of pig produced, for a breeding of 550 places~~
- ~~EUR 0.8 – 1/m³ of stocked slurry/year (EUR 0.9/m³ year on average), for a duck house of 1 000 m².~~

See below

Costs for rigid covers are reported from France and presented in Table 4.152. These costs take into account a depreciation cost~~s~~ for equipment over 20 years (without interest charges and subsidies), which corresponds to the lifespan of the covers. [259, France 2010] [255, BE Flanders 2010]

Table 4.152: Costs for rigid polyester covers reported from France

Type of cover	Capital cost	
	EUR/kg produced pig	EUR/m^3 slurry stocked/year
	Farm with 550 fattening pig places	Farm of 1000 m^2, for duck breeding
Rigid resin polyester cover without central post ([1])	0.01	-
Polyester cover with central post ([2])	0.005	0.8 – 1

([1]) Tax excluded, on-farm installation included.
([2]) Tax and on-farm installation excluded
Source: [259, France 2010]

From Germany, cost data associated with various types of covers, applied for slurry storage are reported, expressed per m^3 of slurry stored, per m^2 of surface or per kg of NH_3 abated. [575, UBA 2011]. A comparison of costs for rigid, flexible and floating covers applied to round slurry tanks of different capacity is presented in Table 4.153. In Table 4.154, emission reduction costs for the different types of covers are given, together with mitigation costs which take into account the fertiliser value (conserved nitrogen) and the costs associated with the extra-volume of water from precipitation that would have to be applied on land, and the tank freeboard needed to contain precipitation water.

Table 4.153: Cost data for different covers of slurry tanks, in Germany

Dimensions ([1])						
Usable storage capacity	500 m^3		1 000 m^3	3 000 m^3	5 000 m^3	
Diameter	13.7 m		17.7 m	27.9 m	35.5 m	
Investment and annual costs ([2])						
Type of cover	Annual costs EUR/m^3/yr	Investment costs EUR/m^2	Annual costs EUR/m^3/yr	Annual costs EUR/m^3/yr	Annual costs EUR/m^3/yr	Investment costs EUR/m^2
Uncovered (reference)	1.78	NA	1.57	1.29	1.17	NA
Concrete cover	2.74	NA	2.38	1.96	1.82	NA
Tent roof	3.67	100	2.74	2.00	1.74	46
Floating film	2.7	34	2.14	1.66	1.47	16
Light bulk materials	2.03	10.2	1.73	1.43	1.3	7.6
Floating bricks	2.42	39.5	2.11	1.73	1.6	39.5
Straw	2.2		1.86	1.49	1.35	

NA= Not available
([1]) A residual volume of 0.5 m (depth) and a freeboard of 0.2 m have been considered.
([2]) For the cost calculation, storage duration of 6 months was assumed; the expenses presented are based on an annual slurry quantity which is twice as large as the usable capacity.
Source: [575, UBA 2011]

Table 4.154: Emission reduction and mitigation costs for different covers of slurry tanks, in Germany

Storage capacity					
Usable storage capacity		500 m^3	1 000 m^3	3 000 m^3	5 000 m^3
Emission reduction and mitigation costs					
Type of cover		**EUR/kg NH_3**	**EUR/kg NH_3**	**EUR/kg NH_3**	**EUR/kg NH_3**
Concrete cover		1.25	1.25	1.25	-
	([1])	*(0.44)*	*(0.45)*	*(0.47)*	-
Tent roof		2.45	1.81	1.33	1.09
	([1])	*(1.64)*	*(1.01)*	*(0.55)*	*(0.32)*
Floating film		1.27	0.94	0.73	0.60
	([1])	*(1.07)*	*(1.29)*	*(0.52)*	*(0.40)*
Light bulk materials		0.36	0.28	0.28	0.27
	([1])	*(0.17)*	*(0.09)*	*(0.09)*	*(0.08)*
Floating bricks		0.88	0.88	0.88	0.88
	([1])	*(0.67)*	*(0.67)*	*(0.67)*	*(0.67)*
Straw		0.63	0.53	0.43	0.41
2 times per year([2])	([1])	*(0.47)*	*(0.36)*	*(0.26)*	*(0.24)*
4 times per year([2])	([1])	*(1.17)*	*(0.94)*	*(0.74)*	*(0.69)*

([1]) Cost data take into account the value of conserved nitrogen, the expenses for the application of precipitation water to land and the cost of tank freeboard for containing precipitation water.
([2]) Costs are given for a frequency of slurry application of two and four times per year.
Source: [575, UBA 2011]

Driving force for implementation
In some Member States, all new and substantially enlarged slurry stores are required to be covered (e.g. UK). In Denmark, since 1987 it is required to store slurry in tanks with tight-covering.

Example plants
Several applications of rigid covers are present throughout the European Union.

Reference literature
[26, Finland 2001], [11, ADAS 2000] [575, UBA 2011]

4.11.2.3 Application of a flexible cover to slurry storages

Description
Various types of flexible covers exist. A description of the main types and characteristics is given below.

Covers tended with central post (or capital)
Flexible covers or tent covers have a central supporting pole with spokes radiating from the top. A fabric membrane is spread over the spokes and is tied to a rim-bracing. This is a circular pipe that is located on the outside around the circumference just below the top of the store. The cover is tightened over the store by evenly spaced vertical straps between the rim-bracing and the tent-rim.

The pole and spokes are designed to withstand wind and snow loads. Non-covered openings must be kept to a minimum, but the development of gases should be avoided as well that might develop.~~ Vents are applied to release any gases that build up ~~under the cover. The cover also incorporates an opening for an inlet pipe and a hatch that can be opened for inspecting the storage's ~~store's~~ contents and to release gases if necessary.

Dome-shaped covers
Curved structural frames are installed over round stores without needing a central pole (see Figure 4.72). Steel components are assembled by bolted joints during the installation on-farm. Known installations can have around 600 m^2 of round surface. Operating windows can be adjusted in the flexible cover.

Source: Kaaritaivutus Kumpula Oy

Figure 4.72: Dome-shaped steel structure for a flexible tent before its placement over the slurry store.

Covers tended flat
These covers consist of a flexible and self-supporting composite material, held by stainless plugs on a galvanised steel structure all around the pit. For geomembrane pits, the construction of a concrete longitudinal beam around of the pit is necessary. A system for the central recovery of rainwater (impluvium with pump) is generally arranged. 'Truck covers' are tunnels made by galvanised steel arches holding a standard truck cover (600 g/m²). The access to the slurry is done by the gable.

Floating flexible covers. **These covers are presented in detail in Section 4.11.2.4**
~~These covers consist of a treated PVC fabric (anti-UV, salt spray, moulds, etc.), of variable density (660 to 950 g/m²). Covers in round storages follow up and down the slurry over their height, sliding their floating edges on a galvanised steel structure. This metal structure channels the rainwater to the center of the cover. In rectangular pits (geomembranes), the cover height is adjusted by a system of winches and a set of pulleys and rope that are fixed at stakes located outside along the pit walls. The rainwater is generally collected in a sump and evacuated using a pump. An opening generally allows easy access to the inside (mixing of the slurry, etc.).~~

Swollen covers
A treated high density (915 g/m^2) PVC fabric is supported by an inflatable pocket that floats over the slurry. The fabric is fixed by guy rope to a structure peripheral at the pit, made out of galvanised steel. The inflatable pocket is supplied by a low pressure blower. An inspection door is frequently opened. [259, France 2010]

Achieved environmental benefits
Reductions of ammonia emissions of 80 – 90 % have been reported for tent roofs or a plastic covers, compared to storage tanks with no cover. During necessary stirring and pumping, odour emission may arise, but overall odour emissions are reduced. ~~A reduction of greenhouse gases, CO_2, CH_4 and N_2O, is also expected.~~

Cross-media effects

Development of toxic gases may occur. They may not have environmental relevance, but must be considered for safety reasons. The development of H_2S may cause some corrosion that can affect the storage structure and the cover construction. Recovery and utilisation of methane from the biogas may be a possibility but at an extra cost.

Operational data

Covers must be durable and need to completely cover the slurry surface. Normally, masts are erected after the container is emptied and cleaned, although some installers can fit masts while slurry is in the tank. Ammonia reductions are in the range of 50 % compared to the natural floating layer (see Table 4.150).

Applicability

From a UK survey it appeared that tent type covers can be applied to 50 – 70 % of the existing steel type storages store stores with only modest modifications needed. Typically this consists of fitting an additional stiffening angle strip around the rim of the storage store. Tent covers can be fitted to existing concrete storages stores without modifications for diameters under 30 m, but a technical survey is recommended beforehand. It is important to calculate the required strength of the construction to ensure it can withstand wind and snow loads, for both the storage store and the storage store with cover. The larger the diameter of the store the more difficult the application of the cover will be, as the cover must be evenly taut in all directions to avoid uneven loads. The northern weather makes the use of floating covers not suitable. [175, Ecodyn 2010]

In Belgium-Flanders non-solid flexible covers must be able to maintain their characteristics for at least 10 years. [255, BE Flanders 2010]

Most A tent covers are held by structures that cannot be applied to square or rectangular existing concrete storages stores, which are common in many EU countries [193, Italy, 2001] [506, TWG ILF BREF 2001]. With earth-banked slurry lagoons, this system presents significant technical difficulties for its implementation.

Economics

The costs for tent covers for stores with diameters of 15 – 30 m have been reported to be about EUR 54 – 180 per m^2 (1999).

The installation of a tent cover on an existing container normally requires that the tank be emptied first and cleaned, operation that and costs, in Denmark, approximately EUR 1/m^3 (EUR 2 000 for a 2 000 m^3 store). The installation of the tent itself costs around EUR 10 per cubic metre for a slurry storage capacity of 7 700 m^3, which corresponds to 17 500 fattening pigs produced annually. The annualised investment costs are reported at 0.2 EUR/m^3 and costs expressed per fattening pig are equivalent to EUR 0.25, including savings from less use of chemical fertiliser, due to reduced ammonia emissions. The cost is estimated at around EUR 2000 for a 2000 m^3 storage tank. [210, Denmark 2010]

For a swollen cover, energy consumption for the blower is considered negligible. For a floating covers, energy consumption for operating the pump for the drainage of rain waters is negligible. [259, France 2010]

Indicative costs for the purchase in France of flexible covers are given in Table 4.155.

Table 4.155: Costs for different types of covers in France

Type of cover	Capital cost (except installation)		Payback time (years)
	EUR/kg produced finishers pig (1) (2)	EUR/m^3 slurry stocked/year (3)	
Capital covers	0.01	0.9 – 2.9	10
Covers tended flat	0.01 – 0.02	1.2 – 2.6	10
Floating covers	0.003 – 0.01	0.4 – 1.3	10
Swollen covers	0.01	1.8	10
Cover of the type 'truck covers'	0.01 (except installation) 0.02 (with installation)	1 (except installation) 2 (with installation)	8

(1) Tax excluded.
(2) Refers to a farm with 550 fattening pig places.
(3) Refers to a duck breeding farm of 1 000 m$^{2.}$
Source: [259, France 2010]

Annual costs, as well as ammonia reduction costs, reported from Germany for flexible covers applied on slurry storage are included in Table 4.153 and Table 4.154 (see Section 4.11.2.2).

Cost data for a fixed flexible tent cover and a floating flexible cover applied to an above-ground slurry tank with a capacity of 1037 m^3 and a surface area of 314 m^3 (20 m diameter and 3.6 m height) are reported from UK and presented in Table 4.156.

Table 4.156: Costs for covering an aboveground slurry tank with flexible covers, in UK

Type of cover	Investment cost (EUR/m^2) (1)	Investment cost (EUR) (1)	Annualised cost (EUR/year) (1) (2)
Fixed flexible tent cover (3)	68.2	21.400	2 050
Floating flexible cover (4)	28.4	9 000	910

(1) Cost data based on exchange rate GBP/EUR = 0.88
(2) Includes capital payback time over 20 years, interest costs and maintenance costs.
(3) Investment costs include tank strengthening, central supporting pole, radial webbing straps, etc.; potential savings, due to avoided rainfall to be spread with slurry, are not included.
(4) Potential savings, due to not avoided rainfall to be spread with slurry, are not included.
Source: [524, UK EA 2012]

From Spain, the investment cost for the use of floating film to cover slurry storage is reported equivalent to 20 EUR/m^2. [379, Spain, 2010]

Driving force for implementation
Slurries that are the output from biogas production, or ~~separated~~ from slurry separation ~~treatment~~ processes, cannot ~~create~~ develop natural floating layers because of the low dry matter content. In these cases a tent cover could be relevant.
In some Member States, all new and substantially enlarged slurry stores are required be covered (e.g. UK). In UK, also all existing slurry stores have to be covered by 2020. [524, UK EA 2012] In Denmark, since 1986 it is required to store slurry in containers with a tightly-fitting cover. [499, AgroTech 2008]

Example plants
Applications have been reported in the UK, and the technique is widely sprea~~ding~~d in France. In Denmark, there are roughly 1500 slurry tanks with tent covers applied on containers of 500 m^3 and over. On smaller containers concrete covers are normally used.

Reference literature
[11, ADAS 2000] [210, Denmark 2010] [255, BE Flanders 2010]

4.11.2.4 Application of a floating cover to slurry storages

Description

Matter is left floating over the surface of slurry store to build up Floating covers over the surface of slurry stores that have the primary objective of reducing ammonia emissions and odour. There are different types of floating covers, such as:

- natural crust
- straw (crust)
- peat
- light gravel (granular light bulk material, such as LECA, perlite, zeolite, etc.)
- plastic pellets (polystyrene balls)
- rapeseed oil and grains
- floating flexible cover (e.g. plastic sheets, blankets and foil
- geometrical plastic tiles.

Natural floating crust

It represents the simplest form/method of slurry covering. A floating crust layer is formed spontaneously on the surface of slurries that have a high dry matter content, to which crust thickness is closely related. [575, UBA 2011] Slurry containing litter and feed residues will naturally separate into a fraction with high solids content and a fraction with virtually no solids. Depending on the type of feed residues and litter contained in the slurry, solids will either sink (e.g. usually feed residues) or rise to the surface (e.g. straw bedding). [499, AgroTech 2008] Natural crust formation over the slurry is enhanced by gasification, i.e. the release of gases that are transported from the slurry to the store surface, by means of bubbles which adhere to fibres and particles that will float on the store surface. During winter, with little anaerobic activity and ebullition, the crust layer may sink and leave the slurry uncovered. This may not be a major problem, because ammonia emissions from uncovered slurry are low during cold seasons. [590, Batfarm 2013]. Crusting is unlikely to occur on stores with a slurry dry matter content of <2 %. [439, Sommer et al. 2006]Under Mediterranean (i.e. Spanish) climatic conditions, a natural crust is easily formed at a rate of about 1 cm in two weeks. Minimising stirring s the build-up of a natural crust.

Straw or high content dry matter manure

They can also be used to establish a floating layer in diluted slurries. Straw is a floating cover that is not suitable for very thin dilute pig slurry as it may sink immediately or if it floats it will be easily affected by wind and rain. It may also lead to blocked pumps and drains. However, when the pig slurry has a dry matter content of 5 % or higher, it is then possible to obtain a straw-induced crust that performs well [11, ADAS 2000] [209, Denmark 2010]

Straw covers should be at least 10 cm thick. A thick layer of coverage consisting of manure or deep litter of high dry matter content is very similar to a straw layer and will therefore have the same effect.

Peat and light gravel and light (Light weight expanded clay aggregate: LECA, perlite, zeolite, etc.)

These covers have been more extensively researched and, from literature, appear to be easily applied. These covers They cannot be reused and have to be replenished every year. The efficiency is not completely satisfactory, resulting in approximately 25 % of ammonia emission reduction in comparison with the uncovered storage. [259, France 2010] **Moved below**

Polystyrene balls (EPS)

Tank covers made of polystyrene (PSE) balls of 20 cm in diameter and 100 g in weight (density of 23.8 kg/m^3) are used and easy to implement. [259, France 2010].

Rapeseed oil or grains ~~or rapeseed~~
These substances might be added on the layer to allow plant growth that will help to bind the straw and to drain rainwater.

Floating flexible covers (blankets, sheets)
Canvas (porous textile membranes) or plastic floating covers rest directly on the slurry surface. They are equipped with an inspection hatch, ventilation openings, and openings for filling and mixing the slurry. Also, a pump is used to drain any rainwater collected on top of the cover. The canvas can be fixed, or kept in place by counterweights hanging over the rim of the ~~storage~~ store. In round stores, sheets are stretched around hoops floating by the perimeter walls.

~~These covers~~ Plastic sheets consist of a treated flexible synthetic ~~treated PVC~~ fabric (anti-UV, salt spray, moulds, etc.), of variable density (660 to 950 g/m²). Covers in round stores ~~storages~~ follow up and down the slurry over their height, sliding their floating edges on a galvanised steel structure, or they may be stretched over and tensioned around a plastic hoop, which floats on the surface by the perimeter walls. This metal structure channels the rainwater to the centre ~~center~~ of the cover. The rainwater is generally collected in a sump and evacuated using a pump. An opening generally allows easy access to the inside (mixing of the slurry, etc.) **Moved from Section 4.11.2.3**

Geometrical plastic tiles
Hexagonal plastic bricks tile up to form a complete cover (see Figure 4.73). Depending on the geometry of the container, around 95 % of the surface is covered. Bricks automatically distribute on the surface and adapt to changes in slurry level. These covers do not prevent rainfall from diluting the slurry. [525, BPEX 2011]

Figure 4.73: Load operation of floating bricks into a slurry tank (Hexa-Cover)

Achieved environmental benefits
~~The~~ Surface covering with floating covers has a significantly restrictive effect on ammonia ~~the~~ evaporation from ~~manure~~ slurry stores ~~storages~~. Covers greatly decrease the air exchange rate between the surface of the slurry and the atmosphere by creating a stagnant air layer above the slurry through which NH_3 has to be transported by the slow process of diffusion, which decreases the ammonia losses. [439, Sommer et al. 2006]

Odour emissions are reduced because the surface covering forms a physical barrier but also ~~and~~ because a biological conversion of odour substances (oxidation of the odorous components by microorganisms) can take place in the covering, as it is in the case of straw covers. [209, Denmark 2010]

The primary objective is odour reduction, but ammonia evaporation is reduced at the same time. Although the covering of the slurry storage is carried out for odour reduction, actual measurements of the odour emissions or reductions are inherently unreliable due to a lack of unambiguous and dependable methods for measuring odour and for interpreting results. However it is clear that there is an effect on evaporation of ammonia

There is some evidence that floating covers may reduce CH_4 emissions from slurry stores. [518, Sommer et al. 1999]

Cross-media effects
Obviously, some floating covers that mix with or are dissolved in the slurry may affect the quality of the slurry or be harmful to grazing animals.

A slight effect on N_2O emissions has been observed. It appears that, in relation to the water balance of the crust, a cover could increase N_2O emissions when dry conditions prevail.

Natural crust – Straw crust
It is reported that organic floating layers, like straw covers, might increase CH_4 and N_2O emissions *are suspected to lead to nitrous oxide emission,* but there is still great uncertainty about the quantification the actual quantitative importance of N2O of this increase from floating crusts the effects are still not completely known. The Intergovernmental Panel on Climate Change, IPCC (2006 IPCC Guidelines for National Greenhouse Gas Inventories) considers an emission factor for N_2O emissions of 0.005 kg of N_2O-N per kg of nitrogen excreted from slurry with an organic crust, which compared to the emission factor for direct emissions from lanspreading of manure (0.01 kg N_2O-N) is considered substantial.

The effect of straw and crust on the overall emissions of greenhouse gases is not fully known; however, covering slurry stores with organic floating layers is not expected to significantly modify the emissions of greenhouse gases, compared to the uncovered stores. [209, Denmark 2010]

It was is estimated that stirring of the slurry would need approximately 10 -– 12 litres of gasoline per tonne of added straw.

Peat and light bulk material (e.g. LECA)
Peat is a non-renewable resource and its digging is related to high indirect CO_2 emissions. It has been measured that peat covers increase methane emissions by 30 %. [259, France 2010] Peat mixes with slurry during stirring, gets waterlogged and has to be renewed after each stirring. However, peat is a natural product and does not create a waste problem

For LECA, reportedly insignificantly reduced methane emissions in one experiment, but, and at the same time, higher emissions of nitrous oxide from LECA covered slurry were also reported.

Polystyrene balls (EPS)
When plastic balls roll around, they expose to the open air the slurry sticking from the previously submerged face and therefore increase emissions. Wide stores are subjected to the wind effect and loose material (i.e. plastic pellets and balls) can accumulate to one side and uncover the slurry surface. Therefore, it is necessary to regularly add balls to cover the uncovered zones, due to the turbulences induced by the configuration of the containers. It is reported that polystyrene balls seem to have a summer effect in increasing greenhouse gases emissions by around 20 %. [259, France 2010][522, Loyon et al. 2007]

Rapeseed oil or grains
Other Effects, due to a reaction between the floating biodegradable cover and the slurry, may increase the emissions of methane (rapeseed oil by about 60 %). In the case of rapeseed oil, anaerobic reactions may produce surfaces with a strong, rancid odour.

Floating flexible cover

Development of gases under closed (plastic) covers is common. ~~, hence the necessity for vents. The~~ If practicable, gases may be used in a biogas installation, but need to be evacuated anyhow. ~~but the efficiency and economics of this depend largely on factors such as daily gas production, distance to biogas installation and use.~~

Geometrical plastic tiles

Please TWG provide information.

Operational data

In general, ~~the covering is 10 cm thick and~~ floating covers are ~~is~~ easily applied, but cannot be placed on empty stores.
~~Turbulences over the surface are induced by the geometry of the container, hence uncovered spots and deteriorated elements need to be regularly refilled or replaced. [259, France 2010]~~ **(moved below)**

Natural crust –Straw crust

In order to maintain the crust, ~~storages~~ stores are preferably filled from below [337, Webb et al. 2005]. Straw should not be chopped too short, to prevent flying away. For the same reason, good operation consists of mixing straw with slurry at the time of addition, ~~placing straw in the empty tank and adding more straw while stirring the slurry~~ during ~~in~~ filling operations. Agitation is done with a pump or with a tractor-driven propeller in large slurry tanks. [209, Denmark 2010].

~~The recommended use of 10 15 kg of straw per m^2 slurry surface will result in an approximately 15 20 cm thick floating layer that is needed to achieve a 20 % reduction of ammonia emissions.~~

In Germany, the minimum requirement in order to build-up a floating cover of chopped straw with a reduction efficiency for ammonia emissions of 80 %, is achieved with a layer of 10 cm (addition of 5 – 10 kg of straw per m^2 slurry surface). [474, VDI 2011] In Denmark, it is recommended to use 10 – 15 kg of straw per m^2 slurry surface, which will result in an approximately 15 – 20 cm thick floating layer. ~~A crust created by floating straw was reported to can achieve~~ A-reduction in ammonia emissions of between 60 – 70 %, on average, is reported from the UK. [11, ADAS 2000].

The abatement achieved is effective at a low cost but has a short lifetime as it deteriorates upon rainfall and climate. The floating layer of straw has a short lifespan and it should be regenerated every year.

Natural organic covering, being it a natural floating layer or with the addition of chopped straw ~~or deep litter~~, has been selected in Denmark as the reference for emissions from slurry stores. ~~containers emissions~~. A factor of 2 % is assumed for nitrogen losses from the total stored nitrogen (total N).

Farmyard manure or deep litter manure can also be used to establish a floating layer. A recommended quantity is to use 0.2 – 0.4 m^3 of manure per m^2 of slurry surface. [499, AgroTech 2008] [591, Denmark 2009] However, this type of cover is rarely used in pig farms; while is typically found in cattle farms. [591, Denmark 2009]

Peat and light bulk material (e.g. LECA, perlite)

~~In the case of~~ Light bulk materials, such as LECA, perlite, zeolite, peat ~~and plastic pellets~~, are distributed in smaller layers ~~have been applied as well~~. Smaller particles are generally more effective than larger particles,~~. They can be relatively~~ being effective with a 3 – 5 cm layer. ~~whereas layer particles need 10 – 20 cm. In practice, rain will reduce a LECA layer and increase emissions, but~~

LECA is a permeable floating cover. It allows air to penetrate the floating layer and provides adequate moisture and surface area for a population of aerobic bacteria to develop. In this way an improved effect on odour reduction is provided. [592, R.Burns, L.Moody 2007] The material does not prevent rain to enter in the slurry store. Wet LECA is less effective, so a greater higher thickness of the cover could compensate for a better efficiency this loss. An annual replacement of 10 % of the material is required. It is easy to install in new and existing slurry stores and has a relatively long lifetime.

LECA can provide a The maximum emission reduction of LECA is about 80 %, but it does not increase above a layer thickness of 5 mm. In Germany, a reduction efficiency on ammonia emissions of 80 – 90 %, compared to an open storage is achieved with the use of LECA [474, VDI 2011]

The efficiency of floating peat covers for reducing ammonia emissions is reported in the range of 80 – 90 %; however, in France, the results of field tests were not completely satisfactory, resulting, with an ammonia emission reduction of approximately 25 %, in comparison with the uncovered pig slurry storage.

Perlite floats easily on the slurry surface, but its effectiveness in reducing ammonia emissions is variable and it was found to be easily blown by wind. [592, R.Burns, L.Moody 2007] From Denmark, it is reported that the size of the lightweight aggregate materials used for floating covers is 4 – 8 mm; it can be delivered by truck, and spread evenly above the slurry. The reported necessary quantity is 20 kg per m^2 of slurry surface, resulting in a floating layer of 100 – 12 cm. [499, AgroTech 2008]

Polystyrene balls (EPS)
As for light bulk materials, plastic pellets can be distributed in smaller layers. Turbulences over the surface are induced by the geometry of the container, hence uncovered spots and deteriorated elements need to be regularly refilled or replaced. [259, France 2010]

Rapeseed oil or grains
Rapeseed oil (or derivatives with high percentages of rapeseed oil) is very easy to apply and does not easily mix with pig slurry. However, it is biodegradable, looses its surface integrity over time and also it greatly increases methane emissions. Oil covers, tested in pilot studies, have shown to reduce emissions; while a 3 mm of oil layer had little effect, a 6 mm layer proved to be very efficient. [590, Batfarm 2013]

Floating flexible cover
No structure alteration is necessary. Agitation is possible. Rainwater can be pumped off. Access for de-sludging is difficult.

Geometrical plastic tiles
The layer immediately above the surface is the most relevant for emission reductions
This type of cover is easy to install in both new and existing slurry stores. It does not prevent rain from entering the store. For hexagonal plastic bricks, the degree of reduction depends on the amount of covered surface. Emissions are reduced by 50 – 95 %, compared with uncovered containers. A reduction of 90 % is assumed for the maximum surface coverage of 95 %. A 90 % coverage is realistically achievable which is associated with a reduction of ammonia loss of 80 %. Odour abatement is estimated in the range of 80 – 90 %.

Emissions
In combination with the effect of reducing ammonia emissions, an inventory reported in [125, Finland, 2001] showed considerable effects from floating covers. The
Observed emission reductions vary achieved though varies with the cover type applied and are is generally higher in summer than in winter. see Table 4.157, gives an overview of the reduction efficiencies reported for different types of floating covers applied on slurry stores.

EXISTING TABLE 4.95, REPORTING DATA FOR THE REFERENCE YEAR 2001, HAS BEEN DELETED

Table 4.157: Performance of different types of floating covers

Type of cover	Source	NH_3	CH_4	Odour	H_2S	Cover durability
		(%)	(%)	(%)	(%)	Years
Natural crust	[575, UBA 2011]	20 – 70				
	[208, Spain 2010]	28				0.5
	[520, Fleming R. 2006]	10 – 90			10 – 90	
	[209, Denmark 2010]	80				
Straw (crust)	[575, UBA 2011]	Up to 90				
	[209, Denmark 2010]	80		80		1.2
	IRPP BREF 2003	60 – 70				
	[520, Fleming R. 2006]	60 – 90		40 – 90	80 – 95	
	[26, Finland 2001]	71				
	[214, Germany 2010]	80				
Peat	IRPP BREF 2003	Up to 90		Up to 90		2
	[259, France 2010]	25	+ 30			
	[26, Finland 2001]	92				
	[521, Portejoie et al. 2003]	77 – 100				
	[474, VDI 2011]	80 – 90				
LECA	[592, R.Burns, L.Moody 2007]	65 – 95		90		
	[26, Finland 2001]	75 – 82				
	[474, VDI 2011]	80 – 90				
	[217, Denmark 2010]	80				
Zeolite	[521, Portejoie et al. 2003]	93 – 98				
Perlite	[520, Fleming R. 2006]	63 – 91		30 – 93	64 – 84	
Plastic pellets (EPS balls)	[522, Loyon et al. 2007]	78 – 97				
	[259, France 2010]	Up to 80	+ 20			
Rapeseed oil	IRPP BREF 2003	Up to 90	+ 60	Up to 90		
	[26, Finland 2001]	92 – 93				
	[523, Rodhe et al. 2010]					
	[520, Fleming R. 2006]	85				
Floating flexible covers (blankets, sheets)	IRPP BREF 2003	Up to 90		Up to 90	90 – 95	10
	[26, Finland 2001]	92				
	[521, Portejoie et al. 2003]	99				
Geometrical plastic tiles	[216, Denmark 2010]	80 (50 – 95)		80 – 96		25
	[520, Fleming R. 2006]	95				

The information contained in the following paragraphs is now included in Table 4.152.
~~At the Spanish climatic conditions, a naturally formed crust allows for average reductions of 28 % compared to that are typical of the central plateau of Spain, with cold winters and very hot summers, emissions of 3.3 kg of nitrogen are lost per cubic metre of undiluted slurry in one year, which accounts for about 28 % less than an uncovered surface. [208, Spain 2010]~~
~~Canvas, floating foil, peat and rapeseed oil show high reductions of about 90 % or more. other techniques show lower reductions or their reducing effect is variable (gravel or LECA). Smaller particles reduce less, although no significant difference between gravel of 5 cm and 10 cm was reported. Also, the results with 10 cm gravel were not consistent.~~

~~LECA can provide a The maximum emission reduction of LECA is about 80 %, but it does not increase above a layer thickness of 5 mm.~~

~~Natural organic covering, being a it natural floating layer or with the addition of chopped straw or deep litter, has been selected in Denmark as the reference for slurry containers emissions. A factor of 2 % is assumed for nitrogen losses from the total stored nitrogen (total N).~~

~~In Germany and Denmark, a layer of straw of 10–20 cm is considered to achieve a 80 % reduction of ammonia emissions. A crust created by floating straw was reported to can achieve a reduction in ammonia emissions on average of between 60 – 70 % was reported from the UK. [11, ADAS 2000], with reference to Bode, M de, 1991.~~

~~For hexagonal plastic bricks, the degree of reduction depends on the amount of covered surface. Emissions are reduced by 50 – 95 % compared with uncovered containers. A reduction of 90 % is assumed for the maximum coverage of 95 %. A 90 % coverage is realistically achievable which is associated with a reduction of ammonia loss of 80 %. Odour abatement is estimated in the range of 80 - 90 %.~~

Applicability
Original text (reference year 2000), already deleted in Draft 1, has been eliminated

The technique is ~~generically~~ generally applicable. Floating bodies are only suitable for liquid pig slurry without a natural floating layer. When the slurry is stirred and sucked in, one should make sure that floating bodies are not sucked in with the slurry in order to avoid losses, clogging, and damage. [575, UBA 2011] Agitation during stirring, filling and emptying may preclude covering with some floating materials. They may cause sedimentation or blockages in pumps. [524, UK EA 2012]

Natural crust formation is an option for farms that do not have to mix the manure and disturb the crust in order to spread slurry frequently. Crust may not form in cool climates. [508, TFRN 2012]

The use of straw covers in large slurry tanks may be problematic, since the larger the slurry storage structure the more difficult is to achieve a uniform application of materials. In rainy climates, the use of dry straw is not recommended because when rained on, the rate at which the straw sinks dramatically increases. [592, R.Burns, L.Moody 2007]

The use of floating flexible covers on slurry stores that are emptied on annual or semi-annual basis, and hence have a large variation in manure level, also requires special installation considerations, to allow an impermeable synthetic cover to travel up and down as the level of stored manure changes. [592, R.Burns, L.Moody 2007]

Geometric plastic tiles are not suitable on farms where it is necessary to mix and disturb the crust in order to spread slurry frequently.

Economics
Normally, covers have the same costs for both new and existing tanks.

Where natural crusts with a sufficient thickness are possible, and slurry is introduced below the crust, a significant ammonia reduction can be achieved at little or no cost. [508, TFRN 2012]

Any tight covering of organic material for slurry containers can be achieved for an approximate cost of EUR 1.09 per square metre of slurry surface, straw price ~~is estimated to be~~ of EUR 0.047 per kg. Straw price varies locally and as a function of annual climatic conditions. In 2012, the price per kg of straw reported from Spain was around 0.04 – 0.10 EUR/kg.

The initial purchase of straw ~~costs~~ represents about 55 % of the total costs, while the remaining 45 % are distributed on machine and staff hours. The initial cost for LECA is around EUR 1.75 per m³ or EUR 7 per m^2. The yearly refilling of 10 % of new tiles might cost EUR 0.2 per m^3

[217, Denmark 2010] The floating layer will have a lifespan of one year, after which a new floating cover must be established. [209, Denmark 2010]

~~The raw expense for buying and implementing a cover of hexagonal tiles is EUR 35–40 per m² of surface. For a slurry tank 4 metres high, the expense is in the range of EUR 8–10 per m³. Since the tiles need little maintainance and are expected to last around 25 years, a tank of an approximate surface of 1 000 m² would imply total annualised investment running costs (annualisation included) of about EUR 0.5 per m³.~~ **See table below**

Investment cost data for some types of floating covers are summarised in Table 4.158. Additional cost data are presented in Table 4.153 and Table 4.154, in comparison with rigid covers.

Table 4.158: Investment costs for some types of floating covers

Type of cover	Investment costs		Annualised investment costs	Remarks
	EUR/m³	EUR/m²	EUR/m³/yr	
Floating bricks (hexagonal tiles)	8 to 10	35 to 40	0.5	Based on a durability of 25 years and a surface area of approximately 1 000 m² (height of storage tank: 4 m)
LECA	1.75	7	0.2	Based on a supplement/refill of 10 % of the surface material
Straw cover		1	0.25	The floating layer is assumed to be regenerated every year
Source: [216, Denmark 2010] [217, Denmark 2010] [209, Denmark 2010]				

Driving force for implementation

In some Member States, local regulations require that slurry stores are covered (e.g. Denmark and Germany from the mid-1980's). ~~Since 1987, Danish legislation has required slurry storages to have a tight covering. The covering can be a natural surface material, cut straw, stall waste or deep litter.~~ In UK, all new and substantially enlarged slurry stores should be covered before use and all existing slurry stores must be covered by 2020. [524, UK EA 2012]

Non-natural covers, like floating bricks are alternative to organic material covers, requiring less maintenance labour.

The ammonia that is not emitted can potentially ~~gain~~ generate more yield on the field, due to increased nitrogen application per hectare.

Non-natural covers, may be useful for slurries that, for coming from other treatments (biogas, separation, etc.), do not have the capability to create natural floating layers because of the low dry matter content. [216, Denmark 2010]

Example plants

~~Floating covers have been applied, but reported results are mainly derived from laboratory and field trials, rather than from actual farm applications in practice.~~

It is estimated that 10 % of the Danish covers are in light tile stones, together with cut straw and canvas tents. [217, Denmark 2010]

In Denmark, natural floating covers or straw-enforced crust are estimated to represent the major part of the total covered slurry surface (about 80 %). [209, Denmark 2010]. In 2004, the proportion of stores with a natural crust applied on Danish pig farms was less than 50 %; 5 %

were equipped with a fixed roof, around 5 % used peat or LECA and almost half of stores were covered with straw added without stirring.

~~Chopped straw and lightweight clay aggregates is widely distributed in Denmark from the mid 90s [499, AgroTech 2008]~~

Reference literature
[26, Finland 2001], [11, ADAS 2000], [556, ADAS 2000] ~~[193, Italy, 2001]~~ [506, TWG ILF BREF 2001] [208, Spain 2010] [209, Denmark 2010] [216, Denmark 2010] [217, Denmark 2010]

4.11.2.5 Application of covers to earth-banked slurry stores (lagoons) ~~storages~~

Description
Covers for earth-banked slurry ~~storages~~ stores are based on flexible impermeable UV-stabilised plastic sheets (e.g. HDPE) that are secured at the bank tops and supported on floats. Floats and tubes are installed to keep in place the cover and allow it to float over the slurry as the level of liquid increases and decreases, while maintaining a void beneath the cover for the purpose of gas collection. Covers may be fitted with collection piping (gas vents) for the gases that develop on the covered surface or to negatively pressurise the cover. [520, Fleming R. 2006]

The use of LECA is also possible for smaller lagoons, but it is considered to be better for application to a tank. Other applied covers are floating plastic elements (e.g. hexagonal bricks), chopped straw or a natural crust.

Achieved environmental benefits
Reductions in ammonia and odour emissions can be achieved. Ammonia emission reductions of about 95 % or more have been reported. Reduced ammonia emissions by 82 % are reported with the application of LECA. Chopped straw covers are reported to reduce ammonia emissions by 70 %, whilst natural covers by 28 %. [379, Spain 2009]

Cross-media effects
For covering a lagoon a large amount of plastic is needed, this can measure up to 70 % more than the actual lagoon surface area, depending on the depth and inclination of the edges. A benefit is that the cover can be reused, whereas other covers are consumables.

Rainwater can be pumped off the top, with the contrasting effects on manure dilution by preventing both the evaporation from the manure and the dilution for rainfall contamination. [525, BPEX 2011] [520, Fleming R. 2006]

~~Lagoon coverings keep out the rain, but they also prevent evaporation, which means that the total volume of slurry to be applied will slightly increase. It has been suggested that where no cover has been applied, it is cheaper to discharge the relatively clean rainwater to a watercourse and to only apply the slurry, rather than applying the larger volume of combined slurry and rainwater.~~
There is a potential to apply the rainwater for irrigation, but it would require careful monitoring of the water for slurry leakage or other contamination. Farmers are not in favour of recycling, for reasons of hygiene and disease control.

Stirring of the slurry would mix the slurry and its LECA layer, which would then, increase~~s the~~ ammonia emissions temporarily. It has been observed that the LECA cover re-establishes itself very quickly after stirring and that emissions again dropp~~ed~~ to a ~~the~~ reduced level. However, LECA as a cover does create problems with landfilling.

Covering will reduce or (in the case of a plastic covering) eliminate oxygen transfer from air to the slurry and will raise the temperature of the slurry by about 2 °C. These effects create an anaerobic condition in which methane will rapidly be formed. Methane emissions are increased by mixing and stirring of the slurry. The lack of oxygen reduces nitrification (and consequently) denitrification, and hence nitrous oxide emissions could be significantly reduced or prevented. With LECA, oxygen can still enter the slurry, which means that (de-)nitrification processes can occur and hence emissions of nitrous oxide are likely to increase.

Operational data
If adequate agitation cannot be performed, problems with sludge accumulation may raise after a number of years.

Precautions are recommended for the winter season to prevent the cover from tearing, i.e. remove rainwater on top of the cover, minimising ice formation. The expected life of the cover is reported to be about 7 years. [520, Fleming R. 2006]

Artificial floating crust cover is the minimum mandatory requirement in Germany (5–10 kg of chopped straw per m^2, depending on the kind of slurry) that is requested by regulation to obtain a minimum reduction of 80 % of ammonia emissions compared to the non-covered surface. **Moved from Section 4.11.2.6**

Applicability
It was concluded that purpose-designed covers can be fitted to existing pig slurry lagoons, unless:

- access is very poor
- a lagoon is very large (cost)
- the banks are uneven and not suitable for anchoring the plastic sheet.

The lagoon must be emptied completely of slurry and sludge to allow a fitting of the cover. Wind damage is not a problem if the cover is well fixed on the sides and if some rainwater is kept on top to weigh it down. Modifications to current agitation and emptying methods may be necessary but, with the relatively low dry matter content of pig slurry, mixing is not a problem.
Durabilities of covers of 10 years have been reported, but the vulnerability to wear and damage from animals is unknown.

~~It was suggested~~ By keeping rainwater out, ~~that~~ plastic covers could effectively increase the capacity of a lagoon by as much as 30 %. This would either give more storage flexibility over time or provide a larger capacity in case of an expansion in farm stocking.

LECA can be blown onto the slurry surface or pumped with the slurry. The latter technique would cause less dust and loss of material and would have a higher rate of distribution. Mixing and pumping with slurry may damage the material and must be performed gently.

If lagoon walls are not accessible and structurally sound, secured covers cannot be used; then the application of floating materials is possible. [524, UK EA 2012]

Economics
In Table 4.159, total annual costs and emission reduction costs for different covers of earth-banked slurry stores (lagoons), in comparison with uncovered lagoons, are reported from Germany. [575, UBA 2011]

Table 4.159: Cost data for different covers of earth-banked slurry stores (lagoons), in Germany

Type of cover	Investment and annual costs (1)		Emission reduction and mitigation costs	
	Annual costs $EUR/m^3/yr$	Investment costs EUR/m^2	EUR/kg NH_3	EUR/kg NH_3 (2)
Uncovered (reference)	1.08	NA	NA	NA
Floating film	1.34	11.5	0.42	0.22
Light bulk materials	1.23	NA	0.26	0.07
Straw	1.35	NA	0.48	(3) 0.31 (2 times per year) 0.84 (4 times per year)

NA= Not available
(1) Cost data refer to a lagoon with a capacity of 7500 m³. A storage duration of 6 months was assumed; the expenses presented are based on an annual slurry quantity which is twice as large as the usable capacity
(2) Cost data take into account the value of conserved nitrogen, the expenses for the application of precipitation water to land and the cost of tank freeboard for containing precipitation water
(3) Costs are given for a frequency of slurry application of two and four times per year.
Source: [575, UBA 2011]

FromUK, examples of costs are reported for covering a slurry lagoon with a capacity of 4540 m^3 and a surface area of 2000 m^2 (50 m x 40 m at top of lagoon and 4 m deep).

Table 4.160 Investment costs for covering a slurry lagoon in UK

Type of cover	Investment costs (1)		Annualised costs (2)
	EUR	EUR/m^2	EUR/yr
Floating flexible cover (floating film) (3)	75 000	37.5	5 681
Light clay aggregates (LECA) (4)	75 000	37.5	NA
Floating bricks (Hexa-cover)	56 800	28.4	4 261 (5)

NA: Not available
(1) Values in EUR as per exchange GBP/EUR = 0.88
(2) Include capital repayment over a 20 years payback period, interest costs and maintenance costs.
(3) Investment costs include the supporting grid and pump to remove rainwater, but do not include potential savings due to not having to spread rainfall with slurry.
(4) 10 % annual replacement is included for 20 years
(5) Floating bricks are 25 % cheaper than a floating flexible cover, but they do not prevent rainfall from entering the store, with consequent need to dispose of the water with the slurry.
Source: [524, UK EA 2012]

From Spain, it is reported that the cost of constructing or expanding an impermeable lagoon store ranges between EUR 12.74 and EUR 24 per m^3 of slurry. The variation depends on the soil type, dimensions of the lagoon and material utilized. [379, Spain 2009]

Costs of floating covers are likely to be EUR 15 – 25/m^2 of exposed slurry surface. Costs of LECA are EUR 225 – 375 per tonne. Abatement costs vary between EUR 0.35 and 2.5 per kg NH_3-N for plastic covers and EUR 2.5 and 3.5 per kg NH_3-N for LECA. Additional costs will be incurred on sites where modifications are needed to the structure, or to emptying and agitation methods. Efficient rainwater management determines the differences in running costs, where LECA covered lagoons may coincide with higher slurry application costs and where application costs will be higher where rainwater can enter the slurry. With plastic coverings, net costs depend on the possibilities for re-use of water for irrigation. The use of biogas (methane) depends on the purpose (heating or engine) and on the installation requirements. It might be profitable, but the cost recovery period might be quite long (over 20 years).

The cost of spreading the rainfall collected from an uncovered lagoon is estimated at EUR 1.6 per m^3. Rainwater collected on the top of a floating flexible cover remains clean and can be pumped to ditches and watercourses. Every 500 mm of rainfall on a 2 000 m^2 slurry lagoon is equivalent to 1 000 m^3 of water. Not having to spread it at a cost of EUR 1.60 m^3 gives a saving of EUR 1 600 per year. In high rainfall areas a cover could almost be cost-neutral.

From Spain, the unit cost for chopped straw used for floating covers is reported at 0.04 – 0.1 EUR/kg of straw. [379, Spain 2009]

Driving force for implementation
In climates where annual rainfalls are consistent, savings at landspreading the slurry are allowed for not transporting and distributing the added volume of rain. [524, UK EA 2012]

Example plants
~~In 2000, one farm applied a cover that had recently been fitted under a MAFF-funded project~~.
In the Netherlands, covers on lagoons have already been in use for a long time ~~ten years~~.
[11, ADAS 2000]

Reference literature
[11, ADAS 2000] [556, ADAS 2000] [208, Spain 2010]

4.11.2.6 Techniques to protect soil and water against emissions from slurry storage

Emissions of nitrate and phosphate to soil and water can be prevented by implementing certain requirements for the construction, maintenance and inspection of installations used for the collection and piping of liquid manure (channels, drains, pits, pipes, slide gates) and the storage of slurry and farmyard manure

4.11.2.6.1 Storage tanks construction and auxiliary equipment for slurry collection and transfer

Some existing text from Section 2.6.4.1, reorganised on the basis of the most appropriate sub-section

Description
Aboveground silos are storage tanks made of concrete ~~constructions~~; the base plate is *in situ* concrete cast, without joints whenever possible; walls are concrete or steel (corrosion-resistant coating or painting). The structure may have a covering lid. Manure flows are made over the rim and below the slurry surface, and unloading pipes must be fitted with at least two safety devices. Sliding gates and pumps must be easily accessible. The reinforced concrete that is used should be impermeable, with high frost and chemical resistance.

For tanks made of prefabricated concrete elements and concrete formwork, the internal wall surfaces and a 0.5 m wide strip of the base need to be protected with a suitable permanently-elastic coating or lining to bridge the cracks. The suitability of this should be attested by an inspection certificate.

Aboveground steel tanks require coating (enamelled or painting) to protect against corrosion. The suitability of the seal at the joint of the wall with the tank base needs to be certified. Base plates are made of in-situ concrete and should be at least 18 cm thick.

Below-ground silos are built *in situ* with the same characteristics as the aboveground concrete silos, but obviously the base is not observable from the outside. In Germany, ~~leakeage~~ leakage checks are mandatory (geomembrane with drainage and leakage control).

Slurry pits are constructed of pre-cast blocks or bricks; they need to be leak-proof with an internal sealing or lining. The same requirements apply to tanks of precast concrete blocks. The maximum slurry level may rise no higher than 10 cm below the pit cover or the floor grille.

Collection facilities such as channels, drains, pits, pipes and gate valves for the collection and piping of liquid manure, slurry and effluents (manure removal channels), the inlet to the slurry pit or pump station and the slurry pit or pump station itself should be fabricated of corrosion resistant material. Return flow pipes of the storage tank are fitted with at least two safety devices. Gate valves have to be adjusted in a way that they are easily accessible and in an impermeable shaft. Pumps should be easily accessible. Constructions of the slurry pit and pump station have to be sealed and impermeable.

Transfer facilities are all structural/technical facilities intended for the homogenisation and transfer of slurry. This category also includes transfer areas with the relevant installations used for transfer (pumps, gate valves). Areas in which slurry is transferred must be impermeable to water and designed to drain into a tank without an outlet (e.g. slurry tank, pump station).

In Figure 4.74, an example of below-ground slurry tank made of 'in-situ' concrete with a liquid-tight geomembrane fixed to the tank.

Source: [593, UBA Germany 2013]

Figure 4.74: Below-ground slurry tank with liquid-tight geomembrane

Achieved environmental benefits
Nutrient input (nitrates and phosphates) into underground and surface water is prevented.

Cross-media effects
TWG provide information

Operational data
The typical size is 1 500 m^3, within the range of 500 – 5 000 m^3, and is realised by round buildings of 20 m of diameter or by boxed buildings with a height of 5.2 m. A freeboard of at least 0.5 metres is always left when filling the store ~~storage~~.

In some Member States (DE, DK, BE) ~~Germany~~ a cover is mandatory and as a minimum can be a floating crust whilst other cover designs depend on the building construction and can be made of granules, a floating plastic sheet, a membrane, a roof or a tent. If a cover is applied, then a reduction in ammonia and odour emissions is expected (see sub-sections in Sections 4.11.2)

After emptying a slurry ~~storage~~ store, inspection and maintenance will prevent ~~the~~ a further risk of leakage. The application of double valves in pipes used for emptying the tank will minimise the risk of an unwanted discharge of slurry onto the farmyard and surrounding premises (surface water). The use of block floodgates is an extra tool to limit leak risks. [259, France 2010] **moved from Section 4.11.2.1**

Applicability
In Germany, construction of underground silos in areas under water protection is not allowed.

Economics
~~Building costs vary from EUR 30 to EUR 39 per cubic metre. The durability of buildings is considered to be around 30 years, hence yearly total costs are around EUR 3.2/m^3 per year. [426, Germany 2010]~~
~~The investment that is needed is greater than aboveground and is in the range of EUR 45 – 60 per m^3. [215, Germany 2010]~~

Cost data reported for the construction of above-ground and below-ground silos for slurry storage are presented in Table 4.161.

Table 4.161 Cost data for above-ground and below-ground slurry silos

Type of silo ([1])	Investment costs (EUR/m³)	Total costs (EUR/m³/yr)	Source
Above-ground	35 (from 30 to 39)	3.2 (from 3.0 to 3.5)	[426, Germany 2010]
Above-ground, in water protection area	40 (from 35 to 45)	3.7 (from 3.5 to 4)	[214, Germany 2010]
Below-ground	55 (from 45 to 60)	5 (from 4.4 to 5.5)	[215, Germany 2010]
([1]) Silos with 1 500 m^3 storage capacity; useable net volume (diameter 20 m, building height 5.2 m, useable height 4.7 m, freeboard 0.5 m).			

Driving force for implementation
Local regulations and location in water protected areas.

Example plants
In Germany, the procedures for defining dimensions, constructional design and materials for slurry stores, together with instructions on maintenance and inspection are described in DIN Standards and are widely applied.

Reference literature
[214, Germany 2010] [215, Germany 2010] [426, Germany 2010] [593, UBA Germany 2013]

4.11.2.6.2 Measures to prevent and inspect leakage from slurry stores

Description
In order to allow inspection of storage tanks for leaks during operation, the construction of a drainage system below the base plate is necessary, in addition to the basic requirements for the construction of slurry tanks to prevent leakage as described in Section 4.11.2.6.1.

Leakage inspection systems collect liquids in a leak-proof space below the base plate of slurry tanks. They consist of the following components:

- impermeable layer
- drainage layer
- drainage pipe
- inspection pipe or shaft.

The impermeable layer is usually made of a heat-sealed flexible geomembrane, which is fixed liquid-tight to the tank to prevent rainwater from infiltration (see Figure 4.74). Alternatively, membranes may only overlap if there is a slope. Above the impermeable layer, the drainage layer is built up of gravel or plastics. Drainage pipes are embedded as a circumferential or an area drainage system to discharge leaked slurry from the tank to the inspection pipe or shaft. Circumferential drainage systems are adequate only in the case of heat-sealed geomembranes. They consist of a drainage pipe that is located below the rim of the base plate around the whole tank. [214, Germany 2010]

In the case of area drainage systems, the drainage pipes are located in an array below the base plate. The drainage layer should have a minimum thickness of 20 cm and drainage pipes should be covered with a layer of at least 10 cm. The single drainage pipes are bundled in an inspection shaft.

Inspection pipes are conducted above-ground level. They should be at least 20 cm in diameter, in order to allow sampling of water. Inspection shafts are usually made from shaft rings with a diameter of 80 cm (see Figure 4.75). Inspection pipes and shaft are covered liquid-tight to prevent rainwater from infiltration.

If water occurs in the inspection devices, a contamination by slurry can be detected in water samples that indicate a leakage of the slurry tank. The distance between the inspection devices should not exceed 15 m.

Achieved environmental benefits
Leakage inspection systems are an effective measure to protect soil and water against nutrient (N and P) losses.

Cross-media effects
Non relevant.

Source: [593, UBA Germany 2013]

Figure 4.75: Inspection shaft for area drainage pipes from a slurry store

Operational data

In addition to proper planning and construction according to the relevant local regulations, water protection requires careful operation and facility maintenance. The responsibilities of the facility operator include regular checks of the tightness of slurry tanks, pipes, and fittings, as well as the operability of the inspection equipment. The operator of a facility is required to monitor its compliance with regards to operation and leak-proofing at all times before and during operation of a slurry tank. In the case the filling-level inspection or inspection of the structural condition of the facility give reason to any suspicion of leakage, an immediate notification to the competent authorities is requested.

In Germany, leakage checks (e.g. pressure tests) of underground pipes must be repeated approximately every 10 – 12 years. The results of the tests have to be kept on file and made available to the competent authorities on request.

Applicability

Applicable only to new-build installations.

Economics

Examples of investment costs for slurry tanks equipped with leakage inspection systems are reported by Germany and presented in Table 4.162.

Table 4.162: Investment costs for slurry tanks and leakage inspection systems in Germany

Dimensions				
Useable storage capacity ([1])	**500 m³**	**1 500 m³**	**3 000 m³**	**5 000 m³**
Height	4.0 m	5.0 m	6.0 m	6.0 m
Inner diameter	13.5 m	20.5 m	26.5 m	34.0 m
Investment costs (EUR)				
Construction and materials				
In-situ, concrete	29 800	48 500	80 500	115 300
Precast concrete elements	34 800	56 500	97 000	139 600
Steel, enamelled	39 200	63 800	107 200	153 300
Additional leakage inspection system ([2])	**400**	**7 300**	**10 500**	**15 000**

([1]) With 20 cm freeboard and 30 cm buffer for rainwater.
([2]) Circumferential drainage system with two inspection shafts.
Source: [593, UBA Germany 2013]

Driving force for implementation
General requirements of water legislation (Nitrates Directive, Water Framework Directive).

A leakage inspection system is mandatory for most slurry tanks in Germany and, at least, for tanks in areas where water resources management is a priority (e.g. water protection areas).

Example plants
Several hundred slurry tanks with leakage inspection systems are in operation in Germany.

Reference literature
[593, UBA Germany 2013]

4.11.2.6.3 Double layer lining for earth-banked slurry lagoons

Description
Earth-banked lagoons (see Section 2.6.4.2) are built with a double-layered geomembrane and a cover. Chopped straw can be used to facilitate the onset of a floating crust as a cover; whilst, other used coverings are granulate or floating plastic sheet. Artificial covers vary in design depending on the lagoon construction.

Capacities vary from 500 to 7 500 m^3. The typical size is 1 500 m^3 on an area of 15 × 30 m, with a building height of 4 m (0.5 m must be kept as a freeboard), to store manure of 1.0 – 1.1 t/m^3 for a time of 6 to 10 months.

Achieved environmental benefits
Nutrient leaching to ground waters and surface waters is prevented.

Cross-media effects
N_2O ~~NO_2~~ emission may be enhanced by the organic crust that develops on the surface.

Operational data
In Germany, for double-layered geomembrane lagoons, leakage control is mandatory. Pipelines are made out of corrosion-resistant material and those for the return flow from the storage tanks are fitted with at least two safety devices. Slide gates and pumps are easily accessible. The slurry pit and pump station are sealed in an impermeable construction. Areas in which liquid manure/slurry is transferred are fenced and are designed to drain into a tank without an outlet (e.g. slurry tank, pump station). In addition to proper planning and construction according to the relevant regulations, water protection requires careful operation and facility maintenance. The responsibilities of the facility ~~manager~~ operator include regular checks of the density of containers, of pipes and fittings as well as the operativeness of the control equipment. Density

checks (e.g. pressure tests) of underground pipes ~~must~~ should be repeated approximately every 10–12 years. Within water protection areas, the intervals must be shorter.

For lagoon systems, one method to identify leakage problems more rapidly is to monitor local ground waters. [204, IMPEL 2009]

~~Artificial floating crust cover is the minimum mandatory requirement in Germany (5–10 kg of chopped straw per m² depending on the kind of slurry) that is requested by regulation to obtain a reduction of 80 % of ammonia emissions compared to the non-covered surface.~~ **Moved to Section 4.11.2.5**

The durability of lagoons is considered to be ~~about~~ 10 – 15 years.

Applicability
This type of storage is commonly used for capacities of up to 5 000 m^3. For larger capacities (up to 7 500 m^3), the homogenisation of the liquid manure is increasingly hampered.

Economics
Investment requirements from EUR 18 to EUR 24 per m^3 have been estimated in Germany, for lagoons with a usable volume of 1 500 m^3. ~~together with~~ The reported total annual costs ~~of around~~ are 1.9 – 2.0 EUR/m^3/yr.

Driving force for implementation
The solution implies lower investment costs than those for concrete silos. ~~and is a valid alternative in water protection zones.~~

The German water legislation requires that earth-banked lagoons be built with a double-layered geomembrane and a cover of floating crust as a minimum.

Example plants
This technique is commonly applied.

Reference literature
[211, Germany 2010]

4.11.3 Reduction of emissions from storage of separated slurry fibre fraction

In connection with the separation of slurry (see Section 4.12.2.5), the fibre fraction that results is about 10 % of the initial slurry volume. It contains the main part of the dry matter and of nitrogen and phosphorus in organic form.

The fibre fraction is used today mainly as a phosphorus fertiliser in agricultural crop production or as a substrate to increase yields in production of biogas. A Danish ~~questionnaire~~ survey in 2007 found that just over half of the fibre produced was applied to the farm land, around 40 % was delivered to biogas plants, while only a small proportion was incinerated or utilised in some other way. To allow its further use, this fraction is stored over variable lengths of time. Covering storages of fibre fractions provides a reduction of emissions and in Denmark is mandatory.

Description
Techniques for storage of separated slurry fibre fraction, which may vary from a simple shelter cover to a closed manure shed, are given below.

- **Temporary storage containers** are used where collection is daily. When the container is full, the fibre is transferred to a more permanent storage. The temporary storage shall be in closed containers or fortified areas with drainage to a manure tank or similar.
- **Storage of fortified area**. If the supply is not daily the fibre fraction must be covered by compost or airtight material which is considered more efficient.
- **Storage of arable stack**. Fractions with dry matter content over 30 % can be stored in an arable stack provided that the storage is covered with a water and airtight shelter.
- **Storage in a manure shed**. Fibre fraction can be stored covered in a manure shed, provided that the fibres are located in a fortified area with a drainage system to a manure tank or the like.

Achieved environmental benefits
Effects of covers on odour are still under study since the creation of spots without oxygen (under the cover) would increase the risk of odour generation.

Similarly, the effect of covers on the emission of greenhouse gases has not been fully understood and a quantification ~~of condensation~~ is, therefore, not possible.

Limited experimental results indicate that the uncovered fibre fraction is an environment with a very high potential for N_2O emission. The value recorded was about 5 % of total N, corresponding to several fold the expected emissions from field application of slurry. [526, Hansen et al. 2006]

Cross-media effects
Effects of covers on odour are still under study since the creation spots without oxygen would increase the risk of odour generation.

Similarly, the effect of covers on the emission of greenhouse gases has not been fully understood and a quantification of condensation is therefore not possible.

Operational data
~~Open air storage show ammonia emissions equal to 25 % of the total nitrogen contents. Covers reduce these emissions to 12.5 % hence at a ratio of 50 %.~~
The results of a Danish study show that the application of an airtight cover to prevent composting during storage of slurry fibre fractions, results in a reduction of NH_3, N_2O, and CH_4 emissions by 12 %, 99 %, and 88 %, respectively. During a 120 days storage period without cover, 4.8 % of the total nitrogen was lost as N_2O; while, only 0.04 % was lost when using a cover. Nitrification activity is a precondition for N_2O emissions, which may explain the mitigation potential of an airtight cover. [526, Hansen et al. 2006]

In general, the effect of covering on greenhouse gas emissions has not been fully understood and a concrete quantification is not possible.

Ammonia emissions from covered fibre stacks are reported to be reduced by 12 – 50 % compared to non-covered stacks. [227, Denmark 2010].

Applicability
Any type of slurry or fibre fraction in any type of storage can be equally covered. Applicable to all farm sizes with slurry separation, though the bigger amounts of fibre, the bigger are investment~~s~~ requirements.

Economics

Investment costs, related to a farm producing 17 500 fattening pigs per year, of may reach EUR 5 per animal place, depending on the type of cover, ranging from a simple shelter cover to a closed manure shed.

Driving force for implementation

Storage losses are avoided, resulting in possible increased yields in biogas production. For fibre fractions used in agricultural crop production, storage is necessary since the material is applied before crop seeding in spring or autumn, which means that, in practice, the fibre fraction is stored for up to half a year before utilisation.

Example plants

Manure Slurry separation is increasingly coming into use in some countries (see Section 4.12.2) hence, the storage of fibre fraction is done simultaneously parallel.

Reference literature

[227, Denmark 2010]

4.12 Techniques for the on-farm processing of manure

4.12.1 Introduction

The section has been integrated with new information and rearranged in order to avoid repetitions. Consequently, part of the existing text has been deleted.

Several techniques are available for manure processing and can be classified into four main categories:

- techniques for treating raw manure or a mixture with other organic matter;
- techniques for treating slurries (raw manure);
- techniques for treating liquid fractions after separation of raw manure;
- techniques for treating solid fractions or solid manures.

Site-specific conditions, constraints and opportunities present at local level, as well as farm requirements reflecting the local environmental conditions, define the optimal combination of techniques belonging to the above groups (e.g. the nitrogen surplus). [590, Batfarm 2013]. In the case local conditions are such that alternative costs (i.e. transport out of the region) are lower than the treatment itself, the treatment of manure is not to be pursued.

Manure processing and treatment is mainly applied with the objective of improving manageability and utilisation of livestock manure; this includes ~~The main reason to treat the manure is~~ a balance of the quantity of nutrients that are going to be spread with the crop requirements, wider options for returning to land the organic matter and nutrients in a more controlled way, improved stability and plant availability of nitrogen and phosphorus. However, if conditions allow (large enough spreading area, compliance with local regulations) the spreading of untreated slurry in order to fertilise crops has to be preferred.

In the Baltic region, the over-supply of phosphorus with fertilisation has been studied and more than 40 techniques for livestock manure treatment have been identified. [218, Baltic Sea 2020 2010]

Other objectives of manure processing may be the reduction of emissions to the atmosphere (NH_3, odours, GHG, etc.), production of energy through anaerobic digestion, removal of pathogens, removal of xenobiotic compounds (emerging pollutants).

A processing strategy can consist of a unitary/single process or a combination of various unitary processes.

In Figure 4.76, a schematic representation of manure processing strategies, which can be applied in cases of nutrient surplus, is presented.

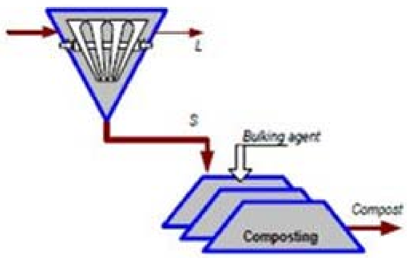
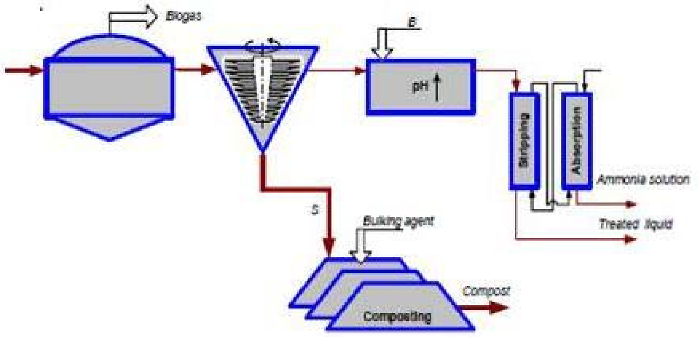
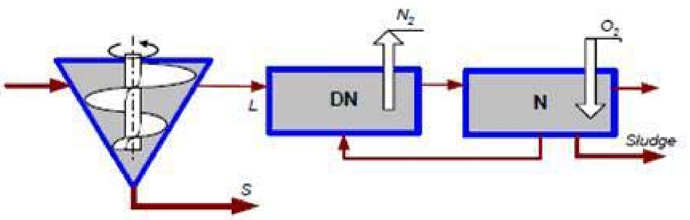
Process and objective	Diagram of the processing scheme
Solid-liquid separation with composting of the solid fraction. External use of compost; on-farm use of liquid fraction as fertiliser	
Anaerobic digestion with solid-liquid separation; composting of the solid fraction and ammonia stripping with consequent absorption. Production of biogas (energy), external use of compost and ammonia concentrate; on-farm use of liquid fraction for irrigation	
Solid-liquid separation and nitrification-denitrification of the liquid fraction. Partially nitrogen removal, and on-farm use of the remaining products	
Source: [594, Agro Business Park 2010]	

Figure 4.76: Example of manure processing strategies

The technical and environmental performances of a manure processing technique or a combination of different techniques (processing strategy) can be affected by:

- the characteristics of the manure
- the features of the individual treatments applied
- the way techniques are operated

The off-farm treatment of manure is not under the scope of this BREF but it is widely applied and is likely to spread more in the future.

In the Netherlands, manure treatment has been taking place since the 1970s when, for the first time, measures were gradually introduced to limit the loss of minerals into the environment. Since then, the limiting measures taken by the government have been steadily tightened and the amount of work in research and development of manure treatment technologies has simultaneously increased. However, the attention on manure treatment is strongly influenced by the disposal costs of untreated manure. In the Netherlands the on-farm treatment of manure is mainly based on separation techniques that are applied as routine technique for intensive livestock farms without land with problems with manure transportation to other places. The basic separation techniques have been developed in the nineties; although new separation techniques have been developed on an experimental scale (like membrane separation), the practical application of the technique at the farm level has not really changed since then.

In Belgium-Flanders, the total ~~operational~~ costs of the most common ~~these~~ techniques vary between EUR 20 and EUR 30 per treated m³. The economic analysis performed showed that only for 30 % of the pig farms manure treatment is economically feasible ~~the companies would be able to process the entire manure production.~~ In areas with a medium to ~~and~~ high manure pressure, slurry treatment is feasible if farms are ~~if companies must be~~ able to spread at least 80 % ~~of their manure~~ on their own farmland. In areas with a high quantity of manure produced, the driving force for implementing manure treatment is even higher.

Economic analyses showed that large scale, high-tech processing techniques are expensive and can only be affordable for high-turn over farms, or in regions with high livestock density, where all alternative solutions for manure management are even more expensive. In these cases, the cooperation between several farmers in the processing facility is necessary.

A summary of the main characteristics of the techniques for processing of manure, described in the section, is given in Table 4.163. Full descriptions and references are given in the relevant subsections.

THE EXISTING TABLE 4.96 HAS BEEN SUBSTITUTED WITH THE NEW TABLE 4.158

Table 4.163: Summary of the main characteristics of techniques for processing of manure

Section	Processing technology	Aim	Main environmental benefits	Main cross-media effects
4.12.2	Mechanical solid/liquid separation of slurry by: • screw press • decanter-centrifuge • flocculation-coagulation • sieves-drum filters • filter pressing • Air flotation • Natural settling	Separation and concentration of the solid and liquid fractions of slurry	Solid fractions easily exported outside the farm, reducing problems derived from nutrient surplus: phosphorus accumulation and nitrate leaching to water	Risk of gaseous emissions. Indirect CO_2 emissions due to electric energy consumption
4.12.3	Aeration of liquid manure/biological treatment: • Aerobic digestion • Mechanical separation and biological treatment • Nitrification/denitrification	Biological decomposition of organic matter	Pathogens and odour emissions reduction. Removal of biodegradable organic matter	Under non-optimal conditions, odour, CH_4 and N_2O emissions may occur
4.12.4	Composting of solid manure: • Composting • Co-Composting of poultry manure with green residues • Composting with a biological inoculums	Obtain a stable product with low moisture content and most of the initial nutrients, free of pathogens	Substantial reduction of transport costs and related CO_2 emissions, due to significant reduction of mass (water evaporation). Production of organic fertiliser. Removal of pathogens. Reduction of odour emissions	Emissions of NH_3, odour and CH_4 during process operation
4.12.5	Anaerobic treatment	Production of biogas. Mineralisation and stabilisation of organic matter.	Reduction of GHG emissions by: • decreasing potential CH_4 emissions • decreasing fossil fuel consumption Reduction of pathogen content and increased hygienisation. Reduction of offensive odour	Uncontrolled leakages of biogas with consequent emission of CH_4. Potential emissions from digestate storage (CH_4, H_2S, NH_3, N_2O)
4.12.6	Anaerobic lagoon system	Combined slurry stabilisation, separation and storage	Improved quality of solid and liquid fractions	High CH_4 emissions
4.12.7 4.12.8	Evaporation and drying of manure. Slurry and wet manure belt dryer	Nutrients and organic matter concentration. Reduced volume for easier and cheaper transport	Dried/concentrated and hygienised product easy to handle, with moderate-high concentration of nutrient (N and P)	Heavy metals are concentrated in the concentrate stream that can limit product application or landspreading. Direct or indirect CO_2 emissions depending on the energy source used

Section	Processing technology	Aim	Main environmental benefits	Main cross-media effects
4.12.9	Slurry acidification	Reduce ammonia emissions by lowering the pH of manure, with consequent ammonium (NH_4-N) retention in the manure	Reduction of ammonia emissions Possible reduction of CH_4 emissions	Emissions of VOC and odours from oxidation reaction due to the addition of a strong acid
4.12.10	Combustion of poultry litter	Energy production by thermal oxidative process of organic material. Energy recovery with possible transformation into electricity	Energy savings. Fertiliser value of the produced ashes	Emissions to air from combustion (NO_X, SO_X, etc.)
4.12.11	Ammonia stripping	Removal of ammonia through volatilisation from a liquid phase, with subsequent recovery in an acidic solution as ammonium salt or by condensation	Less nitrogen content in slurries, with consequent easier management on-farm. Reduced odour emissions from manure landspreading. Recovery of a valuable nutrient (nitrogen)	Energy consumption, with indirect CO_2 emissions
4.12.12	Manure additives	Facilitate handling and management of manure. Stabilise manure and reduce the contents on pathogens	Reduced ammonia and greenhouse gases. Reduced content of pathogens	High variability in efficiency

4.12.2 Mechanical separation of pig slurry

4.12.2.1 Introduction

THE SECTION HAS BEEN REARRANGED; SOME PARAGRAPHS HAVE BEEN REPOSITIONED; OLD EXISTING PARTS, ALREADY DELETED IN DRAFT 1, HAVE BEEN REMOVED

The main scope of liquid-solid manure separation is to obtain one or more components (e.g. phosphorus and dry matter) concentrated in the solid fraction improving manure/slurry management.

Slurry separation does not create any environmental benefits in itself. However, important positive environmental effects derive from how the liquid and ~~the~~ solid~~s~~ fractions are stored and used after separation. The benefits of slurry separation strongly depend on the separation efficiency which can vary significantly, making slurry separation unattractive if the efficiency of the process is poor.

The liquid fraction is usually handled in the same way as ~~unseparated~~ untreated slurry, since ~~because~~ it is stored in storage tank or slurry lagoon and is subsequently delivered to the field. It can also be further processed in-situ. Solid fractions ~~are~~ can be further used for:

- delivery on the field as a solid fraction
- turnover in biogas plants and subsequent delivery to the field as fertiliser
- raw material for the production of compost and soil conditioners
- drying and pelletising the fertiliser product or subsequent combustion
- combustion.

It may be appropriate to combine some of the above mentioned applications, ~~uses~~ as it happens with the biomass exiting a biogas treatment that might be first separated and then dried, pelletised and combusted.

Slurry separation may help to reduce excess of nutrient supply at local level (nitrate leaching and phosphorus accumulation), in areas that drain to the vulnerable aquatic environments such as Natura 2 000 sites, lakes, fjords and sensitive areas for drinking water supply. It is assumed that the solid fraction is not delivered as fertiliser in the same area along with ~~as~~ the liquid fraction but, instead, is further processed (e.g. in biogas plants) ~~and~~ or used for purposes other than agriculture (e.g. for incineration) or delivered as fertiliser in ~~more robust catchment~~ areas with low livestock density and/or nutrient deficiency. [223, Denmark 2010]

The separated fractions (solid and liquid) are easier to manage (transport, use). Landspreading of the liquid fraction results in a faster penetration into the soil, because of the low dry matter content, with consequent lower ammonia and odour emissions and lower contamination of the crops, with lower organic load in terms of COD and BOD. [203, ADAS 2005]

The separated solid fraction can also be used for biogas production.

The management of two separated fractions, the liquid with higher nitrogen content and the solid richer in phosphorus, allows for a more accurate dosing of the nutrients.

An overall assessment of the environmental benefits achievable with slurry separation includes avoided CO_2 emissions from reduced transport and from the possible biogas production, as well as, reduced indirect emissions associated with the production of the avoided chemical fertilisers for the supply of phosphorus. [499, AgroTech 2008]

The major driving force for implementing slurry separation is related to local regulations and conditions, such as scarce availability of land for manure application (e.g. in the Netherlands) or restrictions on the application of phosphorus.

A common potential cross-media effect for all separation techniques is that during operation ~~low~~ some ammonia volatilisation and odour emissions may occur, depending on the specific system in operation, as a result of highly-stirred systems or increased mixing of the slurry. In closed systems, and when coverings are in place, the release of odour is limited. ~~but they are not yet quantified~~

Common techniques ~~and aims have been~~ are described in Section 2.7, and in Table 4.164 the ~~principal~~ main technical characteristics of the techniques are summarised, as reported by the Netherlands. Among other factors, the energy consumption needed to separate manure depends on its dry matter content. Efficiencies and solid phase characteristics normally depend on the slurry type and equipment used for the separation.

In general, high dry matter content yields a better separation result of all dry matter, N, P, and K, hence separation of fresh manure is preferred because stored manure usually carries a lower dry matter content. [219, Netherlands 2010]

Table 4.164: Characteristics and technical data for the most common manure separation techniques in the Netherlands

Technique	Capacity	Capital cost	Phosphorus separation efficiency	Dry matter content in solid phase	Energy consumption	Remarks
	(slurry m^3/h)	(thousand EUR)	(%)	(%)	(kWh/m^3 slurry)	
Sieve bow Screen Brushed screen Drum filter Drum filter with press rolls etc.	10 – 20	10 – 30	<< 30	< 25	0.5(3)	Some types have very low phosphate efficiencies
Screw/auger press Filter press	4 – 15	>25	20 – 40	25 – 35	1.0(3)	Average separation efficiency
Sieve belt press	4 – 30	>70	50 – 75 (1)	20 – 25	0.1(3)	Additives needed, high efficiency
Centrifuge Decanter	4 – 100	>100	60 – 70 (2)	25 – 30	4.0(3)	High efficiency High maintenance

(1) Using additives.
(2) Without using additives.
(3) The energy consumption of a manure separation installation is often given excluding the usage of peripherals such as mixers, pumps, conveyor belt systems, compressors, etc. This leads to an underestimation of the costs in this table. For example: a mobile centrifuge with a high capacity could be outfitted with a generator for the required electrical power. Fuel consumption of this generator could be estimated to be 1 litre of diesel/m^3 manure processed (this yields about 10 kWh/m^3 manure treated).
Source: [219, Netherlands 2010]

Costs mainly depend on the equipment depreciation and maintenance costs. Normal depreciation periods could be 5, 7 or 10 years, whereas maintenance costs could represent between 2.5 and 40 % of the initial investment. The mobile separation units that are frequently deployed over several sites have higher maintenance needs than single farm separator units that are infrequently used (see Table 4.165).

Table 4.165: Minimum costs of ~~manure~~ slurry mechanical separation for an annual capacity of 5 000 m^3 ~~liquid manure per year~~ (costs for storage, installation or transportation and land application are excluded)

Technique	Investment	Depreciation	Electricity	Maintenance	Additives	Total
	EUR	EUR per treated m^3 of liquid manure				
Sieve, screen, Drum separator, etc.	25 000	0.50	0.06	0.25	0	0.81
Screw press Auger press	30 000	0.60	0.12	0.30	0	1.02
Sieve belt press	70 000	1.40	0.01 ([1])	0.70	1.00 ([2])	3.11
Centrifuge	100 000	2.00	0.48	1.00	Option ([3])	3.48

([1]) 1 kWh equals EUR 0.12.
([2]) Additionally needed: flushing water (10 Bar), compressed air (8 Bar).
([3]) Additionally needed: anti-foam agent (PM).
Source: [219, Netherlands 2010]

Sequential separation using different techniques can yield higher phosphate removal efficiencies. ~~In Denmark, a combination of a screen separator and a screw press is also in use.~~ With the use of additives, the phosphate separation efficiency is over 60 %.

When the size of solids in the slurry is very heterogeneous, even with presence of big elements that can block transfer elements such as pumps and pipes, a combination of separation systems may be applied, even though the system is less efficient, such as the use of a grid followed by a finer separation stage.

It should be considered that a single separation process is very rarely sufficient to achieve both a concentrated sludge and a clarified liquid. A multi-stage process, with recycling of liquids and solids is needed if both objectives are important. [203, ADAS 2005]

~~After~~ Separation, but also other manure treatment techniques, should be carried out in such a way that the final product is competitive ~~manure products can compete~~ with chemical fertilisers and ~~with~~ untreated manure by adjusting its properties (e.g. nutrient composition) according to the needs of farmers. ~~As such separating manure in different products improves the efficiency of use of N, P and K, and prevents losses to ground water and surface waters. In addition, the separated thin slurry penetrates more quickly into the soil.~~ [219, Netherlands 2010]

~~In the Netherlands, manure separation techniques are applied as routine technology in intensive poultry and pigs farms that do not have enough land to spread manure onto, and hence have problems with delivering their manure.~~

In the Vendée region, France, a mobile separator circulates from farm to farm to separate the duck slurry. The solid fraction is composted. [259, France 2010]

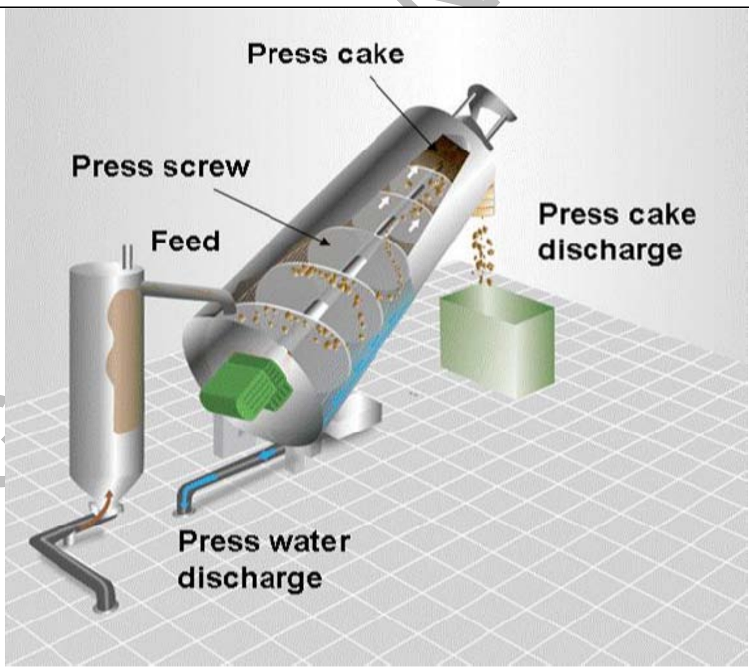
A survey, carried out in 2011, showed that slurry separation was practiced in about 11 000 farms of different sizes, with an outstanding 80 % of farm-size installations located in Italy, corresponding to about 45 % of the total treated manure covered by the survey. The most commonly used separation techniques are drum filters, screw pressing and separation by sieves, representing respectively 42, 33 and 18 % of the total farm-size European installations applying a slurry separation system. [595, Agro Business Park 2010]

Reference literature
[203, ADAS 2005][219, Netherlands 2010] [220, Germany 2010] [221, Denmark 2010] [222, Denmark 2010] [223, Denmark 2010]

4.12.2.2 Screw press and auger separators

Description
This technique is based on the application of pressure to separate by filtration the suspended solids contained in the slurry in a solid and a liquid fraction. ~~In these systems the~~ Slurry is either pumped into the separator directly or it flows ~~flowing~~ through a funnel with the aid of a vibration unit to facilitate the even material flow into the press, in particular when slurry is thick. Then, the slurry enters into a cylindrical screen (0.5-1 mm) by means of a ~~The~~ rotating screw ~~pressure worm~~ which conveys the slurry into the pressure zone. ~~which consists of the cylindrically shaped screen and the hardened stainless steel pressure worm~~ The liquid passes through the screen and is collected in a container surrounding the screen. ~~The rotating pressure worm conveys the slurry into the pressure zone which consists of the~~ At the end of the axle, the fraction rich in dry matter is pressed against a cylindrically shaped screen ~~and the hardened stainless steel pressure worm.~~ The slurry filter cake is compressed during pressure filtration, producing a solid fraction with high dry matter content. Increasing the applied pressure will increase the dry matter content of the solid fraction.

A schematic representation of a screw press is given in Figure 4.77.



Source: [221, Denmark 2010]

Figure 4.77: Screw press scheme

Achieved environmental benefits
The separation of initial N and P content of the slurry in two fractions (liquid and solid) allows reducing problems related to nutrient surplus: phosphorus accumulation and nitrate leaching to water.

See also Section 4.12.2.1.

Cross-media effects
Energy consumption (electricity) to run the equipment, with associated indirect emissions.

During operation low ammonia volatilisation and odour emissions may occur, depending on the specific system in operation. but they are not quantified.

Operational data
It is reported that 4 – 20 tonnes of slurry per hour (and up to 20 tonnes, in Denmark) can be treated, depending on the type of separator and the dry matter content of the slurry. Examples from Germany and Denmark, concerning the characteristics of input and output materials are presented in Table 4.166.

Table 4.166: Characteristic of treated manure in screw press (model assumptions)

Phase	Dry matter (%)	Total N (kg/t)	NH_4 (kg/t)	P_2O_5 (kg/t)	K_2O (kg/t)	Source
Input	7.5	5.6	3.6	3.7	3.7	[220, Germany 2010]
Separated liquid phase	4.4	5.3	3.7	2.8	3.8	
Separated solid phase	30.0	7.8	2.7	10.1	3.0	
Input	6	2.5	-	1.15	-	[221, Denmark, 2010]
Separated liquid phase	3	3.5	-	2.3	-	
Separated solid phase	20 – 30	4 – 5	-	6.9	-	

The energy consumption (electricity) to run the equipment depends on the input material (slurry, digestate) and varies from 0.3 to 1 kWh per tonne of input material.

Applicability
The technique is generally applicable for a wide range of dry matter contents of the slurry, as well as for processing digestate from biogas production. Only slight adaptation is necessary in existing farms e.g. a storage plate for the solid fraction. as storages for the solid fraction are already present.

Economics
Investment costs for a unit with a capacity of 8 – 20 tonnes/hour are reported in the range between Separation units costs are approximately EUR 20 000–45 000. Depending on the capacity of the processing unit and dry matter content of the slurry, investment costs which that, depending on the capacity, can be also expressed as round EUR 2 000 – 5 000 per tonne per hour. With an amortisation period of 10 years and 6 % interest rate, the annualised investment costs are EUR 260 – 650 per tonne or EUR 3 300-4 600 per unit.

From a plant located in Spain treating 10 000 m^3/year, the estimated investment cost of the screw press is EUR 28 000. [594, Agro Business Park 2010]

Extra operating costs are reported from Germany in the range between EUR 0.6 and EUR 1.25 per animal place per year, or between EUR 0.9 and EUR 1.87 per tonne of treated slurry. These are calculated for compared to equipment a unit having characterised by a treating capacity of 10 m^3/h capacity and , 5 kW of power installed (cost of electricity EUR 0.15/kWh) serving in farms of 2 000 or of 5 000 animal places, respectively, which produce and producing 1.5 m^3 of slurry per animal place annually. Treatment costs are also reported at EUR 0.5 – 0.9 per m^3 of input slurry; for a unit with a treating capacity of 10 000 m^3/h, operating costs are reported at 0.66 EUR/m^3. [594, Agro Business Park 2010]

From Denmark, annual running costs are estimated in the range of EUR 0.14 – 0.17 per tonne of input.

In the Netherlands, for a capacity of 4 – 15 m^3/h and an annual treated quantity of 5 000 m^3, investment costs of over EUR 30 000 and operating costs are at least 1.02 EUR/m^3 are reported (see Table 4.165).

~~Human~~ Labour demand ~~necessity~~ in Denmark is estimated to be approximately ~~or~~ 0.1 – 0.25 hour per working day. ~~and costs about 0.002 EUR per tonne.~~

Driving force for implementation
~~Regional~~ Local restrictions on nutrient supply can force the use of systems to reduce transportation costs by means of reduced transported ~~matter~~ volumes.

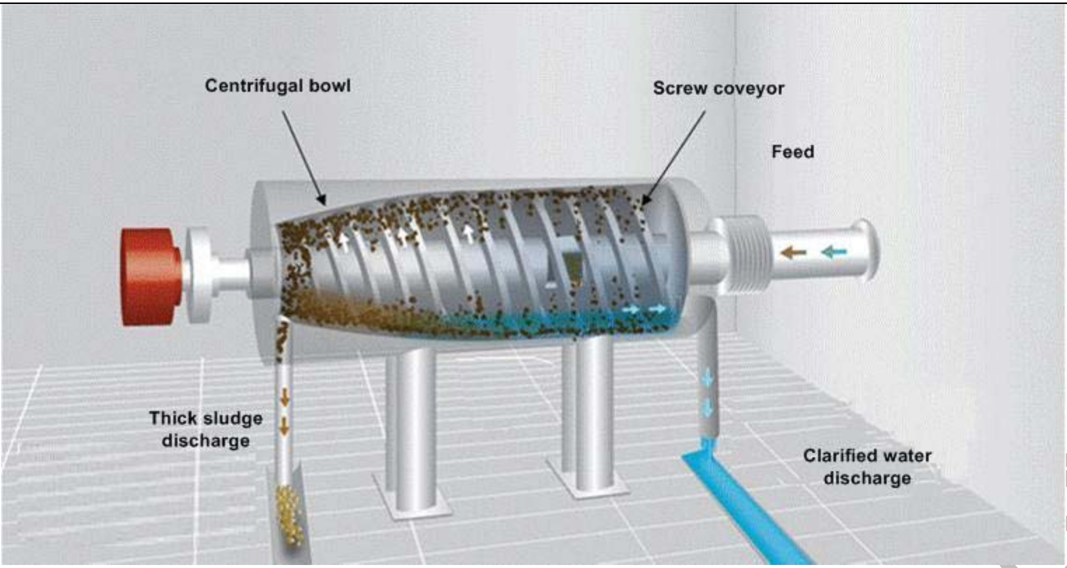
Example plants
In 2009, at least 3 600 screw presses for the separation of slurry were in operation in Europe.

Reference literature
[220, Germany 2010] [221, Denmark 2010] [594, Agro Business Park 2010] [595, Agro Business Park 2010]

4.12.2.3 Decanter centrifuge separator

Description
A centrifugal force is generated to cause the separation of solids from the liquid. There are vertical and horizontal types of decanter centrifuges. The slurry enters the decanter centrifuge in the centre of the machine, which rotates at a high speed, typically 3 000 – 5 000 rpm. The centrifugal force separates solids and liquids at the wall into an inner layer with a high dry matter concentration and an outer layer consisting of a liquid containing a suspension of colloids, organic components and salts. The solid and liquid phases are transported to either end of the centrifuge by rotating the entire centrifuge at high speed and by simultaneously rotating the conveyor at a speed that differs slightly from the speed of the bowl (outer conical shell). The solid particles of the slurry are conveyed towards the conical end and let out through the solid discharge openings, whereas the supernatant flows towards the larger end of the cylinder formed by the bowl and the flights of the conveyor. The liquid phase is discharged through openings at the wide end of the decanter centrifuge. A macerator can be used before the decanter to shred the large particles into smaller ones

A schematic representation of a decanter centrifuge for the separation of slurry is shown in Figure 4.78.



Source: [222, Denmark 2010]

Figure 4.78: Scheme of a decanter centrifuge for slurry separation

Achieved environmental benefits

The separation of initial N and P content of the slurry in two fractions (liquid and solid) allows reducing problems related to nutrient surplus: phosphorus accumulation and nitrate leaching to water. See also Section 4.12.2.1.

Cross-media effects

~~Power consumption of about 2.5 kWh per tonne is required for these systems.~~
Energy consumption (electricity) to run the equipment, with associated indirect emissions.

Operational data

Fixed systems have a capacity of approximately 6 tonnes per hour, whereas mobile units can have a larger capacity of 10–25 tonnes per hour.

In order to enhance separation efficiency, the use of polyelectrolytes is normally considered.

The main characteristics of the input and output ~~matters~~ flows, from typical pig slurry in Denmark applying decanter centrifuge for separation, are shown in Table 4.167.

Table 4.167: Characteristics of the separated fractions from a decanter centrifuge separation of a typical ~~given input~~ pig slurry in Denmark

Treated matter	Dry matter (%)	Total N (kg/t)	Total P (kg/t)
Input	5.0	4.0	1.0
Output: separated liquid phase	2.2	3.2	0.3
Output: separated solid phase	18	6.6	4.3
Source: [222, Denmark 2010]			

Centrifugation is the technique that reports the higher separation efficiencies. The average efficiency of centrifugation, as a separation technique, expressed as a proportion in the solid fraction, is reported to be: 14 % volume, 61 % dry matter, 28 % Total N, 16 % NH_4-N, and 71 % Total P. From Denmark it is reported that the proportion of total nitrogen in dry matter fraction from the centrifuge is between 18 – 28 % and the proportion of phosphorus in solid fraction after separation is between 60 and 70 %. Additional operational data are reported in Table 4.164.

Increasing the retention time by reducing the volumetric feed rate has been observed to increase the efficiency of the separation of slurry. The separation efficiency of dry matter increases at increasing dry matter content of the slurry.

There are differences in the capacity between fixed centrifuges and mobile centrifuges. From Denmark, it is reported that fixed systems have a capacity of approximately 5 – 7 tonnes/hour; whereas, mobile units can have a higher capacity of 10 – 25 tonnes/hour. [596, Denmark 2009]

The energy consumption for the operation of a decanter centrifuge is reported in the range between 2 and 4 kWh/m^3. [594, Agro Business Park 2010] ~~Power~~ From Denmark, energy consumption ~~of~~ is reported at about 2.5 kWh per tonne of treated slurry. ~~required for these systems~~.

Applicability
There are no restrictions for the application of this technique. ~~On the contrary, the same equipment can be also used for different types of slurry (e.g. pigs, sows, cattle, dairy cows and other animals) and can be applied in connection with a biogas plant.~~

Economics
The cost of the fixed configuration of the equipment is reported from Denmark to be in the range of EUR 19 000–21 000 per hourly tonne of capacity, or approximately EUR 115 000 for a system with a capacity of 6 tonnes per hour. The ~~annual~~ running costs have been measured in Denmark as EUR 0.3 – 0.6 per tonne of treated slurry.

Other reported data indicate investment costs in the range between EUR 40 000 – 60 000, for a treating capacity of 1.5 – 2 m^3/h, and treatment costs are reported in the range of EUR 0.6 – 2.3 per m^3 of input slurry. [594, Agro Business Park 2010]. From the Netherlands, for a capacity of 4 – 100 m^3/h, investment costs are reported over EUR 100 000 and operating costs of at least 3.48 EUR/m^3 for an annual treated quantity of 5000 m^3. (see Table 4.164)

~~Human necessity~~ In Denmark, labour requirements are ~~is~~ estimated to be approximately ~~EUR 0.003 per tonne~~ 0.25 h/working day.

Driving force for implementation
Local restrictions on nutrient supply for agriculture can force the use of systems that reduce transport costs by means of reduced volumes to be transported. See also Section 4.12.2.1.

Example plants
The technique itself is known and widely used in industry, in waste water treatment and biogas plants. In Denmark, five pieces of equipment, mobile or fixed, are in use for the separation of pig slurry; three other units are reported to be in operation in Spain. The system is widely used in France, combined with biological treatment (aerobic and anaerobic) and on-farm filtration.

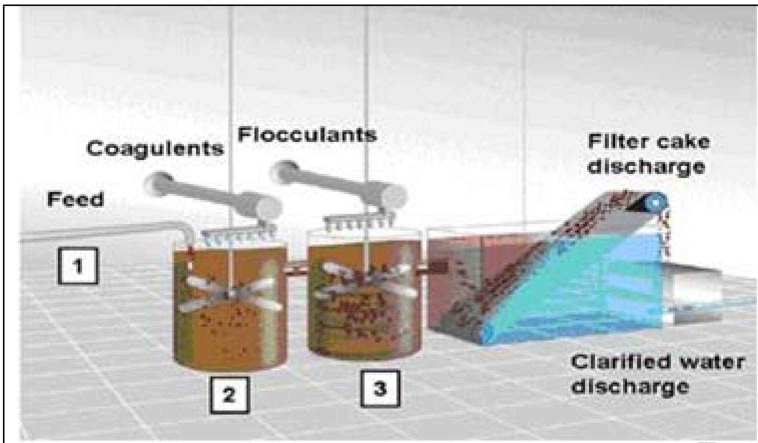
Reference literature
[222, Denmark 2010] [594, Agro Business Park 2010] [596, Denmark 2009]

4.12.2.4 Coagulation – Flocculation

Description
Coagulation-flocculation is not a separation treatment on itself; it is a chemical pre-treatment that improves the subsequent mechanical solid-liquid separation of the slurry.

Multivalent cations and/or chemical polymers (e.g. polyacrilamide, chitosan) are added to the slurry causing coagulation and flocculation. Flocculant agents aggregate organic particles into larger particles whose size and other physical properties make them easy to separate from the liquid fraction. ~~part~~. The addition is done in a small mixer tank, to achieve a satisfactory particle aggregation, before mechanical separation ~~Flocculation is often used as a pre-treatment before mechanical separation~~ in a screw press, band filter, or decanter centrifuge system.

A schematic representation of the flocculation-coagulation process is shown in Figure 4.79.



Source: [223, Denmark 2010]

Figure 4.79: Schematic representation of a flocculation-coagulation pre-treatment for slurry separation

Achieved environmental benefits
The technique can increase the amount of nutrients in the solid fraction compared with other solid/liquid separation techniques. See also Section 4.12.2.1.

Cross-media effects
Electric energy is needed to run the pre-treatment (flocculation-coagulation), with associated indirect emissions.

The environmental and health consequences of flocculants to the environment, when applied to land, have not been fully investigated. The monomers of polyacrylamide (PAM), used in most slurry separation studies, can be toxic, and a potential carcinogenic. It has been shown that its degradation is rather limited in soil; it accumulates in the environment, does not degrade in the biogas production process and easily dissolves in water making it difficult to trace. [527, Hamelin et al. 2010] On the other hand, the results of a study carried out on separated slurry products report the risk to be minimal, if a biological post-treatment is applied, since PAM is degraded in biological processes without acrylamide accumulation. [594, Agro Business Park 2010]

Operational data
The characteristics of the treated matters are shown in Table 4.168, referred to typical ~~Danish~~ pig slurry, in Denmark.

Table 4.168: Characteristics of the fraction after flocculation separation for a given input pig slurry

Treated matter	Dry matter (%)	Total N (kg/t)	Total P (kg/t)
Input	5.0	4.0	1.0
Separated liquid phase	1.5	2.9	0.3
Separated solid phase	30	11.0	7.0
Source: [223, Denmark 2010]			

From Denmark, it is reported that the proportion of total nitrogen in the dry matter fraction after separation with flocculation is equal to 27 %. The respective proportion of phosphorus is reported to be 55 %. [223, Denmark 2010]

Additional operational data from the Netherlands are also presented in Table 4.164 (see Section 4.12.2.1).

The process is reported being very sensitive to polyacrilamyde concentration; an increase from 120 to 140 mg/kg is capable of almost tripling the total dry matter of the solid fraction, but increases ammonia and organic contents. As a result, the use of a polyacrilamyde concentration greater than 120 mg/kg is not recommended where further anaerobic treatment is required. [203, ADAS 2005]

Energy consumption for the application of this pre-treatment (flocculation-coagulation) in combination with sieve-separation treatment is reported in the range of 0.7 to 2.0 kWh per tonne of manure. ~~are needed to run this technique.~~

Applicability
The technique is generally applicable to all types of slurry. Flocculation is often used in combination with screw presses.

Economics
From Denmark, a cost of ~~Around~~ EUR 20 000 ~~are the~~ is reported ~~needed cost~~ for each tonne/hour of capacity, for the application of flocculation-coagulation in combination with a sieve separator, which makes approximately EUR 140 000 for a system with a capacity of 7 tonnes per hour. The annual running costs have been measured ~~as~~ at EUR 1.3 per worked tonne. From other sources, operating costs are reported at EUR 0.8 per tonne of input slurry and the investment costs around EUR 50 000. [594, Agro Business Park 2010]

~~Human~~ Labour necessity in Denmark is estimated to approximately ~~about 0.003 EUR per tonne~~ 0.25 h per working day.

Driving force for implementation
Sedimentation and separation are accelerated. A higher efficiency of mechanical separation techniques is achieved by particle properties modification. See also Section 4.12.2.1.

Example plants
The technique is relatively well known and is widely used for waste water and sewage treatments. It is estimated that in 2009 there were between 30 and 40 units in operation in Denmark for the separation of slurry with chemical precipitation, most of which are used for pig slurry.

The technique is also applied in France and Spain.

Reference literature
[223, Denmark 2010] [203, ADAS 2005] [594, Agro Business Park 2010]

4.12.2.5 Separation by sieves

Description
Sieve separators may be static, vibrant or rotating (drum). The liquid slurry flows through a screen of specified pore size, which allows only solid particles smaller in size than the opening to pass through, and is drained off. This type of separator generally works better for slurry with a low content of solids (<2 %). A compromise between sieve size, separation performance and risk of clogging is normally selected. Indeed, sieve clogging is one of the most usual problems of static screens. Such risk is diminished in vibrant sieves due to vibration. If the flow is too

high, a large amount of water can remain in the solid fraction. On the other hand, such devices need a constant supply of slurry to prevent the particles to dry.

In drum sieves the material is flowing through the inside and the liquid is passing through the drum. Eventually the drum can be mounted with a fibre cloth on the outside to optimize the separation.

Separation by sieves is used as pre-treatment in order to avoid sedimentation phenomena during slurry storage, as a conditioning process before pumping, or in combination with more efficient separation systems.

An example of rotating (drum) sieve separator is given in Figure 4.80.

Source: [594, Agro Business Park 2010]

Figure 4.80: Illustration of a rotating (drum) sieve separator for slurry

Achieved environmental benefits

The separation of initial N and P content of the slurry in two fractions (liquid and solid) allows reducing problems related to nutrient surplus: phosphorus accumulation and nitrate leaching to water.

See also Section 4.12.2.1.

Cross-media effects

See Section 4.12.2.1.

Operational data

Separation efficiency for drum filters is reported to achieve as content is the solid fraction: N 20 %, P 30 – 55 %, total volume 25 – 27 %, and dry matter 12 %. An example of drum separation applied to pig slurry is presented in Table 4.169.

Table 4.169: Example of a pig slurry separated with a drum sieve

	Dry matter (%)	Total N (kg/t)	NH_4 (kg/t)	P (kg/t)	K (kg/t)
Untreated slurry	4.9	5.0	3.5	1.0	3.5
Solid fraction	10.4	5.3	3.5	1.4	3.8
Liquid fraction	2.9	4.7	3.4	0.8	3.3
Source: [594, Agro Business Park 2010]					

Drum filtration is often used in combination with chemical flocculation. The drum sieve has often lower capacity compared to a centrifuge, but fairly good separation efficiency in relation to a low investment. The energy consumption for a drum sieve is reported equal to 1 kWh/m^3 of slurry. Additional operational data, from the Netherlands, are presented in Table 4.164 (Section 4.12.2.1).

Applicability
Generally applicable

Economics
Investment costs are reported to be EUR 3 500 – 8 000 for a static sieve, EUR 15 000 for a vibrating sieve and EUR 25 000 for a drum sieve (at a capacity of 2 – 3 m^3/h). The operational costs for the drum sieve are reported at EUR 0.35 per m^3 of slurry.

For a capacity of 10 – 20 m^3/h, investment costs ranging between EUR 10 000 and 30 000 are reported from the Netherlands, with and operating costs of at least EUR 0.81/m^3 for an annual treated capacity of 5 000 m^3. (See Table 4.164 in Section 4.12.2.1)

Driving force for implementation
See Section 4.12.2.1.

Example plants
Several plants are reported to exist, representing more than 40 % of the total slurry separation systems in use on-farm. [594, Agro Business Park 2010]

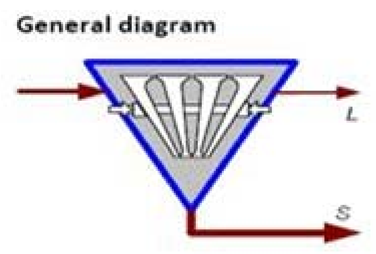
Reference literature
[594, Agro Business Park 2010]

4.12.2.6 Separation by filter pressing

Description
Most of the filter-press separators are screen-type devices which may have a large variety of designs.

- Rotary press – Slurry is continuously fed into a channel, and rotates between two parallel revolving screens. The filtrate passes through the screens as the solid fraction advance within the channel. The solid material continues to dewater as it travels around the channel, eventually forming a cake near the outlet side of the press. The frictional force of the slow moving screens, coupled with the controlled outlet restriction, result in the extrusion of a dry cake. Use of polyelectrolyte is normally considered in order to enhance separation efficiency.
- Filter belt – The band filter is constantly turning on rollers to make the material moving and to gain pressure on the material and thereby the liquid part passes the filter. The filter cake is continuously removed as the belt rotates, so that the raw-slurry loading area and solid-fraction unloading area change over and are cleaned continuously. Often the belt separator is followed by a screw pressing unit, to increase the dry matter content in the fibre fraction.

A schematic representation of a filter-pressing separator is given in Figure 4.81.



L= Liquid fraction
S= Solid fraction
Source: [594, Agro Business Park 2010]

Figure 4.81: Schematic representation of a filter-pressing separator

Achieved environmental benefits
The separation of initial N and P content of the slurry in two fractions (liquid and solid) allows reducing problems related to nutrient surplus: phosphorus accumulation and nitrate leaching to water. See also Section 4.12.2.1.

Cross-media effects
See Section 4.12.2.1.

Operational data
Use of polyelectrolyte (for flocculation/coagulation) is normally applied in combination with filter-pressing, in order to enhance separation efficiency. In this case, attainable separation efficiencies of 30 % TKN and 70 % P, in the solid fraction, are reported. Dry matter of the separated solid fraction is in the range of 25 – 35 %.

For a rotary press, energy consumption is reported equivalent to 0.5 kWh per m^3 of input slurry.

Applicability
Generally applicable.

Economics
Investment costs are reported to be in the range of EUR 25 000 – 125 000 depending on dimensions and type of separator. For a band filter (filter belt), operational costs are reported equivalent to EUR 1.5 per tonne of input slurry.

From the Netherlands, investment costs for a system with a capacity of 4 – 30 m^3/h are reported over EUR 70 000, with operating costs of at least EUR 3.11 per m^3, for an annual treated capacity of 5 000 m^3. (See Table 4.164 in Section 4.12.2.1)

Driving force for implementation
See Section 4.12.2.1

Example plants
At least 100 plants are reported to exist.

Reference literature
[594, Agro Business Park 2010]

4.12.3 Biological treatment of liquid manure

4.12.3.1 Aerobic digestion (Aeration) of liquid manure

Description
Aerobic digestion consists on the biological decomposition of organic matter to carbon dioxide (CO_2) by aeration (with aerobic microorganisms), with the presence of oxygen. Heat released by the decomposition of the organic matter result in thermophilic temperatures inside the reactor over 45 ºC and up to 75 ºC. Under thermophilic conditions, only the biodegradable organic matter can be removed and nitrogen is conserved in the liquid phase. The technique may be combined with another stage for the removal of nitrogen through nitrification/denitrification. The main variables concerning aerobic digestion are: retention time, aeration intensity and whether the process is continuous or carried out in batch mode.

Stored slurry is aerated by means of aerating pumps that blow air in the mass. Aerators can be submerged or floating and usually work intermittently ~~The description of aeration is given in~~ (see also Section 2.7.2.).

Achieved environmental benefit
Aerobic digestion produces an odourless product with lower pathogen content, due to the biological oxidation of volatile organic compounds and the associated heat generation and thermophilic temperatures of the process. ~~Aerobic decomposition of the nutrients reduces odour.~~ Organic load (COD) is removed up to 60 %, depending on the level of aeration. Organic matter is also stabilised.

Cross-media effects
Only well designed and properly managed systems, providing optimum aeration levels, can achieve effective odour and pathogen reduction; i.e. inadequate control of the aeration process may lead to increased release of sulphides and other odorous organic compounds when anaerobic conditions resume.

Variations in slurry characteristics and incomplete mixing can considerably reduce treatment efficiency and consistency. Thus, gaseous emissions may occur in the form of ammonia, where aeration intensity is too high, and as methane and nitrous oxide at low pH and other sub-optimal conditions.

When aerobic digestion is combined with nitrification-denitrification, ammonia nitrogen may be partly (or completely) removed from the manure and emitted into the air (as nitrogen), resulting in a loss of fertiliser value.

If additives are used for the sedimentation of floating substances, the residual sludge may be difficult to dispose of.

Using this technique on duck slurry, a notable quantity ~~production~~ of foam is produced which has to ~~must~~ be controlled by means of biological complements. [561, Flotats et al. 2004]

Because of the microbial activity, a higher quantity of sludge is produced, if compared with the anaerobic treatment.

~~NH_3 and N_2O are emitted to the air [174, Belgium, 2001], as well as methane [194, Austria, 2001]. [506, TWG ILF BREF 2001]~~

Aeration requires a significant energy consumption, which associated to indirect emissions for electricity production.

Operational data

Batch aeration (especially at thermophilic temperatures) is better at reducing pathogen numbers and, in theory, is a more consistent process than continuous treatment. However, it is difficult to control and leads to wide variation in the aeration level.

In the case of incomplete aerobic treatment and if the slurry is stored for a period of time, subsequent anaerobic conditions may cause denitrification to nitrogen gas (N_2). In these cases, 50 – 70 % of the nitrogen may be lost.

It is important to closely monitor the redox potential or oxygen content of the slurry, as partially anoxic conditions can result in the formation of nitrous oxide (N_2O).

Aeration of pig manure may lead to a sludge that is difficult to precipitate and dosage of chalk may then be necessary. The temperature is an important factor, particularly in colder regions where it may be difficult to maintain the required aeration level during winter. However, intermittent aeration (15 minutes/hour) in combination with an achieved BOD_5 reduction of about 50 %, results in a good deodorisation and a very limited sludge production. [506, TWG ILF BREF 2001]

Aeration requires a high amount of energy, but the levels vary with the equipment applied and the size of the installation. Air is added to the system at an approximate rate of 1.5 kg O_2/kg organic matter oxidised. Energy consumption depends also on the composition of the slurry, in terms of BOD and nitrogen (when nitrification is allowed). Levels of 10 – 38 kWh per m^3 of aerated liquid manure have been reported. A good management of the aeration frequency may reduce energy consumption but will lead to ammonia volatilisation.

Applicability

There is wide spread experience with this technique. ~~Aeration is probably more widely applied than composting solid manure, as it requires less input than composting solid manure, which needs whilst composting requires that the manure stacks to be turned.~~

The technique can be applied on pig slurry, other type of liquid manure such as duck slurry or the liquid fraction coming from mechanical separation of slurry. [259, France 2010]

~~Aeration of duck slurry is carried out by the same technique and has a positive effect on reducing odours during and after spreading.~~

Economics

Investment costs for slurry treatment plants operated in Brittany, France, are reported to vary between EUR 45 and EUR 53 per m^3 of annual capacity. [203, ADAS 2005] The total costs, including investment and operational costs are reported to vary greatly depending on the level of treatment and the annual volumes involved. Costs for an aerobic treatment m^3without a mechanical separation, with an annual capacity of 4100 m^3, are reported to be about EUR 8.2 per m^3, in Brittany, France. In cases when a mechanical separation stage is coupled with the aerobic treatment plant, total costs were reported to range from EUR 10.7 per m^3 for the smaller plants (5600 m^3 slurry per year) to EUR 7.6 per m^3 for the larger plants (16 300 m^3 slurry per year). It is also reported that in France the on-farm use of aerobic treatment is given incentives of financial support. [203, ADAS 2005]

In the UK the typical net cost of aeration was found to be around EUR 4.7 per m^3 of pig slurry (1 EUR = 0.88 GBP).

Costs, reported by Finland, ranged from EUR 0.7 – 2 per m^3 of aerated liquid manure in a storage tank to EUR 2.7 – 4 per m^3 of aerated liquid manure in a separate tank.

In France, the cost of duck slurry aeration is estimated at EUR 2.2 per m^3 of slurry, the cost of the anti-foam treatment being included. [370, Franck et al. 2003]

Driving force for implementation
A homogenised product with reduced odour is more convenient to be landspread. Pathogen dissemination is also avoided.

Aerated liquid manure may be used ~~for application on grass or~~ for the flushing of manure gutters, tubes or channels ~~canals~~ to reduce ammonia emissions from housing.

Example plants
This technique is applied in a number of Member States, e.g. about 90 farm-scale installations are reported in UK and 20 in Finland. In Spain the technique is applied to large facilities treating annually an average of 55 000 – 65 000 tonnes of pig slurry. [595, Agro Business Park 2010]

Community facilities for aerobic digestion form an integral part of the NVZ Action Programme in parts of Brittany, France and Belgium. In 2005, around 190 aerobic treatment units were reported in operation in Brittany, France. [203, ADAS 2005]

Reference literature
[409, VITO 1997] [26, Finland 2001] [370, Franck et al. 2003] [203, ADAS 2005] [561, Flotats et al. 2004] [594, Agro Business Park 2010]

4.12.3.2 Mechanical separation and biological treatment of pig slurry (previously Section 4.12.2.5)

Description
The manure is taken from a storage facility or directly from the animal housing and the solid, undissolved components are removed by means of a sieve, sedimentation installation or centrifuge. The purpose of this separation is:

- to avoid possible obstruction of equipment by sedimentation and clogging during the process
- to reduce oxygen demand, and thereby energy costs.

The liquid is pumped through an aeration tank or basin where it remains for 2 to 3 weeks. In the basin, microorganisms (activated sludge) transform organic matter into mainly carbon dioxide and water. At the same time, part of the organic nitrogen is transformed into ammonium. Ammonium is oxidised by nitrifying bacteria into nitrite and nitrate. By applying anaerobic periods using basins without aeration, the nitrate can be transformed by denitrification into N_2.

Activated sludge and cleaned liquid then flow from the aeration basin into another (secondary) settling basin. In this basin the sludge settles, with part of it being reused in the aeration basin. The residue is captured in a storage basin to concentrate it further. This concentrated residue, can be used as fertiliser (sometimes it is composted first).

Achieved environmental benefit
The effluent resulting from mechanical separation and biological treatment contains very low levels of N and P. It leaves the secondary settling basin via its overflow. It can be discharged or stored for use on land as a fertiliser.

Cross-media effects
Electrical energy is required to operate the aeration, pumps, and pre-separation of the solids. ~~In the applied system an~~ Energy use is reported at ~~around was measured of~~ 16 kWh per m^3 of raw manure.

Another disadvantage is that part of the nitrogen emitted into the air is not in the form of N_2 but, potentially, NH_3 or N_2O.

The design and proper functioning of this technique is very important to prevent environmental problems ~~being~~ from being transferred from ~~the~~ water to ~~the~~ air ~~component~~ media. Also, an effluent must be discharged, which in many cases may pose problems. (.~~is not possible or allowed~~.

The fertiliser value of the slurry is lost and may have to be replaced with chemical fertiliser.

Operational data

Data are shown for a farm in Brittany with 250 sows and 5 000 finishers per year with a yearly manure production of about 5 000 m^3. The solids are sieved from the liquid. The results in terms of mass balance, quantities and composition of the products and the costs of the installation for mechanical separation and biological treatment at this specific farm are summarised in Table 4.170, Table 4.171 and Table 4.172.

Table 4.170: Mass balance of the mechanical separation and biological treatment of pig slurry

Component	In	Out				Calculated air emissions
	Manure	Sieved residue	Sludge	Effluent	Total	
Mass	1 000	57	260	580	897	103
Dry matter	56	20	21	5	46	10
Susp. Solids	48			0.3		
Water	944	37	239	575	851	93
COD	52			1		
BOD	6.6			0.05		
N	4.4	0.5	0.7	0.05	1.25	3.15
P_2O_5	3.3	0.6	2.0	0.4	3	0.3
K_2O	3.5	0.2	0.9	1.8	2.9	0.6
Cl	1.9			0.8		
Source: [409, VITO 1997]						

Former Table 4.91 has been deleted.

Table 4.171: Composition of manure and products in g/kg

Component	Manure	Sieved residue	Influent to secondary basin	Sludge	Effluent
Dry matter	56	350	39	80	8.5
Susp. Solids	48		29		0.5
Water	944	650	961	920	991.5
COD	52		36		1.8
BOD	6.6		6.1		0.09
N	4.4	8.1	4.2	2.7	0.08
P_2O_5	3.3	9.9	2.9	7.5	0.6
K_2O	3.5	3.4	3.4	3.4	3.0
Cl	1.9		1.9		1.4
Source: [409, VITO 1997]					

The sieve removes a small mass with a relatively high DM content and phosphate level. The residue contains about 35 % dry matter and can be stacked.

The tables show that much of the N (72 %) is lost ~~disappears~~ into the environment due to nitrification and denitrification. Only about 1 % of the N appears in the effluent. Most of the P_2O_5 is retained in the activated sludge. It should be noted that the information source did not report if BOD was measured over 5, 7 or 20 days.

The residual concentrations in the effluent need to be compared with the locally accepted discharge levels. This may be a problem and application on land might be the only option available for the effluent. The amount and composition of the different products can vary widely. Important factors are:

- the water content of the manure
- the variability of the treatment.

Usually the aeration tanks are open and considerable emissions to the air can be expected of gaseous components (such as odour, ammonia, N_2O). However, in this example, the emissions have not been quantified. Covering of the basins and extraction and treatment of the air or adequate process control will reduce those emissions. Also, an emission of N_2O can be expected.

Applicability
The technique is applicable on both new and existing pig farms. Due to its costs, it may only be applicable on (very) large pig farms. It is based on the applied biological treatment for municipal and industrial waste water. Proper process control is essential, but may be difficult on-farm; outsourcing could thus be a solution. Particularly in colder areas, ~~in winter~~ the minimum winter temperatures required for sufficient biological activity to occur may be difficult to maintain. Ammonia levels can rise and lead to inhibited nitrification.

With more solid types of manure, such as the manure of finishers, large amounts of residual sludge can be expected. In practice this limits the application of this technique to the treatment of sow manure with a DM content of not more than 6 %.

~~In theory,~~ Concerning the poultry sector, the technique is theoretically suitable to duck slurry, but the volume needed and the treatment costs are still not economical for its common on-farm use. [259, France 2010]

Economics
Costs have been estimated for the installation in Brittany described earlier with a capacity of 5 kilo tonnes manure per year. The investment was EUR 134 000 (1994). In Table 4.172 operating costs (including external technological support) are presented, although exclude ~~excluding~~ the costs and returns of marketing the products.

Table 4.172: Estimation of the operating costs of an installation for the mechanical separation and biological treatment of sow manure with a capacity of 5 ktonnes per year in EUR/tonne manure

Cost factor	Cost basis	EUR/tonne manure
Capital	10 yrs, 7 %	3.6
Maintenance	3 % of investment	0.8
Electricity	16 kWh/t and 0.08 EUR/kWh	1.3
Technological support		0.4
Total		6.1
Source: [409, VITO 1997]		

Driving force for implementation
From other examples of where this technique is applied, it is concluded that manure with high water content is preferred. Also, it seems most the cost effective in application on farms of generally more than about 500 sows.

Example plants
In ~~Brittany~~ France, around 300 units are in use. In the department of the Vendée, a mobile separator moves from farm to farm to treat the duck slurry. The solid part is composted. [259, France 2010]

Reference literature
[409, VITO 1997] [410, Greece 2001]

4.12.3.3 Nitrification – denitrification of slurry

Description
Biological conversion of ammoniacal nitrogen is performed in two main steps: nitrification and denitrification. In the nitrification stage, the ammoniacal nitrogen is oxidised into nitrate. This process takes place under aerobic conditions, in the presence of free oxygen. In the denitrification stage, the nitrate is biologically reduced to gaseous nitrogen (N_2), most of which is released into the surrounding atmosphere. Denitrification take place under anoxic conditions, which means that free dissolved oxygen, is not present in anoxic zones of the flocculent mass.

Achieved environmental benefits
Ammoniacal nitrogen is removed from the slurry in the form of inert N_2 gas. Nitrogen removal can improve the manageability of slurry, especially in areas with nitrogen surplus. Odour is reduced compared to untreated slurry.

COD reduction as a function of aeration.

With the application of a biological treatment, emissions of greenhouse gases (methane and nitrous oxide) as well as ammonia emissions are reported to be reduced, if compared with manure storage alone (based on 6 months storage before spreading). [597, Loyon et al. 2007]

Cross-media effects
Higher energy consumption in comparison with a solid/liquid separation.

A higher quantity of sludge is produced (from microbial activity) compared with anaerobic treatment systems.

It can be argued that slurry looses its fertilising value, which can be effectively used where nutrient surplus is not an issue.

Operational data
Aeration is one of the main operational parameters during nitrification, with theoretical requirements of around 4.6 kg O_2 per kg of N. Organic load during denitrification is required to be approximately 6.0 kg COD per kg of Nitrate-N. Pre-treatment such as separation and anaerobic digestion may constrain availability of biodegradable organic carbon during denitrification.

The optimal process temperature is 35 ºC. The typical treatment system has two different outputs: treated liquid effluent and biological sludge.

The results of a study, comparing a nitrification/denitrification treatment (intermittent aeration) to a conventional slurry storage of 6 months before spreading, report a reduction of 30 – 52 % of ammonia emission for a biological system combined with mechanical separation (centrifuge or screw press).A higher ammonia emissions reduction (68 %) is reported for a combination without separation, consisting of storage, biological treatment and decanting. A reduction of greenhouse gas emissions (CH_4 and N_2O) by about 55 % (calculated as CO_2 equivalent) is also reported for any type of biological treatment plant. [597, Loyon et al. 2007]

The technique demands the control of a number of operating parameters, such as: composition of the effluent, applied loads, bacteria populations, temperature, etc. The process is sensitive to the presence of toxic and other substances which can inhibit microbial activity. Resulting sludge needs proper management.

The biological process needs a continuous operation. It is necessary to ensure that slurry has sufficient inorganic carbon for the nitrification stage, and organic carbon for the denitrification process. During the process, oxygen consumption to oxidise organic matter in an aerobic stage should be carefully controlled.

Energy consumption depends on the composition of the stream to be treated, the efficiency on transferring oxygen of the aeration equipment, operational conditions applied, etc. Values in the range of 10 – 25 kWh/m^3 are reported, in comparison with an effective solid/liquid separation, for which energy consumption can be less than 10 kWh/m^3.

Applicability
Applicability is limited by the high investment costs and operational costs for the electrical energy required for aeration.

Economics
For a unit with a capacity to treat 15 000 m^3 of pig slurry per year, reported investment costs are EUR 240 000 – 300 000. For a capacity of 50 000 m^3 of pig slurry per year, investment costs are EUR 700 000-1 200 000.

Operational costs are dependent on the composition of the manure to be treated and they are reported in the range of EUR 0.5 – 3.0 per tonne of slurry. [594, Agro Business Park 2010] [561, Flotats et al. 2004] In the case a solid/liquid separation is carried out prior to nitrification/denitrification, and the solid fraction is composted as a post-treatment, costs can increase to EUR 2.5 – 5.2 per tonne.

Driving force for implementation
In areas of nitrogen surplus, economic investment and operative cost for the removal of nitrogen from slurry could be attractive, if they are lower than the transportation and application costs to long distances.

Example plants
About 240 farms in the region of Brittany, France, most of it classified as a nitrate vulnerable zone under the EC Nitrates Directive, have opted for a biological treatment using nitrification-denitrification (intermittent aeration). [597, Loyon et al. 2007]. In Belgium, Spain and in the Netherlands the technique is also widely applied. [595, Agro Business Park 2010]

Reference literature
[594, Agro Business Park 2010][561, Flotats et al. 2004]

4.12.4 Composting of solid manure

Composting (see Section 2.7.3) can be applied as a further treatment, after the drying of fresh (poultry) manure, after mechanical separation of the solid fraction of slurry or after the addition of enough dry organic material (bulking agent) to liquid manure in order to obtain a solid mixture ~~a relatively solid wet fraction~~.

Composting installations handling manure fall under Regulation 1069/2009/EC, concerning Animal by-Product, and have to be approved in accordance with Article 24 of the Regulation. The requirements applicable to composting plants regarding hygiene, operational parameters and standards of derived product, are set out in Article 10 and Annex V of Regulation 142/2011/EC. The competent authority shall only approve composting plants, if they comply with the above mentioned requirements. Furthermore it has to be ensured that the obtained final product corresponds to the specifications set by potential buyers.

4.12.4.1 Composting

Description

Composting is a controlled aerobic degradation process of organic matter. In the IRPP sector, animal and/or vegetable organic matters, alone or in a mixture are used in the process. Compost, which is the final product, ~~more stable~~ has a stabilised organic matter, low moisture content and most of the initial nutrients. ~~than the initial raw matters. The process involves releases of gases and heat.~~

In the initial phase of the process (decomposition), exothermic reactions produce a temperature increase of the composting matrix, above 50 ºC, with consequent hygienisation of the product by the elimination of pathogens in the manure. Aerobic conditions are needed in order to enable the microorganisms to convert the input material by using the available nutrients, oxygen and water. When oxygen is depleted, manure heaps cool down and aeration should be restored by mechanical turning of the heap, as well as forced aeration. The different composting systems are described below. [528, ITAVI 2001]

In a second stage, curing is produced. Complex organic matter is degraded and humic and fulvic acids are produced. Temperature slowly decreases to room temperature. The whole process lasts between 8 and 16 weeks.

Run-off liquids are collected by shafts and pumped to a tank, from where they can be recycled on the composting silo or windrow. [257, France 2010]

~~Oxygenation is necessary and it is obtained mostly by reversing the windrows (reversal), or by a forced ventilation of the heap. The oxygen addition may not be necessary when biological inoculums are used,~~ **Moved to 4.12.4.3.**

Composting with mechanical reversal of heaps

On farm, the manure is usually arranged in windrows (piles with a trapezoidal or triangular section) and monitored for temperature and moisture. Temperature needs close monitoring, especially during the first days. Run-off waters or slurry can also be added to increase moisture. The windrows are turned over periodically using conventional loading machinery (e.g. a bucket loader) or other available farmyard machinery (e.g. windrow turner). At least two reversals are necessary at an interval between them of 10 days to 3 weeks in order to maintain the air flow in the middle of the heap. After the last reversal it is then necessary to wait at least 3 more weeks. [528, ITAVI 2001]

Reversals have an immediate effect on the temperature. Several reversals are essential to ensure that all the compost has been subjected to a high temperature. The operation of reversal ensures homogenisation of materials, increases passive aeration and provides the proper conditions for the aerobic decomposition. The period that active composting normally lasts ranges from 8 to 12 weeks.

Static aerated piles represent an alternative method which uses air supplied by perforated piping below the pile, therefore the reversal and mixing is avoided.

Composting in-vessels (with forced aeration)

Composting is made in closed concrete silo-channels (composting vessels). The bottom of these modules is equipped with a system of perforated drains, allowing a forced aeration by blowing air. The system is controlled by temperature sensors, allowing recording and adjusting aeration. Once the silo is charged with solid manure, a cover is anchored on the walls of the silo. Forced aeration is maintained for 6 weeks and then the silo is uncovered and emptied to put the compost to mature in a heap. [257, France 2010].

Achieved environmental benefits

The technique produces an organic fertilizer (compost) with part of the original nitrogen content, most of the phosphorus in a concentrated form (due to water evaporation). Nitrate-N is immobilised by bacteria in carbon compounds in the more stable, slowly released organic form. The organic matter is humified and the product is odourless and pathogen-free. ~~The organic fraction has a~~ As a result, during field application of the product, reduced odour, ~~and~~ NH_3 emissions ~~during landspreading~~, and ~~preventing~~ ~~mineral N~~ emissions of nitrogen compounds from leaching into surface and groundwater are expected. [203, ADAS 2005] [257, France, 2010] **Moved from 2.7.3**

The benefits in terms of the fertiliser product obtained depend on the type of manure, the pretreatment technique, the additives and on the composting technique, and cannot be quantified in a general sense. ~~The physical properties, the stability and the organic form of the nitrogen make compost a good fertiliser and soil improver in general~~. **Moved to 2.7.3**

In France the product of composting (compost manure) is considered an organic fertiliser, deodorised and hygienised. It supplies organic matter to the ground and the organic form of nitrogen allows a gradual release to the plants. A priori, compost manure may be applied in the fall and winter without risking an increase in nitrate leaching. [528, ITAVI 2001]

Cross-media effects

~~Composting leads to losses of nitrogen, potassium and phosphorus.~~ In partly aerobic conditions, such as in unsealed manure stacks, 10 – 55 per cent of the nitrogen is lost ~~as emissions,~~ mostly ~~of the nitrogen evaporates~~ into the air as ammonia emissions. ~~, while a small fraction sinks into the soil in water~~. The ammonia losses reduce the fertiliser value of the manure resulting in the need for supplementing chemical fertiliser, with consequent indirect emissions for its production. Loss of carbon during composting also reduces the nutrient content of the resulting product.

Conditions during composting imply a risk for increasing emissions of greenhouse gases because aeration leads to temperature increase and, thereby, also to much higher activity of the anaerobic bacteria. Methane emissions are very likely to occur if inside the composting matrix/mass anaerobic zones are developed, as well as nitrous oxide emissions in case of improper aeration of the whole manure heap (i.e. anaerobic zones in the centre so there can be aerobic/anaerobic transition zones in the compost).

The evaporation of nitrogen can be also reduced ~~prevented~~ by means of a cover. Peat is suggested as the cover, as it is reported that acid sphagnum peat *(Sphagnum fuscum*) has a better N-binding capacity than, e.g. straw, sawdust or cutter chips. However, peat is a non-renewable resource and its extraction leads to significant emissions of greenhouse gases.~~ and this might be grounds for not using it peat for the coverage of manure heaps.~~ On the other hand, it is also reported that no significant effect of covers on aerial emissions during composting was found in a study carried out in France. [528, ITAVI 2001]

If the stack is put on soil, part of the nitrogen that sinks into the soil evaporates, and plants use part of it after the stack is removed. Depending on the amount of run-off, soil surface and soil type, part of the nitrogen may also leach into the surface waters or groundwater.

About half of the potassium in manure may be lost due to composting. Potassium is lost only in run-off water, and these emissions can be reduced by means of a water-tight cover over the compost. The cover prevents the leaching caused by rainwater, but it does not prevent the water produced in the compost from sinking into the ground. If composting is performed in a barn, losses to the soil or from leaching during the composting process are non-existent.

In the composting process, suboptimal conditions may eventually result. Odour emissions would be indicative of the occurrence, as odorous compounds are mostly volatile organic sulphur compounds produced under anaerobic conditions. may give rise to odours, but quantification is difficult In the case of silo composting with forced aeration, odours are controlled by incorporation of a neutralising product into the dry air vapour. The vapour is generated in the turbine and is sent via the ventilation shafts.

Energy consumption is required, in particular when forced aeration is use for composting. Water is needed in the process to maintain a suitable moisture content of the manure. [594, Agro Business Park 2010]

Operational data

Composting periods may last up to 6 months or more, but can be shortened by frequent stirring (turning) and aeration.

The required operational parameters for composting by using animal by-products (including manure) are specified in the European Regulation 142/2011, as well as the specifications of the final compost products. The key operating parameters are reported below.

- Moisture content between 40 – 70 %. [203, ADAS 2005] Below 30 %, bacteria activity is inhibited. In general, solid manures from deep litter housing systems (broilers, turkeys, guinea fowls) are not suitable for a smooth composting process, due to high dry matter content, ranging between 65 and 80 %. The ideal dry matter content should be about 40 to 50 %; for the purpose, moisture (water, slurry, etc.) in sufficient quantity has to be added at the beginning of composting, at the time of building the windrows. As an example, one tonne of solid manure with dry matter at 75 % requires 500 litres of water in order to reach a dry matter content of 50 %. A very moist mixture does not favour composting because it prevents aeration. [528, ITAVI 2001]
- Oxygen supply >0.5 mg/l.
- Porosity of the heap between 30 and 60 % (as Air Filled Porosity AFP)
- Carbon/Nitrogen ratio (C/N) in the range of 20 – 35.
- Temperature of the heap between 50 – 60 ºC. Product hygienisation is ensured by monitoring temperature as an indicator. In general, it is reported that if the material remains for over 6 weeks at 50 ºC, most pathogens will be destroyed (viruses, bacteria and parasites); while, at a temperature of between 40 and 50 ºC for 6 weeks, only parasitic worms are destroyed. At a temperature below 40 ºC for 6 weeks, no sanitation occurs. A general practice is to maintain temperature over 55 ºC for 25 to 30 days [528, ITAVI 2001]. Hygienisation is also achieved if temperature is maintained higher than 55 ºC for 2 weeks or higher than 65 ºC for one week. [561, Flotats et al. 2004]

The use of tarpaulins for covering the windrows limits odor emissions and flies, allows better integration of windrows in the landscape (positive psychological effect on the neighborhood), provides health protection towards birds and rodents, and essential protection in case of heavy rain. A semi-permeable geotextile cover offers the advantage of being permeable to gas and allow good drainage of water on the surface of the windrow. [528, ITAVI 2001]

Ammonia emissions can be reduced by composting manure with a high C/N ratio (20 – 35 %), and by carefully balancing the frequency of heap reversals, in order to meet sufficient aeration with minimum disturbance. Nitrogen losses as high as 70 % have been reported, through ammonia volatilisation. [594, Agro Business Park 2010]

The supply of air to composting and aerobic digestion systems requires a fine balance; too high air flows encourage NH_3 volatilisation; while, low flows encourage methane and nitrous oxide emissions. [203, ADAS 2005]

If an impermeable platform proves to be necessary, a surface to place one or more windrows of approximately 3.5 m broad and a maximum of 2 m high (corresponding to that is to say 6 m^3/m linear) is needed. Also a traffic lane of 4 metres for the machines and 10 to 15 m at the end of windrows are is generally needed for facilitating manoeuvres.

It is reported that the typical dimensions of windrows do not exceed 1.8 – 2 m in height and 3.5 to 4 m in width. [528, ITAVI 2001] In the case windrow height is excessive, (more than 3 m); the resulting compression will not let air to pass. In the case windrows are too small, they will be susceptible to cool down easily. [561, Flotats et al. 2004]

Composting should not be carried out on filtering soils, on waterlogged soils and slopped land. All measures should be taken to avoid stagnation of storm water under windrows and to accommodate the disposal of contaminated water. [528, ITAVI 2001]

The energy use depends on the composting technique applied. Without aeration and turning of the stacks, the energy use would be negligible. Consumption variesd between 5 kWh/tonne of raw manure for turning only, and to between 8 and 50 kWh/tonne of raw manure, for installations that apply ventilation through or over the stacks as well. From France, energy consumption for composting by forced ventilation is reported equivalent to requires 1 980 kWh of electricity per year and 480 l of fuel per year, to treat 600 t of manure. [259, France 2010]

Water needs are reported to be between 250 and 650 l/tonne of manure. [594, Agro Business Park 2010]

Pig Manure

After 3 reversals carried out at day 0, day 10 and day 20, and four months of composting, the straw manure loses 40 to 50 % of its starting weight and 30 % to 35 % of its initial nitrogen. Sawdust and pine bark litters are less suitable to compost. In fact, they lose only 15 – 30 % of the initial weight but 40 % and 48 % of the nitrogen are lost respectively. More suitable is the sawdust litter used for eight months successively on two batches of fatteners. Only less than 20 % of the initial N and 4 % in weight are lost.

Nitrogen losses reported from France, during composting of pig solid manure, in the two cases of manure with straw and with sawdust, are presented in Table 4.173.

Table 4.173: Nitrogen losses during composting of pig solid manure

Nitrogen emissions	Manure with straw	Manure with sawdust
	(%)	(%)
NH_3-N as % N- ex housing (initial N at storage)	27	9
N_2O-N as % N- ex housing (initial N at storage)	2	1
Source: [433, CORPEN , 2006]		

Poultry manure

Composting reduces the nitrogen content in layer droppings by 30 % and manure by 10 %. Average characteristics are shown in Table 4.174.

Table 4.174: Average compostion of poultry composts

Characteristics	Compost of droppings	Compost of manure
% Dry matter	60	56
% Organic matter	60	40
N (kg/t raw manure)	20	22.4
P_2O_5 (kg/t raw manure)	50	21.6
K_2O (kg/t raw manure)	30	27.8
CaO (kg/t raw manure)	100	29.7
Source: [259, France 2010]		

For poultry manure, if reversals are very frequent, losses can be as high as 50 – 60 % of the total N present. With three reversals, losses are generally around 30 – 40 % of the total N present. [28, ITAVI 2001]

Applicability

The process is relatively simple and can be applied on small scale individual farms, using standard farm equipment, but it needs proper control to avoid anaerobic processes that could lead to an odour nuisance. If process control and emission reduction are required, then the composting installation needs to be larger for (cost-) efficient operation.

In France, the process can also be implemented at the field on flat and little permeable soil, in different places every year, (minimum return every 3 years), and close to the land of spreading. The process should not last ~~not~~ more than two months.

Specially designed composting machines or windrow turners do a more efficient job, but the high costs limit their use to large individual farms only. As a result, composting machinery is usually provided by co-operatives or machinery rings. [203, ADAS 2005]

The technique requires enough space available. The area needed for composting manure coming from a 1000 m^2 building is reported to be 800 m^2 for turkeys and between 750 and 1000 m^2 for broilers. [528, ITAVI 2001]

Economics

~~Costs depend on the scale of application. and therefore so vary largely. A cost indication has been given of EUR 12.4 – 37.2 per tonne of manure [3, Vito, 1998].~~

Composting with mechanical reversal of heaps (windrow composting) ~~Reversal option~~

The operating cost ~~price~~, including the clearing out of the buildings, the setting in of the windrows, two reversals and the spreading of the compost, is reported from France as follows:

- for a pigs farm with 550 fattening places, the cost is EUR 0.01 – 0.02 per kg of pig produced;
- in a poultry meat installation of 1 000 m^2, the cost is between EUR 7.9 and EUR 9.9 per tonne of produced manure per year. [259, France 2010]

The purchase of necessary reversing tools in France is often shared, e.g. in CUFE (Cooperative of Use of Farm Equipment). The investment cost for a machine of 4 m width, working with windrows, is reported to be about EUR 42 000. [259, France 2010]

Other examples of investment costs for the necessary composting equipment are reported in Table 4.175.

Table 4.175: Investment costs for equipment used in composting plants

Type of machinery	Investment costs (EUR)	Capacity (m^3/h)
Windrow turner	30 000	100
Windrow turner	100 000	1 000-15 000
Windrow turner	180 000	2 500
Tractor	50 000	
Mixers	20 000-50 000	10 – 100
Drum sieve	70 000	100
Composting plant using mechanical reversal of heaps	35 000 – 100 000	2 000 t/y manure + 1 360 t/y sawdust Cost depends on the buildings or covers constructed
Source: [594, Agro Business Park 2010]		

The operational costs are reported equal to EUR 20/tonne produced, and the income from compost sales ranges from EUR 15 to EUR 30 per tonne. [594, Agro Business Park 2010]

Composting in vessels with forced aeration
From France, it is reported that this system is ~~seems~~ economically viable only for large manure volumes. In a reported example, the investment costs for the equipment to treat 600 tonnes of manure per year, is amortised over 10 years, resulting in an annualised investment ~~by a~~ cost ~~in the range~~ of EUR 0.01 per kg of produced pig (manure resulting from 2700 fattening pigs per year), or EUR 6.2 per tonne of poultry manure (4 buildings of 1000 m^2 each with 150 t of manure per building per year). The operating cost of the system (including clearing out of the buildings, handling of the silos and spreading of the compost) is obviously variable, depending on the production and the size of the farm. From France, the operating cost is reported equal to EUR 0.02 per kg of produced pig and EUR 11.4 per tonne of poultry manure. [259, France 2010]

Driving force for implementation
Composted solid manure has low odour, is more stable, contains fewer pathogens and is relatively dry. This allows easier transportation without the risk of transferring diseases. [506, TWG ILF BREF 2001]

Example plants
The technique is applied at farm level as well as in centralised plants, in ~~several~~ various Member States; in particular, 400 farm-scale plants are reported in UK and 100 in France. ~~e.g. Portugal, Greece, Spain, Latvia and Sweden.~~ [595, Agro Business Park 2010]

In France, around 200 farms ~~stations~~, are affiliated with one commercial organisation, using the alternative of the technique with the forced aeration.

Reference literature
[409, VITO 1997] [26, Finland 2001] [410, Greece 2001] [259, France 2010] [257, France 2010] [528, ITAVI 2001] [203, ADAS 2005] [594, Agro Business Park 2010]

4.12.4.2 Co-Composting of poultry manure with green residues ~~using pine bark~~

Description
See also Section 4.12.4.1.
To control the composting process ~~system~~ and to achieve a better quality of the final product, substances of plant origin ~~such as straw and grass~~ can be added to raise the C content. The application of additives aims to increase the porosity and binding of the N, thereby avoiding emissions to ~~into the~~ air.

Poultry manure can be mixed with green residues; preferably woody crushed residues, ~~crushed,~~ by avoiding mowing, in proportions ~~of~~ from 1 to 1 (and up to 3 to 1) in weight (manure/green residues).

Achieved environmental benefits
Depending on the origin of the manure and ~~of~~ the co-substrate (vegetable matter) that is co-composted, ~~it is possible to dilute the~~ a dilution effect of the nitrogenised load by 30 % to 60 % can be obtained (see Table 4.95).

Cross-media effects
NH_3 emission can be controlled by proper management of the process, on the basis of the C/N ratio; otherwise, they can be ~~is~~ considerable.

Greenhouse gas emissions are very likely to occur during composting (see also Section 4.12.4.1).

Operational data

A typical poultry manure composition is 18 % litter, 50 % droppings, 32 % water, and generally this does not correspond to the ideal composition for composting. Poultry manure contains cellulose and nitrogen, but moisture and the C/N ratio are rather low. A more favorable C/N ratio for composting is 25 – 30 which is achieved with adding green wastes. Regarding moisture, it is necessary to increase the level by adding water from an external supply.
Indicative values of the C/N ratio for different materials are presented in Table 4.176.

Table 4.176: Indicative values of the C/N ratio for different materials

Material	C/N
Slurry solid fraction	9
Cattle manure	18
Laying hen manure	13
Garden residues	23
Straw	128
Sawdust	511
Pine bark	723
Source: [561, Flotats et al. 2004]	

Moved from Description

In one ~~this~~ example, poultry manure was ~~is~~ mixed with pine bark, at a ratio of excreta/bark of 3/1 on a total weight basis. In a comparison with other kinds of auxiliary substances, the pine bark showed the best results for pH level, N evaporation and C content (organic material).

The composting ~~system takes~~ took place at a temperature of 55 – 60 ºC. A minimum porosity of the manure/bark mixture ~~is~~ was maintained to allow ~~for~~ an adequate oxygen supply. The test on compost produced with ~~the~~ addition of pine bark showed an unchanged 70 % organic matter (on DM basis) after 90 days. The nitrogen losses reached about 35 % (on a DM basis) at 90 days and this increased by 1 – 2 % over the next 90 days. The pH at 90 days was below 8, and reached 7.5 at 180 days

In another reported example, straw pig manures are co-composted with woody pig manures (containing woodchips or sawdust). The weight reduction was 24 – 30 % and the nitrogen reduction 35 – 50 %. The presence of straw allowed a temperature increase of 10 – 15 °C, in comparison with composting the sawdust manure alone, over the last three months of composting. [259 , France, 2010]

Maturation time for compost in a heap, after a co-composting treatment, is reported to be longer. In particular, a duration of 4 – 5 months it is reported for maturation when manure was composted with wood waste, in comparison with 6 weeks of active composting when only solid manure was composted. [528, ITAVI 2001]

The composition of turkey manure composted with wood waste in proportion of 1/1 in weight is shown in Table 4.177.

Table 4.177: ~~Average~~ Composition variation of turkey manure ~~poultry manures~~ co-composted with green residues (ratio 1/1 in weight)

Parameter	Unit	Before composting			After composting	
		Untreated manure		Humified mix of green residues and manure	Final compost	
		Raw product	Dry matter	Raw product	Raw product	Dry matter
Dry matter	%	65		50	74	
Minerals	%	17	31	15	33	44
Organic matter	%	53	69	34	41	56
C/N		8.5		9.8	9.4	
N	%	3.0	3.9	1.9	2.2	3.0
NH_4	%	1.0	1.5	0.7	0.5	0.7
Organic N	%	1.9	2.4	1.2	1.7	2.2
P_2O_5	%	2.7	3.7	1.8	2.2	2.9
K_2O	%	2.9	3.7	1.9	1.9	2.6
Cu	mg/kg	62	86	43	89	121
Zn	mg/kg	215	238	144	253	344
Source: [528, ITAVI 2001]						

Data on energy consumption, for the equipment used in composting and co-composting plants, are presented in Table 4.178.

Table 4.178: Energy consumption of equipment used in composting and co-composting plants

Equipment/operation	Energy consumption (kWh/t)
Drum sieve	3
Magnet separator	0.5
Shredding and crushing	2.6
Container composting (11 days)	10
Waste gas purification (11 days of intensive composting)	8.1
Waste gas purification (8 weeks)	19.3
Source: [594, Agro Business Park 2010]	

Applicability

The composting technique is applicable to new and existing farms. ~~Sufficient availability of the required additive, in this case pine bark, is necessary.~~ The bark needs to be dried and ground before it can be added to the manure. Green residues can be pre-composted before their use.

When co-composting is applied with wood waste, the necessary available area that composting normally needs should be multiplied by 1.5, in order to take into account the increased volume. [528, ITAVI 2001]

Economics

Updated cost data are not available.

~~Costs for the amount of manure produced by 200 000 layers have been calculated (in 1997) and are summarised in Table 4.96. the Table below:~~

Table 4.96 Cost data for the composting of the poultry manure of 200 000 layers by means of mechanical turning

Cost factors	EUR/tonne of manure processed	EUR/tonne of compost obtained
Additive	2.4	5.4
Manual work	1.2	2.8
Maintenance and repair	0.8	1.7
Energy	3.7	8.3
Total	8.1	18.2

Driving force for implementation
See also Section.4.12.4.1.

Properly composted solid manure significantly reduces the volume of material to be transported and spread to land and the amount of odour released. During composting, high temperature is achieved and the product is stabilised and sanitised.

Composting and co-composting allow reducing the quantity of nitrogen to be spread, at relatively low investment costs, where constraints to manure landspreading may exist and where here There was a local markets for alternatives to conventional the fertilisers normally used can be found.

Farmers can participate in recovering compostable residues on behalf of the local community, offering an opportunity to solve problems of green waste, locally.

Example plants
Application beyond experimental level has not been reported.
The technique is widely applied in Catalunya, Spain, with 127 farm-scale reported plants and 21 medium-scale plants.

In general, across Europe, the technique is widespread, mainly at cetralised plants where other organic wastes may be included for co-composting. [203, ADAS 2005]

Reference literature
[75, Menoyo et al., 1998] [528, ITAVI 2001] [259, France 2010]

4.12.4.3 Composting with a biological inoculum

Description
Microorganisms of the optional aerobe-anaerobe type (which do not necessarily need oxygen to develop) are used to degrade the organic matter. The manures are inoculated by sprinkling, preferably before the exit of the building. They are then placed in windrows in the same way as for the conventional composting Windrow reversal is not necessary. At the end of 6 weeks to 2 months, the compost is moved from the windrow to a maturation heap.

The bacterial inoculum is a complex an association of wild strain of bacteria of the types bacillus and lactobacillus (1 dose = 10 ml of lactic bacteria and 10 ml of bacillus), selected according to their metabolic criteria and of their aptitude to develop on environment which has not significantly degraded. They all belong to the classification AFNOR IA, posing no danger to humans, animals or the environment.

Oxygen addition may not be necessary when biological inoculums are used. **Moved from Section 4.12.4.1.**

Achieved environmental benefits
Fermentations which take place make it possible to cut down 10 to 55 % of the nitrogenised load, essentially the ammoniacal nitrogen. This reduction varies according to the origin of the manure, the type of litter used (straw, sawdust, shavings of conifer, etc.) and mode of housing for the pigs (accumulated litter, scraped, etc.).

Emission of odour are considerably decreased , since bacteria use preferentially the volatile fatty acids (odorous substances) as energy nutrients. Nitrogen losses by volatilisation in the form of NH_3 are also fewer than with other composting systems. [259, France 2010]

Spreading volumes of manure are reduced, with consequent energy saving associated with transport for spreading.

Less energy is required than for the other composting processes that require reversal or forced ventilation.

Cross-media effects The existing text has been moved above
In case there is no aeration, the risk of methane formation is high.

Operational data
The bacterial inoculum presents no danger; it is harmless for humans, animals and the environment. It is pulverised with one dose in 10 litres of water for 10 tonnes of matter. The composting can be carried out within a period of 6 to 8 weeks without needing to turn over windrows. If a platform is necessary, it is of the same dimension than for a normal windrow composting.

In a reported example of this technique, a mixture made of 57 % poultry manure and 43 % hens slurry was composted after inoculation with a bacterial complex (aqueous solution of 5 to 8 litres for 10 tonnes of mixture to compost). After 127 days of composting, the dry matter content reached about 69 % (an increase of more than 50 %), ammoniacal nitrogen decreased from 54 % to 24 %, whereas the organic matter was around 79 % of the dry matter, therefore very high. Temperatures inside the windrow ranged between 45 ºC and 60 ºC, and were maintained until the end of the test, without reversal. Complete sanitisation was achieved on day 52 of the trial, eliminating the original contaminants, including salmonella and listeria. Odour emissions were substantially reduced. [371, Penaud et al. 2007]

Lower investment and labour costs are required, in comparison with conventional composting techniques.

Applicability
There are no technical restrictions for on-farm application.

Economics
Indicative operating costs are EUR 0.02 per kg of produced fattening pig and EUR 10.2 – 11.9 per tonne of poultry manure per year.

Driving force for implementation
This technique makes composting simpler than the process with periodically reversed windrows or with forced aeration. Less material, machinery, space and energy than for other processes (with reversal of the windrows or forced ventilation) are needed and no reversal is required.

As for the conventional composting, the degradation leads to formation of a product rich in organic matter, more stable and properly hygienised.

Example plants
This technique is developed in France with the use of poultry manure. The technique is also used in hatcheries, by mixing hatcheries waste with poultry manure.

Reference literature
[371, Penaud et al. 2007] [257, France 2010] [259, France 2010]

4.12.5 Anaerobic treatment of manure in a biogas installation

The requirements for plants producing biogas using animal by-products (including manure) are specified in the European Regulation 142/2011 (e.g. hygiene requirements, equipment, location and other parameters).

Description
Anaerobic microorganisms decompose the organic matter contained in manure ~~slurry~~, in a closed reactor in the absence of oxygen, leading to biogas production. The controlled degradation of the organic matter, without oxygen, is influenced by the pH value and temperature. The main components of biogas are methane (60 – 70 %), and carbon dioxide (30–40 %). Other minor components are: H_2S, H_2O, NH_3 and N_2O. The higher the methane content is, the richer in energy is the gas. Biogas production strongly depends on the type of biomass used in the process. During anaerobic decomposition, four biochemical processes are distinguished: hydrolysis, acidogenesis (fermentation), acetogenesis and methanogenesis.

The produced biogas is ~~produced and~~ collected, to serve a heat generating system. A stabilised residue (i.e. digestate) is also produced that can be applied to land as a soil conditioner and source of nutrients (see also Section 2.7.4).

An example of biogas installation from anaerobic treatment of manure is presented in Figure 4.82.

Source: [594, Agro Business Park 2010]

Figure 4.82: Example of biogas installation, from anaerobic treatment of manure, located in Denmark

Achieved environmental benefits
Environmental benefits (direct and indirect) of anaerobic digestion, with energy recovery from the produced biogas, are:

- reduction of CH_4 emissions, that would have been otherwise emitted from outdoor storage of untreated slurry
- substitution of fossil fuels consumption by electricity and/or heat produced by power-heat biogas cogeneration; avoiding associated greenhouse gas emissions
- reduction of NH_3 emissions, from landspreading of digestate (from biogas production) compared to untreated slurry, since the digestate is more homogenous and spreadable, it can seep easier and evenly into the crop root area, enabling better nutrient uptake from crops
- improved bio-availability of nitrogen, leading to less use of chemical fertiliser. Anaerobic digestion does not change the overall N/P ratio but converts the main part of the organic

bounded nitrogen into ammonium, resulting in an increased concentration of ammonium in digested slurry, up to 20 %, compared to undigested slurry.

- reduction of pathogens in digested manure
- reduction of odour emissions. The odour of digestate is not as strong and pungent as from raw slurry and it also disappears faster from a fertilised field
- substantial reduction of COD and BOD due to organic matter breakdown.

~~All emissions are reduced (NH_3, CH_4, N_2O and odour by means of the production of a valuable product, whose The benefits can be expressed in terms of a reduced organic dry matter (to 30 – 40 % of the original amount).~~

~~Additionally, the application of anaerobic fermentation in a biogas installation has a number of other effects:~~

- ~~a reduction of pathogen in digested manure~~
- ~~a reduction of odour emission~~
- ~~transformation of N into NH_3~~
- ~~improved fertilising characteristics of the digested manure~~
- ~~improved characteristics for separation and further treatment or application~~
- ~~a reduction of greenhouse gas emissions.~~

~~The primary effect is therefore a reduction of fossil fuel use and of CH_4 emissions that the co-generation of electricity and heat makes possible~~.

A study reports that environmental benefits associated with the use of digestate from biogas production are very dependent upon the separation efficiency, in particular for carbon, as the separation efficiency defines the extent to which the degradable carbon contained in the slurry is transferred to the biogas plant. Efficient separation can be obtained by using a polymer, but also by using a suitable separation technology (see Section 4.12.2).

Significant reductions in greenhouse gases are possible, provided that, among others, combined techniques are used such as covered and short time storage of the fibre fraction before entering the biogas plant, a two-step biogas production where the post-digestion tank is covered with air-tight cover, a covered storage of the degassed fibre fraction. The benefits are also highly dependent upon the source of energy substituted by the biogas.

Cross-media effects

Emissions of unburned biogas through the biogas motor/engine are around 2 % and can reach 4 % from older technology engines. ~~Fugitive biogas emissions have been measured on a 335 m^3 capacity digester and were equivalent to about approximately 3.4 % of the biogas produced (7.3 m^3 per day [206, Silsoe 2000]~~) Leakages of biogas (e.g. from the anchoring points of the meters) can lead to important emissions of CH_4 and other biogas components (NH_3, H_2S, etc.). Such emissions are known to vary significantly with equipment quality and standard of maintenance. Best practice should aim to minimise fugitive methane emissions, since the operational efficiency of the digestion process will also be enhanced, thus maximising the production of energy. [206, Silsoe 2000] Including emissions during storage, total methane emissions of 6 kg CH_4 per tonne of pig slurry or 4 – 6 tonnes CH_4 per tonne of poultry manure are reported from Belgium-Flanders.

In general, anaerobically digested slurry has a larger share of the total-N in the form of NH_4-N. The higher content of NH_4-N, in combination with the increased pH in the digested slurry, may lead to higher ammonia losses from storage or/and landspreading, compared with raw slurries. Due to the reduced content of organic matter, a natural crust is seldom formed on top of the liquid when it is stored in tanks, leading to higher potential for emissions to air. [533, Baltic Sea 2020 2011] It is reported that ammonia emissions from storage of the degassed slurry can be high and stores should be covered and/or slurry immediately cooled, although losses during landspreading are reported to be lower than for untreated slurry [500, TWG IRPP, 2010]. These effects may counterbalance the positive effect of a faster infiltration to the soil, so overall losses may be similar with untreated slurry after surface application

A high technical knowledge is needed on-farm, to manage the whole process.

EXISTING TABLE 4.97 AND RELATED INTRODUCTION HAVE BEEN REMOVED. SHOULD TWG MEMBERS WISH TO KEEP IT IN THE IRPP BREF, IT WILL BE ADDED IN CHAPTER 9, AS AN ANNEX

~~Fugitive biogas emissions have been measured on a 335 m^3 capacity digester and were equivalent to about approximately 3.4 % of the biogas produced (7.3 m^3 per day [206, Silsoe 2000])~~ **Reported above**

Operational data

In general, digesters operate with a maximum dry matter content of 12 %, and at constant temperature (with up to 2 ºC variation) of 30 – 45 ºC (mesophilic) or 52 – 55 ºC (thermophilic, with accepted temperature variation of only 0.5 ºC). Plants operating at mesophilic temperatures are therefore easier to run, so most farm-scale plants as well as many centralised plants are of this type. [594, Agro Business Park 2010]

The mesophilic anaerobic digestion is used to process waste material with around 40 % of volatile suspended solids. The process takes place in large digestion tanks, in one or two stages, and the hydraulic retention time is 15 – 40 days. Propellers are normally installed in the digestion tanks to ensure the digestate remains homogenous and gives a maximal release of biogas. [594, Agro Business Park 2010]

In the case of thermophilic digestion, the digester is heated to 55 ºC and digestion takes in 12 – 14 days. However, the technology is more expensive, since more energy is needed and more sophisticated control instrumentation. The advantages of thermophilic plants are higher levels of biogas production, faster throughput, improved hygienisation of the digestate, and lower viscosity during the process, facilitating mixing. [594, Agro Business Park 2010].

The condition necessary for the successful formation of methane is a minimum water content of 50 % in the initial substrate. [373, UBA 2009]

Around 14 – 25 m^3 of biogas production per m^3 of slurry may be obtained, containing around 65 % of methane.~~ and methane concentration (65 %)~~. Calculations for biogas plants in Denmark show an average production of 22 m^3 biogas per tonne of slurry containing 6 % dry matter (on average) [594, Agro Business Park 2010]. With pig slurry, it is common to calculate a specific methane production of about 200 litres per kg of dry matter (or about 6.5 kWh).

In order to maintain digestion, part of the waste heat of electricity production is needed to retain the temperature of the biogas plant. About a third of the heat produced from such combined heat and power units (CHP) is typically used for the anaerobic digestion process itself [355, Warwick 2007]. This amount depends on scale and configuration

To get the required temperature, manure can be warmed up by using part of the produced biogas or by heat exchange with the water cooling the gas engines. In farm-scale applications, heating of the manure is not always applied. The required ~~amount of heat for the mixers and pumps to run the equipment in subsistence is estimated to be about 10 – 20 % of the gross energy production of the installation.~~ parasitic energy load to maintain the digester is estimated to be around 5 – 20 % of the gross energy production of the installation, depending upon scale and configuration. The use of 20 – 25 m^3 of biogas in co-generation units can produce 35 to 40 kWh of electricity and 55 to 75 kWh of heat energy. [203 , ADAS, 2005]

From Germany, net biogas power production is reported equivalent to 2.5 kWh per m^3 of biogas, and, 2.0 kWh per m^3 biogas as net heat production (after own use of heat and power in the process). [594, Agro Business Park 2010]

The resource efficiency of a combined heat and power (CHP) system is about 35 % for the electrical production, and is about 85 % if all the produced heat is recovered. [259, France 2010]

The gas is stored in a gas buffer before being used in a heater or a gas engine. Before the gas can be used, sulphur must be removed by a biological, adsorptive (active coal or ferro-chloride) or chemical technique (quenching) in larger installations, in order to protect the gas engine.

A double membrane cover system is used to collect an added quantity of biogas from the heated slurry digestate storage tank during the cooling phase out of a continuous digester. [517, Petersen et al. 2011]

Due to the general manure management induced by the anaerobic digester, it is estimated that global farm emissions in Finland, are reduced by 40 % for ammonia, while odour, and methane ~~and N_2O~~ are reduced by 80 % [229, Finland 2010]. N_2O emissions associated with anaerobic digestion are reported to be negligible, compared to the overall annual N_2O emissions from the farm.

Since only a small proportion of the total manure mass is decomposed in a sealed anaerobic digester, the total content of nutrients in the digested manure does not differ much from raw slurries. However, data show a reduction in slurry dry matter content of around 25 % between raw and digested slurries. The organic forms of nitrogen and phosphorus are converted into water soluble and readily available NH_4-N and P. Digested manures show a 10 – 15 % higher proportion of NH_4-N. The fertiliser value of digested slurries is the same as for raw slurries.

Calculations made for the quantification of avoided greenhouse gases emission, as a result of fossil fuels substitution with biogas, show that the CO_2 neutral energy produced by the biogas process saves 2 kg CO_2-equivalent emissions per m^3 biogas. In addition, model calculations applied in Denmark show a reduction of naturally developed greenhouse gases (methane and nitrous oxide) of approximately 1.2 kg CO_2-equivalent per m^3 biogas. In total, a potential of 3.2 kg CO_2-equivalent reduction in greenhouse gases emission per m^3 biogas are estimated.[499, AgroTech 2008]

Applicability

There are no technical restrictions to the on-farm application. The cost efficiency is likely to increase with an increasing volume of fermented slurry. The minimum farm size according to the literature (see reference literature) is 50 LU ~~[194, Austria, 2001]~~. [506, TWG ILF BREF 2001]

~~Different kinds of manure can be treated, but poultry manure (grit) requires frequent cleaning and removal of the sediment in the reactor, despite the intensive mixing of the biomass.~~

The biogas production capacity of pig slurry is relative low; hence, it often requires the addition of a proper substrate to increase efficiency. Possible sources of such substances are energy plants, green wastes, sewage sludge, and food residues. [373, UBA 2009] For this reason, in France, ~~and~~ Denmark and Spain, biogas production is not considered technically and economically viable with only slurry as a substrate. ~~Slurry provides a good quantity of microbes to run the process but a relatively reduced amount of digestible matter that is what methane is produced from. Hence it is necessary to co-supply the process with other raw materials having a stronger biogas production capacity~~. [259, France 2010] In Spain, a Slurry Biodigestion Plan has been developed, with the objective of reducing greenhouse gases in the livestock sector.

Economics

The economics of anaerobic digestion systems are highly site-specific and depend on factors such as land and labour costs, effluent discharge regulations and energy prices produced by other sources. Where government incentives include a premium price for the electricity produced and in the case of environmental pressures that force farmers and related industries to consider alternative means to manage manure and organic wastes, the technique with associated biogas production can be economically viable.

A reported example from Finland of a farm with 263 places for farrowing sows and 784 places for weaners, indicates details an investment of EUR 3 536 per animal place and a running cost of EUR 40 per animal place per year. The annualised costs are given for at EUR 656 per animal place. [229, Finland 2010] Electricity generated on-farm is reported equivalent to 453 000 kWh and the produced heat 700 000 kWh (equivalent to 77 000 litres of fuel oil), allowing the farm to be self-sufficient in heat and electricity. [229, Finland 2010]

An example of biogas plant for a small-scale farm is reported from Denmark, where pig slurry alone is used as a substrate for biogas production. The farm has a capacity equivalent to 2 950 fattening pig places (> 30 kg) and 500 sow places. Operational data and costs associated with the production of biogas are presented in Table 4.179.

Table 4.179: Operational and costs data for a biogas plant applied on a small-scale farm, operating with pig slurry only

Parameter	Values
Produced slurry (tonnes/year)	9 650
Products sold	100 % electricity 50 % excess heat
Prices for products (EUR/kWh)	Electricity: 0.103 Heat: 0.040
Methane produced (Nm^3/year)	118 985
Total investment costs (EUR) ([1])	624 000
Annual operational costs (EUR)	43 405
Annual capital costs (EUR) ([2])	60 118
Total annual costs (EUR)	103 523
Annual income (EUR)	55 040
Annual (negative) earnings after tax (EUR)	-48 483

([1]) No financial incentives were received.
([2]) Interest rate of 7.0 %, inflation rate of 1.5 %, taxation of 30 % and amortisation over 15 years.
Source: [533, Baltic Sea 2020 2011]

Driving force for implementation

The high prices for energy and the availability of financial support schemes for sustainable energy production were responsible for the application of this technique. High investment costs are a major deterrent for the implementation of this technique; for this reason, in some Member States the use of biogas in connection with the covering of the pig slurry stores storage store is stimulated by financial incentives (e.g. Italy, France, Germany and Spain).
In France, economic bonuses are provided for the installation of equipment according to the size of the system, and other bonuses for up to EUR 30/MWh are available where energy is valorised with efficiencies over 40 %. [259, France 2010]

Farms can reach electrical self-sufficiency in electricity and have significant heat production for free. [229, Finland 2010] The heat produced by power-heat cogeneration can also be transferred to external users for residential district heating and commercial heating requirements.

Environmental policy targets for renewable energy, together with uncertainty about oil prices may encourage the use of this technique. [203 ADAS]
Co-processing with animal wastes from the food and meat industry may increase due to increased costs of disposal brought about under the Animal By-products (ABP) Regulations. [203, ADAS 2005]

Example plants

Centralised manure co-digestion installations where manure and/or energy crops and organic biological waste are used as input are common. In 2011, there were around 6 000 anaerobic digesters in Germany, 180 in the Netherlands and 23 in agricultural areas of Belgium-Flanders. Around 30 farm-scale digesters are located in the UK, 50 – 60 in Denmark and 3 in Belgium-Flanders. A biogas plant in Austria has been reported in operation since 1995.

~~Germany has the largest number of biogas installations on farms (more than 4500 in 2010ca. 650 in 1998), but most other countries have <100 and some have only a few (3 in Belgium-Flanders).~~ In 2003, in Italy ~~has~~ ~~installed~~ about 50 low-cost digesters were installed, using gas which develops under the covers on slurry storage ~~store~~ operating at low temperatures. ~~Some centralised anaerobic digesters, which take livestock manures and other wastes, have been constructed in some countries, e.g. Denmark and Germany and Belgium-Flanders.~~

Reference literature

[39, Germany 2001] [206, Silsoe 2000] [373, UBA 2009] [203, ADAS 2005] [355, Warwick 2007] [594, Agro Business Park 2010]

4.12.6 Anaerobic lagoon system

Description

This type of liquid manure storage system is designed and operated to combine manure stabilization and storage. Lagoons (shallow ponds) are used to store farm slurry, waste water as well as to perform an anaerobic treatment of slurry. ~~This technique has been described in~~ (see also Section 2.7.5).

Slurry is put into a settling basin (lagoon), from where it overflows or is pumped in the anaerobic lagoon system (often 3 to 5 earth-banked structures). The solid part (sludge sedimentation) is used in landspreading; while, the liquid, after the anaerobic treatment, is sent to irrigate and fertilise fields. Anaerobic treatment can be followed by a final aerobic stage before the fluid fraction is applied or discharged (if the characteristics and legal conditions allow for it [364, Portugal 2010]).

The technique may involve mechanical separation of slurry before filling the lagoon, with subsequent separate treatment of the solid and liquid fractions; with the liquid being sent to the lagoon system. Mechanical separation of slurry can prevent the capacity decrease of lagoons caused by sludge sedimentation and can reduce the organic matter in the liquid part.

Anaerobic lagoons are designed for varying lengths of storage (up to one year or longer), depending on the climatic region, the content of volatile solids of the slurry, and other operational factors.

Achieved environmental benefits

The environmental benefit of anaerobic treatment depends on the quality of the liquid and its application after treatment. The aim is to improve the quality of both solid and liquid manure fractions so that they can be used as fertiliser.

Information on anaerobic lagoons also refers to the discharge option or to application in situations where otherwise this would have had an unwanted environmental impact. It is questioned whether in these cases anaerobic lagoons solve or add to the problem of manure application.

Cross-media effects

In general, from an anaerobic system CH_4 emissions are expected to be significant. Odour may develop from the lagoons, as well as NH_3 and N_2O [506, TWG ILF BREF 2001]. After separating out the liquid fraction, a solid fraction remains, this then has to be treated (e.g. composting).

Energy is required for separation of the solid fraction and for pumping the liquid between basins. In some Member States, natural height differences in the countryside are used to make the liquid flow by gravity from one lagoon to the other. At the end of the separation a liquid fraction remains that has to be disposed of.

Operational data
The lagoon system is considered to be relatively easy to operate. Generally, an installation separates the solid fraction mechanically. The liquid manure that remains can stay in the different lagoons for up to a year. The final aerobic step is optional, consequently some installations have an aeration installation, and some do not ~~don't~~.
~~Analyses of the liquid during the different stages of treatment may be applied.~~

It is reported that, under cold weather conditions (below 22 ºC), CH_4 emissions are linearly related to the slurry temperature. At higher temperatures, the variation of CH_4 emissions depends on the slurry composition, wind speed and air temperature. [496, Sharpe et al. 1999]

Results ~~that are currently obtainable in~~ reported by Portugal ~~by the~~ for slurry treatment in anaerobic lagoons as the final step of a ~~chain of slurry~~ combination of treatments are ~~reported~~ presented in Table 4.180. The associated emission levels ~~to~~ for the most important parameters indicate that effluents from anaerobic lagoons ~~can~~ could be used for landspreading, but ~~are~~ would hardly be compatible ~~for~~ with discharge in watercourses, since the liquid would not comply with emission limit values set for waste water discharges to surface waters, in particular for BOD_5 (40 mg/l O_2) and total suspended solids (60 mg/l). ~~collectors~~. [364, Portugal 2010]

Table 4.180: Characteristics of effluents from slurry treated in anaerobic lagoons

Treatment	BOD_5 mg/l O_2	Total suspended solids mg/l	Total N mg/l	Total P mg/l
Mechanical separation, plus 4 – 5 anaerobic lagoons	191 – 500	147 – 200	526 – 1 100	21 – 27
NB: Data refer to annual averages of analyses carried out in three different farms.				
Source: [364, Portugal 2010]				

Applicability
Anaerobic lagoons are applied to farms with a large number of animals and with sufficient land to allow for a series of lagoons to be applied to cover the different treatment steps. Lagoons are particularly suitable for large capacities. Note however, that the temperature requirements for the anaerobic process make the technique less suitable for areas that have cold winters.

Economics
Costs vary, depending on the geophysical characteristics of the soil and, ~~on the~~ size of the installation and the purpose intended for the treated slurry.

Driving force for implementation
Legislation on waste waters to be applied to land or discharged to surface waters has contributed to the application of anaerobic lagoons in some Member States, such as in Portugal and Greece. Recently, in Portugal, new legislation was enforced to limit the discharge in watercourses, setting stricter values, hardly achievable by the use of anaerobic lagoons.

Example plants
In Portugal, the treatment of pig slurry in anaerobic lagoons, preceded by a mechanical separation of the solids is usually applied. The technique is also applied on farms in Portugal, Greece and Italy.

Reference literature
[410, Greece 2001] [364, Portugal 2010]

4.12.7 Evaporation and drying of pig manure

Description
The objective of this treatment is to obtain a dried, easily to handle, product from solid manure or slurry, with most of the nutrients (N, P) and organic matter of the original material. Depending on the required moisture content of the final product, a preliminary evaporation step is required, where water is removed from slurry. The heat source employed for the evaporation may consist of recovered waste heat from a combined heat and power engine or from other processes. There are two variations of the evaporation technique:

- Vacuum evaporation – At temperatures lower than 100 ºC (typically 50 – 60 ºC) and pressure conditions below the vapour pressure of the liquid, water and other volatile components evaporate and are subsequently recovered by condensation. Evaporation units are usually formed by two or multiple steps. If pH inside the evaporator is maintained under pH 5.5, it is ensured that that ammonium will be recovered in the concentrate.
- Atmospheric evaporation – Evaporation takes place at atmospheric pressure and moderate temperature from the liquid fraction of aerobically treated slurries. The manure is ground and mixed first. Using a heat exchanger, the manure is heated to 100 °C by means of warm condensate and kept at this temperature for about 4 hours, while degassing occurs. Any foam that has been formed is degraded. The gases are processed into by-products.

Following the evaporation stage, In the next step the manure is brought into a drying machine and compressed (1.4 bar). Any water vapour that is formed is compressed, which raises its temperature to 110 °C. This hot vapour is then used in a heat exchanger, thereby drying the manure using the sensitive heat of the vapour. There is a thin tube wall between the manure and the vapour on which the vapour condenses before being discharged.

Achieved environmental benefits
The technique allows obtaining a dried product with a higher nutrient concentration, which facilitates its management,. the drying of pig manure with only a relatively low energy level consumption and with reduced emissions to air and water.

Organic matter is sanitised (depending on the time and temperature of the process); the volume of slurry/manure is reduced (reducing transport costs).

Cross-media effects
Energy consumption is required for thermal drying of manure. For an industrial scale facility, a reported estimation of the thermal requirements is 15 – 18 kW/m^3 for an acidified-digested slurry entering the evaporator with a dry matter content of 25 – 30 %. [594, Agro Business Park 2010]

The application of mechanical vapour compression (drying machine) has an energy consumption of about 30 kWh per tonne of water evaporated.

In the case of atmospheric evaporation, emissions of ammonia, VOC and non condensable odorous compounds occur; while, with vacuum evaporation there are no emissions to air, since the evaporated fraction is recovered as condensate. If atmospheric evaporation is preceded by aerobic treatment (aerobic digestion and total or partial nitrification-denitrification, with C and N removal), emissions will be limited. [256, Lemmens et al. 2006][594, Agro Business Park 2010]

The potential gaseous emissions from the drying step have to be recovered (e.g. by scrubbing), in particular to avoid ammonia (NH_3) or organic volatiles (VOC) emissions. If the input slurry comes from anaerobic digestion process, the volatilisation of organic matter is reduced and the biogas produced by the anaerobic digestion can cover part (10 – 20 %) of the thermal energy needs. Ammonia emissions from the drier can also be controlled by using the input slurry from a previous nitrification-denitrification or acidification process.

Cu, Zn and other metals are present in the dried product (depending of their concentration in the raw manures); this fact could limit the use of dried manure on field crops.

Operational data

The products of this technique are pulverised manure with 85 % dry matter content and an effluent, which is the residual condensate. This condensate is low in N and P and has a COD of less than 120 mg/l. A water removal efficiency of over than 85 % is reported. In addition, 95 % of the nitrogen (if previously acidified), and almost all P and K of the input manure could be conserved in the dried product.

The maximum dry matter content of the concentrate that can be achieved with the vacuum evaporation technique is around 25 %. [256, Lemmens et al. 2006] It is also reported that a pig slurry with 2.5 – 3.5 % of dry matter can be concentrated until 25 – 30 %. If the pH is maintained <5.5, the recovery of nitrogen remaining in the concentrate will be higher than 98.0 %.

The efficiency of atmospheric evaporation is high (up to 90 % of nutrients recovery) but with high dependency of previous treatments (organic matter removal/N removal or acidification treatment) [594 , Agro Business Park , 2010]

The system is affected by the heterogeneity of the manure, foam formation and corrosion. The selection of the constructive materials is of high importance, in particular for the resistance to high temperature and corrosion.

Concerning energy consumption, an increasing number of evaporation steps results in a significant decrease in energy consumption. A single-step evaporator requires 1.1 – 1.25 tonnes of steam for each tonne of water evaporated; while, a 5-stage vacuum evaporator requires 0.25 tonnes of steam per tonne of water evaporated. [256, Lemmens et al. 2006] The estimated heat needed for a large-scale unit, operating with vacuum evaporation, treating 6 – 8 m^3/h of acidified pig slurry with a dry matter content of 0.9 – 1.2 %, is reported at 250 – 280 kW/m^3. [594, Agro Business Park 2010]

Applicability

~~This~~ The technique has been developed for use on large farms. The maximum capacity is 15 – 20 m^3 per day. Application is possible for new and existing farms. Subsidies (e.g. to power production) are usually necessary to make economical feasible these kind of treatment facilities [594 , Agro Business Park , 2010].

Economics

Costs depend on several factors and a general indication is difficult. Investment costs are (partly) determined by the water evaporation capacity, type of evaporator, configuration used (e.g. number of stages), the construction material, available heat, etc. An example of investment and operating costs reported from Belgium-Flanders is presented in Table 4.181, for a vacuum evaporation plant with a capacity of 14 000 tonnes per year, treating pig slurry. [256, Lemmens et al. 2006]

~~The costs for an installation (excluding housing) were estimated at EUR 160 000 – 200 000 (1994). The operating costs were calculated as EUR 2.3 per m³.~~

THE EXISTING TABLE 4.99 (REFERENCE YEAR 1997) HAS BEEN SUBSTITUTED BY THE FOLLOWING NEW TABLE WITH MORE RECENT COST DATA.

Table 4.181: Costs for a vacuum evaporation plant for pig slurry, with a capacity of 14 000 tonnes/year

Parameter	Unit	Costs
Investment costs	EUR	490 000
Annualised investment costs	EUR/t	6
Operating costs (including pre-treatment)	EUR/t	4.5
Total costs (including storage, buildings, infrastructure)	EUR/t	17
Source: [256, Lemmens et al. 2006]		

At industrial scale, vacuum evaporation units are usually formed by two or multiple steps. The energy consumption for single-step evaporators is very high and accounts for most of the cost for the evaporation system. Each added evaporation step reduces the energy consumption by 33 % (although investment cost is increased).

Driving force for implementation
Local restrictions on nutrient supply may force the use of such technique, since the resulting product is easier and cheaper to transport and landspreading. Apart from obtaining a concentrate with a higher nutrient concentration than the original manure/slurry, another objective of water evaporation is to obtain water as a condensate, which could then be reused.[203, ADAS 2005]

The dried product could be considered as sterilised (depending on the time and temperature of the process) and, depending on its quality, it may represent an income as organic fertiliser.

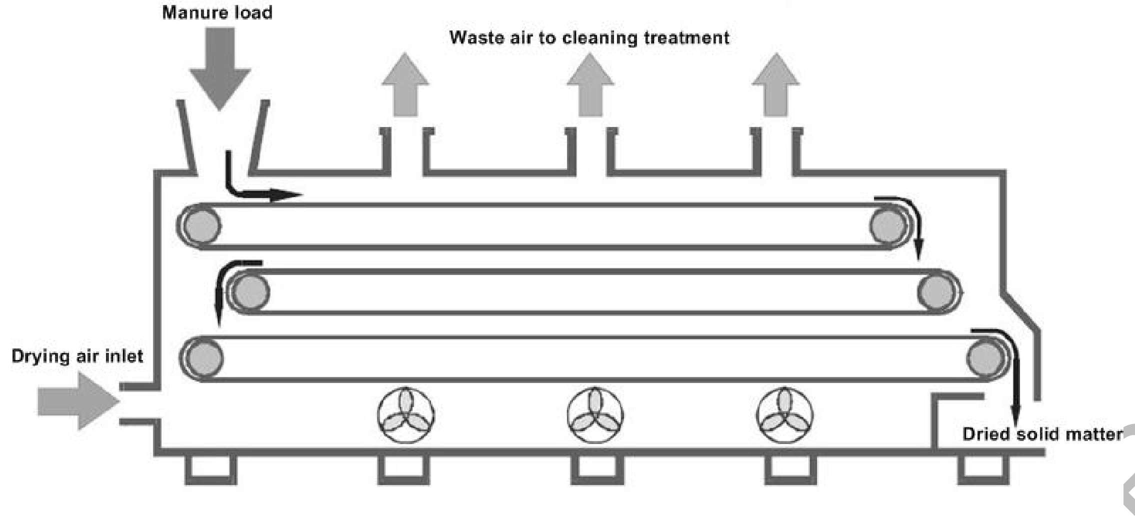
Example plants
The technique is used in Belgium-Flanders in several manure treatment systems. Three plants are reported to operate in Spain with the atmospheric evaporation. Vacuum evaporation is applied at least in 3 plants in Spain and one plant in France. [594, Agro Business Park 2010]

Reference literature
[409, VITO 1997] [203, ADAS 2005] [256, Lemmens et al. 2006] [594, Agro Business Park 2010]

4.12.8 Slurry and wet manure belt dryer

Description
This technique is ~~mostly~~ used to dry the free-flowing solid fraction that is obtained in slurry separation processes, the solid residue produced from biogas plants or non-separated slurry mixed with dried manure. It aims at a product with reduced volume and higher dry matter content ~~Belt dryers use~~ by using heat convection for drying.~~ the slurry~~. Warm air flows through the belts where the manure to be dried is transported, absorbing and removing moisture.

The transport belts are made of wire tissue or perforated steel plates, and heated air flows through them. In drying chambers one or several transport belts are arranged one above the other (see Figure 4.83) downloading matter each one to the one below.



Source: [226, Germany 2010]

Figure 4.83: Scheme of a manure belt dryer

When the material is downloaded to the lower belt, it is mixed and homogenized. The lowest degree of air turbulence and the best water vapour enrichment are sought, in order to minimise dust and to maximize the moisture removal.

Achieved environmental benefits

Relatively solid matter is processed into a dry, stable product that is suitable for storage and transportation and that develops no or only slight odour. It is assumed that the technique is used in combination with the biogas production and its parallel utilisation in a combined heat and power (CHP) production system.

Cross-media effects

The exhaust drying air that contains high ~~values~~ levels of ammonia needs to be ~~is~~ cleaned ~~in~~ by an acid scrubber. The salt (6 – 7 % of nitrogen in ammonium sulphate solution) that exits the scrubber has a recognised commercial value. In the scrubber, 8 to 12 kg of sulphuric acid are ~~requested~~ needed ~~in the scrubber~~ per tonne of digestate.

A thermal power of 700 kWh per tonne of solid matter is required to heat up the drying air, which is assumed to be available on-farm, free of cost, deriving from the CHP system used to burn the biogas. Additional electric energy is needed to run the belt system, about 2 – 5 kWh/t per tonne of raw slurry, before separation. ~~of more electrical power~~

Operational data

Equipment is available with a capacity of 1 – 2 tonnes per hour of separated solid fraction (corresponding to 5 – 10 tonnes per hour of raw slurry, before separation ~~matter per hour~~)
An example of input/output characteristics of manure processed with a belt dryer is presented in Table 4.182.

Table 4.182 Input and output characteristics of the manure processed in the manure belt drying process

	Dry matter	Total N	NH_4-N	P_2O_5	K_2O
	kg/t	kg/t	kg/t	kg/t	kg/t
Input	300	8.4	2.7	10.1	3.0
Output	800	14.5	0.74	27.11	8.0
Source: [226, Germany 2010]					

It is assumed that around 90 % of NH_4-nitrogen is extracted from the treated matter ~~also lost as emission~~ during the drying process, which corresponds to 0.30 kg of nitrogen per tonne or to 0.66 % of the total nitrogen load. When the technique is combined with an acid scrubber, almost all ammoniacal nitrogen would be collected; otherwise it would be lost as emissions.

The solid fraction obtained after separation is stabilised and reduced in volume. Non-separated slurry can be dried by mixing it with previously dried material. From a treated digestate, a solid mass is obtained of about 8–9 % of the original volume that is also sanitised of most pathogens.

Various models of dryers have been recently commercialised for wet ~~poultry~~ manure application, using the described principle. Droppings must be spread in relatively thin layers (5 to 15 cm) over a perforated support (belt or other) to obtain dry matter rates from 80 to 85 %.
[259, France 2010]

Applicability
Only slight adaptation is necessary to the farm equipment, since only a screw press ~~pressure worm~~ separator (see Section 4.12.2.2) is required for raw slurry for the first slurry separation.

The technique is preferably used in farms with over 2 000 animal places, or in combination with biogas production, to dry the fermentation residues by using the heat from cogeneration units.

Economics
Investment costs for drying units are reported from Germany ~~are on sale for~~ in the range between EUR 300 000 and EUR 400 000 per unit, which corresponds to ~~that means~~ EUR 80 000 – 120 000 per tonne and hour. With an amortisation period of 10 years and 6 % interest rate, the investment can be annualised as EUR 10 000 – 15 600 per tonne, or EUR 39 000 – 52 000 per year, per drying unit.

A complete installation for biogas digestate, inclusive of building and stores ~~storages~~, costs about EUR 700 000 in Italy. Annualised investment costs are reported at ~~is~~ EUR 3 – 4 per tonne of dried material produced; while, annual running costs are reported from Italy to range between~~. To run the system,~~ EUR 0.8 and EUR 1.5 ~~are necessary~~ per tonne of dried digestate produced. The maintenance and control of the system requires ~~, including~~ 0.01 – 0.02 hours of ~~human~~ labour per tonne of dried material per year.

Driving force for implementation
Where transportability is a limiting factor, this technique may have an economic value. Storage volumes are significantly reduced.

Example plants
It has been reported that one farm in Italy is running the technique, and others were planning to be equipped with the system.

Reference literature
[226, Germany 2010] [231, Italy 2010] [259, France 2010]

4.12.9 Slurry acidification

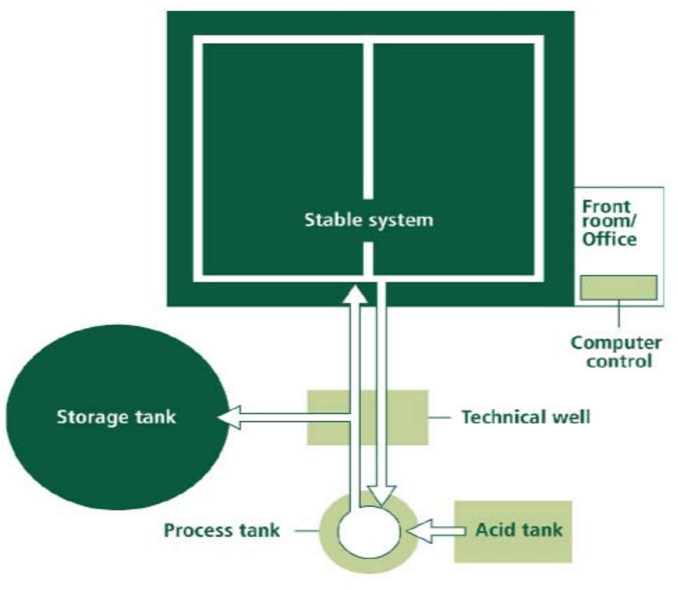
Description

Slurry acidification is a technique for reducing ammonia emissions from pig farms by adding sulphuric acid to the slurry. The equilibrium between NH_4-N and NH_3 in solutions depends on the pH (acidity). Low pH favours retention of NH_4-N (in the form of ammonium sulphate) at the expense of ammonia (NH_3-N) which is emitted in the gaseous form. ~~This technique consists of treating the slurry by lowering its pH to 5.5, aerating and homogenising it.~~

The slurry is pumped from the pig houses ~~stables~~ to a process tank by means of a valve pit, where sulphuric acid is added in the right dose to lower the pH to 5.5. The amount of sulphuric acid is controlled by a pH sensor. In the process tank, ~~and where the~~ slurry is also aerated and homogenised by injecting compressed air, to prevent sulphate ions changing into noxious hydrogen sulphide and to improve the fluidity of the slurry as part of the dry matter content is degraded. Part of the treated slurry may be used to flush ~~is pumped back into~~ the storage pits under the ~~stable~~ housing floors, in a sufficient quantity to allow 10–15 cm of slurry, ensuring that pH in the slurry pits is kept at about 5.5. In this way, ammonia volatilisation ~~of~~ from further dung dropping into pits is inhibited.

The rest of the ~~unused~~ treated slurry is pumped from the process tank into a storage tank from where it can be transported and spread on the field as fertiliser, at a later stage. ~~is up taken for final utilisation.~~ All process steps are automatically controlled and monitored. [594, Agro Business Park 2010]

A schematic representation of the ~~treatment~~ slurry acidification system is shown in Figure 4.84.



Source: [228, Denmark 2010]

Figure 4.84: Schematic representation of a slurry acidification system

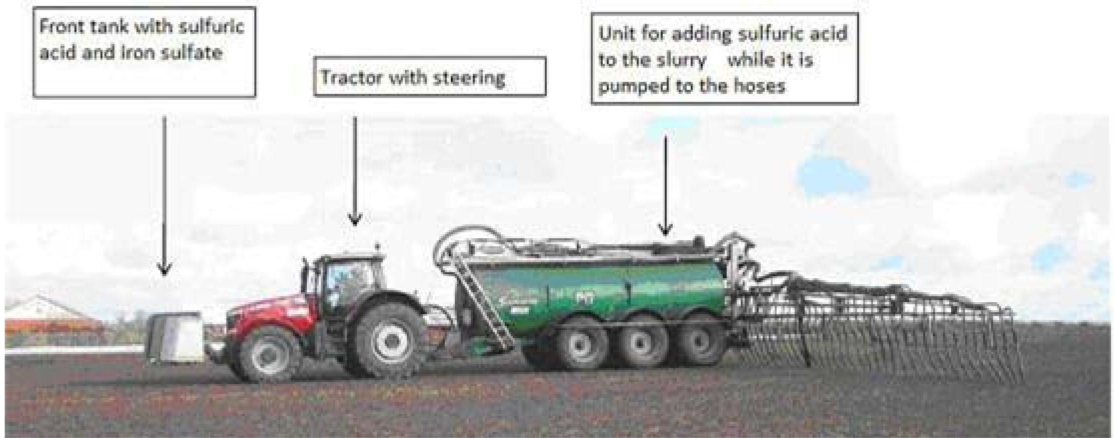
One reported variation of the technique is based on the acidification of the slurry directly in the storage tank, by adding sulphuric acid while the slurry is agitated, just before it is transferred to the field for landspreading (see Figure 4.85).

NB: In the left figure, the aggregate is agitating the slurry via pumping, while sulphuric acid is added in the pipe. In the right figure, slurry is agitated via propeller; while sulphuric acid is added in the pipe.

Source: [599, Denmark 2012]

Figure 4.85: Systems for slurry acidification directly in the storage tank

Acidification can also be done continuously during landspreading of the slurry. Sulphuric acid is transported and stored in a suitable (officially approved) container mounted in front of the tractor that pulls the liquid manure spreader/slurry tanker (see Figure 4.86). The acid is pumped through pipes, from the container positioned in front of the tractor to the outlet of the manure spreader, where the liquid manure is mixed with the acid in a static mixer before the slurry is pumped into the device used to apply the acidified slurry on the soil, such as a trailing hose. The system continuously controls the rate of acid being added to the slurry by online pH measurement of the acidified slurry. The amount of spread slurry is also continuously measured.



Source: [598, Denmark 2011]

Figure 4.86: Equipment for slurry acidification during spreading

Achieved environmental benefits

Slurry acidification strongly inhibits ammonia evaporation, by formation of ammonium sulphate, from the process steps of pig farms where acidified slurry is used: housing, storage and field application. As a result of inhibition of ammonia evaporation, acidified slurry retains more nitrogen making the treated slurry ~~is~~ richer in nutrient value which will ~~in nitrogen and~~ eventually result~~s~~ in measurably higher crop yields when spread as fertiliser.

In theory, methane emissions from housing and outdoor storage could be substantially reduced, due to inhibition of methanogenic bacteria at the low pH.

Similarly, potential nitrous oxide emissions from storage could be reduced, if acidification prevents a surface crust formation, due to the reduced microbial activity in the slurry.
The lowered pH also inhibits microbial activity in the slurry, preventing bacteria from producing gases like methane, nitrous oxide and hydrogen sulphide (H2S).

As the evaporation of ammonia is strongly inhibited in acidified slurry, more nitrogen compounds are kept in the treated slurry making it is richer in nutrient value which in nitrogen and eventually results in measurably higher crop yields when spread as fertiliser.

Reduction of ammonia emissions significantly improves air quality in the animal houses providing The human animal welfare and a better working environment. are hence improved because of lower ammonia emissions.,.

Cross-media effects
Handling strong acids on farms is hazardous. [508, TFRN 2012] A fully automated system, with no manual contact with sulphuric acid and automated management of the slurry (including discharging operations), is necessary for safety reasons. [228, Denmark 2010] Corrosion also may occur. [571, Eurich-Menden et al. 2011]

Slurry acidification leads to qualitative changes in odour emissions, rather than an increase in overall odour. Peaks of odour can arise as a result of daily aeration/mixing and pumping of manure. No effects on odour concentration have been reported. Conversely, A potential emission loss of gaseous hydrogen sulphide exists if sulphate is reduced to H_2S in stored slurry; at the same time, the level of NH_3 evaporation is significantly reduced by the acidification. [598, Denmark 2012]

If acidified slurry is used in a plant producing biogas, there is a theoretical risk of bacterial inhibition based on high proportion of acidified slurry.

The technique may lead to marginal soil acidification, increasing the need for liming. All practical experiences shows this is a minor issue corresponding minimise the importance of this issue since the supplied acidity corresponds to less than 10 percent of the additional liming needed. Theoretically, 1.4 kg lime should be landspread to neutralise each kg of sulphuric acid used for slurry acidification. [598, Denmark 2012]

In the case of acidification inside slurry storage tank, due to foaming of the slurry, a freeboard of 0.8 – 1 meter is required in the tank; therefore, the storage capacity of the tank cannot be fully utilised.
Little or virtually no waste is produced.

Operational data
Untreated slurry has typically a pH of 6.5 – 8. In order to ensure the reducing effect on ammonia evaporation, the acidification should bring the pH to a level not higher than 6.0. In commercial operations, the pH is often brought down to a value of 5.5, in consideration of the instability of acidified slurry and its varying buffer effect. Target pH depends on the time span from acidification until landspreading. Therefore, slurry that is acidified to a pH below 6.0 should be landspread as fertiliser within 24 hours; the pH should be maintained below 5.5 in the case the slurry is not brought to fields within 21 to 90 days. If spreading of the acidified slurry is delayed more than 90 days, then the pH should be verified in order to ensure that it is still less than 6.0 or more acid should be added.

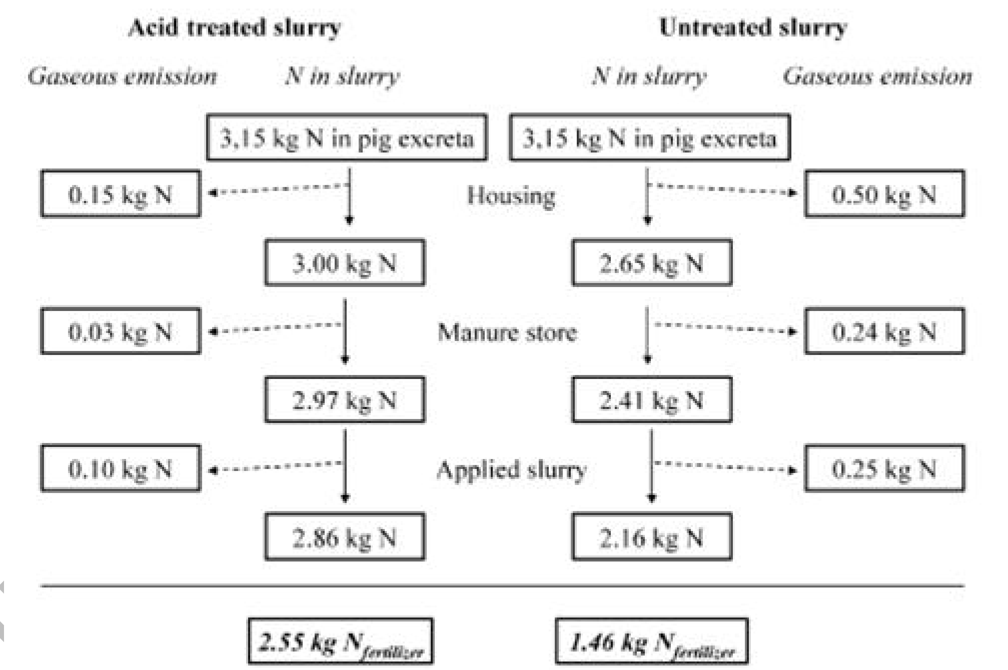
In general, the amount of sulphuric acid needed for a tonne of slurry is approximately 2.5 – 3 litres, corresponding to about 4.6 – 5.5 kg of acid. [599, Denmark 2012] Other sources report a consumption of sulphuric acid in the range of 5 to 7 kg for each tonne of raw slurry, to reduce the pH to between 5.5 and 6. [594, Agro Business Park 2010]

Installations are farm-fitted with a process tank, automated valves and piping systems ~~and the small net of~~ where necessary ~~piping~~.

The technology typically ~~only~~ requires the slurry to be treated only once. The whole process is fully automated allowing the farmer to continuously monitor all operational and environmental aspects of the slurry management system (continuous measurement of pH, amount of slurry treated and stored, and status of sulphuric acid supply). ~~and remotely monitored~~.

~~The pH remains stable in the storage after the sulphuric acid is added, until the final utilisation of the slurry.~~

Comparative data from a whole-farm assessment carried out in Denmark, concerning the application of slurry acidification, report that gaseous N emissions produced per growing/finishing pig (30–100 kg live weight) without ~~no~~ slurry acidification are 0.50 kg N from housing, 0.24 kg N from manure storage, 0.25 kg N from application of slurry to land. When using ~~From~~ acidified slurry, emissions are 0.15 kg N, 0.03 kg N and 0.10 kg N respectively for housing, storage and land application. The nitrogen balance at the base of the whole-farm assessment is presented in Figure 4.87, where data for the acidified slurry are compared with those for untreated slurry. The fertiliser value of the acidified slurry is estimated at 2.55 kg N, to compare with a value of 1.46 kg N in the case of untreated slurry.



Source: [600, P.Kai et al. 2008]

Figure 4.87: Whole-farm assessment of slurry acidification effect on excreted nitrogen

Similarly, from a whole-farm assessment, carried out in Denmark on the basis of laboratory tests simulating slurry storage, a reduction of methane is reported from 3.29 kg to 2.2 kg CH_4 per tonne of ~~manure~~ slurry stored in houses ~~stables~~, and 1.94 kg to 0.78 kg CH_4 per tonne of slurry in stores. ~~the storage and Reported~~ A reduction of N_2O is reported from 0.013 kg to 0.0022 kg N_2O per tonne from housing ~~stables~~, and 0.033 kg to 0.021 kg N_2O per tonne from stores ~~storages~~. [228, Denmark 2010]

In summary, emissions are reduced by 75 % in houses with fully-slatted floors and by approximately 80 % in houses ~~combination~~ with partly-slatted floors. Another 50 % reduction is induced in covered storages, 90 % in uncovered storages and 67 % in land application of slurry the manure by trailing hoses.

A total reduction of 65 – 70 % for ammonia emissions is also reported by another source, for housing and slurry storage. [594, Agro Business Park 2010]. An estimated 60 % reduction in ammonia emissions is reported when slurry is acidified during field application. [508, TFRN 2012]

The increased energy, associated with the use of slurry, is estimated at 1.8 – 3 kWh/m^3 of slurry. [594, Agro Business Park 2010]

Examples of increased odour problems have been reported occurring locally near the process tank of the acidification unit. Elimination of the problem is feasible by mounting a carbon filter at the process tank.

Applicability

The technique is generally applicable. since It is reported that around 80 percent of existing Danish sheds can be modified for acidification without bigger major renovations.

The alternative of acidification during spreading has not been tested with irrigation systems and broadcast spreading. With injection techniques the effect of emissions reduction is expected to be limited.

Economics

One A acidification unit for a pig house stable (which can handle up to 6 sections, with 400 m^3 of slurry each) is installed for at an investment of about EUR 200 000. The annualised investment cost is around EUR 13 300, based on a 15 years depreciation period. The annual running costs, consist of the maintenance cost and is yearly run for the cost of the service contract (EUR 2 000), of the extra electricity power consumption (about 3 kWh per tonne of treated slurry) and the costs for the sulphuric acid. Supplier's estimations of the total annual yearly running costs range from EUR 1 to 2 per tonne of treated slurry.

The extra-costs for the technique are reported to vary between 1.4 and 7 EUR/ap/yr. In Table 4.183, the extra operational costs for the slurry acidification technique, reported by Denmark in relation to the number of produced fattening pigs, are presented.

Table 4.183: Cost data reported for slurry acidification in relation to the number of pigs, in Denmark

Produced fattening pigs (32 – 107 kg)	Total annual extra costs ([1])	Total extra costs per produced pig ([2]) ([3])		Total extra cost per kg N reduced incl. value of saved N
	EUR/yr	EUR/pig	%	EUR/kg N reduced
2 700	20 130	6.8	10	14.4
5 400	22 300	3.4	5	7.5
9 000	24 600	2.1	3	4.4
18 000	33 000	1.2	2	2.5
27 000	41 600	0.8	1	2.0
34 200	48 100	0.7	1	1.6

([1]) Value of N is excluded.
([2]) Value of saved N is included.
([3]) Reference for production cost: EUR 69 per produced pig.
Source: [594, Agro Business Park, 2010]

For a slurry acidification unit treating 10 000 m^3 slurry per year, the breakdown of estimated operational costs is reported in Table 4.184.

Table 4.184: Operational costs for a slurry acidification unit treating 10 000 m^3/yr, in Denmark

Parameter	EUR/m^3
Energy consumption	0.17
Acid consumption	0.72
Maintenance and service	0.29
Total costs	1.18
Source: [594, Agro Business Park 2010]	

A total additional cost of approximately EUR 20 per ha is reported where acidified slurry is applied, for both variations of slurry acidification: in storage tank and during landspreading; this extra cost includes depreciation of the investment.

Driving force for implementation
Farmers in Denmark are required to adopt low-emission measures to obtain an environmental permit to expand their animal production.

The ammonia saved from evaporation has an economic value by inducing fewer needs for mineral fertilisation when the slurry is applied to fields.

The use of slurry acidification during landspreading facilitates the application of the acidification technique, since the system is not dependent on alterations within the pig housing.

Example plants
~~One supplier installed over one hundred farms in Denmark.~~
Slurry acidification is reported to be in operation in Denmark (around 125 farms) and Spain (over 20 farms with medium and large scale applications) [508, TFRN 2012] [595, Agro Business Park 2010]

The systems for slurry acidification in storage tanks and during landspreading are relatively new technologies.

Reference literature
[228, Denmark 2010] [598, Denmark 2012] [599, Denmark 2012]

4.12.10 Combustion ~~Incineration~~ of poultry litter ~~manure~~

In general, on-farm combustion plants for poultry litter have capacities below the threshold value of 3 tonnes per hour set by the Industrial Emission Directive 2010/75/EU, Annex I, Activity 5.2: 'Disposal or recovery of waste in waste incineration plants or in waste co-incineration plants for non-hazardous waste'.

Description
~~The installation described has a capacity of 0.5 tonne manure (55 % dm) per hour and is operated for 5000 hours per year.~~
Untreated poultry deep litter, the solid fraction from slurry mechanical separation, thermally dried or other solid manure can be combusted and converted into energy. The recovered thermal energy can be also transformed into electricity.

Air (oxygen) is introduced in excess to thermally oxidise (T >900 ºC) carbon, hydrogen, and sulphur contained in manure's organic matter. In case of complete combustion, all volatile solids (VS) are transformed to gases and ashes will contain only inorganic material. If combustion is not complete (insufficient oxygen or low degree of turbulence) volatile solids can be found in the ashes and CO in the exhaust gasses.

A steam generator is used to recover thermal energy. The generated steam can be transformed to electricity in a steam turbine. For manure with high moisture content, a previous drying (and pelletising) process may be appropriate in order to increase energy efficiency of the plant. [594, Agro Business Park 2010]

Different types of furnaces can be used such as grate incinerators (grilled beds), rotary kilns or fluidised bed reactors. (See BREF on Waste Incineration for more detailed information about combustion technologies and thermal treatment systems).

Conventional combustion chambers (grate incinerators)
Broiler litter ~~manure~~ is automatically fed from ~~a manure~~ storage into a first combustion chamber at a temperature of 400 °C, where it is gasified on a moving grate by an airflow supplied at the bottom of the litter layer~~. From this chamber the gas/ash mixture enters~~ During the gasification process, the poultry litter is transported over the grate through a second combustion chamber~~. In this chamber~~ where the mixture is rapidly heated~~,~~ (i.e. within three seconds)~~,~~ up to a temperature of 1 000 to 1 200 °C under controlled oxygen supply. ~~As a result of the high temperature all the odorous components are eliminated.~~ The hot flue-gases leaving the second chamber go through a heat exchanger, in which water is heated to a temperature of about 70 °C.

Fluidised Bed Combustion
Combustion air is blown from below through a 'bed' of sand or other inert material at high enough velocity to keep the material suspended. The sand is preheated to raise the temperature so incoming material will ignite and burn efficiently. The constantly moving mass provides good heat transfer within the bed which helps to deal with the high ash and variable moisture content. Fluidised beds suspend solid fuels on upward-blowing jets of air during the combustion process. The result is a turbulent mixing of fuel, gas and solid sand particles. The tumbling action provides more effective chemical reactions and heat transfer. [553, bhsl 2011]

A tall furnace retains combustion gases at a temperature over 850 ºC, for over 2 seconds in accordance with the Animal By-Product Regulation (EC) 1069/2009. Temperature is regularly monitored. The retention time is a calculated based on the flowrates of gas and the height of the stack.

The litter is transferred from poultry sheds to a bio secure storage area, from where no further contact takes place with the farm production or operatives. The fuel is automatically transferred into the combustion chamber and the whole process is remotely managed.

The heated water that is produced after the combustion is used for ~~the floor~~ heating ~~of two broiler~~ production houses ~~with a total surface of about 5000 m^2~~.

Achieved environmental benefits
Combustion of poultry litter as fuel for the production of heat allows for the substitution of fossil fuels with renewable sources. The calorific value of poultry litter is reported to range between 10.8 and 12 MJ/kg. [564, bhsl 2012] [553, bhsl 2011] from UK and 14 – 16 MJ/kg dry matter from Belgium.[256, Lemmens et al. 2006].

The main factor affecting energy recovery is the water content of the manure. Based on data from incinerators in the UK, it is reported that the combustion of poultry manure can produce about 500 kWh of electrical energy from each tonne of chicken manure with 60 % dry matter [256, Lemmens et al. 2006].

Changing from LPG or propane indoor combustion to biomass heating reduces moisture production and therefore humidity in the poultry houses, which generates a damp atmosphere and accelerates NH_3 formation from droppings. The reduced humidity in the houses enables also a more efficient management of the ventilation and reduced requirement in litter (up to 20 %).

Another ~~The~~ benefit of this technique is the production of an ash that can be used as a fertiliser. ~~and of hot water which is used for heating the housings, and which therefore saves fossil fuel use~~ since it is rich in phosphorus and potassium. However, availability of phosphate to crops is still under study. [594, Agro Business Park, 2010] [256, Lemmens et al. 2006]

Cross-media effects

Potential risk of emissions (e.g. NO_X, SO_X, H_2S, HCl, PCDD and PCDF, dust, metals). Equipment to control emissions from the combustion process is required in all cases.

Once the installation has started, no additional fuel is necessary to incinerate the litter ~~manure~~ given its DM content of 55 %. The flue gases are filtered ~~emitted to the atmosphere~~ through a ~~Teflon dust filter. The~~ dust filter that reduce~~s~~ the dust concentration ~~in the flue gas from 1000 to 30 mg/m³. The separated dust is added to the remaining ash of the combustion chambers, otherwise~~ Ashes removed by the air cleaning system have to be disposed in controlled landfills. [594, Agro Business Park 2010]

Odour emissions are low due to the high temperatures achieved in the combustion chamber. SO_2 emission ~~is~~ can be limited as a result of added chalk.

Operational data

Poultry litter comprises a heterogeneous mixture of manure, bedding material, waste feed, broken eggs and feathers removed from the poultry sheds which composition seems consistent enough for geographic areas due to animal by-product rules and the industry's own quality production standards (e.g. bedding materials and used feed).
~~The raw material used is broiler litter manure with a DM content of 55 % and a low litter content. For each production cycle about 1 tonne of wood shavings is spread on the surface of the shed floor of 5000 m2. To fix the sulphur components small amounts of chalk are added to the litter manure.~~

The technique results in a substantial reduction of volume and mass (70 – 90 % of mass reduction). This residue can be sold as fertiliser

~~Of this mixture only 10 % remains after incineration. In the reported example an installation with a potential capacity for litter the manure of 200 000 broilers was installed. If the installation was operated at full capacity, it would be able to incinerate 500 kg of litter manure per hour. However, the installation is operated at a reduced capacity, with an input from 130 000 broiler places, treating 6 to 7 tonnes per day, which also serves the energy demand for heating.~~

Reported fluidised bed combustion units have a range of capacities of 2.4, 5.5 and 12 – 13 tonnes per day of litter manure as fuel, with thermal outputs from 200 to 995 kWh.

Any fall in combustion temperature is detected by the automatic control system that allows supplementary fuel to be used to keep the operating temperature at 850 ºC. This temperature is required to ignite moisten fuels, to prevent the agglomeration of potassium, to achieve 100 % combustion of fixed carbon, to thermally decompose all organic pollutants present in poultry litter.

Example of associated emission levels from a fluidised bed combustion plant for poultry litter, in comparison with the combustion of virgin wood shavings, are given in Table 4.185. Data are compared with the emission limit values (ELVs) set by Directive 2010/75/EU, for waste incineration plants. The plant used for combustion of poultry litter has a capacity of 5 tonnes/day, thermal output of 500 kW of heat and 50 kW of electricity; bedding material used for the poultry housing consists of virgin wood shavings. The plant is equipped with a dust abatement system and continuous monitoring of emissions.

Table 4.185: Achievable emissions levels from a fluidised bed combustion plant for poultry litter, in comparison with fresh wood shavings and ELVs set by Directive 2010/75/EU for waste incineration plants

Parameter	Unit	Directive 2010/75/EU ELVs as daily average (1)	Associate emission levels (AELs)	
			Emissions from poultry litter (2)	Emissions from virgin wood shavings
NO_X	mg/Nm³	400	359.86	380.91
SO_2	mg/Nm³	50	0.03	5.21
Dust	mg/Nm³	50 (3)	0.97	56.13
Heavy metals	mg/Nm³	0.5	0.04	NA
Mercury	mg/Nm³	0.05	0	NA
Cd and Tl	mg/Nm³	0.05	0	NA
Dioxins and furans	ng/Nm³	0.1	0.09 (4)	NA
PAH	µg/Nm³	Value not specified	40.40	NA
CO	mg/Nm³	100	30.67	88.71

NA= Not available
(1) All values refer to standard conditions: temperature 273.15 K, pressure 101.3 kPa, dry gas. Concentrations are corrected to reference conditions of 11 % oxygen by volume.
(2) Bedding material: virgin wood shavings with <40 % moisture content.
(3) Emission limit value for co-incineration of biomass (waste).
(4) Euro environmental emissions data
Source: [553, bhsl 2011]

NOx emissions ranging from 258 to 498 mg/Nm³ at 6 % O_2 are reported from Belgium-Flanders.

Several techniques are available for controlling solid and gaseous emissions from combustion plants applied for incinerating poultry litter. The techniques are described in detail in the BAT Reference Document for Waste Incineration (WI BREF).

Applicability
The technique ~~installation~~ can be applied on new and existing farms. The capacity can be adjusted to the available litter ~~manure~~ production. ~~There were~~

No technical limitations are reported to its application on a farm scale; however, the for high moisture content of the manure, energy recovery may not be sufficient to justify the implementation of the technique. For a dry matter content of the manure below 30 %, the process would result in net energy consumption. From a dry matter content of 30 % and above, energy can, in theory, be recovered in a well-designed combustion plant, with higher net energy production for dry matter contents of about 60 %. If pre-drying of the manure is needed, the applicability of the technique should be assessed case-by-case.

High investment costs for emission control equipment and detailed measurements, requested for compliance with the current European legislation, make the technique difficult to apply for farm-scale installations.

Economics
Cost data are reported for an installation in UK, with an annual capacity of around 3 200 tonnes of poultry litter, 75 % of which (around 2 400 tonnes) is coming from a farm of 378 000 broiler places. The plant operates 5 976 hours per year, producing hot water which is piped to the bird houses to heat the next batch of broilers. The approximate investment costs amount to EUR 1.58 million (based on 1 EUR = 0.88 GBP), which comprises the following: [564, bhsl 2012]:

- Plant and fuel handling: EUR 810 000. It includes the installation of the fluidised bed combustion system, all material and labour costs.
- Building for a bio-secure fuel storage area: EUR 160 000. It automatically conveys the litter to the combustion unit without contact from farm staff.
- Heating network (water supply, buffer tanks, internal and external piping, pumps and controls, etc.): EUR 510 000. It refers to the heating infrastructure that stores, pumps and delivers heat into the poultry houses, including all installation and materials.
- Project management and contingency: 7.5 % of expenditure.

The payback time of the above investment, on a farm using LPG as the energy source, is reported equivalent to 3.64 years and the free cash flow over 10 years is EUR 4.7 million, taking into account the following assumptions:

1. Approximately 10 % of the litter used in the plant is recovered as ash, having a value after transportation of around EUR 68 per tonne.
2. UK incentives equivalent to EUR 53 per MWh of heat used for the first 1313 MWh each year, followed by EUR 22 for each subsequent MWh. [564, bhsl 2012]
3. Benefits deriving from improved housing conditions for the birds (from optimised heating and ventilation) and consequent better performance.

For an installation that is operated for about 5 000 hours per year and an yearly input of 2 500 tonnes of manure, the gross running costs are reported equivalent to about 18 EUR/tonne of litter, based on current cost data and level of application of a flue-gas treatment and related emissions monitoring requirements. [565, NFU 2012]. Comparable costs are reported for a farm-scale installation, with a capacity of 0.5 tonnes manure per hour, with a dry matter content of 55 %. Investment costs in the range of EUR 300 000 – 350 000 are reported from Belgium-Flanders; with operating costs of EUR 18 per tonne, assuming an annual operation of 5 000 hours. [256, Lemmens et al. 2006].

An approximate estimation of the investment cost for the required emission monitoring equipment and testing, in order to comply with the Directive 2010/75/EU, Annex VI, Part 6, is in the range of EUR 130 000 – 150 000. These costs may be considered too high, making the technique unviable and unsustainable for small, farm-scale plants. [553, bhsl 2011]

THE EXISTING TABLE 4.101, WITH OLD COST DATA (REFERENCE YEAR 1997), AND RELATED TEXT HAVE BEEN DELETED

Driving force for implementation
Farms can become self-sufficient in heat supply. Excess heat, not needed by the farm, can be supplied to a local public heating system or used to generate electricity. The sales of energy will, therefore, bring revenue, depending on individual EU Member State regulations and market price.

Example plants
The technique is applied in Germany. In the Netherlands, one large centralised installation is in operation, with an installed capacity of 36 MW, designed to transform 420 000 tonnes/year of poultry litter (with minimum 55 % of dry matter) into electricity (240 GWh annually) and reusable minerals for agriculture. Farmers from all over the country can bring their poultry litter to be incinerated. A large-scale centralised installation ~~example~~ was reported also from the UK, where 12.7 MW are produced by using approximately 140 000 tonnes of litter ~~manure~~ per year.

In France, companies attempted to set up systems of smaller dimensions; ~~but for technical and legislative problems,~~ however, no installation of this kind has been successful because of technical and legislative problems. [259, France 2010]

In 2010, a small-scale fluidised bed combustion system was installed in Norfolk, England operating on virgin wood chips and awaiting for appropriate regulation to operate with poultry litter. [565, NFU 2012]

In general, incineration (combustion for energy production) of solid manure is a technology growing within the broiler production sector. [264, Loyon et al. 2010]

Reference literature
[409, VITO 1997] [553, bhsl 2011] [564, bhsl 2012] [594, Agro Business Park 2010] [256, Lemmens et al. 2006]

4.12.11 Ammonia stripping

Description
Removal of ammonia is achieved through volatilisation from a liquid phase, by means of a gaseous counter-flow (air or steam) and subsequent recovery by absorption in an acid solution, as ammonium salt or by condensation. ~~This technique is a physical separation of ammonia from the fraction of slurry that exits from manure separation~~.

The liquid phase is charged in the upper part ~~up in~~ of a vertical a column where a stripping gas is ~~blown~~ introduced from the bottom (air or steam for 'air stripping' or 'steam stripping'). The gas flows through the column in counter-current to the liquid, thus extracting ammonia (stripping) in gas form. To enhance the liquid/gas contact, the columns are filled with specifically shaped pieces of inert material (packed column).

Stripped ammonia ~~air~~ is recovered by absorption in a second column, where it is washed in counter-current with sulphuric acid solution to produce ammonium salt. In steam stripping, the output gas is condensed to eventually produce a water solution of ammonia.

Achieved environmental benefits
~~The purpose of the treatment is the removal of ammonia from the slurry to enter the marketed commodity.~~

The removal of ammonia from the slurry results in a mitigation of potential ammonia emissions.

A reduced volume of the slurry (reducing transport costs) and recovery of nutrients (N, P and K in the concentrate fraction) are achieved.

During slurry landspreading, odours are reduced, N is managed easier and its loads to the fields are reduced.

Cross-media effects
Stripped gases are washed or condensed, thus they need to comply with general emission limits. Otherwise, stripping produces no emissions, taking place indoors.

Energy consumption is increased.

Operational data
The two fundamental control parameters of the process are the temperature and the pH, as they establish the equilibrium between ammonia (NH_3) and ammonium (NH_4^+); pH is usually set between 9 and 10, by adding an alkaline solution, or by previous CO_2 stripping. For air stripping, typical working temperatures are set below 100 ºC; whereas, higher temperatures are characteristic of steam stripping. ~~The higher the process temperature, the less gas is sent through the column.~~

Ammonia reduction is reported up to 95 %, under optimal conditions. [594, Agro Business Park 2010] Organic nitrogen, nitrites and nitrates are not removed.

Energy consumption for air stripping is dependent on the process temperature, since at higher temperatures less air is needed to be sent through the column. The consumption of electrical energy is reported from Belgium at ~~about~~ 2.3 kWh/m^3 liquid, if the process is run at 20 °C, and 0.85 kWh/m^3 if the operating temperature is 50 °C. Energy consumption, for the stripping column only, is also reported equivalent to 14 kWh/kg stripped nitrogen. [594, Agro Business Park 2010]

In the case of steam stripping, electricity consumption is 0.45 kWh/m^3 liquid; while, consumption for thermal energy is equivalent to the production of 100 kg of steam per m^3.

Applicability
The liquid to be stripped must have a very low content of dry matter; hence the technique is used in combination with separation techniques. Mechanical separation of the solid/liquid fractions is usually required as a pre-treatment to reduce dry matter content and avoid clogging.
The technique may be used in combination with anaerobic digestion, as a pre-treatment that improves ammonia stripping efficiency, reduces contamination of the final product by organic matter, and provides energy and heat required for the process.

Economics
~~The units themselves cost several hundreds of thousands EUR~~.
Investment costs are reported from Italy at EUR 350 000. For a plant located in Slovenia, treating 15 m^3/h of slurry, the estimated investment cost for the stripping column was reported equivalent to EUR 250 000. [594, Agro Business Park 2010]

For a mobile unit combining a centrifugal solid/liquid separator and an ammonia stripping equipment, followed by an ammonia catalytic process, investment costs are reported ~~costs for the treatment with mobile units~~ in the range of EUR 350 000 – 400 000. The related operating costs are EUR (125 × 2) per m^3 of treated slurry, for the displacement of the integrated mobile unit, ~~both the separator and the stripping unit, plus~~ EUR 3.10 per m^3 for the separation stage, and EUR 4.46 – 4.95 per m^3, for ammonia stripping plus the catalytic oxidation stage. [256, Lemmens et al. 2006] [529, Veneto Agricoltura 2012]

Operational costs have been reported at EUR 2.5 – 4.5 per kg of stripped N (only for the stripping column). For the absorption stage, at least an equivalent range of costs should be considered.

In Denmark, ammonia stripping is considered disproportionately expensive. [499, AgroTech 2008]

Driving force for implementation
~~Placing the final product on the market as fertiliser or~~
Both, liquid ammonia solution or solid ammonia salts obtained by condensation and evaporation, could be used directly as fertilisers, as feedstock in the fertiliser industry or sold to other industrial applications (e.g. waste water treatment in the paper industry).~~-might be an interesting added income.~~ The reported income is up to EUR 0.35 per kg of nitrogen recovered in a 0.1 N ammonium sulphate solution, to be sold to fertiliser manufacturers.

The concentrate (where P and N are contained) is partially hygienised (depending on the operation time/temperature).

Example plants
In Belgium-Flanders, a mobile system is ~~already~~ in use. A farm in Slovenia and one in Italy (with an annual capacity of 32 000 tonnes of manure) are also reported to operate the technique. [594, Agro Business Park 2010] [595, Agro Business Park 2010]

Reference literature
[256, Lemmens et al. 2006] [529, Veneto Agricoltura 2012] [594, Agro Business Park 2010]

4.12.12 ~~Pig~~ Manure additives

THIS SECTION HAS BEEN REARRANGED WITH INFORMATION PREVIOUSLY PLACED IN SECTION 2.7.6. SOME TEXT HAS BEEN RELOCATED WITHIN THIS SECTION.

Description
Chemical and biological compounds are added to manure or feed to change its characteristics and properties. The objectives for the addition of each additive may be different: reducing gaseous emissions ~~compounds (NH_3 and H_2S~~ and odours, improving indoor environment in animal housings, stabilising ~~to inhibit~~ pathogenic microorganisms and avoiding insects development, increasing fertilising value of the manure, facilitating the handling and use of manure ~~and to change the physical properties of the manure to make it easier to use~~ by increasing its fluidity. The use of some specific feed additives is covered in Section 4.3.6.

Types and categories of manure additives are given below:

- Masking and neutralising agents
- Adsorbers
- Urease inhibitors
- pH regulators
- Oxidising agents
- Flocculants
- Disinfectants and antimicrobials
- Biological agents.

Achieved environmental benefits
A better use and management of manure on the farm can be achieved with a more homogenous manure, namely because having greater homogeneity makes it easier to dose the manure in the landspreading. A lesser volume of manure will be produced due to using less water in the easier cleaning of the pits. ~~In some cases, a decrease in ammonia emissions could be achieved~~.

The effectiveness of each additive is highly dependent on the correct dosing, right timing and good mixing with the manure. It is also reported that satisfactory results are not always achievable. [561, Flotats et al. 2004] [499, AgroTech 2008] For most of the above mentioned additives, the documented effects by scientific trials are poor. [594, Agro Business Park 2010]

Savings of energy are ~~is~~ possible because of a lower use of cleaning machines. ~~A~~ Savings in water are ~~is~~ also achieved.

Specific achieved environmental benefits are also reported under 'Operational data'.

Cross-media effects
No significant ~~negative~~ general cross-media effects have been reported. Specific cross-media effects are reported under 'Operational data'.

Operational data
The purchase cost, quantity required, frequency of application, and hazard potentials of an additive are the most important parameters for its use. As slurry will be continually accumulating in a store, manure additives will need to be added at some frequency. The use of additives can be considered situation-specific, mainly depending on the needs of the farmer. [560, IGER 2000]

- **Masking and neutralising agents.** These are a mix of aromatic compounds (e.g. heliotropin, vanillin) with a strong scent/smell that work by either masking the manure odour or neutralizing the odorous volatile compounds. The effectiveness of masking agents is difficult to predict due to varying odour characteristics and changing weather conditions. The individual constituents of odours remain unchanged and the additive tends to separate from the odour downwind. Masking agents are susceptible to degradation by the microorganisms in the slurry. Frequent application is required [560, IGER 2000] Masking agents can also be added to the feed (e.g. artemisia extract, mint oil). [561, Flotats et al. 2004]
- **Adsorbers.** There are a large number of substances that have demonstrated an ability to adsorb ammonia. These materials have a high surface area, aiming at absorbing odorous compounds before they volatise. [561, Flotats et al. 2004]. Some types of zeolites called clinoptilolite can be added either to the manure or to feed for the high cation exchange capacity and affinity for NH_4^+. Clinoptilolites have been extensively studied but results of nitrogen binding are controversial and costs are relatively high. [151, Link CR 2005] [205, ADAS 2000] An increase in ammonia emission in duck rearing was reported in association with the use of clinoptilolite. [152, Link CR 2006]. The use of other clay minerals, such as bentonite, has been reported having odour reducing properties. [560, IGER 2000] [561, Flotats et al. 2004]. In experiments with the addition of zeolite and bentonite to pig slurry, it has been found that the microbial activity sharply decreases, with consequent expected reduction of odorous substances released by manure. Other reported results of trials carried out in Denmark, suggest that the addition of a rock mineral containing silicon, derived from zeolite, had no effect on odour or ammonia emissions. [499 , Agro Tech 2008] The substances mentioned above are also able to improve soil structure and have the added benefit that they are not toxic or hazardous. Peat gives similar results and is also sometimes used. However, the extraction of peat is associated with significant biogenic CO_2 emissions.
- **Urease inhibitors.** These compounds stop the degradation of urea to ammonia. There are three main types of urease inhibitor:
  - Phosphoramides. Applied directly to the soil, they show a good effect. They work better in acid soils, but could affect soil microorganisms
  - Yucca extract (Y. schidigera). Many trials have been done to assess its potential but the available information is controversial, showing good results in some cases, but no effect at all in other cases. It is added in the feed and not absorbed by the animals; thus, it reaches manure in a uniform way. There is also evidence that it improves feed conversion ratio and weight gain. Nevertheless, the way these additives function is not well investigated [561, Flotats et al. 2004] (see Section 4.3.6.4).
  - Straw, considered as an adsorbent in many references. However besides the absorbing effect, it also increases the C:N ratio. Its use is controversial because in many other works it shows an increase in ammonia emissions.
- **pH regulators.** There are three ~~two~~ main types:
  - Acid regulators, usually inorganic acids (phosphoric, hydrochloric, sulphuric). The addition of acids (e.g. H_2SO_4) for lowering the pH, keeps nitrogen in the NH_4 form which does not volatilise; it slows down the activity of methanogenesis bacteria preventing the formation of CH_4 and allowing the carbon to remain in the manure. More details are given in Section 4.12.9. [228, Denmark 2010]
  - Lime. Lime addition stabilises manure and reduces the content of pathogens. By mixing quicklime (CaO) with solid manure, the temperature rises exothermically to between 55 ºC and 70 ºC and the pH increases to 9 – 11, with a resulting bactericidal effect. The reactive lime used in the process promotes drying of the manure; it is also a 'liming agent' for changing the soil pH, in view of manure application.
  - Ca and Mg salts. These salts interact with manure carbonate, decreasing the pH. They could increase the fertilising value of the manure but could also increase the salinity of the soil (chlorides). They are used ~~sometimes, but~~ mainly in combination with other additives. Superphosphate (mixture of calcium salt and orthophosphoric

acid) is the product more often used in the poultry farm; it has a draining action on the litter. It is used in doses of 100 –200 g/m^2 and remains active over 5 days. Superphosphate and phosphoric acid were studied in poultry farms in France, as inhibitors of microbial growth. [259, France 2010] On the other hand, the addition of phosphorous (P) to manure may represent a local problem, where specific regulations concerning phosphorus are applied (e.g. in the Netherlands).

- **Oxidising agents.** Their effects are through:
  - oxidation of the odour compounds (e.g. sulphides)
  - providing oxygen to aerobic bacteria. Aerobic conditions promote oxidation of hydrogen sulfide and other malodorous gases by microorganisms
  - inactivating the anaerobic bacteria that generate odorous compounds.

  The most active oxidising agents are hydrogen peroxide, potassium permanganate, chlorine gas, or sodium hypochlorite. They are hazardous and not recommended for farm use. Some of them (e.g. formaldehyde) could be carcinogens. Ozone (O_3) is also used as a strong oxidant that can react with specific odorous compounds in the slurry and also reduce microbial activity. Its use to treat the slurry results in a pH increase, with consequent increased ammonia emissions and lower fertiliser value of the treated slurry. Ozone treatment can be combined with acidification. (See Section 6.4.3). Ozone application has demonstrated its efficacy but operational costs are very high.
- **Flocculants** are mineral compounds (ferric or ferrous chloride and other iron or zinc salts) or organic polymers. ~~Phosphorus is highly decreased but their use generates waste that is difficult to manage.~~ These additives react with sulphides [561 , Flotats et al, 2004], reduce BOD, suspended solids and PO_4^{-3} in the liquid stream, generating an insoluble precipitate, usually with a high content of P. The resulting waste may be difficult to manage. (See Section 4.12.2.4)
- **Disinfectants and antimicrobials are** chemical compounds that inhibit the activity of the microorganisms involved in odour generation. They are expensive to use and with sustained use an increase in dosing is needed.
- **Biological agents.**

  The addition of micro-organisms and nutrients in the slurry increases the microbial activity which degrades organic matter not digested by animals. In addition, odorous substances are reduced and N is transformed to its organic form. Furthermore, thinner slurry is expected that would be easier to handle and deliver. Nutrients may be fats, sugars, or extract from plants and algae. [499, AgroTech 2008] [561, Flotats et al. 2004] Biological agents are available as lyophilised preserved cultures or live cultures of natural strains or adapted decomposition strains (stimulators of microorganisms that are naturally present in the substrates). They can be divided into:
  - Enzymes. Enzymes are complex protein structures, promoting catalytic regulation and direct/indirect stimulation of biochemical processes and decomposition of the organic structures. [287, Jelínek et al. 2007]. Their use is to liquefy solids. They are not hazardous. The actual effect depends strongly on the type of enzyme, the substrate and a proper mixing.
  - Bacteria:
    - Exogenous strains. Their competition with natural strains makes getting good results more difficult. Their use is better in anaerobic pits or lagoons to reduce the organic matter producing CH_4 (sowing of methanogenic bacteria is more efficient and sensitive to pH and temperature). High efficacy but frequent re-sowing has to be carried out.
    - Promotion of natural strains by adding carbonate substrates (increased C:N ratio). This effect is based on the use of ammonia as a nutrient, but natural strains of bacteria need a sufficient source of C to develop an efficient synthesis process, changing ammonia on the organic N of cell tissue. Re-sowing has to be carried out too, to avoid reverting to the starting point. They are not hazardous and no significant cross-media effects have been reported.
  - Some biotechnological agents, containing a selected sorbent, adsorb odour substances or other harmful gaseous catabolites of organic matter decomposition.

According to their nature, biotechnological agents can be applied to feed or drinking system, litter, floor or under slats.[287, Jelínek et al. 2007]

Of all the additives described, those aiming at changing the physical properties of the manure to make it easier to handle, in particular biological agents, are commonly used at the farm level, and give in most cases a positive effect. These additives are not hazardous. Their use results in an increase in manure flowing, elimination of superficial crusts, reduction of soluble and suspended solids and a reduction in the stratification of the manure. However, these effects were not demonstrated in all, comparable, cases. Moreover, since the manure is more homogeneous, it facilitates the manure's agricultural use (i.e. allowing for better dosing).

New biotechnological agents are marketed to reduce ammonia and greenhouse gases, but their efficacy is controversial and should be verified on a case-by-case basis. [287, Jelínek et al. 2007] The way these additives function is not well investigated. [561, Flotats et al. 2004]

A summary of the main characteristics reported for the different groups of manure additives is given in Table 4.186.

Table 4.186: Summary of the main characteristics for different groups of manure additives

Type of additive	Characteristics	Advantages	Disadvantages
Masking agents	Aromatic oils with strong odour that masks manure's odours	• Quick effectiveness • Low cost • Simple and safe to use	• Short-term efficiency and not predictable • No effect on ammonia
Blocking/Neutralising agents	Aromatic oils that neutralise the volatile compounds causing odours	• Effectiveness relatively quick • Simple and safe to use	• Highly variable efficacy, difficult to reproduce • No effect on ammonia
Absorbing agents	Compounds with high surface area that absorb odorant compounds	• Can reduce odour under specific circumstances	• Highly variable efficacy
Chemical additives	• Oxidising agents • Precipitating agents • pH control agents • Electron acceptors	• Can reduce emissions of some compounds	• Can have undesirable effects on other compounds • Occasionally, dangerous products or difficult to manipulate
Microbiological agents	Bacterial populations degrading the organic substances	• Can reduce odour and gaseous emissions • Can reduce crust formation and improve fluidity • Can transform ammoniacal-N into organic-N • Can improve efficiency of solid/liquid separation of slurry	• Very variable efficacy, not reproducible • Efficacy on-farm not as good as in laboratory trials
Source: [561, Flotats et al. 2004]			

Additional equipment for distributing and mixing the products might be required.

Applicability
In most cases, additives can be used in existing or new farms with no technical restrictions.

Economics
Costs may vary widely, ~~but most of the commercial products sold nowadays are between EUR 0.5 and 1 per pig~~ depending on the type of additive. Estimated costs are reported from EUR 5 to EUR 30 per fattening pig; while others studies report levels of EUR 0.25 – 1.25 per fattening pig. [561, Flotats et al. 2004] In general, the operational costs are typically equivalent to the price of the additive; therefore, they are easy to calculate in each case.

Driving force for implementation
This technique is easily applicable and helps farmers to reduce ammonia and sometimes odour emissions, mostly at the landspreading stage, but also during housing and storage.

In general, the benefits of manure additives, compared to "end of the pipe" solutions, are that a better indoor air quality is provided to both the animals and farmers and, at the same time, are relatively easy to implement in existing housing. [499, AgroTech 2008]

As problems with slurries are influenced in some way by microbial mediated processes, manipulation of these processes by bacterial/enzymic agents may be an effective means of control.

Example plants
There are many commercial products registered in the EU. Many farms in different Member States use them routinely ~~as routine~~.

In Czech Republic, about 35 tested biotechnological agents are offered as manure additives. [287, Jelínek et al. 2007]

From a survey carried out in 2011, it is reported that two farms in Belgium use manure additives (excluding pH regulators), 500 farms in the UK use additives in the form of bacteria and enzymes in livestock manure (assuming 10 % of them to be pig farms and 90 % cattle farms) and 20 farms in France use additives especially in response to odour problems. [595, Agro Business Park 2010]

Reference literature
[405, Tengman C.L. et al. 2001] [560, IGER 2000] [287, Jelínek et al. 2007] [561, Flotats et al. 2004]

4.13 Techniques for the reduction of emissions from the application of manure to land

THIS SECTION HAS BEEN RE-ARRANGED; SOME PARAGRAPHS HAVE BEEN MOVED AND NO LONGER APPEAR IN THE ORIGINAL POSITION. SOME TEXT (REPEATING CONCEPTS OR PROVIDING OUTDATED INFORMATION) HAS BEEN DELETED

The landspreading of slurry and solid manure and the irrigation of dirty water are commonly applied techniques. Slurries and solid manures are valuable fertilisers but may also be potential sources of pollution. Mineral elements contained in the manure can be lost as emissions, if the application of manure is not properly done.

The available amount of effluent and its composition ~~and concentrations~~ can be adjusted ~~reduced~~ by the application of nutritional techniques and by the efficient use of water (Sections 4.3 and 4.4). Landspreading is generally the last stage of manure handling and represents a crucial step in maintaining the benefit of techniques applied upstream to control emissions.

Seasonal timing of manure application to correspond to crop needs, i.e. when nutrient uptake is maximised, is as important as the equipment or technology applied for landspreading. [590, BATFARM 2012]

In addition, soil characteristics and conditions nearby water courses ~~water streams presence~~ and climate features, are all fundamental factors to consider.

However, since NH_3 emissions occur at the soil surface before the applied N has entered the soil, ~~pool of soil mineral N.~~ specific abatement measures are needed to reduce ammonia emissions, such as application by injection and fast incorporation. [337, Webb et al. 2005]

National Codes of Good Agricultural Practice (COGAP) are required by the Gothenburg Protocol (see Section 1.4.1) to reduce emissions of acidifying and ozone producing gases, in particular to reduce NH_3 emissions. Codes should take into account local soil conditions, manure types and farm structures.

The knowledge of the real load of nutrients contained in the manure is another crucial factor in limiting the unnecessary fertilisation. Published values provide useful indications ~~but for massive applications, farmers must rely on~~ whilst sample analysis is expensive and not always provides accurate figures, being largely affected by the sample representativity. Technologies are developing to improve the capability and transportability of the ~~analysis~~ analytical instrumentation, or even for on-farm instant reading. Within these new technologies, NIRS (near infrared reflectance spectroscopy) and conductivity meters are the most promising [251, ADAS 1999] and are now commercially available already used for on-farm testing of slurries in the UK.

To ensure that the intended amount of nutrients contained in the slurry and solid manure has been applied to the crop, it is important that the machinery used to apply manure is chosen, calibrated and operated to give accurate application. This means that it should be suitable for being set up to apply the intended rate of manure in m^3/ha or tonnes/ha, and achieving an evenly spread pattern. [390, ADAS 2001]

Techniques to reduce the emissions from landspreading could be divided into two categories:

- **techniques that reduce ~~the~~ emissions that occur during** the landspreading activity; ~~these are predominantly~~ mainly air emissions (ammonia and odour) and noise

- **techniques to reduce ~~the~~ emissions after** or as a consequence of landspreading; ~~this~~ these concern~~s~~ emissions to soil, to~~ and~~ surface water and groundwater (N, P, etc.), and to some extent to air.

4.13.1 Balancing the spreading of manure with the available land and soil/crop requirements

Description

Essentially, emissions from manure application to soil and groundwater can be prevented by balancing the application rate with the requirements of the soil expressed in terms of the capacity of nutrient uptake by soil and vegetation.

Nutrient uptake by soil and vegetation is a complex ~~phenomenon~~ process and depends on the soil and weather conditions during application, the season and the type of grass or crop that is grown. Ideally, to prevent the application of excess nutrients, no more manure should be applied than soil/crop requirements allow. Given a certain nutrient concentration and manure volume, a crop/soil combination should be determined whose requirements match the amount of nutrients available. In other words, ~~maximum application rates for N and P may change certain types of land use or~~ a certain type of land use may have an impact on ~~the~~ livestock production (including numbers of animals that can be reared), or the other way around, a maximum manure application is determined for a given crop requirement. In addition, attention should be paid to the organic-N already present in the soil, which is not necessarily released during the cropping season, in order to avoid an excessive supplement of manure which would add N in excess.

Achieved environmental benefits

~~It is difficult to quantify the effect of the use of the soil nutrient balance.~~ The aim of soil nutrient balance is to avoid having an increasing excess of nutrients in the soil from the application of manure. Sometimes it is possible to deliberately cause a temporary excess of a nutrient, such as P, to make it available to crops to be grown on the same land.

Balancing the nutrients can reduce the environmental costs from soil and groundwater being contaminated by extended periods of application of excess nutrient levels.

Cross-media effects

If it results in lower application concentrations, the use of a soil nutrient balance will also affect other emissions associated with manure application, such as air emissions (ammonia).

Operational data

Tools ~~(see also Section 2.8)~~ that can be applied for balancing the manure spreading with the available land are:

- a soil nutrient balance
- a rating system, i.e. rating the number of animals on ~~to~~ the available land.

The nutrient balance calculates the difference between the total input of nutrients into the soil and the total output of nutrients. Various tools have ~~A universal model has~~ been developed to calculate the amounts ~~this balance for national purposes. This shows any excess~~ of nutrients (N and P) applied and to give ~~gives~~ an indication of the efficiency of nutrients use. ~~in the agricultural sector. The calculation has inputs for~~ Calculations consider as nutrient input the soil buffer, the use of mineral fertiliser, manure and other organic wastes, the atmospheric deposition of N and biological N-fixation, as well as crop use.

The application rate is the ratio between the concentration of nutrients in the manure and the manure volume, and the area available for landspreading (kg/ha per year). Typically, in pigs and poultry manure, the ratio between P_2O_5 and N content is roughly equivalent to the ratio of typical crop demand for these nutrients.

In most Member States, informative systems are in use ~~An example is the 'Tried & Tested Nutrient Management Plan' in use in the UK. that is a tool~~ to guide farmers in making effective 'fertilising plans', ~~planning~~, calculations, reporting, inventory and simple record keeping to manage nutrients in soils down to the field level. ~~The management is targeted with indications given in the 'Fertiliser Manual' on the~~ Nutrient recommendations for crops and grass are also available. ~~This~~ These tools are ~~is~~ typically used to meet NVZ compliance in interested areas and are mandatory in some Member States for legal reporting.

An example of tool used for determining a proper balance between manure spreading and available land is in use in the UK, the 'Tried & Tested Nutrient Management Plan'. It consists of a tool to guide farmers in making effective planning and simple recording to manage nutrients in soils. [336, UK 2010] It is complemented by a decision support system that can accurately predict the fertiliser nitrogen value of applied manures on a field-specific basis, taking into account the manure type, composition (total N, ammonium N and uric acid N), soil type, application season and technique, ammonia and nitrate losses, and organic N mineralisation. It can be used either before applying manure, to check the likely effect of a spreading policy, or to assess the actual fertiliser N value of a spread manure using manure application details and weather data. Another tool in use in the UK is called 'PLANET', a nutrient management software tool available for farmers. It consists of several modules that carry out different calculation, record keeping and reporting functions.

Rating the number of animals to the available land is a more pragmatic approach, and is applied in, for example, Italy, Portugal and Finland. The EC has calculated the N balance and Nitrogen Production Standards for different animal categories and has presented this in the given reference: [558, EC 1999]. In Table 4.187, an example is given for maximum allowable number of animals per hectare of land, calculated on the basis of 'standard' emission factors for nitrogen (kg N/ap/yr), applied in the EU and a maximum load of nitrogen per hectare of soil equivalent to 170 kg N/ha (Nitrate Directive).

Table 4.187: Calculated maximum allowable animal number per hectare

Type of livestock	Maximum allowable number of animals per hectare to comply with the EU limit of 170 kg N/ha
Sows with piglets (till 25 kg)	5.3 – 8.1
Fattening pigs (25-105)	13 – 23
Laying hens	207 – 486
Broilers (1.8 kg)	327 – 739
Ducks (3.3 kg)	175 – 415
Turkeys (13 kg)	101 – 189
Source: [558, EC 1999]	

Applicability
The nutrient balance is used to calculate national scenarios on necessary reductions of nutrient inputs from manure (and other sources). It can provide data for recommendations on policy instruments for reducing nutrient loads. These recommendations will affect the application of techniques used to reduce nutrient concentrations and will encourage the development of new application techniques.

The administration of minerals is conducted in at least one Member State and can be considered as a system derived from the nutrient balance but to be used at the ~~a~~ farm level. Its application would require ~~need~~ a detailed knowledge of the amounts of feed, the concentration of the nutrients, the characteristics of the animals' production, and an analysis of the manure output. This kind of administration is applied on-farm, but one of the drawbacks is considered to be the amount of administrative work and the time required to keep record of all the data.

Rating the number of animals to the available land is a more pragmatic tool.

Economics
Costs can be approached in two ways: (1) costs associated with the administrative tasks of the application of a mineral balance on-farm and (2) costs associated with the effects of applying the mineral balance, in terms of amounts of manure to be distributed elsewhere. Costs in the second category were estimated to increase by 60 % under the application of CAP 2 000 and the mineral balance.

Driving force for implementation
In several Member States ~~the Netherlands~~, the application of a mineral balance has been made obligatory by legislation. The designation of nitrate vulnerable zones (NVZ) as defined in the Nitrate Directive (91/676/EEC) and increasing economic and environmental pressures ~~has~~ promoted an increased use of nutrient balances (N-balance).

Concerning phosphorous, it is likely that the implementation of Programmes of Measures under the Water Framework Directive (2000/60/EC) will require action in some drainage basins, to reduce phosphorus and this may result in further restrictions on manure spreading. [204, IMPEL 2009]

Example plants
This type of management appears to be common all over Europe. In the Netherlands, a mineral balance system is applied. In the UK, the 'Tried & Tested Nutrient Management Plan' is in use. In France, the national regulation requires farmers to manage their fertilisation by using a proper fertilising programme. In Denmark, a system where each farmer has to report his plans for fertilising the field in the coming growing season is used. Several software systems can be used for computing the "fertilising plan'.
The rating of the number of animals to the available land is applied in different countries (e.g. Italy, Portugal and Finland).

Reference literature
[555, MAFF 1998], [44, IKC 1993] [558, EC 1999] [249, Webb et al. 2001] [500, IRPP TWG 2011]

4.13.2 Groundwater protection schemes

Description
The main components of a groundwater protection scheme ~~as applied in Ireland~~ are:

- a land surface mapping to display the ~~vulnerability of an area to contamination; i.e. the definition of~~ groundwater sources and resources (aquifers), which together define groundwater protection zones
- the groundwater protection responses for ~~of a location to~~ ~~the~~ potentially polluting activities, depending on factors such as risk (hazard) and aquifer category.

Achieved environmental benefits
By defining the vulnerability of an area, the contamination of groundwaters by N, P, K, microbial pollutants or metals is prevented. The schemes are considered ~~as~~ tools that can direct ~~the~~ landspreading (e.g. advise on distances to vulnerable zones) to less vulnerable areas and define the appropriate landspreading management.

Cross-media effects
The application of groundwater protection schemes is likely to restrict the land surface area where application of manure is allowed, and by doing so may lead to manure production levels rising above the amount that can now be applied. If applying groundwater protection schemes it would be opportune to develop a programme in parallel that deals with the possible ways to treat the excess manure, such as on-farm treatment as discussed in Section 4.12.

Operational data
Every case is assessed individually taking into account all local factors in order to reach the best solution, achieve sustainability and match the set standards within the specific area, e.g. different decisions may be necessary if the farm is located within or is impacted by a water protection zone, a decision should be made concerning the technique to apply in order to meet the requirements, taking into account costs and profitability.

Applicability
Groundwater schemes can be applied wherever a potential risk of groundwater contamination exists.

Economics
The economic impact on the activity is related to the individual measures that can or must be applied.

Driving force for implementation
Schemes have been developed in many Member States based on European Water Framework Directive 2000/60/EC, Groundwater Directive 2006/118/EC and national legislation for the protection of groundwater.

Example plants
Groundwater protection schemes are applied in several Member States counties in Ireland.

Reference literature
[23, EPA (UK) 1999]

4.13.3 Manure landspreading management practices

Description
A proper The management of the landspreading of manure takes account of the nutrient balance as well as and surface water and groundwater protection schemes. It combines all of the following aspects:

- application on suitable areas
- defining and observing buffer zones
- proper timing of application
- defining of spreading rate.

Codes of practice advise advice setting up an application plan and distinguishing between different planning stages [386, DEFRA 2009].

In the first stage, suitable areas are selected. Land is excluded, where manure should not be spread at any time or where there is a considerable risk of run-off, such as (very) steep slopes and surroundings sensitive to smell. Buffer zones should be defined and observed, in particular to avoid contamination of watercourses or the farmyard. Specific rules apply, such as minimum distances (50 – 100 m) to springs, wells or boreholes. These distances increase when the springs or shallow wells are downhill. Decisions at this stage may benefit from the recent developments in soil testing and field mapping.

In the second stage, the amount of nutrients supplied by the manure must be matched with the capacity of the land it is applied to and the needs of the crop to be grown. Determination of the spreading rate (kg/ha or m^3/ha) should be matched to the based on amount of land availability, crop (or grass) requirements of the crop (or grass) to be grown, and the amount of nutrient in the slurry, taking into account the nutrient status of the crop and other organic manures and chemical fertilisers applied. In most reports, reference is made to the leaching of nitrate and a maximum of 250 kg of total N/ha from manure per year is recommended for land outside NVZ. This amount can be lower where phosphorus amounts are a limiting factor.

The third stage optimises application timing by estimating estimates the risk of pollution from spreading and aims to minimise run-off, according to the characteristics of the land concerned, in particular soil and climatic conditions (e.g. spreading when it is cooler (evening), more humid and less windy, before or during light rain). [508, TFRN 2012]

Achieved environmental benefits
A management system for timing the landspreading operations, recording solid and liquid manure application at different times, results in quantifiable farm-scale reductions in ammonia emissions.

The planning of the application of manure reduces emissions of odour, loss of nutrients due to leaching, and run-off.

Potential emission reductions achievable through these measures will vary depending on local soil and climatic conditions and, therefore, measures that may be included in the management system for manure application will be specific to local conditions. [508, TFRN 2012]

Cross-media effects
~~No negative counter-effect has been individuated.~~
Individual manure management strategies may present some adverse effects when mitigating one pollutant, with possible shifting from one environmental media to another or increased emissions of other pollutants.

Safety aspects associated with machinery operations carried out at certain times, particularly during hours of darkness, should also be considered.

Operational data
The timing of the application aims at further optimising the use of the available nutrients in manures. Soil, weather conditions and the crop growing season must be taken into account when planning the application.

Soil conditions
Land with a very high risk of run-off (water-saturated, snow-covered, frozen, flooded areas, watercourses, etc.) should be avoided. Limits to the spreading rate are suggested at 50 m^3/ha for slurry and 50 tonnes/ha for dry manure (UK) to high-risk land. For poultry, this usually means 5 – 15 tonnes/ha. Manure should not be applied on snow-covered and hard frozen fields, on fields that are cracked, or on fields that have been drained within the last year.

As an example for UK conditions, the application of 50 m^3/ha of pig slurry with 4 % of dry matter, containing 4.0 kg/m^3 of total N, will supply 200 kg/ha of total N. If this is applied in December to the surface of an arable land on a heavy-textured soil, it would provide 80 kg/ha of N (i.e. 40 % of 200 kg/ha total N) for the nitrogen requirement of the crop that will grow towards spring. If the same amount of slurry, with the same characteristics is applied on a sandy soil, the amount of available nitrogen for the next crop would be 50 kg/ha of N (25 % of 200 kg/ha total N). [389, ADAS 2001]

Weather conditions
The application of manure should be avoided in periods that are too dry and windy, such as in the summer months. However, in some areas where heavy winter rains occur, the soil has a reduced bearing capacity and will compact faster in those periods, so the drier season needs be taken advantage of. Ammonia emissions can be reduced by optimising the timing of application, i.e. cool and humid conditions, in the evening and night, before or during light rain (though water-logging of soils can make spreading conditions unfavourable) and by avoiding spreading during warm weather conditions. [508, TFRN , 2012]

Crop growing season
Manure should be spread as shortly as possible before maximum crop growth so that a maximum nutrient uptake will occur.

Results of studies, carried out in UK to investigate the timing of manure application on free draining soils and for different types of plants, have concluded the following:

- For winter cereals, N leaching losses, for the application in autumn of pig slurry to cropped land, were equivalent to 19 – 20 % of total N applied, which indicates a lack of crop N uptake (by the winter wheat crops). Compared with autumn timings, spring application timings are likely to give the highest amounts of crop N uptake and, consequently, the lowest amounts of diffuse N pollution by nitrate leaching. However, different soil conditions, such as water-saturated arable soils in spring and ‘dry’ grassland soils in summer, may potentially lead to increased ammonia emissions, because infiltration rates into the soil are lower than at other times of year, but also because warmer temperatures increase ammonia emissions. Most commonly, slurry applications are limited to the period between February and May, due to potential crop damage and reduced crop N uptake.
- On grassland, spring slurry applications before silage harvest (first cut) are likely to cause the least diffuse pollution from N compounds, because the risks of nitrate leaching losses are low and crop N uptake will be the greatest, reducing the soil mineral N pool available for nitrous oxide production. However, slurry applications to short grass swards in summer are likely to lead to elevated levels of ammonia emissions compared with autumn to spring application timings. [244, ADAS 2006]

In another study, carried out by using a tool called 'MANNER' simulating UK conditions (e.g. rainfall, soil and crop conditions), results suggest that, in order to avoid an increased NO_3^- leaching from conserved NH_4-N in the manure, as a consequence of measures to reduce NH_3 emissions, manures and slurries should not be incorporated prior to autumn-sown crops, but should be applied from October onwards to grassland and where possible, to late autumn-sown combinable crops, or, to arable land which will be planted in the spring. Additional conclusions of the study propose that manure from laying hens and broilers should not be incorporated before October, on any type of soil. If increased NO_3 leaching was to be avoided, incorporation would need to be delayed until January on most soil types, and until early March on light soils in wet areas. [249, Webb et al. 2001]

Of the many complaints about unpleasant odours from farms, most relate to landspreading. The following points should, therefore, be considered before spreading:

- respect the recommended or mandatory timing set by local rules, and avoid spreading when people are more likely to be at home, unless it is absolutely necessary;
- pay attention to wind direction in relation to neighbouring houses;
- avoid spreading under warm humid conditions;
- use spreading systems which minimise the production of dust or fine droplets;
- apply a light cultivation of land within 24 hours after the application of manure.

Applicability
The management of manure application can be applied without any limitation or requirements. The planning of manure application should play a role in the planning of new units and should consider any limitations that already exist.

Economics
In order for farmers to comply with an application management plan, which will result in increased efficiency of slurry N utilisation and a reduction of emissions (nitrate leaching, ammonia and/or nitrous oxide emissions); extra storage capacity is required to enable them to programme more spring and fewer autumn/early winter application timings. In addition, improved spreading equipment, in particular for slurry application, will be necessary (e.g.

bandspreaders), so that slurry can be applied evenly to growing crops in spring with minimal soil compaction and crop damage to optimise N utilisation. [244, ADAS 2006] From UK in particular, costs associated with an application management plan, based on the use of broadcast spreaders and designed to avoid autumn/winter slurry applications, are presented in Table 4.188.

Table 4.188: Costs for implementing spring slurry application practices in a typical pig farm in UK in order to limit nitrate leaching losses

Parameter	Investment costs	Annual amortised costs (2)	Remarks
	EUR (1)	EUR/year (1)	
Extra storage capacity	50 000	3 980	Assumed slurry storage costs: EUR 40/m^3. Annual amortised repayment costs based on an interest rate of 5 % over a 20 year period
Slurry tanker fitted with a trailing hose boom	28 400	3 700	Annual amortised repayment costs based on an interest rate of 5 % over a 10 year period
Total cost		7 680	
Savings in fertiliser N applications (2)		465 – 750	Based on a N fertiliser cost of EUR 0.34/kg
Net cost		*~ 9 600*	*Amortised over 10 – 20 years*

(1) Costs calculated at the exchange rate of EUR/GBP = 0.88.
(2) Savings in N chemical fertiliser applications, resulting from reduced nitrate leaching losses in spring, compared with autumn/winter application timings and from reduced ammonia emissions from band spread.
Source: [244, ADAS 2006]

Driving force for implementation
Requirements for compliance with existing legislation and Codes of Good Agricultural practice.

High fertiliser prices, improved handling and spreading equipment, improved awareness and knowledge of farmers and advisers, facilitate better planning and use of manure as a fertiliser during landspreading. The improved nitrogen availability through a proper manure utilisation makes the investment in low-emission spreading equipment the best solution from an economic point of view. Once the benefits become evident, measures related to a proper application management plan tend to be adopted routinely.

Legal procedures from neighbouring residential areas and fines for pollution of watercourses can be avoided by properly planning the application

It is considered that planned manure application can save costs rather than generate costs. Legal procedures from neighbouring residential areas and fines for pollution of watercourses can be avoided by properly planning the application.

Example plants
~~Some farms in the UK and Ireland apply~~ 'Codes of Good Agricultural Practice' describing farm waste management are commonly applied.

Reference literature
[554, EPA (IE) 1998], [31, MAFF 1999] [386, DEFRA 2009] [389, ADAS 2001] [390, ADAS 2001] [244, ADAS 2006]

4.13.4 Manure application systems

4.13.4.1 Use of low-emissions manure (solid or liquid) application techniques ~~Basic systems~~

Description
Different application techniques are used for solid manure and for slurry. Generally, their use is followed by incorporation of the manure (solid or liquid), except for the direct-injection techniques used for the application of slurry.

Application of solid manure
Section 2.8.3 describes the following three main types of spreaders used for spreading solid manure:

- rota spreader: a side discharge spreader with a rotor that throws the solid manure out to the side, while spinning
- rear discharge spreader: a trailer body fitted with a moving floor or other mechanism which delivers solid manure to the rear of the spreader. The spreading mechanism can have either vertical or horizontal beaters, plus in some cases spinning discs
- dual purpose spreader: a side discharge spreader with an open top V-shaped body capable of handling both slurry and solid manure.

The latter two show much better performances in getting an accurate and even spread distribution. However, for reducing ammonia emissions from landspreading solid manure, the important factor is not the technique on how to spread but the incorporation.

Application of slurry
Nitrogen is preserved better during the storage and spreading of liquid manure than in the solid manure handling chain. Ammonia losses mostly occur immediately after spreading.
The following slurry application systems are applied (see also Section 2.8):

- low-pressure broadcast spreader
- band spreader
- trailing shoe
- injector (open slot)
- injector (closed slot)
- high-pressure injection
- irrigator.

The low-pressure broadcast spreader and the techniques described in Sections 4.13.4.2, 4.13.4.3 and 4.13.4.4 ~~Techniques 1 to 5~~ are spreading systems for slurry that can each be fitted onto a vacuum tanker or pumped tanker or used with an umbilical system as described in Section 2.8.

The low-pressure broadcast spreader consists of a tanker equipped with a discharge nozzle and splash-plate applicator. It spreads the slurry over the whole soil surface ("broadcast") and is considered the reference (baseline) for assessing emission reduction efficiencies from slurry application performed with other techniques, when not followed by quick incorporation [508 , TFRN, 2012]. This technique does not significantly contribute to lower ammonia losses; in addition, if slurry is applied in a growing arable crop, incorporation is not possible. [35, NL 2010]. Due to the above mentioned characteristics, the technique is not discussed any further in the next sections.

High-pressure injection forces the slurry into the soil under pressure, without breaking the soil by tines or discs. The technique does not seem to have gained wide application; therefore, it is not discussed in the next sections.

Acidification of slurry, prior or while spreading, is also applied using standard equipment. (see Section 4.12.9).

A summary of the main characteristics of the slurry distribution systems (excluding irrigators because of the lack of data) is presented in Table 4.191 and a few notes are added in the text.

Achieved environmental benefit
Each technique has its limitations and is not applicable in all circumstances and/or on all types of land. Techniques that inject slurry show the highest reduction, but techniques that spread slurry on top of the soil followed by incorporation shortly afterwards can also achieve a high reduction. [35, NL 2010]

Achieved levels of emissions reduction by applying different techniques are considered to be very site-specific and vary according to the slurry dry matter content, the prevailing weather conditions, the soil type and the crop conditions, but mostly by the nitrogen application rate.

In the case of slurries, the dilution has an important influence on ammonia losses. It is considered that from a 6 % DM slurry, nitrogen emissions are typically 20 % higher more than from a 2 % DM slurry. Reduced losses from low DM slurries are associated with more rapid infiltration into the soil, compared with high DM slurries which remain longer on the soil or plant surface. [389, ADAS 2001]

Techniques for landspreading of solid manure, in general, do not influence ammonia emissions. Incorporation by ploughing or harrowing after application reduces ammonia losses by burying the majority of manure. [441, Webb et al. 2011]

Cross-media effects
The use of heavy equipment causes soil compaction and damage, with consequent potential risk for water pollution, especially in late winter/early spring.

Surface broadcasting is typically uneven, especially under windy conditions and may also damage grass swards and contaminate crops with microorganisms that can impede silage fermentation. [440, Webb et al. 2010]

Techniques that reduce NH_3 emissions may induce an increase in N_2O emissions, due to the higher rate of nitrogen entering the soil and less aerobic conditions (deeper and wetter soils). However, under some circumstances, such increases do not inevitably occur. [440, Webb et al. 2010]

Operational data
The conditions during slurry application ~~very much~~ affect the performance of the techniques. Ammonia abatement efficiencies vary depending on:

- ammonia volatilisation. – It may be reduced by minimizing exposure of the manure surface to air and by increased contact with the soil.
- the slurry dry matter content. Dilution of the slurry, or separating the solids reduces NH_3 emissions. It is considered that from a slurry with 6 % of dry matter (DM), ammonia emissions are typically 20 % higher than those from a 2 % DM slurry. Reduced losses from low DM slurries are associated with faster infiltration rate into the soil, compared with high DM slurries which remain longer on the soil or plant surface. [389, ADAS 2001]. Dilution requires ~~needs~~ water and creates a larger volume to be applied, whereas removing solids requires the handling of a solid fraction and a liquid fraction as well. The higher the accuracy of application, the lower the dry matter content of the slurry can be, thus requiring chopping or separation to some extent before the slurry can be applied. Injection or incorporation of manure minimises exposure to the air.
- the prevailing weather conditions. Ammonia emissions increase with increasing air temperature, wind speed, solar radiation [508 , TFRN, 2012] [440, Webb et al. 2010]

- the soil type. Well draining and dry soils, which allow faster infiltration, will give rise to lower emissions than wet soils with reduced infiltration rate. However, some soils may become hydrophobic when very dry, which can also reduce infiltration and therefore increase emissions. [508 , TFRN , 2012]
- the crop conditions. Spreading slurry with trailing hoses to crops reduces ammonia losses compared with application to bare soil, because crop restricts solar heating and wind speed, and a certain proportion of the volatilized ammonia can be absorbed by the crop. Crop height is important mainly in band spreading in cereal crops, having significant height. In contrast, slurry application to grass crops takes place in early spring or immediately after cutting. At these times, the grass crop height is so short that the crop does not influence volatilisation of ammonia from the applied manure. [442, Hansen et al. 2008]
- nitrogen application rate. Ammonia emissions are normally increased with increasing total ammoniacal nitrogen (TAN) concentration and application rate. The level of emission also varies from different manure types. [508, TFRN 2012]

The application of solid manure is always followed by incorporation. Even short delays (4 – 6 h) in incorporating the manure after application reduce the efficacy of controlling ammonia emissions. Hence incorporation should be done as soon as possible (see Section 4.13.5). [440, Webb et al. 2010]

Other factors that may influence ammonia and nitrous oxide emissions following solid manure spreading are:

- Higher application rates, increasing the proportion of N lost as ammonia.
- Climatic conditions, such as air temperature, radiation, wind speed and rainfall may affect emissions. Ammonia losses are expected to increase with increasing temperature. However, crusting of the surface layer of manure at higher temperatures may reduce emissions. Formation of N_2O increases with temperature.
- Rainfall is a parameter which influences NH_3 emissions in a contradictory way. On one hand, due to NH_4–N leaching from manure to the soil less ammonia is emitted but, on the other hand, due to increased hydrolysis of uric acid to NH_4^+, more NH_3 can then volatilise.
- While no influence of soil type on NH_3 emissions from solid manure has been demonstrated to date, N_2O emissions from agricultural soils were found to be higher from fine soils than from coarse-textured soils. Nitrous oxide production can increase with increasing soil moisture. However, increasing soil moisture and decreasing temperatures (e.g. over the winter period) are expected to favour the reduction of N_2O to N_2.

The energy that tankers need to transport the manures depends on volumes and on soil condition and slope.

Applicability
A number of factors must be taken into account in determining the applicability of each technique. These factors include:

- soil type and condition (soil depth, stone content, wetness, travelling conditions)
- topography (slope, size of field, evenness of ground)
- manure type and composition (slurry or solid manure)
- crop type and its growth stage.

Economics
Costs of landspreading techniques are in the range of 0.1 – 5 EUR/kg NH_3-N saved, with the lowest costs corresponding to application with immediate incorporation. Costs are very sensitive to farm size, and whether or not specialist contractors are involved. [601, ALTERRA, IIASA 2012][508, TFRN, 2012]

The investment costs of slurry spreading systems vary considerably depending on the specifications for each machine, whether they have hydraulic/electric controls, single/double/triple axles or other extras. Slurry tankers constructed to take attachments will have a stronger chassis or special brackets fitted compared to standalone slurry tankers.

Example of cost data, estimated in UK and Germany, in relation with reduction rates of ammonia emissions, and expressed as value of extra-N uptake due to conserved nitrogen (bonus), are presented in Table 4.189. The value of the conserved nitrogen (bonus) depends on fertiliser prices and ammonia abatement efficiency. A reduction technique is cost-neutral if the reduction costs are identical or lower than the amount of the corresponding bonus. The estimations have been made in comparison with the use of a broadcast spreader, assumed as the reference technique.

Table 4.189: Bonus for conserved nitrogen, achieved by applying low-emission spreading techniques for slurry

Technique	Example from Germany		Example from UK	
	Associated NH_3 emission reduction	Bonus	Associated NH_3 emission reduction	Bonus (1)
	(%)	(EUR/m^3 slurry)	(%)	(EUR/m^3 slurry)
Trailing hose	30	0.27	40	0.53
Trailing shoe	50	0.45	65	0.85
Open slot injector (discs)	60	0.54	80	1.07
Closed slot injector (cultivator)	90	0.81	-	
Immediate incorporation	-	-	95	1.27
Incorporation within 1 h	90	0.81	-	-
Incorporation within 4 h	70	0.63	-	-
Source	[575 , UBA , 2011]		[254, Webb J.M. et al. 2009]	
(1) Values are calculated at the exchange rate of EUR/GBP = 0.88.				

Costs for the spreading of slurry and associated ammonia emission reduction costs depend on the equipment used, the exploitation of its capacity for slurry application and the farm size. In Table 4.190, cost data reported from Germany, related to the spreading of slurry, are presented for different spreading and incorporation technique and farm size.

Table 4.190: Costs for slurry spreading and associated ammonia emission reduction costs for different application techniques and farm size, in Germany

Farm size and characteristics						
Annual process capacity (m^3/year)	1 000	3 000		10 000	30 000	100 000
Characteristics	Single farm, with necessary equipment	Slightly larger farm or a cooperative of smaller farms, using the equipment cooperatively		A cooperative or a larger farm	Contractors and large farms	
Process capacity (m^3/h)	low	high	low	low	-	-
Spreading costs (EUR/m^3 slurry)						
Broadcast spreader ([1])	6.61	3.22	4.31	3.04	3.19	2.49
Trailing hose	8.76	3.99	5.08	3.38	3.32	2.57
Trailing shoe	9.68	4.63	5.87	4.11	4.10	-
Open slot injector (discs)	9.97	4.89	6.16	4.37	4.67	2.89
Closed slot injector (cultivator)	10.38	5.71	7.49	4.96	5.30	3.04
Incorporation within 1 h	7.43	4.04	5.13	3.86	4.02	3.31
Incorporation within 4 h	7.10	3.71	4.80	3.53	3.69	2.98
Dilution with water 1:1	*11.1*	*6.08*	*8.81*	*6.49*	*5.95*	*4.4*
Ammonia emissions reduction costs (EUR/kg NH_3)						
Trailing hose	8.80	3.16	3.16	1.42	0.50	0.34
Trailing shoe	6.29	2.89	3.20	2.20	1.86	-
Open slot injector (discs)	4.60	2.28	2.53	1.82	2.02	0.55
Closed slot injector (cultivator)	3.43	2.27	2.89	1.75	1.91	0.50
Incorporation within 1 h	0.75	0.75	0.75	0.75	0.75	0.75
Incorporation within 4 h	0.81	0.81	0.81	0.81	0.81	0.81
Dilution with water 1:1	*7.37*	*4.69*	*7.37*	*5.65*	*4.52*	*3.13*

([1]) Reference system.
Source: [575 , UBA/KTBL, 2012]

Driving force for implementation

High fertiliser prices, improved handling and spreading equipment, improved awareness and knowledge of farmers and advisers, facilitate better operativity and manure utilisation.

Reduced ammonia losses result in a reduced use of expensive chemical fertilisers. Therefore, the improved nitrogen availability makes more profitable the investment in low emission spreading equipment.

Compared to broadcasting spreading, these techniques minimise the occurrence of herbage contamination; this is particularly relevant for grassland, where slurry contamination can reduce grazing palatability or silage quality and may transfer pathogens between farms if manure or equipment is shared.

These techniques also allow slurry application on growing arable crops (particularly cereals), which, in general, are not suitable to receive slurry applied by broadcast spreader (splash plate). [601, ALTERRA, IIASA 2012]

The use of low-emission techniques can increase flexibility of slurry application. [601, ALTERRA, IIASA 2012].

Band-spreading and injection techniques considerably reduce the odour associated with manure application; therefore, allowing application on areas or at times that would otherwise be unavailable, due to complaints. [508, TFRN, 2012]

Additionally, band-spreading and injection techniques can allow more accurate slurry application rates than broadcasting (reference technique). [508 , TFRN , 2012]

Example plants
All techniques are applied in Europe.

In the last decade, several animal farmers have outsourced manure application to specialised contracting firms, who use large machines with high capacity in terms of m^3 manure and/or m^2 land applied per man/hour. This has led to considerably lower costs and to the use of available techniques at a much larger scale in many more countries. [601, ALTERRA, IIASA 2012]

Reference literature
[42, Netherlands 1999] [389, ADAS 2001] [390, ADAS 2001] [406, Netherlands 2002] [UNECE, (1999). "Control techniques for preventing and abating emissions of ammonia", EB.AIR/WG.5/1999/8/Rev.1.] [441, Webb et al. 2011] [601, ALTERRA, IIASA 2012]

Table 4.191: Characteristics of four different slurry application techniques

Features	Broadcast spreader	Diluted slurry irrigators	Band spreader (Trailing hose)	Band spreader (Trailing shoe)	Injector	
					Open slot (shallow)	Closed slot (deep)
Reduction of NH_3 emissions (%)	Reference	30	30 – 50	40 – 65	56 – 80	80 – 90
Land use		Grassland, arable land	Grassland, arable land	Mainly grassland Arable (pre-seeding) and row crops	Arable land, grassland	Arable land, bare soil
Range of dry matter	Up to 12 %	<2 %	up to 9 %	Up to 6 %	Up to 6 %	Up to 6 %
Applicability		Flat land, any cultivation growth stage, size and shape of fields Not applicable where irrigation is not required	Slope (for tankers <15 %, for umbilical systems<25 %), not for viscous slurry or with high straw content, size and shape of fields should be considered, growing crop Can be used on solid seeded crops and wide units may be compatible with tramlines	Slope (for tankers <20 %, for umbilical systems <30 %), not viscous slurry, size and shape of the field, grass height should be >8 cm Not suitable in growing solid seeded crops, but possible use in the rosette stage and in row crops	Slope <12 %, greater limitations for soil type and conditions, not viscous slurry Unsuitable on high stone content; shallow soils; high clay soils (>35 %) in very dry conditions, peat soils (>25 % organic matter content).Tile drained soils susceptible to leaching	(See open slot)
Requires separation or chopping	No	Clarification	Up to 6 % no Over 6 % yes	Yes	Yes	Yes
Relative work rate	●●●	●●●	●●	●●	●●	●
Uniformity across spread width	●	●●●	● (simple) ●●● (advanced)	●●●	●●●	●●●
Crop damage	●●	●●●	●●●	●●●	●●●	●●●
Cost (EUR per kg NH_3-N saved)		0.5 – 1	0.5 – 1.5	0.5 – 1.5	0.5 – 1.5	0.5 – 1.2
Extra costs (EUR/m^3)	-		0.79 – 1.21	0.92 – 1.41	0.7 – 1.1 extra costs compared with trailing hose	0.66 extra costs compared with trailing hose

● Normal (lowest grade)
●● Improved
●●● Advanced (best evaluation)

Source: [42, Netherlands 1999] [389, ADAS 2001] [390, ADAS 2001] [[236, Denmark 2010] [237, Denmark 2010] [238, Denmark 2010] [500, IRPP TWG 2011] [35, NL 2010] [440, Webb et al. 2010] [508 , TFRN, 2012] [575 , UBA , 2011] [387, Denmark 2010] [417 DK not a reference] [419 DK not a reference] [234, Spain 2010] [235, Spain 2010] [236, Denmark 2010] [237, Denmark 2010] [238, Denmark 2010]

4.13.4.2 Irrigators

4.13.4.2.1 Dilute slurry ~~Low-pressure~~ irrigators

Description

Dilute slurry (less than 2 % of dry matter content) can be landspread by water irrigation systems, including rain guns, boom-mounted splash plates, pulse-jet and rotary boom systems.

Moreover, controlled rates of untreated slurry, or the clarified fraction ~~of~~ from mechanically separated slurry, can be ~~are~~ mixed to irrigation waters and applied to grassland or growing crops on arable land. ~~for irrigation, and are distributed at a low pressure by irrigation systems such as pivots and mechanical wings.~~ Slurry is pumped from the stores, injected into the irrigation water pipeline and brought to low pressure sprinklers, pivots or travelling irrigators, which spray the mix onto land. [508, TFRN 2012] These widely used systems only need to be fitted with hanging hoses fitting the nozzles at the proper height to allow sprays to direct toward the soil and not onto plants (see Figure 4.88).

Source: [242, CRPA 2009]

Figure 4.88: Irrigation boom fitted with hanging nozzles to spray slurry-mixed water close to the soil surface

Achieved environmental benefits

Ammonia emissions from dilute slurries, with low dry matter (DM) content, are lower than those from undiluted slurries, due to faster infiltration into the soil which prevents both ~~the~~ ammonia volatilisation and ~~the~~ formation of crusts on the ground. [508, TFRN 2012] The use of intermittent operation may also limit the odour nuisance.

Energy requirement for low-pressure irrigators is low. Reduced soil damage and compaction are achieved.

Cross-media effects

With irrigation systems, the duration of the spreading operation is much longer. Also, the high volumes of dilute slurry applied by irrigation may exceed the infiltration capacity of the soil, leading to higher emission rates in the period immediately after spreading.

Operational data

Emission reduction is proportional to the extent of dilution. A dilution (reduction in dry matter content) of 50 % (1:1 water to slurry) can reduce emissions by 30 %. [508 , TFRN, 2012]. Dilution rates may be up to 50:1 water to slurry. [601, ALTERRA, IIASA 2012] ~~Pig slurry is diluted at 4 %.~~ If the system is properly operated, sprays are directed close to the ground, reducing losses for evaporation and aerosol drifts.

Ammonia emissions ~~emitted~~ during irrigation (before reaching the soil) of ~~the~~ dilute pig slurries (0.5 – 0.9 % of DM) was measured ~~ranges~~ from 0.1 to 2.6 % of the total ammoniacal ~~available~~ N (TAN) applied, with an average of 1.3 %. Emissions are expected to be greater from the raingun than boom-mounted splash plate systems. Emissions following irrigation are estimated of approximately 10 % of the applied TAN. **Moved from Section 2.8**

Applicability
The application is possible at virtually any growth stage, ~~making it possible~~ allowing to achieve a maximised utilisation of nitrogen by plants.

Due to the risk of contamination, this technique would not be appropriate for crops grown to be eaten raw.

The application is often only possible in areas easily connected to farmstead by fixed pipework. The pumping distance is influenced by pump capacity, topography and pipe dimensions; therefore, it may pose an added limitation.

The application of dilute slurry with irrigators should meet crop water needs; otherwise, dilution of slurry would result in increased hauling costs and may exacerbate nitrate leaching.

The technique is not appropriate where irrigation is not required.

Economics
Costs in the range of EUR 0.5 – 1.0 per kg of NH_3 abated. [508 , TFRN, 2012]

Driving force for implementation
The technique can be used where there is a need for water irrigation systems.

Example plants
Red text moved from Section 2.8
It is estimated that approximately 20 % of total pig slurry output in the UK is applied to land by irrigation systems, including rainguns, boom-mounted, pulse-jet and rotary boom systems. The technique of low-pressure irrigators is in common use in UK, particularly for dirty water application. Static sprinklers are used for smaller applications; whereas, travelling low rate irrigators are used for larger applications. Irrigation techniques with sprinkling systems are moderately spread in Italy in farms with anaerobic digestion plants. [240, Italy 2010]

Reference literature
[242, CRPA 2009] [247, IGER 2003]

4.13.4.2.2 Pulse-jet irrigator

Description
A hose is mounted on a rotating arm and delivers a pulse of slurry or dirty water every 30 – 90 seconds over some 60 m along the radius of the circle. The arm rotates in 9 degree steps to give a circular pattern and achieving full coverage over a number of rotations (see Figure 2.42).

About 100 litres of liquid are gradually pumped into a pressure accumulator tank and are discharged when the pressure reaches a pre-set level. The slurry emerges from large jets (49 mm and 19 mm diameter) as a solid stream for about 3.5 seconds and breaks up into large droplets as it passes through the air. Then, the pressure tank refills, the nozzle moves round and the next pulse is discharged, typically about 45 seconds later, depending on the size of pump used.

Achieved environmental benefits
There is virtually no risk of soil compaction and minimal risk of water pollution due to the controlled application to land.

Cross-media effects
The disadvantage of increased aerial emissions compared to low-level placement techniques is relatively low, due to the very large droplet size.

The energy use of the technique is about 0.5 – 0.8 kWh/m^3.

Operational data
The ultra-low application rate (0.1 – 2 mm/hour) and high degree of accuracy allow nitrogen to be supplied to crops when needed. There is virtually no risk of soil compaction and minimal risk of water pollution as the application rate can be kept below the rate of infiltration into the soil, for any soil type (e.g. 4 mm/hour for a clay soil on level ground, and 1mm/hour on a 16 degree slope).

Adjoining circles are overlapped for placing centres at approximately 105 m from one another. A central area of 7.5 m around the machine receives a low application rate and represents the 1.6 % of the full 60 m circle, or the 2 % of the overlapped 52.5 m circle. In the overlapping pattern, small roughly triangular areas which are not fully covered and therefore receive as well a lower application rate for a 1.3 % of the area of the 60 m circle. Both types of area with low application are not considered significant.

Emissions are estimated to be similar or less than any broadcast system (included the dependency on weather and humidity). While the exposure may be greater at the time of discharge, applications well below the infiltration rate reduce emissions by allowing rapid absorption and reducing the time of residence over the ground. The slurry infiltration is also improved by causing very little ground compaction.

The energy use of the technique is also very low at 0.5 – 0.8 kWh/m^3. [246, UK 2010]

Applicability
The irrigator should not be sited closer than 75 metres to any watercourse to allow an effective 15 m no spreading distance. Grassland, cereals, root crops and brassicas are suitable to slurry spreading by this technique at the condition that plants be sturdy enough to stand the large droplet size.

The pulse jet irrigator can handle undiluted pig slurry at up to 5 % dry matter content. It can also be used to apply dirty water. [246, UK 2010]

Due to the risk of contamination, this technique would not be appropriate for crops grown to be eaten raw.

Economics
The approximate total cost of an operating system is between EUR 11 000 and EUR 19 000, varying depending on the system's dimension and capacity. Irrigators cost EUR 4 000 or EUR 8 000, for a coverage of 0.5 or 1.0 hectares respectively. The cost of pumps of a capacity of 3 to 10 m^3 per hour vary from EUR 4 800 to EUR 8 800. Connecting pipe work in medium density polyethylene (MDPE) need to be sized on slurry dry matter content, pumping hour capacity and length of transport. The cost of 1 000 m pipe and fittings for 3 % DM slurry pumped at 6 m^3/hour (that requires 63 mm MDPE main pipe) may cost around EUR 2 400 (values in EUR as per exchange GBP/EUR = 0.88).

Driving force for implementation
The low application rate and high degree of accuracy allow nitrogen to be supplied to crops when needed.

Example plants
Over 700 units have been sold in the UK by one producer over the past 20 years, with numbers varying between 15 and 100 units per year.

Reference literature
[246, UK 2010][552, FIAgrE 2010]

4.13.4.3 Band spreader (or trailing hoses) and trailing shoes

Description
Plastic or rubber hoses hang from a 12 – 28 ~~16 – 24~~ metres wide bar mounted onto the slurry trailer, at a distance of 30 – 50 cm to each other. The bar is positioned at a height so that hoses trail over the soil surface and release ~~the~~ slurry directly onto it, generally, in 5 – 10 cm wide parallel bands (see Figure 4.89). The working width can be as low as 6 m and as wide as 36 m. [575, UBA 2011]

A development of the band spreader is the trailing shoe application system. Trailing shoe spreaders have a working width of 3 to 18 m. The individual trailing hoses are generally situated 16 to 35 cm apart. The difference with trailing hoses is that the outlet of each slurry application pipe is equipped with a special distributing unit, which is usually designed as a shoe-like reinforcement that slides (or floats) on soil surface. The design of the distributor is such that the crops are pushed aside or the herbage is parted more effectively than the hose during the distribution process, even if the hose is very close to the ground. ~~in which a metal shoe parts the herbage. and~~ In this way, slurry is deposited in bands below the crop canopy, on the soil surface, with the minimum of herbage or crop contamination. (See Figure 2.46). [575, UBA 2011]

In low-height herbage, the distinction between the two techniques can be less obvious, and therefore the ammonia emissions reduction efficiency of both machines is expected to be similar in shorter crops. By contrast, for taller canopies, a trailing shoe can be more effective at reducing ammonia emission than a trailing hose, due to the more precise delivery of the slurry to the ground surface; therefore, providing a reduction of the slurry exposure to air. [601, ALTERRA, IIASA 2012] [440, Webb et al. 2010] [508 , TFRN , 2012]

Source: [223, Denmark 2010]

Figure 4.89: Example of trailing hoses mounted on a bar

Achieved environmental benefits
Because the slurry is placed directly on~~to~~ the ground in narrow bands, ~~and is not dropped from a height above the surface, to avoid aerial~~ dispersions are avoided and, therefore, the total surface of the slurry in contact with air is significantly smaller than if the slurry was spread by splash plate, and thereby the potential emission of ammonia and odour will be much smaller.

The ammonia emission abatement potential is higher when slurry is applied below well-developed grass or crop canopies, rather than on bare soil, as the canopy protects the applied slurry from wind and solar radiation. With the use of the trailing shoe spreader, ammonia emissions reductions can be further reduced because slurry can be precisely placed below grass canopy with the minimum canopy contamination. In fact, the trailing shoe allows the slurry to be incorporated into the upper soil layer (0 – 3 cm). [575, UBA 2011] Therefore, the emission reduction efficiency of band-spreading is dependant on the crop canopy and on the application precision below the crop canopy with minimal contamination of herbage. [508, TFRN 2012]

The slurry is also placed on the ground in bands which means little plant contamination and narrow surface of emissions.

Application with slurry trailing hoses increases nitrogen utilisation, with consequent reduced purchase of mineral fertiliser nitrogen; thus, reducing the energy consumption and associated indirect emissions for manufacturing the fertiliser [602, Denmark 2010].

Odour emissions are also reduced compared to broadcast spread systems. [233, Denmark 2010]

Cross-media effects

Emissions of nitrous oxide from slurry applied on grassland surfaces are 0.2 kg N_2O-N per hectare which corresponds to an emission of approximately 0.25 to 0.50 % of the applied N.

As for the broadcast spreader, there is a potential risk for emissions of nitrous oxide from surface application of slurry with trailing hoses. In a reported study, it was found that emissions of nitrous oxide from grassland treated with slurry were 0.2 kg N_2O-N per hectare (which corresponds to an emission of approximately 0.25 to 0.50 % of applied N) [602, Denmark 2010].

Trailing hoses may result in wide bands; therefore, in the Netherlands, they are not allowed on grasslands. [35, NL 2010]

Operational data

The rate of utilisation of the ammonium-N is considered 56 %.

The system hence is commonly credited for 30 – 50 % of ammonia emissions abatement in relation comparison with to broadcast spreading. From Spain, a reduction efficiency of 25 – 58 % is reported [235, Spain 2010] for band spreaders, whilst from Denmark is reported to be 42 % [233, Denmark 2010].

With the use of trailing shoes, ammonia emissions are reduced by around 49 % are reduced by around 50 % [234, Spain 2010] [248, ADAS 2001], and up to 60 % [35, NL 2010]. For applications to grasslands or to lands with crop height over 10 cm, the advantages are increased.

Applicability

Trailing hoses can be used for all many types of slurry, e.g. untreated slurry, degassed slurry from biogas plants, liquid fraction from slurry separation, and acidified slurry.

Black text moved from Section 2.8

The technique is applicable to grass and arable land, e.g. for applying slurry between rows of growing crops. Because of the width of the machine, the technique is not suitable for small, irregularly shaped fields or steeply sloping land. The hoses may also become clogged if the dry matter content of the slurry is high (>7 – 10 %), or if the slurry contains large solid particles, e.g. if the straw content of the slurry is too high [508, TFRN 2012]. However, the clogging of pipes is usually avoided by including a chopping system but, this adds significantly to the cost of the system [508, TFRN 2012].

In cases where contractors are not used for slurry application, it is necessary for the farm operator to be able to handle the technology correctly, be in possession of skills to navigate big equipment on the fields, in order to reach the potential environmental effects of the technology. [233, Denmark 2010]

The technology is depending on an adequate slurry trailer with sufficient strength and equipment for mounting the trailing hose bar.

Economics

Ammonia emission reduction costs and spreading costs reported by Germany for different farm sizes are presented in Table 4.191.

Compared with splash plates, band spreaders have slower work rate and, therefore, higher tractor costs per unit of spread slurry. In comparison with splash plate machinery, repair costs are higher, due to higher soil/machine contact and more moving parts [254, Webb J.M. et al. 2009].

A trailing hose system with the same capacity as broadcast spread system ~~is judged to have~~ has an additional price of EUR 12 000 – 25 000 ~~approximately EUR 15 000~~. ~~Yearly~~ Annual running costs are considered around EUR 1 per m^3/year (from 0.9 to 1.1 EUR/m^3/year). [233, Denmark 2010]

From UK, the approximate investment costs for trailing shoe machines, without the tractor, are reported (prices February 2009, at the exchange rate of EUR/GBP = 0.88) between EUR 32 000 and EUR 46 500 for a tanker mounted machine and EUR 15 500 for an umbilical mounted machine [254, Webb J.M. et al. 2009]. Running costs for the combined tractor and band spreader, in comparison with the use of a broadcast spreader (splash plate), are reported in Table 4.192. Reported cost data take into account machinery depreciation, interest rate, insurance, fuel, maintenance, labour.

Table 4.192: Estimated running costs for a band spreader system and a broadcast system for the application of slurry

	EUR/working hour	EUR/m^3 of slurry
Band spreading		
Tractor	30.6	1.13
Band spreader	19.9	0.74
Total	50.5	1.87
Broadcast spreading		
Tractor	30.6	1.02
Splash plate	7.7	0.26
Total	38.3	1.28

NB: Cost data are based on the following assumptions:
- Exchange rate of EUR/GBP = 0.88.
- Assumed purchase prices: EUR 58 000 for a 150 – 180 HP tractor; EUR 13 600 for the splash plate tanker; EUR 32 000 for the band spreader.
- 1 000 and 500 hours/year of operation respectively, for the tractor and the band spreader.
- The spreading rate of the broadcast spreader is assumed to be 9 % higher (30 m^3/h) than the band spreader (27 m^3/h).

[254, Webb J.M. et al. 2009]

Extra costs that have been calculated in Spain are shown in Table 4.193. Cost comparisons are made with broadcast spreader (splash plate) and incorporation within 24 hours.

Table 4.193: Extra cost related to slurry application with band techniques

Technique	Extra cost per volume EUR/m^3 of slurry	Extra cost per production EUR/kg produced meat
Band spreader	0.79 – 1.21	0.0099 – 0.0151
Trailing shoe	0.92 – 1.41	0.0115 – 0.0176

Source: [234, Spain 2010] [235, Spain 2010]

It is estimated that the fuel consumption by using trailing hoses is at the same level as for the splash plate technology.

Driving force for implementation
Nitrogen utilisation by plants is improved as emissions are reduced. Application of slurry with trailing hoses increases nitrogen utilisation compared to splash plate. Therefore, there is an increased saving potential on the purchase of mineral fertilisers [602, Denmark 2010].

Example plants
Since broadcast spread (splash plate) has been forbidden in Denmark for approximately 10 years, all slurry surface applications are done by using trailing hoses. Hence the practical experience is extensive and the durability of the system is very well tested.

Reference literature
[233, Denmark 2010] [234, Spain 2010] [235, Spain 2010]

4.13.4.4 Injector (open slot)

Description
~~Sharp spring tines in S-shape or harrow discs are used to cultivate the soil cutting grooves where the slurry is placed. Injectors are installed at a distance of 20–40 30 cm on bars of up to 9–12 metres bars. Application is 3–8 cm deep if crops are growing or grass is in place. Deeper injections to 10–15 cm are possible to bare arable soils, where a higher amount of soil closes behind the tine. Injection bars are typically six metres wide.~~ **Moved to Section 4.13.4.5**

Cutting discs or steel knives from a harrow tine are used to cut slots in the soil forming grooves into which slurry is deposited. The injected slurry is fully or partially located below the soil surface at a depth of 3 – 8 cm and grooves will normally be left open after slurry application. Open slot injectors have a working width of ≤ 6 to 12 m and individual hoses are generally situated at a spacing of 20 – 40 ~~30~~ cm from each other (see Figure 2.47).

Achieved environmental benefits
In open slot injection, a limited part of the slurry gets in contact with the open air reducing ammonia and odour emissions. Odour and ammonia emissions reduction depends on how large a proportion of the applied slurry can be accommodated in the grooves formed.

Experiments on grassland show that N utilisation is higher after shallow injection than after surface spreading [35, NL 2010]. This means that the potential for nitrate leaching to the environment is decreased.

Slurry application with injection systems increases nitrogen utilisation, with consequent reduced purchase of mineral fertilisers; thus, reducing the energy consumption and associated indirect emissions for manufacturing the fertiliser [602, Denmark 2010].

Cross-media effects
Since the slurry is placed under the soil surface ~~underground~~, N_2O emissions may be ~~seem to be~~ enhanced by the lack of oxygen, ~~that as a consequence~~ which facilitates processes of denitrification. It has been reported that in winter crops and for grassland, slurry injection will increase the emissions of nitrous oxide by 25 – 100 %, which corresponds to an emission of approximately 0.5 to 1.0 % of applied N [237, Denmark 2010] [238, Denmark 2010].

Slurry injection systems require higher tractor power (higher fuel consumption) than broadcast or band-spreading equipment, given that a tine or a disc is to be pulled through the soil. In comparison with a trailing hose system, the extra traction caused by injection with a narrow tine in approximately 10 cm depth is reported equivalent to 1.4 – 1.8 kW per tine (or per unit of injection aggregate) and it is estimated to be equivalent to 7.5 kW extra power per tonne of applied slurry. Generally, depending on the design of the injector tools, an extra force of 2 to 4 kW per metre of injector boom is needed.

A loss of yield may be caused by the fact that injection will result in more driving tracks in the crop.

Operational data

Most commercial systems available in Denmark are disc-aggregates. The injection system is dependent on an adequate slurry trailer with sufficient strength and equipment for mounting the injection bar; it is expected to last 10 years.

Application by slot discs, through which the slurry is applied, avoids crop soiling; however, the turf is damaged. More recent slot techniques aim to minimise this damage by means of smaller slot depth [575 , UBA, 2011] or minimum till cropland prior to planting [601, ALTERRA, IIASA 2012].

Ammonia volatilisation after slurry application depends on various factors (e.g. high temperatures), among which the most important are the time elapsing ~~before~~ until incorporation and the amount of manure that is left in contact with air. Therefore, the emissions reduction achieved depends on the extent to how much slurry is incorporated into the soil, i.e. on how large a proportion of the applied slurry can be accommodated in the grooves formed. To be effective in both reducing ammonia emissions and increasing the availability of nitrogen to the crop, injection should reach a depth of ≥5 cm and the space between injector tines should be ≤30 cm. The effect of slurry injection depends on the soil type, soil dryness and the technique used.

Former text is now presented in a summarised version in the Table below.

From France, it is reported that the spreading of slurry using deep injection (150 mm) with open slot allows a reduction of NH_3 volatilisation of 60 % [259, France, 2010].

For shallow open slot injection in grassland or cropland, it is estimated that odour reduction after slurry application is between 0 and 50 %, compared with the trailing hose system. [236, Denmark 2010] [387, DK 2009]

In Table 4.194, ammonia emissions associated with slurry application with injectors and relative improvements compared to broadcast and band spreading (trailing hose) are presented.

Table 4.194: Ammonia emissions reduction achieved by slurry injection in comparison with surface application techniques, in Denmark

Injection	Soil/Crop/Season	Emissions of NH_3-N as % of Total N		Emissions reduction rates (%)		Source
		Trailing hoses	Injection	Compared with trailing hose	Compared with broadcast spreading ([1])	
Open	Cropland with growing crops; spring	11.7	6.4	45	68	[603, Denmark 2009]
Open	Grassland; spring	13.5	10.1	25	56	[387, Denmark 2010]
Open	Grassland; summer	17.6	13.2	25	44	[387, Denmark 2010]
Closed	Bare soil (cropland without crops; ploughed land); spring	4	0.68	83	90	[604, Denmark 2009]

([1]) Data elaborated on the basis of a factor of 1.7 of higher emissions of broadcast spreading technique compared to trailing hose, for Danish conditions [442, Hansen et al. 2008].

Applicability

The technique is applicable to many types of slurry, such as biogas slurry, separated fraction and acidified or untreated slurry.

The technique is suitable for application on grassland and on growing crops. It is not applicable on very stony soil or on very shallow or compacted soils, where it is impossible to achieve a uniform penetration ~~of the tools knives or disc coulters~~ to the required working depth.

Economics

Ammonia emission reduction costs and spreading costs reported by Germany for different farm sizes are presented in Table 4.191.

For the purchase of the injection equipment, extra investment costs of ~~up to~~ EUR 33 000 are needed compared to ~~buying~~ the trailing hose. Systems would run for EUR ~~0.9-1.1~~ 2.4 – 2.6 per tonne of applied slurry on growing winter crops and EUR 2.2 – 2.4 per tonne of applied slurry distributed on grassland. The additional costs compared to trailing hose are presented in Table 4.195.

In a comparison with a broadcast spreader (splash plate) without incorporation within 24 hours after spreading, extra costs have been calculated under Spanish conditions (assuming at least 50 % reduction in emissions), ranging between EUR 1.01 and 1.41 per m^3 of applied manure, or in other units, from EUR 12.6 to 17.6 per tonne of pig produced. [379, Spain 2006]

In Table 4.195, reported additional fuel requirements as well as extra costs associated with open (shallow) and closed (deep) slot injection, for different operating conditions applied in Denmark, are presented.

Table 4.195: Extra energy and costs associated with open (shallow) and closed (deep) slot injection for different operating conditions, applied in Denmark

Injection type	Scope of application	Working depth	Extra fuel consumption		Extra annual running costs ([1])
		cm	Litres/ha	Litres/tonne of applied slurry ([2])	EUR/m^3 slurry applied annually
Open	Cropland with growing crops	3 – 8	2 – 5	0.1-0.2	0.9 – 1.1
Open	Grassland	3 – 8	2 – 5	0.1-0.2	0.7 – 1
Closed	Bare soil (cropland without crops; ploughed land)	10 – 15	4.9	0.2	0.66

([1]) Costs are compared to the trailing hoses system with related total cost of 1.5 EUR/m^3.
([2]) Slurry application at 25 tonnes per hectare.
Source: [236, Denmark 2010] [237, Denmark 2010] [238, Denmark 2010]

Driving force for implementation

The improved efficiency in nitrogen distribution results in an improved ammonia utilisation by plants which finally results in economic savings from lesser use of mineral fertilisation ~~costs~~ for the same quantity of crop.

Example plants

In Denmark, about 15 % of the pig slurry and 53 % of the cattle slurry were applied by injection in 2004. Injection of slurry to grassland and bare soil has been growing in recent years in Denmark; it is considered an available and proven technique.

The technique with deep injection (150 mm) is largely applied in France [259, France, 2010]

Reference literature
[236, Denmark 2010] [237, Denmark 2010] [238, Denmark 2010] [575, UBA 2011]

4.13.4.5 Deep injector (closed slot)

Description
Typically, the working depth of the closed slot deep injector ranges between 10 and 15 cm or, in some cases, deeper, up to 20 cm. Cultivators with sharp S-shaped spring tines or disc harrows are used to cultivate the soil and deposit slurry into it, before soil closes again the groove by means of press wheels or rollers fitted behind the injection tines or discs. The working width is generally of 3 to 6 m and the individual injectors are normally placed at a spacing of 20 – 40 ~~30~~ cm.

Achieved environmental benefits
Since almost all slurry is channelled and covered below the soil surface, odour and ammonia emissions are effectively reduced. A higher nitrogen utilisation may result in a decreased potential for nitrate leaching to the environment.

Cross-media effects
See Section 4.13.4.4

Operational data
Most commercial systems available on the Danish market are tine-aggregates. The system requires an adequate slurry trailer with sufficient strength and equipment for mounting the injection bar. The injection system is expected to last 10 years.

Compared with the surface distribution on bands (trailing hose), reduction~~s~~ on ammonia emissions is ~~are~~ about 85 %, which corresponds to an average reduction of around 90 %, compared to broadcast spreading [35, NL 2010]. Effectiveness in ammonia abatement increases with working depth. In Table 4.194, an example of ammonia emission reduction for closed slot injection is reported, in comparison with open slot injection.

For deep injection of slurry in bare soil, odour emission is reduced to a minimum, at least for a number of odoriferous substances. [236, Denmark 2010]

An increased utilisation of the applied nitrogen (and therefore higher yields) has been proven with the use of the technique, resulting in a potential for a decreased leaching of nitrates to the environment.

The slurry is fully covered after injection, by closing the slots. Deeper injection is required when greater volumes of manure have to be injected, in order to avoid manure oozing/leaking to the surface. [601, ALTERRA, IIASA 2012]

It is reported that the working depth and ease of soil penetration increase with the soil water content. Thus, an estimate of soil strength can be used as one parameter to determine the optimum timing for the slurry injection, in order to achieve sufficient working depths. [440, Webb et al. 2010]

Applicability
The technique is applicable to many types of slurry, such as slurry from biogas production, separated fraction and acidified or untreated slurry.

Applicable on arable land; however, it is mainly restricted to the pre-sowing season and widely spaced row crops (e.g. maize). The technique may be applicable in areas without vegetation and where there are no crops to damage. Mechanical damage (cutting of the roots during injection) may decrease yields in growing solid-seeded arable crops. Yield reductions may derive also from drying of the soil and anaerobic and toxic conditions from concentrating the manure in the injection slots. This effect may be greater with multiple applications over the season. [440, Webb et al. 2010]

Other limitations include soil depth, clay and stone content, slope. High tractor power requirements are needed; an increased risk of leaching is reported in the case of tile-drained soils. [601, ALTERRA, IIASA 2012]

Deep injection on grassland has been proven not practicable. [35, NL 2010]

Economics
For the purchase of the injecting equipment extra investment costs of ~~up to~~ EUR 33 000 are needed compared to ~~buying~~ the trailing hose. Systems would run for around EUR ~~0.66~~ 2.2 per tonne of applied slurry on bare soil. The additional costs of closed slot injection, in comparison with open slot injection, are presented in Table 4.195.

Ammonia emission reduction costs and spreading costs reported by Germany for different farm sizes are presented in Table 4.190. [575, UBA 2011]

Driving force for implementation
Increased utilisation of applied nitrogen, with savings from reduced use of chemical fertilisers.

Example plants
Injection of slurry to bare soil has been growing in recent years in Denmark and is considered as a well known, available and proven technology.

Reference literature
[236, Denmark 2010] ~~[237, Denmark 2010] [238, Denmark 2010]~~ [575, UBA 2011] [601, ALTERRA, IIASA 2012]

4.13.5 Incorporation of solid manure or slurry

Description
Incorporation into the soil of manure spread on the surface ~~into land~~ is done by either ploughing ~~plow~~ or other shallow cultivation equipment, such as discs or cultivators, depending on soil type and conditions. The manure is ~~must be~~ completely buried under the soil to achieve maximum reduction efficiency of ammonia emissions.
Where injection techniques for slurry are not possible or unavailable, ~~the technique may also be used for slurries.~~ incorporation may also be carried out after slurry spreading, by means of conventional soil cultivation equipment. The slurry is spread using a broadcast spreader and incorporated shortly after distribution.

Achieved environmental benefits
As ammonia losses take place quickly after spreading, ammonia emissions and odour ~~in the neighbourhood~~ are reduced by limiting the time of exposure of the manure to air.
The reduction of NH_3 volatilisation depends on the incorporation procedures, in particular the time lag between application and incorporation, as well as weather conditions between application and incorporation, and the degree of burying into soil [508, TFRN 2012]. High emission reductions can be achieved with immediate incorporation (as soon as possible after spreading); in contrast, a large part of the ammonia emissions has already occurred when incorporation is carried out after 4, 6, 12 or 24 hours. [35, NL 2010].

Cross-media effects
Single-run equipment is heavy and can produce problems of soil compactation; while, equipment for double-run incorporation is lighter but the tractor ~~engines~~ consume more fuel. ~~energy.~~

Incorporation of solid manure into soil may increase direct emissions of N_2O. The nitrogen availability of solid manure for a growing crop is lower than that of liquid manure, due to the higher concentration of organic matter that enhances N immobilization and denitrification. Whether solid manure leads to higher NH_3 and N_2O emissions than slurry or chemical fertilisers, depends on several factors, including manure C:N ratio and organic matter degradability [517, Petersen et al. 2011]. On the other hand, the results of other studies remain ambiguous on the impact of incorporation of solid manure after application with respect to N_2O emissions. [441, Webb et al. 2011]

For untreated and treated slurry, contrasting results have been reported on N2O emissions. The variability depends mainly on soil properties and organic matter content of the slurry. [517, Petersen et al. 2011]

If no crops are present to take up the readily available N, manure incorporation increases the risk of N loss via leaching, with a possible shift of pollution from air to water; but, it reduces the risk of surface run-off from subsequent rainfall events. For this reason, the timing of slurry and solid manure application needs to balance all these aspects. [508, TFRN 2012]

Operational data

To achieve incorporation immediately after spreading, a second tractor is needed for the incorporation machinery, which must follow closely behind the manure spreader. Usually the incorporation is carried out by a second person working with the plough, or other tool depending on the type and the conditions of the soil, but it could also be done by one person: in which case the manure~~d~~ spread on the field (one tank load) is incorporated before reloading the tank.

Figure 4.90 shows incorporation equipment combined with a large ~~big~~ tanker owned by a contractor, but this combination is also possible with a smaller tanker and a separate tractor. In this way the incorporation can be done together with the manure spreading in only one handling. [406, Netherlands 2002]

Source: [406, Netherlands 2002]

Figure 4.90: Incorporation equipment combined with a big tanker

For immediate incorporation strategies on small fields (approx. 2 ha), if only one person is available to spread and incorporate the manure, there is a significant advantage in incorporating the manure as soon as each pass of the spreader is complete (except for very small fields). This causes an increase by 15 % of the time spent for the operation.

Using two people (simultaneous pass) does not reduce NH_3 emission, compared with one person operating both machines (spreading and then incorporating at the end of each pass), because the work rate of the incorporator is usually lower than that of the applicator. Using two operators does, however, save time, ranging from 36 % on a 2 ha field to 51 % on a 20 ha field. The absolute duration of the operation may be more important than the percentage of time saved. On a 2 ha field, a reduction in time spent from 3.5 h to just over 2 h may be of little importance in the overall farm management; however, on a 10 ha field, a reduction in time from approximately 20 h to 10 h would allow the job to be completed in one day. [243, Webb J. et al 2006]

As a conclusion, the incorporation strategy needs to be properly designed, according to the size of the field, the work rates of incorporation equipment and the available manpower.

Immediate incorporation, thus a minimal time delay between manure application and incorporation, is not always achievable. Some time would pass between surface spreading and incorporation during which ammonia volatilisation takes place from the manure spread on the surface.

The degree of ammonia emissions reduction depends also on the method of incorporation. Direct incorporation of manure by a mouldboard plough results in a higher reduction efficiency than incorporation by a fixed tine cultivator or a disk harrow, due to the deeper working depth achieved by ploughing [35, NL 2010] [243, Webb J. et al 2006] and 100 % burying of slurry/manure. However, it is sometimes possible that tines or discs are more efficient than ploughing, because of the faster work rates achieved; while, with mouldboard ploughing there will be a longer overall time lag between spreading and incorporation. [35, NL 2010] [243, Webb J. et al 2006] [500, IRPP TWG, 2011]

In Table 4.196, a summary of experimental results concerning ammonia emissions reduction achieved with the use of different application machines is presented.

Table 4.196: A summary of experimental results on ammonia emissions reduction with different manure incorporation equipments

Incorporation equipment	Type of manure	Reduction in NH_3 emissions, compared with surface broadcast application	
		Average value ([1]) (%)	Range ([2]) (%)
Plough	Slurry	92	78 – 99
Disc	Slurry	80	69 – 90
Tin	Slurry	66	-
Harrow	Slurry	68	60 – 69
Plough	Solid	91	86 – 95
Disc	Solid	63	-
Tin	Solid	57	-
Harrow	Solid	90	-

([1]) Data represent the average of reported reduction efficiencies.
([2]) The range is obtained by calculating the average values of each publication considered.
Source: [440, Webb et al. 2010]

Other experimental results, presenting ammonia emissions expressed as kg/ha NH_3-N or as % of TAN applied, and the effect of different incorporation methods, are presented in Table 4.197.

Ploughing results in higher emission reductions than other types of machinery for shallow cultivation. [243, Webb J. et al 2006]

Table 4.197: Average ammonia emissions and reduction efficiencies from spreading of solid manures followed by immediate incorporation using different equipment

Manure Type	No incorporation		Plough			Disk			Tine		
	NH_3-N	TAN	NH_3-N	TAN	Reduction	NH_3-N	TAN	Reduction	NH_3-N	TAN	Reduction
	kg/ha	%	kg/ha	%	%	kg/ha	%	%	kg/ha	%	%
Pig	63.1	68	3.2	4	95	25.4	26	60	26.2	26	58
Layer	71.5	67	2.6	3	96	22.3	21	69	33.7	31	53
Broiler	27.6	56	0.0	2	100	5.6	13	80	5.2	11	81
Source: [243, Webb J. et al 2006]											

The effect of the machinery used for incorporation and the time delay after spreading solid manure until incorporation, in comparison with the ammonia emissions without incorporation, are presented in Table 4.198. Data are derived from a review of reports and peer reviewed articles.

Table 4.198: Reduction of ammonia emissions achieved by incorporation of solid manure after application

Animal category	Incorporation (Time lag after application)			Equipment used for incorporation
	<4h	4h	≥24h	
	Ammonia emissions reduction as % of emissions measured without incorporation			
Fattening pigs	92 (4)	64 (9)	63 (8)	Plough
Broilers	-	61 (5)	37 (5)	Disc
Broilers	-	81 (2)	77 (2)	Plough
Broilers	-	44 - 53 (3)	24 (2)	Disc - Harrow
Laying hens	97 (1)			Mouldboard plough
Laying hens	79 – 83 (3)			Harrow - Chisel plough - Rotary cultivator
	Average emission reduction, as % of emissions measured without incorporation			
	<4h	4 – 24 h		
Pigs	92	56		
Poultry	85	50		
NB: In brackets the number of datasets used. *Source*: [441, Webb et al. 2011]				

From Denmark, calculated emissions for the application of pig solid manure followed by incorporation with different time lags and equipments are presented in Table 4.199.

Table 4.199: Calculated ammonia emissions from application of pig solid manure followed by incorporation, with different equipment and time lags

Incorporation method	Season	Incorporation (time lag after application)			
		No incorporation	6 hours	4 hours	1 hour
		(NH_3-N emission % of TAN)			
Ploughing	Spring	65	39	22	13
Ploughing	Summer	80	48	32	16
Ploughing	Autumn	55	33	12	11
Ploughing	Winter	45	27	7	9
Harrowing	Spring	65	41	36	27
Harrowing	Summer	80	54	48	35
Harrowing	Autumn	55	30	27	21
Harrowing	Winter	45	22	20	17
Source: [442, Hansen et al. , 2008]					

An extensive literature review [441, Webb et al. 2011], supported by a statistical analysis of measurement results, concluded that incorporation of pig and poultry solid manure after application results in increased N_2O emissions; however, a wide variability of data has been observed. Results are presented in Table 4.200.

Table 4.200: Emissions of N_2O after spreading and incorporation of solid manure

Parameter	Emissions of N_2O-N as % of TAN	
	Pig manure	Poultry manure
Average value after spreading	0.3	0.1
Median value, after spreading	2.8	0.6
Average value after incorporation	3.5	8.9
Source: [441, Webb et al. 2011]		

The influence of contrasting effects of ammonia emissions reduction during manure storage, the nitrogen loss during spreading and incorporation of broiler litter, as well as nitrate losses through leaching, has been investigated; the results are presented in Table 4.201.

Table 4.201: Example of the effect of storage conditions and application conditions of broiler litter on subsequent emissions during application

Storage conditions	Application conditions	NH_4-N losses as % of total N ex-housing	NO_3-N losses as % of total N ex-housing
Conventionally stored	Surface spreading	24.6	5.9
Sheeted heap	Surface spreading and ploughing the soil within 4 hours	4	13.7
Source: [536, Sagoo et al. 2007]			

Data from different geographical areas report that reductions in ammonia emissions of 70 – 80 % are achievable when solid manure is directly incorporated within 2 hours and a reduction from 60 to 70 % if it is incorporated within 4 hours [35, NL 2010] [259, France 2010]. The incorporation within 6 – 24 hours after application with broadcast spreader reduces ammonia emissions of 16 – 42 %, under Spanish climatic conditions, compared to broadcast spreading without incorporation within 24 hours [239, Spain 2010]. In France, it is considered that for a satisfactory reduction rate of ammonia, incorporation has to be carried out in less than 12 hours after spreading [500, IRPP TWG 2011].

Ploughing 24 hours after landspreading is less effective in reducing emissions, with a mean reduction of about 65 % (from 47 to 78 %) compared with surface application. Discing the 'fresh' manure into the soil is less effective than ploughing, with reductions in ammonia losses of 30 – 90 % after 4 hours and around 25 % (range 0 – 45 %) after 24 hours. This happens because only 40 – 60 % of the manure is buried by the discs compared with complete burial by ploughing. [207, ADAS 2004] **See new data reported above**

Table 4.202 shows that incorporation of broiler litter is always effective compared to non-burial, but also shows that emissions at landspreading depend on the readily available nitrogen that may be kept in manure that has been covered during storage. The results in the table imply losses during storage of 13.2 % and 1.3 % for the conventionally non-covered stored manure and the sheet-covered manure. [207, ADAS 2004] This means that the readily available nitrogen that is lost in non-covered storages may be lost in a large proportion at landspreading if incorporation is not quick enough or if it is not applied. In other words, rapid incorporation is necessary in order to realise the reductions in ammonia loss from sheeted storage. If the sheeted broiler litter is not rapidly incorporated into the soil following landspreading, the ammonia saved during storage is subsequently easily lost at landspreading.

Table 4.202: Comparison of system ammonia losses from different procedures of application to land of differently stored broiler litters

Type of application and incorporation	Losses upon spreading		System losses	
	Conventional	Sheeted	Conventional	Sheeted
Surface	11.4	25.8	24.6	27.1
Ploughed within 4 hours	2.4	2.8	15.6	4.1
Disced within 4 hours	6.3	10.8	19.5	12.1
Ploughed within 24 hours	2.5	6.9	15.7	8.2
Disced within 24 hours	8.0	21.9	21.2	23.2

Source: [207, ADAS 2004 Gleadthorpe].

Currently In the Netherlands, the technique of incorporating the manure within 4 hours is being commonly applied more commonly. A good matching of logistics (tank spreading capacity and incorporation capacity) is a very important factor for achieving incorporation within 4 hours. In this instance, While a tank is reloading slurry, the person responsible for the incorporation catches up with the work. It is common practice to have a good logistic plan., for example in harvest time, for grain or other crops. It is good practice to combine the unloading of the combine harvester or other harvest machinery with the transport of the grain or the other crops to the storehouses in a short time. [406, Netherlands 2002]

Applicability

Manure incorporation is considered generally applicable. The manure application on a field itself only takes a very short time (within hours) and there is no need to wait for the incorporation.

Incorporation within 4 hours may be considered is thought to be difficult to organise, because the farmers do not usually own all the machinery required and do not have enough personnel. The field size might affect efficiency of manure incorporation, meaning that on a large field, operations may not be completed in one working day if run by one person. The farmers therefore need to rely on contractors and therefore the timing of operations is not completely under their control. However, it is also reported that is doubtful whether organising incorporation within a shorter time than 12 or 24 hours may cause a logistics problem [35, NL 2010].

The applicability of the technique is limited to arable land that can easily be cultivated after spreading solid manure or slurry. For glassland, incorporation is not possible [35, NL 2010], or it is possible only when changing to arable land (e.g. in a rotation system) or when reseeding.

Economics
Extra costs for incorporation after application by splash plate (broadcast spreader) are presented in Table 4.203. ~~referring to volumes of applied manure and to produced pig and compared to non application.~~.

Table 4.203: Extra costs for manure application by splash plate, followed by incorporation, in comparison with no incorporation

Method of incorporation	Extra cost in EUR per m^3 of applied manure	Extra cost in EUR per kg of produced pig
Ploughing	0.53 – 0.61	0.0066 – 0.0076
Discing	0.23 – 0.26	0.0029 – 0.0033
Source: [379, Spain 2006]		

Costs for direct incorporation of solid manure are reported in the range of EUR 0.5 to 2 per kg NH_3-N saved. [601, ALTERRA, IIASA 2012]

Ammonia emission reduction costs, spreading and incorporation costs, reported by Germany for different farm sizes, are presented in Table 4.190. [575, UBA 2011]

Driving force for implementation
Regulations in many Member States are enforcing slurry/manure incorporation after spreading. For example, in Denmark, slurry applied on bare soil must be incorporated within six hours. [236, Denmark 2010]

Fast incorporation of solid manure or slurry improves nitrogen availability (fertiliser value of manure) for crop production. [517, Petersen et al. 2011]

Some incorporation activities may be seen as a tillage operation a farmer already planned to do (also when no manure was applied). In that case incorporation is not an extra activity (labour, energy, costs) that should be counted as extra costs for the reduction of emissions. [35, NL 2010]

Example plants
Incorporation is widely applied.

Reference literature
[239, Spain 2010] [243, Webb J. et al 2006] [259, France 2010] [35, NL 2010]

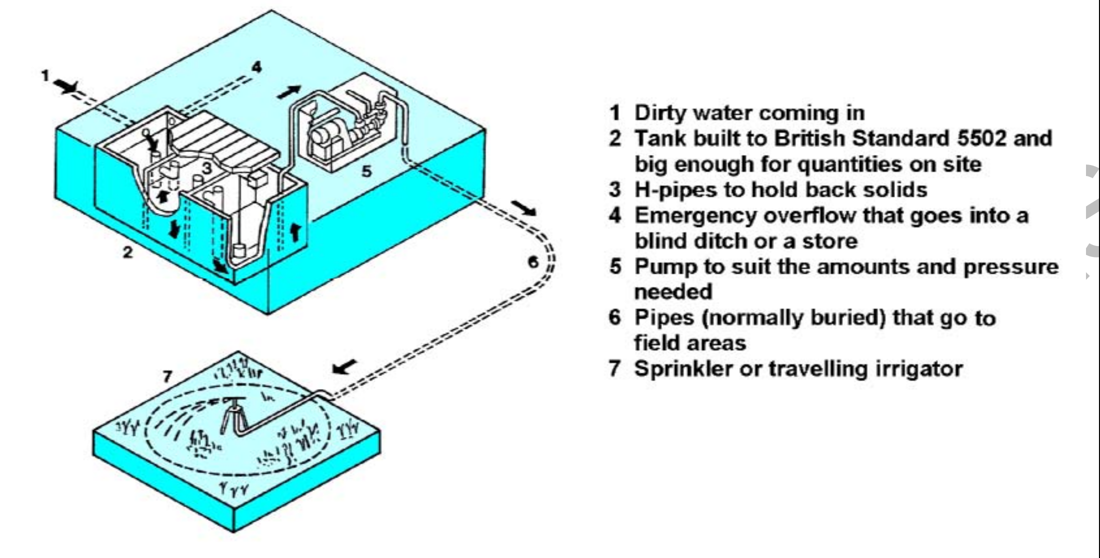
4.13.6 Low-rate irrigation system for dirty water

Description
Dirty water ~~is considered to be~~ encompasses all the water from a farm that contains residues of cleaning ~~(milking parlours)~~ or other installations and farmyard run-off, and generally has a high BOD level (1 000 – 5 000 mg/l). Low-rate irrigation is applied on farms in the UK to bring dirty water onto land as far as the available land is suitable. The same restrictions on application apply ~~as~~ for the application of slurry.

This technique uses settlement tanks or lagoons to collect the dirty water before it is pumped onto land. Particles can settle to prevent the system from clogging, or solids removal can be done in the machine itself. This fraction will have to be disposed of.

The water is pumped from the stores and brought into a pipeline that goes to a sprinkler or travelling irrigator, which sprays the water onto land.

A schematic representation of a low-rate irrigation system for dirty water is shown in Figure 4.91.



Source: MAFF, Code of Good Agricultural Practice for the Protection of Water. MAFF, 1998

Figure 4.91: Example of low-rate irrigation system

Achieved environmental benefits

The technique is considered to have benefits in preventing ~~avoiding~~ dirty water entering the sewer system or being discharged into nearby surface waters. However, low-rate irrigation should be carried out within the capacity limits of the receiving soil and should follow the general rules of good landspreading management (see Section 4.13.3).

Cross-media effects

Energy is required to operate the system. Sufficient land must be available for spreading. However it may reduce the amount of land available for applying slurry. Odour can arise during spreading, and weather and soil conditions must be taken into account.

Operational data

Low-rate irrigation systems use suitable tanks or earth-banked stores to collect liquids and let them settle. They use an electric pump, small bore piping and sprinklers (up to 5 mm per hour) or a small travelling irrigator (up to 50 m^3/ha or 5 mm per run) to spread liquids onto the land. The required storage period will depend on the risks of causing pollution from run-off when spreading the dirty water.

The system requires ~~needs~~ an emergency overflow to store water in excess of its capacity (in case of heavy rainfall). The pump must be designed for the required pressure, depending on distance to the sprinkling system and the life inside the system. The capacity is variable and adapted to the average volume expected.

Applicability

Sufficient land adjacent to the farm is preferred, as it avoids the use of long pipelines covering large distances. The sprinkler system will have to be moved regularly to prevent contamination of the soil. The system requires regular maintenance to avoid clogging of the pipes and to prevent odour from residues from collecting in the system. Only lightly charged water can be used for this system.

Economics

Please TWG provide information.

Driving force for implementation

Separate handling of dirty water from slurry, offers more flexibility in slurry management, i.e. less storage volume is required, less quantity needs to be spread by slurry application techniques.

Example plants

The technique is widely applied in the UK.

Reference literature

[386, DEFRA 2009] [242, CRPA 2009]

4.14 Techniques to reduce noise emissions

Description

Limited information has been submitted on techniques for reducing noise emissions from intensive livestock farming. Noise is still not considered an issue of high environmental importance in the sector, but with rural areas becoming increasingly populated noise (as well as odour) emissions may become more relevant. At the same time, reduced on-farm noise levels are considered to be beneficial for relevant to the animal production, which itself that requires a quiet and peaceful environment.

In general, noise reduction can be achieved by:

- planning of activities on the farm premises
- using natural barriers
- applying low-noise equipment
- applying technical measures to equipment (limited)
- applying additional noise abatement measures.

The impact of activities with potentially high noise levels can be reduced considerably by avoiding operating at nights and on weekends. Unnecessary disturbance of the animals during feeding and inter-house transfer should also be avoided, as this generally gives rise to increased noise levels. However, it is less stressful for birds to be handled in the dark and this is why bird catching and subsequent transport, often take place during night-time or in the early morning [40, NFU/NPA 2001].

In ventilation systems, preference should be given, wherever possible, to low-noise fans. Noise radiation increases with impeller diameter and speed. For a given diameter, a low-speed fan is quieter than a high-speed fan.

In order to reduce noise emissions from machinery and implements, it is possible in certain cases to adopt passive noise abatement measures (encapsulation or sound screens, e.g. made from straw bales which absorb and deflect the radiated sound). Silencers/sound attenuation devices in waste airshafts have not proven successful, as they quickly become ineffective due to dust deposits.

Potential techniques to control or reduce noise emissions from a number of on-farm activities are described in the sections below.

Achieved environmental benefits

Noise emissions are reduced.

Cross-media effects

Some measures are also expected to reduce energy requirements.

Operational data

4.11.1 Control of noise from ventilation fans

Fans may be the cause of nuisance complaints, not least because they are often run more or less continuously, both day and night, in the warmer (summer) months.

Prevention of continuous noise

1. by Choice of ventilation system or equipment

One method of eliminating noise from fans is to employ Natural ventilation systems are preferred, including ACNV (automatically controlled natural ventilation), which also have energy saving benefits. A wide range of welfare and production factors governs the application of natural ventilation systems but these systems are not universally applicable. The problem with ACNV systems is that they do not allow accurate control of the air movement in the animal housing.

Fans can be selected to minimise noise. High-speed fans with two pole motors should be avoided because they tend to be very noisy. In addition, the smaller dimensions of these fans are also associated with smaller openings and cowls that have higher resistance to airflow. Generally, the slower the fan the less noise it will make.~~ Particularly for poultry, cowls and air inlets can be designed with sufficient area so as to avoid any unnecessary pressure drops.~~

In certain circumstances, fan noise can be reduced by inlet-silencers. The nature of the exhaust air from livestock units makes this option suitable only for fan-pressurised ventilation systems, which are not commonly applied.

2. ~~by~~ Design of ventilation and building construction
~~The location of the fans is a significant factor.~~ Employing low-level extract fans on side walls will be more effective for reducing the propagation of noise from within buildings than roof-mounted units, as the noise can be better absorbed by the building structure or by the earth or vegetation. For poultry farms, low-level fans can also facilitate dust control, but they may be less effective at dispersing odour than high-level fans.

~~System resistance affects fan and ventilation system performance. Fan installations should be designed with~~ Adequate inlet and outlet areas ~~to~~ ensure optimum performance. An efficient design ~~will~~ enables the minimum number of fans to be employed in ventilating the buildings. Fan outlet cowls and stacks ~~provide some noise reduction capability. They~~ should be rigidly constructed of timber or purpose-built pre-fabricated plastic or GRP. The use of un-stiffened sheet metal, which can vibrate, should be avoided.

The characteristics of a building structure affect the noise pattern. The build up of noise in and around a building is determined by its absorption properties. Smooth reflective surfaces cause noise levels to build by multiple reflection. By contrast, rough surfaces, such as straw bales, absorb sound.

Woodland and hedges absorb noise from pig farm buildings. A deep belt of tree planting will both reduce noise and mask noise generated by the wind. Noise reduction is relatively low at about 2 dB for 30 m of plantation.

3. ~~by~~ Operational measures
For the minimum required ventilation of poultry housing, a small number of fans operating continuously are ~~is~~ less noticeable than a large number of fans operating intermittently to achieve the same ventilation rate. An increase of 3 dB(A) as a result of twice as many fans running will be highly significant with night-time background noise levels below 30 dB.

Control of noise from discontinuous on-farm activities
~~4.13.1 Control of noise from discontinuous on-farm activities~~

~~**Description**~~
~~Many on-farm activities are carried out in a discontinuous way. Measures to reduce noise emissions from these activities generally relate to proper timing and careful location of the activity on site. The measures apply to the following activities:~~

I. Feed preparation
On-farm milling and mixing of feed preparation ~~plants are a source of noise. Typically produce Typical external~~ noise levels of 63 dB(A).~~ have been measured, with mills giving particular cause for concern.~~ Mills are often automated so that they can be used during the night hours to reduce operating costs by using lower cost ‘off-peak’ night rate electricity. ~~If complaints are likely then this option should be reconsidered.~~ ~~There may be a need to consider housing~~ Mills and other noisy equipment should be housed within an acoustically insulated enclosure or building. Mills which use mechanical rather than pneumatic meal transfer systems are likely to be both quieter and substantially more energy efficient. The main noise-generating units, such

as hammer mills and pneumatic conveyors, should be operated at times when background noise is known to be highest.

II. ~~Use of feed~~ Conveying equipment

Noise from pneumatic conveyors ~~generate high-pitched noise. Noise~~ can be minimised by minimising the length of the delivery pipe ~~runs so that the installed power is low~~. Low-capacity systems, which operate for longer, are likely to generate less overall noise than large, high output units. Conveyors, including augers, are quietest when full of material. ~~Avoid~~ Conveyors or augers should not run ~~running~~ empty.

III. Feed delivery

~~Many units do not prepare feed on site. Feed delivered to a site is usually pneumatically conveyed into holding bins. Noise from feed delivery vehicles comes from:~~

- ~~vehicles moving around the site~~
- ~~pneumatic conveying equipment.~~

~~The impact of these sources of~~ Noise can be minimised by:

- locating feed bins or feed storage silos as far away as practical from residential and other sensitive properties;
- organising feed bin locations to reduce delivery vehicle movement on site;
- avoiding long conveyor distances, and minimising the number of bends on fixed pipes so that the maximum unloading rates can be achieved (to minimise noise duration).

IV. Feeding operations on pig units

~~Noise levels within pig buildings can be very high. As an For example, peak~~ Noise levels of 97 dB(A) and higher have been measured from excited stock in anticipation of feeding. ~~This excitement is often associated with manual feeding or noisy conveyor systems delivering feed at feeding time. These~~ Peaks of animal noise can be reduced by the use of appropriate mechanical feeding systems. If stocks are to be hand fed then they should be in small batches (separate from other batches) or, if noise is inevitable, stock should be fed at times of higher background noise levels. Feeders can be used that have holding hoppers, which can be filled ~~at a different time from feeding. The hopper is then emptied instantly at the programmed~~ before feeding time so the pigs have no pre-feeding stimulus to create excitement and noise. Passive *ad libitum* feeders can be used for some classes of stock and they greatly reduce stress and minimise noise. For new feeding equipment installations, this should be considered ~~as~~ the preferred option.

V. Building openings

~~For sites where feeding noise still causes a problem, it is essential that, where practical,~~ Whenever possible, all doors and other major openings of the pig buildings should be ~~are~~ closed during ~~at~~ feeding time.

VI. Fuel delivery

~~To reduce the effect of noise from the delivery tanker,~~ Fuel storage tanks should be located as far away as possible ~~practical~~ from other property such as residential housing for what is convenient and practical. ~~Locating fuel storage tanks at a position where the livestock buildings lie between gas/oil storage and other property can reduce sound propagation.~~

Fuel storage tanks should be located as far away from other properties such as residential housing.

VII. Manure and slurry handling on pig farms

Measures to reduce noise produced when pig manure is handled are listed below.

- Design and maintain ~~Scraped manure systems often include a large number of~~ opening gates along scraped passages~~. These gates and others to which pigs have access should be designed and maintained~~ so that the pigs are unable to rattle gates and their fittings.

- ~~Covered scraped defecating dunging areas indoors should present fewer problems because scraper tractor noise is contained within the structure.~~
- ~~Scraped areas outside the buildings should be kept~~ Keep to a minimum scraped areas outdoor to ~~help~~ reduce noise from scraper tractors ~~operating outside~~.
- Locate slurry and manure storage ~~areas should ideally be located at the end of the site furthest~~ away from nearby dwellings. ~~The building layout should, where practical, be organised so that slurry tanker filling points are located on the side of buildings away from the site boundary or residential property. This uses the effect of distance and the sound reducing qualities of the building to absorb and deflect the noise.~~
- Pressure washers and compressors ~~generate considerable noise and~~ should normally be used inside buildings~~. Their use outside, e.g. to clean vehicles, should be avoided on sensitive sites. Wherever possible, machinery should be washed under cover and in locations away from residential housing and other sensitive properties.~~

VIII.Manure and slurry handling on poultry farms
Measures to reduce noise produced when poultry manure is handled are listed below.

- When cleaning out poultry buildings, ~~some loader noise is contained within the building. The movement and manoeuvring of loaders filling trailers outside the building should be organised to minimise the amount of machinery movement.~~ if there is sufficient headroom, trailers should be loaded inside the building.
- ~~Always ensure that loaders and tractors are~~ Well maintained~~. Particular attention should be given to~~ vehicle exhaust systems and silencers.
- ~~The instruction and training of~~ Teach and train staff in the operation of loaders~~ can significantly reduce machinery noise~~.
- ~~For new buildings, consider their orientation and placement with regard to manure and product handling so that, where practical, machinery movement is~~ Concentrated manure and product handling at the ends of buildings furthest away from other property such as residential housing.
- ~~On some egg production units, manure is conveyed directly to a separate storage building. This enables trailers to be loaded mainly within the building.~~
- Prevent conveyors used for manure handling ~~are a source of noise,~~ from emitting squeaks and clicks. They should be located within the building structure as much as possible. ~~Where they pass between buildings the length of run should be as short as possible and the provision of sound absorbing barriers such as straw bales or more permanent panelling should be considered. Fully loaded~~ Conveyors ~~reduce vibration and noise. They~~ should not be allowed to run empty.
- Use pressure washers and compressors ~~generate considerable noise and should normally be used~~ inside buildings~~. Their use outside, to clean vehicles, should be avoided on sensitive sites. Wherever possible, machinery should be washed under cover and in locations away from residential housing and other sensitive properties.~~

IX. Application of noise barriers
~~4.11.3 Application of noise barriers~~

~~**Description**~~
~~Control of noise from a site can be achieved by the use of~~ Barriers~~. These~~ are most effective against high frequency noise. Long wavelength, low frequency noise will pass around or over the barriers. ~~Barriers must be absorptive of the noise, otherwise it will be reflected.~~

Earth banks can be used to combine the effect of barriers with the absorption of vegetation, and can be useful when constructed along the boundaries of pig units. Straw bales can be used to provide a tall, effective, temporary noise barrier because of their thickness and mass, and because of their absorptive surfaces. ~~Straw bales should not be used in or near pig buildings where they may increase the risks of fire or where the consequences of a fire would be a greater~~

~~danger to pigs or farm workers.~~ Tall, solid, wooden fences reduce noise propagation. These can be sited on top of earth banks to increase the overall height of the obstacle.

~~The achievable reduction depends on the type of barrier.~~

~~Barriers can be applied in any situation. The local situation will determine, whether a structural barrier, such as wooden fences or earth banks, can be applied.~~

The application of low-noise fans, design measures to reduce airflow resistance, and operational measures (intermittent operation) can all reduce energy consumption. ~~However, low-level wall-mounted fans are considered to be less efficient than roof-mounted fans so additional fan capacity would be required. In addition, it was reported that~~ Low-level wall-mounted fans create more odour around the unit than roof-mounted fans with ‘rain-rings’.

Indicative effects of some applied measures are given in Table 4.204.

Table 4.204: Reducing effect of different noise measures

Category	Reduction measure	Reduction effect (dB(A))
Technical	Natural ventilation	variable
	Low-noise fans	ND
	Application of silencers	ND
Design and construction	Low-level sidewalls	ND
	Hedge/vegetation barrier	2
Operational	Small number/continuous operation	3
NB: ND = no data		

Applicability
All measures are generally applicable.
~~In the case of new farms, many of the siting measures can be applied as part of the site planning. In that case use should be made of any natural contours. For existing systems the relocation of activities may technically be possible for some activities only, but relocation of large constructions, such as animal housing, may be constrained as it requires relatively high investments.~~
~~Measures related to operator’s practice and timing can be applied at any time, for both new and existing farms.~~

Economics
Please TWG provide information.

Driving force for implementation
New piggery and new poultry developments should take account at the design stage of the noise control benefits of low-level and side-mounted fans and of acoustic barriers. The applicability of natural ventilation systems should also be considered.

Example plants
All measures are generally applied.

Reference literature
[393, ADAS 1999] [559, ADAS 1999].

4.15 Techniques for the treatment and disposal of residues other than manure and animal carcasses

ORIGINAL TEXT, ALREADY DELETED IN DRAFT 1, HAS BEEN ELIMINATED

Description
Residues to be handled in a farm are listed in Section 2.11. Common practices to treat liquid and solid residues have been described in ~~the~~ Sections ~~from~~ 2.11 ~~to~~ and 2.13.

With respect to liquid residues, the mixing of waste water with slurry followed by further treatment or separate treatment through low rate irrigation is common practice. The reduction of emissions from those techniques is described in Section 4.13.

Uncontaminated precipitation water from roofs and roadways can, as a rule, be allowed to soak away locally or be discharged into drainage ditches or main outfalls. Any possibilities for reuse (such as cleaning) involving collection and separate storage could be considered.

Only allowing the use of tested cleaning agents and disinfectants can reduce the harmfulness of waste water.

There are various ways to dispose of solid residues. ~~In general, the burning of residues (packaging material and plastics) in the field, although still allowed in many places, is not considered an environmentally sound technique.~~ Burning of residues in the field is forbidden. In case solid wastes are incinerated, the incineration plant must hold a permit from the competent authority in accordance with the Industrial Emission Directive 2010/75/EU, Chapter IV and Annex VI, where technical provisions relating to waste incineration plants and waste co-incineration plants are given. Measure to prevent or to reduce as far as possible negative effects on the environment (air, soil and water) caused by the incineration of waste are described in the European BAT Reference Document for Waste incineration (WI BREF). Waste incineration or co-incineration plants may be equipped with heat recovery systems.
~~In-farm incineration should be avoided since it is a difficult process to control and temperatures may not reach the levels required for proper incineration, resulting in air emissions of substances associated with incomplete burning (e.g. cancerous substances). It may be an option to burn the residues to provide energy for heating; but no data have been submitted allowing an assessment of this. The burning of plastics, rubber, tyres and other materials in the open should not be allowed.~~

On-farm burying or landfilling of residues was ~~is~~ also widely practised in the past ~~and may be an option in the short term,~~ but is no longer legally allowed. ~~sustainable may not serve this purpose~~ in the ~~long term.~~ Soil and groundwater contamination may occur, depending on the characteristics of the residues that are being buried. Initial cost savings may then turn into a financial burden, i.e. for cleaning and renovation of the site. ~~Residues that are buried include building materials, such as asbestos cement roof sheets.~~

Achieved environmental benefits
Achievable benefits are all related to the type of material and potential for energy saving.

Cross-media effects
~~No negative counter-effect has been individuated.~~
None reported.

Operational data
Duty of care
Everyone who handles waste, from the person producing the waste to the person who finally disposes of or recovers it. Waste must be kept secure so it does not leak, spill, or blow away and can only be given to an authorised person (e.g. a registered waste carrier) and be transferred with the release of signed transfer notes. [386, DEFRA 2009]

Treatment of liquid residues
A few actions can be applied to reduce the amount and harmfulness of waste water on a farm. Precipitation water from uncovered exercise yards, outdoor feeding areas and dung slabs should be collected and used. When dimensioning the storage capacity for liquid manure and dung water, the volume of precipitation water to be taken into account has to match the average precipitation volumes and the size of the areas involved, less any evaporative loss.

By extensively employing dry cleaning methods with a subsequent use of jet cleaners, water consumption and waste water accumulation can be significantly reduced.

Treatment of solid residues
Best Practicable Environmental Option (BPEO) should be followed. This approach follows the waste hierarchy framework (reduction, reuse, recovery, disposal) and it applies principles of proximity (treatment of waste as close as possible) and of precaution (immediate application of cost-effective measures to prevent environmental degradation).

Within this framework the following on-farm options can be applied:

- reuse of residues
- composting of residues
- energy recovery.

Reuse focuses on re-usable or refillable packaging. Possibilities for the on-farm composting of residues other than manure appear very limited; with secondary cardboard packaging having the most opportunity. Energy recovery includes the already applied oil burners, but other materials may be applied with the new developing energy recovery technologies. Techniques typically applied on intensive poultry and pig farms have not been reported.

Treatment of hazardous waste
Examples of farm wastes that are classified as hazardous include waste oil, asbestos, lead acid batteries and agro-chemicals containing dangerous substances. Hazardous wastes must not be mixed with them or with non-hazardous waste or other substances and materials. Hazardous wastes must be collected and disposed of separately, complying with local rules and must be transferred accompanied by “consignment notes”. [386, DEFRA 2009]

Applicability
These measures are generally applicable.

Economics
Some costs are associated with the treatment techniques applied. In particular, incineration and landfill of residues will have to observe increasing legislative requirements that will raise the costs of applying and operating these techniques.

Costs for other ways of disposal or recovery include:

1. collection and transport costs
2. disposal and recovery costs
3. landfill tax (if disposed by landfill).

Costs to the farmer will depend on a number of factors including:

1. farm location and distance to suitable facilities
2. quantity of the residues
3. nature and classification of the residues
4. final treatment method
5. market demand for secondary materials.

Driving force for implementation
It is expected that agricultural residues will increasingly be considered as industrial waste. Requirements laid down in various directives concerning waste, such as the EU Landfill Directive (Directive 1999/31/EC), ~~and~~ the ~~Waste Incineration Directive~~ Industrial Emissions Directive 2010/75/EU, Chapter IV and Annex VI on waste incineration and the Waste Framework Directive 2008/98/EC, will form major forces to change the treatment of agricultural residues.

Other forces that drive the change in the treatment of residues are considered to be the demands from retailers and consumers, growing public concern about the environmental and human health impacts of products, increasing costs for disposal, and developing EU Directives applying the ‘polluter pays’ principle.

Example plants
The described measures are commonly applied.

Reference literature
[403, EA 2001]

4.16 Storage and disposal of animal carcasses

Common practices related to the handling and storage and disposal of animal carcasses (dead animals) have been described in Section 2.12.

Animal carcasses are considered animal by-products which are covered by Regulation (EC) 1069/2009 of 21 October 2009, that aims at excluding animals which have died (other than those slaughtered as fit for human consumption) and other condemned materials from the animal feed chain and to achieve safe processing and disposal of animal by-products. Regulation 1069/2009 distinguishes between three different categories of animal by-products and derived materials (with category 1 involving the highest risk) and provides provisions for the disposal of material from each category.

For the disposal of animal carcasses, waste incineration and co-incineration are indicated among the authorised procedures.

Commission Regulation (EU) 142/2011 of 25 February 2011 lays down general and specific operating conditions for incineration and co-incineration plants treating only animal by-products and derived products, for two different threshold capacities, more than 50 kg per hour or per batch (high-capacity incinerators or co-incinerators) and at or less than 50 kg per hour or per batch (low-capacity incinerators or co-incinerators).

Specialised services are commonly used to collect carcasses from farms and to process them in centralised treatment facilities. Large centralised incineration facilities, treating different types of waste, fall under a regulatory framework and are designed to meet the provisions set out in the Industrial Emission Directive 2010/75/EU, Chapter IV and Annex VI, or equivalent requirements. The European Reference Documents reporting the Best Available Techniques for these activities are the BAT Reference Document (SA BREF) on Slaughterhouses and Animals By-products Industries and the BAT Reference Document on Waste Incineration (WI BREF).

Large, centralised incinerators allow better control than small-scale incinerators, concerning issues related to animal health, (e.g. potential for spreading disease through vehicle movement) as well as to control emissions to air (combustion efficiency and control of air pollutants). On the other hand, the impact on disease control from storing and delivering animal carcasses off-farm is difficult to evaluate.

In some Member States, small-scale animal carcass incinerators may be found in operation on-farm; while, in other Member States they are prohibited.

Emissions from small-scale on-farm incinerators have been reported for different types of fuel, and for operating conditions with or without an afterburner. Typical emissions from combustion are dust, SO_X, NO_X, CO_2 and CO.

Carbon dioxide emissions are primarily governed by the carbon content of the fuel burnt and the wastes incinerated. The combustion efficiency is an important additional factor, which determines the full oxidation of carbon to CO_2. The use of afterburners is essential to minimise emissions of VOC, CO and particulate matter; however, it should be noted that even small-scale incinerators equipped with an afterburner, but poorly operated and/or maintained (e.g. overloaded) can give rise to much greater emissions of most pollutants than a simpler design, not equipped with an afterburner, but carefully operated system [476, AEAT 2002]. Sulphur dioxide emissions are directly proportional to the sulphur content of the fuel used and waste incinerated.

Examples of average emissions in concentration and per operating cycle are presented in Table 4.205 and Table 4.206.

Table 4.205: Examples of emission concentrations in flue-gases from small-scale on-farm incinerators

		Incinerators with afterburners			Incinerators without afterburners		
Type of animal		**Poultry**	**Poultry**	**Pig**	**Poultry**	**Pig**	**Pig**
Fuel		**Propane**	**Propane**	**Diesel**	**Kerosene**	**Gas oil**	**Oil**
Dust ([1])	mg/Nm^3	58	90	36	107	173	277
SO_2	mg/Nm^3	179	34	376	456	127	313
HCl	mg/Nm^3	58	8	24	112	26	56
CO	mg/Nm^3	1 030	1 620	1 650	348	1 180	5 840
NO_X ([2])	mg/Nm^3	381	303	376	225	129	352
VOCs ([3])	mg/Nm^3	61	484	117	869	78	3 490
Dioxins and furans ([4])	ng/Nm^3	0.19	0.1	0.1	0.08	0.21	0.05
CO_2	%	7.2	6.9	7.6	7.7	7.5	9

([1]) Dust as total particular matter.
([2]) NO_X as NO_2.
([3]) VOC as total organic carbon.
([4]) I-TEQ=international toxic equivalent.
Mass concentrations are standardised at 11 % O_2, dry gas, temperature 273.15 K, pressure 101.3 kPa.
Source: [476, AEAT 2002]

Table 4.206: Examples of total emissions by operating cycle from small-scale on farm incinerators

		Incinerators with afterburners			Incinerators without afterburners		
Type of animal		**Poultry**	**Poultry**	**Pig**	**Poultry**	**Pig**	**Pig**
Fuel		**Propane**	**Propane**	**Diesel**	**Kerosene**	**Gas oil**	**Oil**
Dust (1)	kg/cycle	0.06	0.08	0.08	0.25	0.79	0.3
SO_2	kg/cycle	0.19	0.03	0.88	1.1	0.64	0.31
HCl	kg/cycle	0.06	0.01	0.06	0.26	0.12	0.06
CO	kg/cycle	1.1	1.4	3.9	0.84	5.3	6.3
NO_X	kg/cycle	0.41	0.27	0.88	0.51	0.58	0.38
VOCs (2)	kg/cycle	0.07	0.43	0.27	1.8	0.35	3.8
Dioxins and furans	ng/cycle	190	90	220	210	910	50
CO_2	kg/cycle	106	246	367	200	505	302

([1]) Dust as total particular matter
([2]) VOC as total organic carbon
([3]) I-TEQ=international toxic equivalent
Source: [476, AEAT 2002]

Poor loading of incinerators is considered to be a major problem causing inefficient combustion and increased emissions. Small-scale incinerators are legally required to burn at or below 50 kg an hour; therefore, the manufacturers design the plants to cope with this load and no higher.

Good housekeeping practices are essential to ensure hygienic on-farm storage of the animal carcasses; these wastes are stored in sealed containers that are normally refrigerated.

4.17 Optimisation of the whole-farm environmental impact – Adoption of a whole-farm approach

Description
Emission reduction measures applied to a specific stage of the animal rearing process have an influence on the emissions potential of the next stage, due to the interdependency of the various phases of livestock manure management. In general, a reduction of ammonia emissions from the housing system results in a higher concentration of nitrogen in the stored manure; while, a measure to reduce emissions from manure storage results in an increased amount of available nitrogen for field application, with a consequent higher risk of ammonia emissions during landspreading and higher potential for nitrate leaching to water. On the basis of these observations, management strategies which retain ammonia during one process step are only beneficial if they do not subsequently exacerbate losses from the following step. Therefore, an integrated approach for a whole-farm emissions reduction should be promoted, based on a manure management strategy that avoids pollution swapping.

Combinations of measures/techniques applied at the different production stages do not simply add up in terms of overall emission reduction efficiency; in addition, the abatement efficiency of a technique may depend on the measures/techniques applied in the previous production stages. Furthermore, techniques may have associated cross-media effects that result in significant indirect emissions related to the use of energy (fossil fuel, electricity), chemical products (fertilisers, additives) or materials which extraction/production may cause damage to the environment.

A whole-farm environmental and/or economic assessment of the combination of techniques may be determined by calculations based on available data (e.g. emission factors, reduction rates, consumption of energy and other resources, costs) and estimations of cross-media effects. This approach allows distinguishing between techniques or combinations of techniques that lead to an overall environmental improvement and techniques which may result in a trade-off of pollutants. Tools have been developed for the environmental and economic assessment of the combination of techniques; some examples are reported in Chapter 9.

Achieved environmental benefits
Overall emissions reduction through an optimised manure management and use of manure nutrients (particularly nitrogen).

Avoid pollution swapping from one production stage to another.

Cross-media effects
None reported.

Operational data
Different combinations of techniques, applicable to the main stages of the rearing process, have been assessed for the main animal categories (fattening pigs, laying hens and broilers) on the basis of a methodology developed by Denmark (see Chapter 9). The assessment has been carried out in comparison with reference techniques and combinations of techniques, considered as common use for the specific animal category and associated with a basic environmental performance. The selected combinations of techniques used for the assessment are indicated below. It should be noted that these combinations are not intended to define BAT for the specific animal category; the aim is to present examples of the environmental performance for the whole farm and, in general, to illustrate the usefulness of the approach. The specific assessment tool takes into account not only ammonia emissions but also nitrogen emissions to water and greenhouse gas emissions.

The environmental assessment is also combined with an economic analysis, which is used to assess economic constraints to the applicability of techniques and their possible combination, in particular with regards to the size of the farm.

In Table 4.207, Table 4.208, Table 4.209 and Table 4.210, the combinations of techniques submitted to environmental and economic assessment are reported.

Table 4.207 Examples of assessed combinations of techniques for fattening pigs

Combination	Nutrition	Housing system (with or without end-of-pipe technique)	Manure storage	Field application	NH_3 reduction (whole farm) %
Selected reference	One-phase feeding	Fully-slatted floor with deep pit	Open storage, no covering	Broadcast spreading, no incorporation within 24 hours	0
1	Low protein feed (N excretion reduced by 16 %)	Fully (or partly) slatted floor with vacuum system	Floating cover (natural crust)	Band spreader (trailing hose)	35.8
2	Phase feeding	Fully (or partly) slatted floor with vacuum system	Floating cover (natural crust)	Band spreader (trailing hose)	38.2
3	Phase feeding with addition of amino acids	Fully-slatted floor with vacuum system	Rigid cover (plastic)	Open slot shallow injection	55.0
6	Two-phase feeding	Fully-slatted floor with vacuum system for frequent slurry removal + wet scrubbing system	Floating cover (straw)	Band spreader (trailing hose)	69.3
6A	Two-phase feeding	Fully-slatted floor with vacuum system for frequent slurry removal + biofilter	Floating cover (straw)	Band spreader (trailing hose)	67.8
7	Two-phase feeding	Solid concrete floor with full litter	Rigid cover (concrete or tent)	Spreading with a suitable technique(e.g. rotaspreader, rear-discharge spreader) with incorporation within 4 hours	+60.6 ([1])
8	Two-phase feeding	Fully (or partly) slatted floor with vacuum system for frequent slurry removal + slurry acidification	Slurry acidification + storage without cover	Band spreader (trailing hose)	81.4
9	Two-phase feeding	Partly-slatted floor with vacuum system for frequent slurry removal + slurry cooling	Floating cover (straw) or rigid cover (concrete or tent)	Band spreader (trailing hose)	50.3
10	Two-phase feeding	Partly-slatted floor with vacuum system for frequent slurry removal + slurry cooling	Rigid cover (concrete or tent)	Shallow injection or acidification applied to grass and black soil and band spreader (trailing hose) in other crops	50.3

([1]) The combination of techniques is associated with an increase in ammonia emissions, compared to the selected reference.

Table 4.208 Examples of assessed combinations of techniques for broiler production

Combination	Nutrition	Housing system (with or without end-of-pipe technique)	Manure storage, manure processing	Field application	NH_3 reduction (whole farm) %
Selected reference	Phase feeding	Deep litter	Uncovered storage	Immediate incorporation (within 4 hrs after application)	0
1A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Deep litter	No storage. Immediate application of manure	Immediate incorporation (or within 4 hrs after application)	47.3
1B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Deep litter	No storage. Immediate application of manure	Incorporation within 4 hrs after application	53.1
2A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Deep litter	Uncovered storage	Incorporation within 4 hrs after application	33.7
2B	Phase feeding with amino acid supplementation (10 % level of reduction)	Deep litter	Uncovered storage	Incorporation within 4 hrs after application	41.1
3A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Deep litter	Covered storage	Incorporation within 4 hrs after application	38.1
3B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Deep litter	Covered storage	Incorporation within 4 hrs after application	44.9
4A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Deep litter with litter drying by circulating fans	Covered storage	Incorporation within 4 hrs after application	60.1
4B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Deep litter with litter drying by circulating fans	Covered storage	Incorporation within 4 hrs after application	64.5
6A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Deep litter + wet acid scrubbing system)	Covered storage	Incorporation within 4 hrs after application	66.6
6B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Deep litter + air cleaning (70 % wet acid scrubbing system)	Covered storage	Incorporation within 4 hrs after application	70.3

Table 4.209 Examples of assessed combinations of techniques for laying hens in enriched cages

Combination	Nutrition	Housing system (with or without end-of-pipe technique)	Manure storage	Field application	NH_3 reduction (whole farm) %
Selected reference	Phase feeding	Enriched cages, non ventilated belt for manure removal (2 times a week)	Uncovered storage	Immediate incorporation	0
1A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Enriched cages, non ventilated belt for manure removal (2 times a week)	Uncovered storage	Immediate incorporation	58.9
1B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Enriched cages, non ventilated belt for manure removal (2 times a week)	Uncovered storage	Immediate incorporation	63.4
2A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Enriched cages, ventilated belt with manure drying (weekly)	Covered storage	Incorporation within 4 hours after application	56.4
2B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Enriched cages, ventilated belt with manure drying (weekly)	Covered storage	Incorporation within 4 hours after application	61.3

Table 4.210 Examples of assessed combinations of techniques for laying hens on litter

Combination	Nutrition	Housing system (with or without end-of-pipe technique)	Manure storage	Field application	NH_3 reduction (whole farm) %
Selected reference	Phase feeding	Deep litter	Uncovered storage	Immediate incorporation (or incorporation within 4 hours)	0
3A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Aviaries with littered floor, ventilated belt with manure drying (weekly)	Covered storage	Immediate incorporation (or within 4 hours)	69.8
3B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Aviaries with littered floor, ventilated belt with manure drying (weekly)	Covered storage	Immediate incorporation (or within 4 hours)	73.2
3C	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Aviaries with littered floor, without ventilated belt with manure drying (weekly)	Covered storage	Immediate incorporation (or within 4 hours)	27.0
3D	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Aviaries with littered floor, without ventilated belt with manure drying (weekly)	Covered storage	Immediate incorporation (or within 4 hours)	35.1
4A	Phase feeding with amino acid supplementation (N excretion reduced by 10 %)	Deep litter (deep pit with partly littered floor), forced drying of manure in pit	Covered storage	Immediate incorporation (or within 4 hours)	79.4
4B	Phase feeding with amino acid supplementation (N excretion reduced by 20 %)	Deep litter (deep pit with partly littered floor), forced drying of manure in pit	Covered storage	Immediate incorporation (or within 4 hours)	81.7

Applicability
There are no restrictions to the applicability.

Economics
Estimated costs for implementing the combinations of techniques chosen as examples of the whole-farm approach are based on economic data provided for each technique and reported in the relevant sections of Chapter 4. In Chapter 9, the detailed cost data used for the assessment are presented, together with general economic assumptions.

Total costs have been calculated as increased production costs (EUR per animal place) and as costs of emission reduction (EUR per kg reduced NH_3 emission). Cost estimations have been determined for different capacity farms, in particular for:

Sows: 750, 1 500 and 3 000 animal places.
Fattening pigs: 2 000, 4 000 and 6 000 animal places.
Laying hens: 40 000 and 80 000 bird places.
Broilers: 40 000 and 80 000 bird places.

The comparison of cost estimates for various combinations of techniques, with different overall emission reduction performances, provides the following indications:

- combinations of techniques that include end-of-pipe measures show a significantly higher economic impact in terms of EUR/animal place;
- the economic impact on different size farms is evident in the pig sector, with higher costs for farms having a capacity between 750 to 1 500 places for sows and between 2 000 and 4 000 places for fattening pigs;
- in general, higher costs are associated with higher ammonia removal efficiencies; however, some combinations showing comparable environmental performances may be associated to significantly different costs.

The results of the economic assessment for combinations of techniques indicate the importance of using a whole-farm approach in order to determine the overall environmental efficiency generated from the combination of measures taken in all steps of the production process, from nutritional measures to manure management.

Driving force for implementation
Livestock manure is a valuable source of nutrients for soil and crops. The efficient use of manure nutrients to agricultural land can substantially reduce the need for chemical fertiliser. An effective use of manure nutrients, in particular nitrogen, requires considering the whole manure management system.

A whole-system approach can prevent or limit the environmental consequences further up or down the production chain system and/or ensure adjoining systems are taken into account when making a decision on emission control techniques.

A whole-system approach enables identifying the most cost efficient techniques or combination of techniques that can achieve the same level of environmental protection.

Example plants
Decision support tools for the environmental and economic assessment of techniques or combinations of various techniques are available within the European Union, in particular, tools developed by Denmark, Germany, Spain, based on comparable approaches, although, with different assumptions and level of detail (see Chapter 9).

In the UK, the National Ammonia Reduction Strategy Evaluation System (NARSES) tool is currently used to model flows of total nitrogen and total ammoniacal nitrogen (TAN) through the livestock production and manure management system, with NH_3 losses given at each stage as a proportion of the TAN present within that stage.

Reference literature
[508, TFRN 2012] [500, IRPP TWG 2011] [204, IMPEL 2009] [612, TWG comments 2012]

5 BAT CONCLUSIONS

SCOPE

These BAT conclusions concern the following activities specified in Section 6.6 of Annex I to Directive 2010/75/EU, namely:

6.6. Intensive rearing of poultry or pigs:

(a) with more than 40 000 places for poultry

(b) with more than 2 000 places for production of pigs (over 30 kg), or

(c) with more than 750 places for sows.

In particular, concerning the above-mentioned activities, these BAT conclusions cover the following processes:

1. Nutritional management of poultry and pigs
2. Storage of animal feed and feed additives
3. Milling and grinding of feed
4. Rearing (housing) of poultry and pigs
5. Collection and storage of manure
6. On-farm processing of manure
7. On-farm treatment of manure
8. Landspreading of manure
9. Storage of animal carcasses.

These BAT conclusions do not address the following activities:

10. Animal slaughtering and disposal of animal carcasses covered by the Reference Document on Best Available Techniques for Slaughterhouses and Animal By-products Industries (SA).

Other reference documents which are of relevance for the activities covered by these BAT conclusions are the following:

Reference documents	Activity
Waste Incineration (WI)	Incineration of animal carcasses
Emissions from Storage (EFS)	Storage and handling of raw materials and products
Energy Efficiency (ENE)	General energy efficiency
Economics and Cross-media Effects (ECM)	Economics and cross-media effects of techniques

Where these BAT conclusions address the landspreading of manure, this is without prejudice to the provisions of the Council Directive 91/676/EEC ([1]) concerning the protection of waters against pollution caused by nitrates from agricultural sources and the Water Framework Directive 2000/60/EC ([2]).

([1]) OJ L 375/1, 31.12.1991, p.1
([2]) OJ L 327/1, 22.12.2000, p.1

Where these BAT conclusions address the storage and disposal of animal carcasses, this is without prejudice to the provisions of the EC Regulation 1069/2009 ([3]) laying down rules as regards animal by-products and derived products not intended for human consumption.

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection.

DEFINITIONS

For the purposes of these BAT conclusions, the following definitions apply:

Term used	Definition
Farm	A complex composed by one or more plants (i.e. animal housing systems, manure storage facilities, manure processing or treatment facilities)
New farm	A farm first operated following the publication of these BAT conclusions
Existing farm	A farm which is not a new farm
New plant	A plant introduced on the site of the farm following the publication of these BAT conclusions or a complete replacement of a plant on the existing foundations, following the publication of these BAT conclusions
Existing plant	A plant which is not a new plant
Major upgrade	An upgrade of the plant involving a major change in the requirements or technology for the housing system and/or storage of manure
Sensitive receptor	Area which needs special protection because of its landscape, wildlife, or an area of land that drains into waters which could become polluted by nitrates or other substances

Definition for certain animal categories

Term used	Definition
Weaners	Young pigs reared from a live weight of between 8 kg and 28 – 30 kg
Fattening pigs (growers/finishers)	Pigs reared from a live weight of between 28 – 30 kg to a final weight of 120 – 170 kg
Sows	Female pigs during the rearing period of mating, gestating and farrowing; from after puberty and before farrowing (gilts) to after the first farrowing (sows)
Poultry	Chickens, turkeys, ducks, guinea fowls, etc. reared for the production of eggs or for the production of meat
Laying hens	Grown female chickens for laying eggs
Pullets	Hens less than one year old
Broilers	Chickens raised for meat production

([3]) OJ L 300/1, 14.11.2009, p.1

Definition for certain substances and emissions

Term used	Definition
Dust (particulate matter)	Particles of any shape, structure or density which may be collected by filtration from indoor ambient air or air outlet(s) of an animal housing system
Odour emissions	Volatile odorous substances measured by olfactometry (EN 13725) and expressed as European Odour Units (ou_E)
N excreted	Nitrogen eliminated from animal metabolic processes through urine and faeces
P excreted	Phosphorus eliminated from animal metabolic processes through urine and faeces
Slurry	Liquid manure

GENERAL CONSIDERATIONS

Averaging periods and reference conditions for air emissions

Unless otherwise stated, emission levels associated with the best available techniques (BAT-AELs) given in these BAT conclusions refer to the mass of substances emitted per animal place, for all rearing cycles carried out during one year (i.e. **kg substance/animal place/year**).

In the case of direct measurements, all values for concentrations in exhaust air refer to standard conditions: dry gas at a temperature of 273 K, and a pressure of 1 013 hPa.

BAT-AELs for odour emissions given in these BAT conclusions are based on concentration values referred to standard conditions of undiluted gas (a temperature of 293 K and a pressure of 1 013 hPa), without correction for the humidity content.

5.1 General BAT conclusions

Unless stated otherwise, the BAT conclusions presented in this section apply to all farms for the rearing of poultry or pigs.

The sector-specific or process-specific BAT conclusions included in Sections 5.2 - 5.3 apply in addition to these general BAT conclusions.

5.1.1 Environmental management systems (EMS)

1. In order to improve the overall environmental performance of the farms for intensive rearing of poultry or pigs, BAT is to implement and adhere to an environmental management system (EMS) that incorporates all of the following features:

1. commitment of the management, including senior management;
2. definition of an environmental policy that includes the continuous improvement of the installation by the management;
3. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;
4. implementation of procedures paying particular attention to:

    (a) structure and responsibility
    (b) training, awareness and competence
    (c) communication
    (d) employee involvement
    (e) documentation
    (f) efficient process control
    (g) maintenance programmes
    (h) emergency preparedness and response
    (i) safeguarding compliance with environmental legislation;

5. checking performance and taking corrective action, paying particular attention to:

    (a) monitoring and measurement (see also the Reference Document on the General Principles of Monitoring)
    (b) corrective and preventive action
    (c) maintenance of records
    (d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

6. review of the EMS and its continuing suitability, adequacy and effectiveness by senior management;
7. following the development of cleaner technologies;
8. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;
9. application of sectoral benchmarking on a regular basis.

Specifically, for intensive rearing of poultry or pigs, it is also important to consider other items listed under BAT 2.

Applicability
The scope (e.g. level of details) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the farm, and the range of environmental impacts it may have.

5.1.2 Good housekeeping

2. In order to prevent or reduce the environmental impact and improve the overall performance of the intensive rearing of poultry or pigs, BAT is to use all the techniques given below:

	Technique	Applicability
a	Proper selection of the site and spatial arrangements of the activities in order to: 1. Reduce unnecessary transport of animals and materials (including manure) 2. Ensure adequate distances from sensitive areas requiring protection 3. Take into account prevailing climatic conditions (e.g. wind) 4. Consider potential future development capacity of the farm	Applicable to new farms
b	Educate and train staff, in particular for: 1. Regulations concerning livestock farming, including animal welfare, and manure management 2. Transport and spreading of manure 3. Planning of activities 4. Emergency planning 5. Repair and maintenance of equipment	Generally applicable
c	Prepare a contingency plan for dealing with unexpected emissions and incidents such as pollution of water bodies. It should include: 1. A plan of the farm showing the drainage systems and water/effluent sources 2. Plans of action for certain potential events (e.g. fires, leaking or collapsing of slurry stores, uncontrolled run-off from manure heaps, oils spillages) 3. Available equipment for dealing with a pollution incident (e.g. for plugging land drains, damming ditches, scum boards for oil spillages)	Generally applicable
d	Regularly check, repair and maintain structures and equipment, in particular: 1. Cleanliness of the facility 2. Slurry storages for any sign of damage, degradation, leakage 3. Slurry pumps, mixers, separators, irrigators	Generally applicable

3. In order to prevent or reduce emissions to the environment from feed storage, BAT is to use all the techniques given below:

	Technique	Applicability
a	Regularly inspect and maintain the feed silos and transport facilities (valves, tubes)	Generally applicable
b	Periodic complete emptying of the feed silos (every few months) to allow inspection and prevent biological activity in the feed	

5.1.3 Efficient use of water

4. In order to use water efficiently, BAT is to use a combination of the techniques given below:

	Technique	Applicability
a	Use meters to keep a record of water use	Generally applicable
b	Detect and repair water leakages	
c	Use high-pressure cleaners for cleaning animal housing and equipment at the end of each batch of livestock	
d	Select suitable equipment (e.g. nipple drinkers, round drinkers, water troughs) for the specific animal category while ensuring water availability (*ad libitum*)	
e	Verify and (if necessary) adjust on a regular basis (e.g. every 6 months) the calibration of the drinking water equipment	
f	Collect and separately store uncontaminated precipitation water for possible reuse as cleaning water	Generally applicable?

5.1.4 Treatment and reuse of lightly contaminated run-off waters

5. In order to reduce water emissions from run-off waters, BAT is to treat and/or reuse lightly contaminated run-off waters by using one or a combination of the technique given below:

	Technique	Applicability
a	Separate highly contaminated run-off waters from lightly-contaminated waters through a "first flush system" and biological treatment of the lightly-contaminated run-off waters by means of swales, ponds, constructed wetlands or soakaways	The applicability is limited by the availability of land with a water-tight deep area. In cold climates, the technique may be only used for part of the year; a storage system for run-off water is then normally needed during winter
b	Use a low-irrigation system for lightly contaminated water. Water containing residues of cleaning or other run-off water from the farm is settled in tanks or lagoons before application onto land. Suspended particles can settle or solid removal can be carried out; the resulting solid fraction is disposed of	Applicable only for run-off waters with a proven light level of contamination. The technique requires availability of sufficient and suitable land adjacent to the plant

5.1.5 Efficient use of energy

6. In order to use energy efficiently, BAT is to use a combination of the techniques given below:

	Technique	Applicability
a	Proper design of the animal housing and selection of equipment (e.g. ventilation system, motors, heating and lighting systems)	Generally applicable
b	Monitor energy consumption for the whole production process and for the different production phases	Generally applicable
c	Ensure the accuracy of the temperature sensors	Generally applicable
d	Use controlling devices such as dimmers and thermostats	Generally applicable
e	Regularly maintain and repair equipment (e.g. heaters, ventilators, controlling devices)	Generally applicable
f	Separate heated areas from unheated areas	Generally applicable

5.1.6 Noise emissions

7. In order to reduce noise emissions from the farm, BAT is to use one or a combination of the techniques given below:

	Technique	Applicability
a	Select a building structure with noise absorption properties for the housing of animals or other noisy operations (e.g. manure processing or treatment)	Applicable to new plants
b	Plan carefully any potentially noise generating activities, particularly to avoid nights and weekends	Generally applicable
c	Avoid unnecessary disturbance of animals during feeding and inter-house transfer (e.g. plan the catching and transfer of poultry during night-time or early morning, in the dark)	Generally applicable
d	Use low-noise equipment in the design and operation (e.g. low noise level fans, extract fans on side walls instead of roof-mounted units, use of a small number of fans operating continuously)	Generally applicable
e	Prepare and deliver feed to the animal housing using techniques such as: 1. enclosure of equipment (e.g. mills, pneumatic conveyers) 2. minimise delivery pipes lengths 3. close doors and major openings of the building during feeding time 4. operate conveyers and augers full of feed materials 5. locate feed bins and feed storage silos in order to reduce delivery vehicle movement on site and as far away as practicable from residential and sensitive areas	Generally applicable
f	Use an appropriate mechanical feeding system which reduces the pre-feeding stimulus, such as: 1. feeders equipped with holding hoppers 2. passive *ad libitum* feeders	Applicable to pig housing systems Passive *ad libitum* feeders are applicable to new pig plants or at the time of a major upgrade of existing plants
g	Apply measures to reduce noise from manure and slurry handling, such as: 1. locate storage and handling areas furthest away from residential houses and other property 2. keep outdoor scraped areas to a minimum in order to reduce noise from scraper tractors 3. use pressure washers and compressors inside buildings 4. if sufficient headroom is available, load trailers (with litter, manure) inside buildings 5. properly maintain conveyers for manure handling and avoid running them empty	Generally applicable
h	Apply noise barriers such as: 1. earth banks 2. straw bales 3. tall, solid wooden fences	Generally applicable

5.1.7 Treatment and disposal of residues other than manure and animal carcasses

8. In order to reduce the generation of waste and prevent diffuse emissions from the treatment and disposal of residues other than manure and animal carcasses, BAT is to use a combination of the techniques given below:

	Technique	Applicability
a	Store residues in suitable containers or small bins for municipal or special service collection	Generally applicable
b	Use approved cleaning agents and disinfectants in order to reduce the harmfulness of the resulting waste water	Generally applicable
c	Recover feed and crop residues by mixing them with manure or slurry or for other uses	Generally applicable
d	Recover and regenerate residues/waste e.g. by composting, anaerobic digestion	Applicability of a particular recovery/regeneration technique depends on the characteristics of the residues/waste

5.1.8 Storage of animal carcasses

9. In order to prevent emissions from the storage of animal carcasses, BAT is to store animal carcasses in sealed and refrigerated containers.

5.1.9 Manure management

10. In order to minimise emissions to soil and groundwater from the on-site transport and spreading of manure, BAT is to use a combination of the techniques given below:

	Technique	Applicability
a	Identify groundwater sources, resources (aquifers), and groundwater protection zones by mapping the farm surface	Generally applicable
b	Identify a proper manure application rate on the basis of a risk assessment plan, taking into account the specific content of nitrogen and phosphorus of the manure, the nutrient uptake of the cultivated plants and the characteristics of the soil	Generally applicable
c	Assess the receiving land to identify risks of causing water pollution and transfer of pathogens to water, taking into account: 1. Type of soil and slope 2. Soil conditions 3. Climatic conditions 4. Rainfall and irrigation 5. Crop rotations	Generally applicable
d	Assess the spread areas at regular intervals to check for any sign of run-off	Generally applicable
e	Avoid manure spreading during weather conditions in which the soil could be seriously damaged or when the risk for run-off and the leaching of nutrients could be significant. In particular, manure should not be applied when the field is: 1. Water-saturated 2. Flooded 3. Frozen 4. Snow covered 5. Steeply sloping	Generally applicable
f	Keep safe distances between areas of manure spreading and watercourses, boreholes, hedges and neighbouring properties (leaving an untreated strip of land)	Generally applicable
g	Time the spreading of manure as close as possible before maximum crop growth in order to maximise nutrient uptake	Generally applicable
h	Ensure adequate access to the slurry/manure store and that loading of manure can be done effectively without spillage	Generally applicable
i	Check that machinery for the spreading of manure is in good working order and set at the proper application rate	Generally applicable

5.1.10 Monitoring of emissions and process parameters

11. BAT is to monitor the total excreted nitrogen in poultry or pigs manure by using the following monitoring technique with at least the frequency given below:

	Technique	Frequency	Applicability
a	Calculation using a mass balance based on the feed intake, dietary content of crude protein and animal performance (feed conversion ratio)	Every time in the event of changes to: (a) the animal diet or nutritional management (b) the types of animal species reared on the farm	Generally applicable

12. BAT is to monitor total excreted phosphorus in poultry or pig manure by using the following monitoring technique with at least the frequency given below:

	Technique	Frequency	Applicability
a	Calculation using a mass balance based on the feed intake, dietary content of phosphorus and digestible phosphates and animal performance (feed conversion ratio)	Every time in the event of changes to: (a) the animal diet or nutritional management (b) the types of animal species reared on the farm	Generally applicable

13. BAT is to monitor ammonia emissions to air from the rearing of poultry or pigs by using one of the following monitoring techniques with at least the frequency given below:

	Technique	Frequency	Applicability
a	Estimate ammonia emissions from excreted nitrogen in the different production phases of the farm (animal housing, manure storage, field application) by using a mass balance calculation based on standard retention (or emission) rates expressed in percentage of the amount of total nitrogen present at each production stage. (see BAT 11)	Every time in the event of changes to: (a) the animal diet or nutritional management (b) the groups of livestock reared at the farm (c) significant modifications to any process step due to the implementation of BAT	Generally applicable
b	Direct measurement of ammonia emissions to air by using EN standard methods or other methods (ISO, national or international) ensuring data of an equivalent scientific quality. The measurement is performed at the air outlet of the animal house	Adjusted to the specific needs (e.g. vicinity of sensitive receptors, size of the farm)	Only applicable to animal houses equipped with a forced ventilation system fitted with a single channelled air outlet
c	Indirect measurement of ammonia emissions to air by measuring the concentration in different points inside the house. The ventilation rate, necessary to determine the emission mass flow, is determined either by calculation or by means of tracer gases	Adjusted to the specific needs (e.g. vicinity of sensitive receptors, size of the farm)	Applicable to animal houses equipped with natural ventilation

14. BAT is to monitor odour emissions from the rearing of poultry or pigs by using the following monitoring technique with at least the frequency given below:

	Technique	Frequency	Applicability
a	Determination of odour concentration by dynamic olfactometry (EN 13725)	Adjusted to the specific needs (e.g. vicinity of sensitive receptors, size of the farm)	Due to the cost of measurements, applicability is generally limited to farms situated close to residential areas or other sensitive receptors

15. BAT is to monitor dust emissions from animal housing systems by using one of the following monitoring technique with at least the frequency given below:

	Technique	Frequency	Applicability
a	Direct measurement of dust emissions by using EN standard methods or other methods (ISO, national or international) ensuring or international) ensuring data of an equivalent scientific quality. The measurement is performed at the air outlet of the animal house	Adjusted to the specific needs (e.g. vicinity of sensitive receptors, size of the farm)	Applicable to houses equipped with a forced ventilation system fitted with a single channelled air outlet. Due to the cost of measurements, the applicability is generally limited to houses with litter-based floors (where dust emissions may be significant), and to farms situated close to residential or other sensitive receptors
b	Indirect measurement of dust emissions by measuring the dust concentration at different points inside the house. The ventilation rate, necessary to determine the emission mass flow, is determined either by calculation or by means of tracer gases	Adjusted to the specific needs (e.g. vicinity of sensitive receptors, size of the farm)	Applicable to houses equipped with natural ventilation. Due to the cost of measurements, applicability is generally limited to houses with litter-based floors (where dust emissions may be significant), and to farms situated close to residential or other sensitive receptors

16. BAT is to monitor groundwater composition in order to monitor the impact of the farm by using the following monitoring technique with at least the frequency given below:

	Technique	Frequency	Applicability
a	Monitor groundwater quality by means of EN standard methods or other methods (ISO, national or international) ensuring data of an equivalent scientific quality. Parameters normally monitored include: 1. Nitrogen compounds (i.e. nitrates, nitrites, ammonia) 2. Total phosphorus 3. Total coliforms 4. Escherichia coli 5. Metals (e.g. Zn, Cu)	Once a year or adjusted to the specific needs	Due to the cost of measurements, applicability is generally limited to farms situated close to sensitive water bodies or in case of unexpected emissions (e.g. strong precipitation events) and incidents

17. BAT is to monitor the relevant process parameters with at least the frequency given below:

	Technique	Frequency	Applicability
a	Water use by means of suitable meters	Every three months	Generally applicable
b	Electric energy consumption by means of suitable meters	Every three months	Generally applicable
c	Fuel consumption on the basis of the purchase documentation	With each delivery	Generally applicable
d	Number of incoming and outgoing animals	With each delivery	Generally applicable
e	Feed consumption on the basis of the purchase documentation	With each delivery	Generally applicable
f	Feed additives consumption on the basis of the purchase documentation	With any delivery	Generally applicable
g	Use of pharmaceutical products	With each delivery	Generally applicable
h	Effective functioning of forced and/or natural ventilation system	Weekly	Generally applicable
i	Effective functioning of emission abatement systems, e.g.: 1. pH of scrubbing liquid 2. Air flow and pressure drop of the abatement system	Daily	Generally applicable to plants equipped with emission abatement systems

5.2 BAT conclusions for the intensive rearing of pigs

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all farms for the intensive rearing of pigs.

5.2.1 Nutritional management for the intensive rearing of pigs

18. In order to reduce nitrogen excretion from pig rearing, while meeting the nutritional needs of the animals, BAT is to use a diet formulation and nutritional strategy which includes one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Use a balanced diet with an optimum feed conversion rate based on net energy, low crude protein content and digestible amino acids	Generally applicable
b	Phase feeding with a diet formulation adapted to the specific requirements of the production period	For small farms (<xxxx animal places), applicability may be limited due to the need for sophisticated and expensive equipment which may require skilled labour
c	Add controlled amounts of essential amino acids to a low crude protein diet	Generally applicable
d	Use additives that improve the animal growth and promote performance in feed conversion	Generally applicable
([1]) A description of the techniques is given in Section 5.4.1.1.		

BAT-associated environmental performance levels (AEPL) for total excreted nitrogen from pig rearing are given in Table 5.1.

Table 5.1: BAT-associated environmental performance levels (AEPL) for total excreted nitrogen from pig rearing

Parameter	Animal category	BAT-AEPL (kg N excreted/animal place/year)
Total excreted nitrogen, expressed as N	Weaners	2 – 3.5
	Fattening (growers and finishers)	8 – 12
	Mating, gestating sows	17 – 22
	Lactating sows	23 – 28

The associated monitoring is described in BAT 11.

19. In order to reduce phosphorus excretion from pig rearing, while meeting the nutritional needs of the animals, BAT is to use a diet formulation and a nutritional strategy which includes one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Phase feeding with a diet formulation adapted to the specific requirements for the production period	For small farms (<xxxx animal places), applicability may be limited due to the need for sophisticated and expensive equipment which may require skilled labour
b	Addition of phytase to the diet	Generally applicable within the constraints to maintain appropriate calcium levels in the diet to ensure growth performance of the animal
c	Use of highly digestible inorganic phosphates for a partial replacement of conventional sources of phosphorus in the feed	Generally applicable within the constraints associated with the availability of highly digestible inorganic phosphates

([1]) A description of the techniques is given in Section 5.4.1.2.

BAT-associated environmental performance levels (AEPL) for total excreted phosphorus from pig rearing are given in Table 5.2.

Table 5.2: BAT-associated environmental performance levels (AEPL) for total excreted phosphorus from pig rearing

Parameter	**Animal category**	**BAT-AEPL (kg P_2O_5 excreted/animal place/year)**
Total excreted phosphorus, expressed as P_2O_5	Weaners	1.4 – 1.9
	Fattening (growers and finishers)	4.5 – 6
	Mating, gestating sows	11 – 14
	Lactating sows	<15

The associated monitoring is described in BAT 12.

5.2.2 Air emissions from pig housing

5.2.2.1 Ammonia emissions from housing systems for mating/gestating sows

20. In order to prevent or reduce ammonia emissions from housing systems for mating and/or gestating sows, BAT is to use one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Reduce the emitting manure surface, while facilitating the cleaning of surfaces and slurry (manure) removal to external storage. For this purpose, the following techniques may be used:	
	1. Fully-slatted floor with vacuum system for slurry removal	Not applicable for gilts after service and pregnant sows. Limited applicability to existing houses; applicable when the existing solid floors allow building on top (sufficient height) or to fully-slatted floor systems with a storage pit underneath on the occasion of a renovation
	2. Partly-slatted floors with vacuum system for slurry removal	Limited applicability to existing animal houses; applicable when the existing solid floors allow building on top (sufficient height) or on partly-slatted floors with a storage pit underneath, on the occasion of a renovation
	3. Partly-slatted floors with slanted walls in the manure channel	Applicable to new animal houses. The technique is applicable to existing individual houses converted into group housing with a wide enough free run area between the row of crates and to houses equipped with feeding stations. An additional restriction to the applicability to existing houses may relate to an insufficient pit depth (too shallow)
	4. Partly-slatted floors or fully-slatted flat decks with a scraper	Applicable to new animal houses. For existing houses, applicability may be limited by the design of the existing manure pit which might require substantial modification
	5. Partly-slatted floor with reduced manure pit	Applicable for temporary animal accommodations (e.g. service and transit rooms). For existing houses, applicability may be difficult, depending on the design of the existing manure pit. For housings with an internal concrete solid floor, an extension with an external alley with a storage pit might be possible
	6. Frequent slurry removal by flushing	Applicable to new partly-slatted floor houses for gestating sows. Full benefits are achieved when the technique is used in combination with a biogas plant from anaerobic treatment of manure. Configurations using flushing gutters or flushing tubes are technically difficult to implement to existing houses. For the configuration using a permanent layer of slurry, some adaptation is needed for its implementation

	Technique ([1])	Applicability
	7. Kennel or hut housing on partly-slatted floors	Generally applicable to new and existing animal houses using natural ventilation. The technique may require a large space availability
	8. Solid concrete floor with full litter	Applicable to new animal houses. For existing houses, applicability may be limited by technical constraints, depending on the existing manure pit design. When electronic feeders are installed, implementation of the technique may present technical limitations
	9. Litter-based pens with feeding/lying boxes on solid floor	Applicable to new animal houses. For existing houses, applicability is limited to systems with concrete solid floors
b	Cooling the manure surface to minimise ammonia evaporation. For this purpose, the following techniques may be used:	
	1. Partly-slatted floors with slurry cooling	Applicable to new animal houses. For existing houses, implementation is possible only for manure pits with a vacuum system or flushing where the cooling pipes can be placed above the concrete floor. In the case of mixed slatted and bedded housing systems, the technique can be applied only to the part of the pen equipped with slats
	2. Partly-slatted floors with manure surface cooling fins.	Applicable to individual and group animal housing. For existing houses, applicability depends on the design of the existing manure pits
c	Use of an air cleaning system, such as:	
	1. Wet acid scrubber	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered technically difficult. Due to the high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Two-stage or three-stage air cleaning system	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, the implementation is considered technically difficult. Due to the high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Section 5.5.1.

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for mating and gestating sows are given in Table 5.3.

Table 5.3: BAT-AEL for ammonia emissions from the housing of mating and gestating sows

Parameter	Animal category	BAT-AEL ([1]) (kg NH_3/animal place/year)
Ammonia expressed as NH_3	Mating and gestating sows	1.2 – 2.5
([1]) The lower end of the range is associated with the use of an air cleaning system.		

The associated monitoring is described in BAT 13.

5.2.2.2 Ammonia emissions from housing systems for farrowing sows

21. In order to reduce ammonia emissions from housing systems for farrowing sows (including suckling piglets), BAT is to use one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Reduce the emitting manure surface, while facilitating the cleaning of surfaces and slurry (manure) removal to external storage. For this purpose, the following techniques may be used:	
	1. Partly-slatted floors with slanted walls in the manure channel	Applicable to new animal houses. The technique is applicable to existing individual houses converted into group housing with a wide enough free run area between the row of crates and to houses equipped with feeding stations. An additional restriction to the applicability to existing houses may relate to an insufficient pit depth (too shallow)
	2. Partly-slatted floors or fully-slatted flat decks with a scraper	Applicable to new animal houses. For existing houses, applicability may be limited by the design of the existing manure pit which might require substantial modification
	3. Partly-slatted floors with a reduced manure pit	Applicable to new animal houses. For existing houses, applicability may be difficult, depending on the design of the existing manure pit
	4. Frequent slurry removal by flushing	Applicable to new partly-slatted floor houses for farrowing sows. Full benefits are achieved when the technique is used in combination with a biogas plant from anaerobic treatment of manure. Configurations using flushing gutters or flushing tubes are difficult to implement to existing houses. For the configuration of the technique using a permanent layer of slurry, some adaptation is needed for its implementation
	5. Stall housing with partly-slatted floors	The applicability to new houses may be limited by animal welfare considerations

	Technique ([1])	Applicability
	6. Crates with fully-slatted floors and a combination of water and manure channels	The applicability to new houses may be limited by animal welfare considerations. The applicability to existing houses depends on the design and conditions of the pit, since discharge openings are required underneath each crate. In addition, existing crates built on partly-slatted floors cannot be re-used
	7. Crates with fully or partly-slatted floors and manure pan	The applicability to new housing systems may be limited by animal welfare considerations. Applicable to existing housing with fully or partly-slatted floors
	8. Litter-based pens with feeding/lying boxes on solid floor	Applicable to new animal houses. For existing houses, the applicability depends on the design and type of floor already existing
b	Cooling the manure surface to minimise ammonia evaporation. For this purpose, the following technique may be used:	
	1. Partly-slatted floors with manure surface cooling fins	Applicable to individual and group animal housing systems. For existing houses, the applicability depends on the design of the existing manure pits
c	Use of an air cleaning system such as:	
	1. Wet acid scrubber	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Two-stage or three-stage air cleaning system	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Section 5.5.1.

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for farrowing sows are given in Table 5.4.

Table 5.4: BAT-AEL for ammonia emissions from the housing of farrowing sows (including suckling piglets)

Parameter	Animal category	BAT-AEL ([1]) (kg NH_3/animal place/year)
Ammonia expressed as NH_3	Farrowing sows (including suckling piglets)	2.5 – 4

([1]) The lower end of the range is associated with the use of an air cleaning system.

The associated monitoring is described in BAT 13.

5.2.2.3 Ammonia emissions from housing systems for weaning pigs

22. In order to reduce ammonia emissions from housing systems for weaning pigs, BAT is to use one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Reduce the emitting manure surface, while facilitating the cleaning of surfaces and slurry (manure) removal to external storage. For this purpose, the following techniques may be used:	
	1. Pens or flat decks with fully or partly-slatted floor with vacuum system for slurry removal	Limited applicability to existing animal houses; applicable when the existing solid floors allow building on top (sufficient height) or on fully-slatted floor systems with a storage pit underneath in the occasion of a renovation
	2. Partly-slatted floors or fully-slatted flat decks with a scraper	Applicable to new animal houses. For existing houses, applicability depends on the design of the existing manure pit which might require substantial modification
	3. Partly-slatted pens with convex floor and separated manure and water channels	Applicable to new animal houses. For existing houses, the implementation of sloped walls and flush gutters is relatively easy in pens with a central convex or for partly-slatted floors with a slopped concrete floor, though still requiring some adaptation. The implementation of two separate channels into existing houses is considered difficult
	4. Frequent slurry removal by flushing	Applicable to new fully-slatted or partly-slatted floor houses for gestating sows. Full benefits are achieved when the technique is used in combination with a biogas plant from anaerobic treatment of manure. The technique configurations using flushing gutters or flushing tubes are difficult to implement to existing houses. For the configuration of the technique using a permanent layer of slurry, some adaptation is needed for its implementation
	5. Solid concrete floor with full litter with or without external features	Applicable to new animal houses. For existing houses, applicability depends on the existing design of manure pit. When electronic feeders are installed, the implementation of the technique may present technical limitations. In general, the technique is not applicable in warm climates to naturally ventilated houses
	6. Kennel or hut housing on partly-slatted floors	Generally applicable to new and existing animal houses using natural ventilation. The application may require large space availability
	7. Pens with partly-slatted floors	For existing animal houses, applicability depends on the design of the existing manure pits

	Technique ([1])	Applicability
	8. Pens or flat decks with fully-slatted floors and concrete sloped underground floor	The applicability to existing animal houses requires a sufficient depth of the manure pit and a discharge system placed in a central position of the pen
	9. Manure collection in water	Applicable to new animal houses. For existing houses, applicability depends on the design of the existing manure pit and may present significant limitations
	10. Pens with solid concrete floor with litter	Applicable to new animal houses and existing houses already equipped with solid concrete floor
b	Cooling the manure surface for minimising ammonia evaporation. For the purpose, the following technique may be used:	
	1. Fully or partly-slatted floors with manure surface cooling fins.	Applicable to individual and group housing. For existing houses, applicability depends on the design of the existing manure pits
c	Use of an air cleaning system, such as:	
	Wet acid scrubber	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	Two-stage or three-stage air cleaning system	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Section 5.5.1.

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for weaning pigs are given in Table 5.5.

Table 5.5: BAT-AEL for ammonia emissions from the housing of weaning pigs

Parameter	Animal category	BAT-AEL ([1]) (kg NH_3/animal place/year)
Ammonia expressed as NH_3	Weaning pigs	0.2 – 0.4

([1]) The lower end of the range is associated with the use of an air cleaning system.

The associated monitoring is described in BAT 13.

5.2.2.4 Ammonia emissions from housing systems for fattening pigs (growers, finishers)

23. In order to reduce ammonia emissions from housing systems for fattening pigs, BAT is to use one or a combination of the techniques given below:

	Technique (1)	Applicability
a	Reduce the emitting manure surface, while facilitating the cleaning of surfaces and slurry (manure) removal to external storage. For this purpose, the following techniques may be used:	
	1. Fully-slatted floor with vacuum system for slurry removal	Limited applicability to existing animal houses; applicable when the existing solid floors allow building on top (sufficient height) or on fully-slatted floor systems with a storage pit underneath in the occasion of a renovation
	2. Partly-slatted floors with vacuum system for slurry removal	Limited applicability to existing animal houses; applicable when the existing solid floors allow building on top (sufficient height) or on partly-slatted floors with a storage pit underneath, on the occasion of a renovation
	3. Partly-slatted floors with slanted walls in the manure channel	Applicable to new animal houses. The technique is applicable to existing individual houses converted into group housing with a free run area between the row of crates wide enough and to houses equipped with feeding stations. An additional restriction to the applicability to existing houses could be an insufficient pit depth (too shallow)
	4. Partly-slatted floors or fully-slatted flat decks with a scraper	Applicable to new animal houses. For existing houses, applicability may be limited by the design of the existing manure pit which might require substantial modification
	5. Partly-slatted pens with convex floor and separated manure and water channels	Applicable to new animal houses. For existing houses, the implementation of sloped walls and flush gutters is relatively easy in pens with a central convex or for partly-slatted floors with a slopped concrete floor, still requiring some adaptation. The implementation of two separate channels into existing houses is considered difficult
	6. Partly-slatted floors with slurry V-shaped manure belts	Applicable to new animal houses
	7. Partly-slatted floor with reduced manure pit	Applicable for temporary animal accommodation (e.g. service and transit rooms). In existing houses, applicability may be difficult, depending on the design of the existing manure pit. For housings with an internal concrete solid floor, an extension with an external alley with a storage pit might be possible

	Technique ([1])	Applicability
	8. Frequent slurry removal by flushing	Applicable to new partly-slatted floor animal houses. Full benefits are achieved when the technique is used in combination with a biogas plant from anaerobic treatment of manure. Configurations using flushing gutters or flushing tubes are difficult to implement to existing houses. For the configuration using a permanent layer of slurry, some adaptation is needed for its implementation
	9. Kennel or hut housing on partly-slatted floors	Generally applicable to new and existing animal houses using natural ventilation. The application may require large space availability
	10. Solid concrete floor with full litter	Applicable to new animal houses. For existing houses, applicability may be difficult, depending on the existing design of the manure pit. When electronic feeders are installed, the implementation of the technique may present technical limitations. In general, the technique is not applicable in warm climatic areas to naturally ventilated houses
	11. Litter-based pens with feeding/lying boxes on solid floor	Applicable to new animal houses. In existing houses, the applicability may be difficult, depending on the design and type of floor already existing
	12. Solid concrete floors with littered external alley	Not applicable to cold climates. Difficult applicability to existing animal houses, due to design limitations
	13. Straw flow system	Applicable to new animal houses and existing houses already equipped with solid concrete floor
b	Cooling the manure surface for minimising ammonia evaporation. For the purpose, the following techniques may be used:	
	1. Partly-slatted floors with slurry cooling	Applicable to new animal houses. For existing houses, implementation is possible only for manure pits with a vacuum system or flushing where the cooling pipes can be placed above the concrete floor. In the case of mixed slatted and bedded housing systems, the technique can be applied only to the part of the pen equipped with slats
	2. Partly-slatted floors with manure surface cooling fins.	Applicable to individual and group animal housing. For existing houses, applicability depends on the design of the existing manure pits

	Technique (1)	Applicability
c	Use of an air cleaning system, such as:	
	1. Wet acid scrubber	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Two-stage or three-stage air cleaning system	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
(1) A description of the techniques is given in Section 5.5.1.		

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for fattening pigs are given in Table 5.6.

Table 5.6: BAT-AEL for ammonia emissions from the housing of fattening pigs

Parameter	Animal category	BAT-AEL (1) (kg NH_3/animal place/year)
Ammonia expressed as NH_3	Fattening pigs	1.0 – 1.7
(1) The lower end of the range is associated with the use of an air cleaning system.		

The associated monitoring is described in BAT 13.

5.2.2.5 Dust emissions from pig housing systems

24. In order to reduce dust emissions from pig housing systems, BAT is to use one or a combination of the techniques given below:

	Technique (1)	Applicability
a	Minimise the formation of dust emissions by selecting suitable materials and operating conditions. For this purpose, the following techniques may be used:	
	1. Apply non-litter floors or bedding materials that minimise dust formation	Generally applicable
	2. Operate the ventilation system to produce low air velocity at the floor level	Generally applicable
	3. Perform regular maintenance of the equipment used to control the indoor climate, feed and water distribution	Generally applicable

	Technique ([1])	Applicability
b	Reduce dust concentration in the ambient air of pig houses by fogging	Applicable to new and existing animal houses. Applicability may be limited by the animal sensation of thermal decrease during fogging, in particular at sensitive stages of the animal's life and/or for cold climates
c	Use of an air cleaning system, such as:	
	1. Bioscrubber	Applicable to animal houses using a slurry-based system. The applicability to existing houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Biofilter	Applicable to new animal houses. The applicability to existing houses may entail adaptation of the exhaust air ducts, with significant additional requirements for ventilation. A sufficient area outside the facility is needed to accommodate the filter packages. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	3. Wet acid scrubber	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	4. Two-stage or three-stage air cleaning system	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Section 5.5.1.

BAT-associated emission levels (AEL) for dust emissions from pig housing systems are given in Table 5.7.

Table 5.7: BAT-AEL for dust emissions from pig housing systems

Parameter	Animal category	BAT-AEL ([1]) (kg dust/animal place/year)
Dust	All types of pigs	0.1 – 0.24

([1]) The lower end of the range is associated with the rearing of weaning pigs.

The associated monitoring is described in BAT 15 for direct emission measurements and in BAT 17 in the case surrogate parameters are used.

5.2.2.6 Odour emissions from pig housing systems

25. In order to reduce odour emissions from pig housing systems, BAT is to use one or a combination of the techniques given below:

	Technique (1)	Applicability
a	Use an animal housing system promoting the following effects: 1. reduced emitting manure surface 2. fast discharge of manure from slats 3. frequent removal of manure 4. lowering the temperature of stored manure	Generally applicable
b	Adopt a balanced diet adapted to the specific feed requirements for the production period, with an optimum feed conversion rate (See BAT 18)	Generally applicable
c	Minimise the diffusion of odour emissions by selecting a suitable ventilation system, with low air velocity at the floor level	Generally applicable
d	Reduce odour concentration in the ambient air of the pig housing by fogging	Applicable to new and existing animal houses. Applicability is limited by the animal sensation of thermal decrease during fogging, in particular for sensitive stages of the animal's life and/or for cold climatic conditions
e	Treat odorous compounds by atomisation of capturing and reacting agents (brumisation)	Generally applicable; however, the long-term effects of the technique are not fully assessed
f	Use floating balls in the manure channel	Applicable to new animal houses. The applicability to existing houses is restricted to plants equipped with pits that do not have slanted walls
g	Use an air cleaning system, such as:	
	1. Bioscrubber	Applicable to slurry-based animal houses. The applicability to existing houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult
	2. Biofilter	Applicable to new animal houses. The applicability to existing houses may entail adaptation of the exhaust air ducts with significant additional requirement s for ventilation. A sufficient area outside the facilities is needed to accommodate the filter packages
	3. Wet acid scrubber	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

	Technique ([1])	Applicability
	4. Two-stage or three-stage air cleaning system	The applicability to existing animal houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Sections 5.5.1.3 and 5.5.1.4.

BAT-associated emission levels (AEL) for odour emissions from pig housing systems are given in Table 5.8.

Table 5.8: BAT-AEL for odour emissions from pig housing systems

Parameter	Animal category	BAT-AEL ([1]) (ou_E/s^{-1} per animal)
Odour	All types of pigs	6 – 30

([1]) The lower end of the range is associated with the rearing of weaning pigs; the upper end of the range is associated with the rearing of farrowing sows.

The associated monitoring is described in BAT 15 for direct emission measurements and in BAT 17 in the case surrogate parameters are used.

5.2.3 Efficient use of energy in pig farms

26. In order to reduce and optimise energy consumption in pig farms, BAT is to use a combination of the techniques given below (in addition to the general techniques listed under BAT 6):

	Technique ([1])	Applicability
a	Minimise thermal losses while adapting heating and ventilation to the physiological needs of the pigs	Full implementation is possible only in new animal housing systems
b	Insulation of the walls, floors and ceilings of houses	Generally applicable at the time of renovation of the buildings, taking into account the local prevailing climatic conditions, the choice of materials and their properties
c	Use more energy-efficient lighting	Generally applicable
d	Use energy-saving fans and an optimised ventilation system	Full implementation is possible only in new animal houses
e	Use wood and other biomass fired boilers for water heating	Applicable where boilers can be located close to animal housing, to avoid pipe networks. Only pig nurseries can utilise heating energy throughout the year
f	Use heat exchangers for warming up water. The following systems may be used: 1. air-air 2. air-water 3. air-ground	In general, the technique is not applicable on existing animal houses and naturally ventilated housing, since it requires a centralised ventilation system. Air-ground heat exchangers require the availability significant free space due to the need for large soil surface. The applicability of heat exchangers is also limited by economic considerations

	Technique ([1])	Applicability
g	Use of heat pumps for heat recovery in air-air or air-water circuits	Applicable on new animal houses or for existing houses already equipped with centralised ventilation. The applicability of heat pumps based on geothermal heat recovery is limited by the need for significant space availability. The applicability of heat pumps fed with water from wet scrubbing systems is only possible if a large quantity of water can be stored
([1]) A description of the techniques is given in Section 5.5.6.		

5.2.4 Emissions from manure storage

27. In order to reduce ammonia and other nitrogen compound emissions from the tank storage of liquid slurry from pig houses, BAT is to use a combination of the techniques given below:

	Technique ([1])	Applicability
a	Use stable tanks that are able to withstand mechanical, chemical and thermal influences	Generally applicable
b	Reduce the ratio between the surface area and volume of the slurry tank	Generally applicable when installing a new tank; however, an excessive height of slurry stores may involve an increased safety risk
c	Use slurry tanks with a sufficient capacity that allows operating at a lower level of fill	Generally applicable
d	Empty slurry tanks in spring before the warm season, in order to reduce the quantity of stored slurry	Applicable to above-ground stores and for climatic regions where there is a substantial temperature increase during summer
e	For slurry stored in open storage containers, use discharge points as close as possible to the base of the containers	Generally applicable
f	Cover slurry stores. For this purpose, the following techniques may be used:	
	1. Rigid cover	Applicable to new slurry stores, at the time of construction. The applicability to existing stores may be difficult due to economic considerations and structural limitations that may not allow accommodating a rigid cover
	2. Flexible covers: o Tent cover o Dome-shaped cover o Cover tended flat o Swollen cover	Applicable to new and existing slurry stores. The type of flexible cover may be chosen on the basis of the existing structure, the prevailing weather conditions and the size of the tank. Generally, not applicable in cold climates

	Technique ([1])	Applicability
	3. Floating covers: o Natural crust o Straw and/or high dry matter content manure o Plastic pellets o Peat and light bulk materials o Rapeseed oil and grains o Floating flexible covers o Geometrical plastic tiles	Applicable to new and existing plants, subject to the following restrictions: The use of floating bodies is only applicable for liquid slurry without a natural floating layer. Agitation of the slurry during stirring, filling and emptying may preclude the use of some floating materials which could cause sedimentation or blockages in the pumps. Natural crust formation may not form in cool climates or for dry matter content in the slurry <2 %. A straw crust may be difficult to apply on large storage structures, due to a non-uniform distribution of the material. A dry matter content of the slurry of about 4 – 5 % is needed for a good performance of the technique. Geometrical plastic tiles (bricks) are not suitable where a frequent spreading of slurry requires mixing and disturbs the crust
([1]) A description of the techniques is given in Section 5.5.2.1.		

28. In order to reduce ammonia and other nitrogen compound emissions from the earth-banked storage of liquid slurry from pig houses, BAT is to use a combination of the techniques given below:

	Technique ([1])	Applicability
a	Use slurry storage that ensures protection of the underlying soil	Generally applicable
b	Minimise stirring of the slurry	Generally applicable
c	Cover the earth-banked slurry storage by means of flexible and/or floating covers a. Flexible plastic sheets b. Natural crust c. Straw and/or high dry matter content manure d. Light bulk materials e. Floating flexible covers f. Geometrical plastic tiles	Generally applicable. When using flexible plastic covers, implementation may require the complete emptying of the lagoon to allow fitting of the cover
([1]) A description of the techniques is given in Section 5.5.2.2.		

29. In order to reduce ammonia and other nitrogen compound emissions from the storage of solid manure from pig houses, BAT is to use a combination of the techniques given below:

	Technique ([1])	Applicability
a	Store solid manure on a solid impermeable floor equipped with a draining system	Generally applicable
b	Select a storage facility with a sufficient capacity to hold the manure between periods in which the application to land is not possible	Generally applicable
c	Position the storage location taking into account the general wind direction and/or adopt measures that can serve as windscreens	Generally applicable

	Technique (1)	Applicability
d	Reduce the ratio between the surface area and volume of the manure stack	Generally applicable
e	Cover solid manure stacks	Applicable to solid manures that are stored in heaps which are not added to on a frequent basis
f	Use a concrete silo for storage	The applicability to existing farms may be limited by constraints associated with the requirements for proper planning and construction of the silo (i.e. space availability, distance from the animal houses). Applicable in the cases when a storage capacity to cover several months is required
(1) A description of the techniques is given in Section 5.5.2.3.		

5.2.5 On-farm processing of pig manure (solid or slurry)

30. In order to improve the quality of pig manure for its use as fertiliser, BAT is to process the manure by applying one or a combination of the techniques given below:

	Technique (1)	Applicability
a	Mechanical separation of pig slurry: • Screw press and auger separator • Decanter-centrifuge separator • Flocculation-coagulation • Separation by sieves or filter pressing	Applicable when a reduction of nitrogen and phosphorus content is needed due to limited available land for manure application. The applicability in existing farms depends on the available storage equipments
b	Mechanical separation of slurry combined with biological treatment (with or without nitrification-denitrification)	Applicable to slurry with a dry matter content ≤6 %. Due to high investment costs, the applicability is generally restricted to large pig farms
c	Aerobic digestion (aeration) of liquid manure	Generally applicable. In cold climates, it may be difficult to maintain the required level of aeration during winter
d	Composting of solid manure	Generally applicable. Where emission reduction measures are required for the composting process (i.e. for reducing odour emissions), applicability may be restricted to large pig farms
e	Anaerobic treatment of manure in a lagoon system	Applicable to farms where sufficient land is available to allow for a series of lagoons covering the different treatment steps. Temperature requirements limit the applicability of this technique in cold climates
f	Anaerobic treatment of manure in a biogas installation	Due to high investment costs, applicability is limited to farms presenting favourable conditions (i.e. financial support schemes, energy prices)
g	Drying of manure 1. Evaporation and drying of manure with heat exchanger and dryer 2. Drying of manure by belt dryer	The applicability is limited to large farms where it could be combined with biogas production
(1) A description of the techniques is given in Section 5.5.3.		

5.2.6 On-farm treatment of pig manure

31. In order to reduce the potential for gaseous emissions from pig manure and make its use easier as fertiliser, BAT is to treat the manure by applying one of the techniques given below:

	Technique (1)	Applicability
a	Slurry acidification	The applicability depends on the availability of land for a slurry richer in nitrogen, and other limitations associated with soil acidification and a consequent need for liming
b	Ammonia stripping	Applicable in combination with separation techniques (see BAT 30 (a) and (b), for liquid fractions with a very low content of dry matter
c	Use of manure additives, to modify characteristics and properties of manure	Generally applicable
(1) A description of the techniques is given in Section 5.5.4.		

5.2.7 Emissions from landspreading of pig manure

5.2.7.1 Landspreading of solid manure from pig housing systems

32. In order to prevent or reduce ammonia and other nitrogen compound emissions from the application of solid manure to land, BAT is use all the techniques given below (in addition to the general techniques listed under BAT 10):

	Technique (1)	Applicability
a	Use a suitable spreading technique: 1. Rotaspreader 2. Rear discharge spreader 3. Dual-purpose spreader	Generally applicable
c	Incorporation of manure into land within four hours after spreading	Not applicable to grassland
(1) A description of the techniques is given in Section 5.5.2.6.		

5.2.7.2 Landspreading of liquid manure (slurry) from pig housing systems

33. In order to prevent/reduce ammonia and other nitrogen compound emissions from the application of liquid manure to land, BAT is use a combination of the techniques given below (in addition to the general techniques listed under BAT 10):

	Technique (1)	Applicability
a	Use a suitable spreading technique:	
	1. Dilute slurry irrigators	Applicable to areas easily connected to the farmstead by pipework. Due to the risk of contamination, these techniques (1 and 2) are not appropriate for crops grown to be eaten raw
	2. Pulse jet irrigators	The technique should not be applied to areas within 75 metres of watercourse to allow for a clearance area of at least 15 m without manure
	3. Band spreader (trailing hose or trailing shoe)	Not applicable to small, irregularly shaped fields or steeply sloping land. The applicability may be limited when the straw content of the slurry is too high or when the dry matter content of the slurry is >7 %

	Technique ([1])	Applicability
	4. Injector (open slot)	Not applicable on very stony soil or very shallow or compact soil where it is difficult to achieve a uniform penetration. The applicability may be difficult on very steep fields due to the risk of runoff and where winter crops may be damaged by machinery
	5. Deep injector (closed slot)	The applicability is restricted to the pre-sowing season on arable land and widely spaced row crops, due to potential mechanical damage to the vegetation. Other limitations to applicability may be associated with the soil depth, clay and stone content and slope. Not applicable on grassland
b	Incorporation of manure into land within four hours after spreading	Applicable to arable land
([1]) A description of the techniques is given in Section 5.5.2.7.		

5.2.8 Emissions from the whole production process for pigs rearing (including sows)

34. In order to prevent or reduce ammonia emissions from the whole production process for the rearing of pigs (including sows), BAT is to use a combination of techniques that can achieve an overall reduction efficiency for ammonia emissions of at least XX %.

5.3 BAT conclusions for the intensive rearing of poultry

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all farms for the intensive rearing of poultry.

5.3.1 Nutritional management for the intensive rearing of poultry

35. In order to reduce nitrogen excretion from the rearing of poultry, while meeting the nutritional needs of the animals, BAT is to use a diet formulation and nutritional strategy which includes one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Use a balanced diet with an optimum feed conversion rate based on net energy, low crude protein content and digestible amino acids	Generally applicable
b	Phase feeding with a diet formulation adapted to the specific requirements for the production period	Generally applicable
c	Addition of controlled amounts of essential amino acids to a low crude protein diet	Generally applicable
d	Use of additives that improve the animal growth and promote performance in feed conversion	Generally applicable
([1]) A description of the techniques is given in Section 5.4.1.1.		

BAT-associated environmental performance levels (AEPL) for total excreted nitrogen from the rearing of poultry are given in Table 5.9.

Table 5.9: BAT-associated environmental performance levels (AEPL) for total excreted nitrogen from the rearing of poultry

Parameter	Animal category	BAT-AEPL (kg N excreted/animal place/year)
Total excreted nitrogen expressed as N	Laying hens	0.4 – 0.6
	Broilers	0.25 – 0.35
	Ducks	0.5 – 0.6
	Turkeys	1.2 – 1.4

The associated monitoring is described in BAT 11.

36. In order to reduce phosphorus excretion from the rearing of poultry, while meeting the nutritional needs of the animals, BAT is to use a diet formulation and a nutritional strategy which includes one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Phase feeding with a diet formulation adapted to the specific requirements for the production period	Generally applicable
b	Addition of phytase to the diet	Generally applicable within the constraint of maintaining appropriate calcium levels in the diet to ensure growth performance of the animal
c	Use of highly digestible inorganic phosphates for a partial replacement of conventional sources of phosphorus in the feed	Generally applicable within the constraint associated with the availability of highly digestible inorganic phosphates
([1]) A description of the techniques is given in Section 5.4.1.2.		

BAT-associated environmental performance levels (AEPL) for total excreted phosphorus from the rearing of poultry are given in Table 5.10.

Table 5.10: BAT-associated environmental performance levels (AEPL) for total excreted phosphorus from the rearing of poultry

Parameter	Animal category	BAT-AEPL (kg P_2O_5 excreted/animal place/year)
Total excreted phosphorus expressed as P_2O_5	Laying hens	0.35 – 0.37
	Broilers	0.18 – 0.19
	Ducks	0.30 – 0.35
	Turkeys	0.65 – 0.68

The associated monitoring is described in BAT 12.

5.3.2 Air emissions from poultry housing

5.3.2.1 Ammonia emissions from housing systems for laying hens

37. In order to prevent or reduce ammonia emissions from housing systems for laying hens, BAT is to use one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Enriched cage systems, with or without manure drying, such as:	
	1. Enriched cages with one or two manure removals per week	Not applicable to the rearing of pullets
	2. Small groups of hens in enriched cages with one manure removal per week	Applicable to the rearing of pullets and laying hens for consumer egg production
b	Non-cage systems, such as:	
	1. Deep litter with a deep pit, manure belt or scraper	The applicability to existing cage systems may be limited by the requirement for a complete revision of the housing system. The applicability may be difficult for existing systems with a manure pit underneath, due to the required placement of a manure belt or scraper
	2. Deep litter with forced air manure drying	The technique can be applied only to laying hen houses with sufficient space underneath the slats
	3. Deep litter with a perforated floor and forced drying	Applicable to new housing systems for laying hens. Due to high implementation costs, the applicability to existing houses may be limited
	4. Aviary with a manure belt, with or without veranda or forecourt free range area	Applicable to new housing systems for laying hens. The applicability to existing houses depends on the width of the shed. Applicable for the rearing of pullets, only in configurations without a veranda or outdoor forecourt area
	5. Aviary with underfloor manure drying	Applicable to new housing systems for laying hens. The applicability to existing houses depends on the possibility for a deeper manure pit

	Technique (1)	Applicability
c	Use of an external tunnel for manure drying	Applicable to new housing systems for laying hens. The applicability to exiting houses depends on the possibility to remove manure by belts and extract warm air from the house to supply the drying tunnel
d	Use of an air cleaning system, such as:	
	1. Wet acid scrubber	The applicability to existing houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, the implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Two-stage or three- stage air cleaning system	The applicability to existing bird houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, the implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

(1) A description of the techniques is given in Sections 5.6.1.1 and 5.6.1.6.

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for laying hens are given in Table 5.11.

Table 5.11: BAT-AEL for ammonia emissions from the housing of laying hens

Parameter	Type of housing	BAT-AEL (kg NH_3/animal place/year) (1) (2)
Ammonia expressed as NH_3	Cage housing system	0.03 – 0.10
	Non-cage housing system	0.09 – 0.19

(1) The lower end of the range is associated with the use of an air cleaning system.
(2) For the rearing of young hens (pullets), the lower end of the range is achievable.

The associated monitoring is described in BAT 13.

5.3.2.2 Ammonia emissions from housing systems for broilers

38. In order to prevent or reduce ammonia emissions from housing systems for broilers, BAT is to use one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Deep litter housing system with natural or forced ventilation, equipped with a non-leaking drinking system. For this purpose, the following techniques may be used:	
	1. Litter-based system with circulating fans	Applicable to new and existing broiler houses. For existing houses, the applicability depends on the height of the ceiling
	2. Litter-based system with circulating fans and a heat exchanger	Applicable to new broiler houses. The application to existing houses is normally possible; however, it may depend on the type of ventilation already in place
	3. Litter-based system with (equally spread) recirculated air by indoor fans and heaters	Applicable to new broiler houses. For existing houses, applicability depends on the height of the ceiling
	4. Tiered floor system with bedding on manure belt and forced air drying. The technique is generally used in combination with the patio system (see below) applied for the first growing stage of the broiler	Applicable to new broiler houses. For existing houses, applicability depends on the height of the ceiling
	5. Patio system for hatching and growing broiler chicks for a limited time. The technique is applied in combination with other systems where the broiler is raised to the final weight (see techniques above)	Applicable to new broiler houses. For existing houses, applicability depends on the height of the ceiling
	6. Use of biological additives in the litter	Applicable to litter-based new and existing houses for broilers, at the beginning of the breeding period
b	Use of an air cleaning system, such as:	
	1. Wet acid scrubber	The applicability to existing houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Two-stage or three-stage air cleaning system	The applicability to existing bird houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Sections 5.6.1.1, 5.6.1.5 and 5.6.1.6.

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for broilers are given in Table 5.12.

Table 5.12: BAT-AEL for ammonia emissions from the housing of broilers

Parameter	BAT-AEL ([1]) (kg NH_3/animal place/year)
Ammonia expressed as NH_3	0.02 – 0.06
([1]) The lower end of the range is associated with new plants or with the use of an air cleaning system.	

The associated monitoring is described in BAT 13.

5.3.2.3 Ammonia emissions from housing systems for ducks

39. In order to prevent or reduce ammonia emissions from housing systems for ducks, BAT is to use one or a combination of the techniques given below:

<u>Question for TWG</u>
Should the ideal amount of litter per animal place/year be indicated for the techniques with littered floors?

	Technique ([1])	Applicability
a	Housing system with natural or forced ventilation, equipped with a non-leaking drinking system. For this purpose, the following techniques may be used:	
	1. Solid floor with full litter, manure removal at the end of the rearing cycle	Applicable to new and existing duck houses
	2. Littered floor combined with partly-slatted floor, manure removal at the end of the rearing cycle	Applicable to new duck houses. For existing houses, applicability depends on the design of the existing structure
	3. Fully-slatted floor with variable frequency for manure removal	The applicability is limited to the rearing of Barbary/Muscovy ducks (Cairina Moschata)
b	Use of an air cleaning system, such as:	
	1. Wet acid scrubber	The applicability to existing houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Two-stage or three-stage air cleaning system	The applicability to existing bird houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
([1]) A description of the techniques is given in Sections 5.6.1.3 and 5.6.1.6.		

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for ducks are given in Table 5.13.

Table 5.13: BAT-AEL for ammonia emissions from the housing of ducks

Parameter	BAT-AEL ([1]) (kg NH_3/animal place/year)
Ammonia expressed as NH_3	0.07 – 0.13
([1]) The lower end of the range is associated with the use of an air cleaning system.	

The associated monitoring is described in BAT 13.

5.3.2.4 Ammonia emissions from housing systems for turkeys

40. In order to prevent or reduce ammonia emissions from housing systems for turkeys, BAT is to use one or a combination of the techniques given below:

Question for TWG
Should the ideal amount of litter per animal place/year be indicated for the techniques with littered floors?

	Technique ([1])	Applicability
a	Housing system with natural or forced ventilation, equipped with a non-leaking drinking system. For this purpose, the following techniques may be used:	
	1. Solid floor with full litter, forced ventilation and manure removal at the end of the rearing cycle	Applicable to new and existing houses for the rearing of young male and female turkeys and the fattening of female turkeys
	2. Solid floor with full litter, natural ventilation and manure removal at the end of the rearing cycle	Applicable to new and existing houses for the fattening of male turkeys (stags)
	3. Use of biological additives in the litter	Applicable to litter-based new and existing houses for turkeys, at the beginning of the breeding period
b	Use of an air cleaning system, such as:	
	1. Wet acid scrubber	The applicability to existing houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Two-stage or three-stage air cleaning system	The applicability to existing bird houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
([1]) A description of the techniques is given in Sections 5.6.1.2, 5.6.1.5 and 5.6.1.6.		

BAT-associated emission levels (AEL) for ammonia emissions from housing systems for turkeys are given in Table 5.14.

Table 5.14: BAT-AEL for ammonia emissions from the housing of turkeys

Parameter	BAT-AEL ([1]) (kg NH_3/animal place/year)
Ammonia expressed as NH_3	0.2 – 0.5
([1]) The lower end of the range is associated with the use of an air cleaning system.	

The associated monitoring is described in BAT 13.

5.3.2.5 Dust emissions from poultry housing systems

41. In order to reduce dust emissions from poultry housing systems, BAT is to use one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Minimise the formation of dust emissions by selecting suitable materials and operating conditions. For this purpose, the following techniques may be used:	
	1. Apply bedding materials that minimised dust formation	Generally applicable
	2. Operate the ventilation system at low air velocity in the floor area	Generally applicable
	3. Perform regular maintenance of the equipment used to control the indoor climate, feed and water distribution	Generally applicable
b	Reduce dust concentration in the ambient air. For this purpose, the following techniques may be used:	
	1. Fogging	Applicable to new and existing poultry houses. The applicability may be limited by the bird sensation of thermal decrease during fogging, in particular for sensitive stages of the bird's life and/or for cold climates
	2. Ionisation	Applicable to new bird houses
	3. Oil spraying	Applicable to new and existing poultry houses for birds of at least 21 days of age. The applicability to houses for laying hens may be difficult due to the amount of equipment generally present in the shed that could be contaminated by the oil
c	Use of an air cleaning system, such as:	
	1. Water trap	Applicable to new and existing poultry houses equipped with gable end fans
	2. Water scrubber	The applicability to existing poultry houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	3. Dry filter	Applicable to new and existing poultry houses equipped with gable end fans

	Technique ([1])	Applicability
	4. Biofilter	The applicability to existing poultry houses may entail adaptation of the exhaust air ducts with significant additional requirements for ventilation. A sufficient area outside the facilities is needed to accommodate the filter packages. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	5. Wet acid scrubber	The applicability to existing poultry houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	6. Two-stage or three-stage air cleaning system	The applicability to existing poultry houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Sections 5.6.1.5 and 5.6.1.6.

BAT-associated emission levels (AEL) for dust emissions from poultry housing systems are given in Table 5.15.

Table 5.15: BAT-AEL for dust emissions from poultry housing systems

Parameter	Animal category	BAT-AEL (kg dust/animal place/year)
Dust	Laying hens	0.03 – 0.06 ([1])
	Broilers	<0.02
	Ducks	<0.05
	Turkeys	0.1 – 0.4 ([2])

([1]) The lower end of the range is associated with the use of cage systems.
([2]) The lower end of the range is associated with the rearing of young turkeys.

The associated monitoring is described in BAT 15 for direct emission measurements and in BAT 17 in the case surrogate parameters are used.

5.3.2.6 Odour emissions from poultry housing systems

42. In order to reduce odour emissions from poultry housing systems, BAT is to use one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Use of a poultry housing system promoting the following effects: • reduced emitting manure surface • early drying of manure • reduced litter moisture (by controlling drinking lines, condensation from roofs, walls, etc.)	Generally applicable
b	Adoption of a balanced diet adapted to the specific feed requirements for the production period, with an optimum feed conversion rate (see BAT 34)	Generally applicable
c	Minimise the diffusion of odour emissions by selecting a suitable ventilation system, with low air velocity at the floor level	Generally applicable
d	Reduce odour concentration in the ambient air of poultry housing by fogging	Applicable to new and existing poultry houses. The applicability is limited by the bird sensation of thermal decrease during fogging, in particular for sensitive stages of bird's life and/or for cold climatic conditions
e	Treat odorous compounds by atomisation of capturing and reacting agents (brumisation)	Generally applicable; however, the long-term effects of the technique are not fully assessed
f	Use of an air cleaning system, such as:	
	1. Biofilter	The applicability to existing poultry houses may entail adaptation of the exhaust air ducts with significant additional requirements for ventilation. A sufficient area outside the facilities is needed to accommodate the filter packages. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	2. Wet acid scrubber	The applicability to existing poultry houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors
	3. Two-stage or three-stage air cleaning system	The applicability to existing poultry houses is possible where a forced ventilation system is used; however, where the ventilation system consists of multiple fans or multiple outlets, the implementation is considered difficult. Due to high implementation costs, this technique is more suitable for farms located close to residential or other sensitive receptors

([1]) A description of the techniques is given in Sections 5.6.1.5 and 5.6.1.6.

BAT-associated emission levels (AEL) for odour emissions from poultry housing systems are given in Table 5.16.

Table 5.16: BAT-AEL for odour emissions from poultry housing systems

Parameter	Animal category	BAT-AEL (1) (ou_E/s^{-1} per animal)
Odour	All type of poultry	0.2 – 0.5
(1) The upper end of the range is associated with the rearing of turkeys.		

The associated monitoring is described in BAT 15 for direct emission measurements and in BAT 17 in the case surrogate parameters are used.

5.3.3 Efficient use of energy in poultry farms

43. In order to reduce and optimise energy consumption in poultry farms, BAT is to use a combination of the techniques given below (in addition to the general techniques listed under BAT 6):

	Technique (1)	Applicability
a	Minimisation of thermal losses while adapting heating and ventilation to the physiological needs of the poultry	Full implementation is possible only in new poultry housing systems
b	Insulation of the houses walls, floors and ceilings	Generally applicable at the time of renovation of the buildings, taking into account the local prevailing climatic conditions, the choice of materials and their properties
c	Use of heat-reflecting membranes	Applicable on new and existing houses, in particular in warm climatic areas
d	Use of more energy-efficient lighting (i.e. LED lights)	Generally applicable
e	Use of energy-saving fans and an optimised ventilation system, including circulating fans with or without a heat exchanger (see BAT 37)	Full implementation is possible only in new poultry houses. For existing houses, the applicability of circulating fans depends on the height of the ceiling
f	Use of wood and other biomass, including bedding material and poultry litter, to fire boilers for water heating	Applicable where boilers can be located close to poultry housing, to avoid pipe networks
i	Use of poultry litter as a fuel (see also technique f)	Applicable to new and existing farms
g	Use of heat exchangers for warming up water. The following systems may be used: • air-air • air-water • air-ground	In general, the technique is not applicable on existing poultry houses and naturally ventilated housing, since it requires a centralised ventilation system. Air-ground heat exchangers require significant free space availability due to the high demand for soil surface. The applicability of heat exchangers is also limited by economic considerations

	Technique [1]	Applicability
h	Heat recovery with heated and cooled littered floor (combideck system)	Applicable to new poultry houses. For existing houses, the applicability depends on the possibility to install closed underground storage for the circulating water. In addition, applicability may be limited by economic considerations due to the need of ripping the floors in order to lay down under-floor circuits
([1]) A description of the techniques is given in Section 5.6.2.		

Question for TWG

Is the air-air heat exchanger the only one used in the poultry sector?

5.3.4 Emissions from poultry manure storage

44. In order to reduce ammonia and other nitrogen compound emissions from the storage of solid manure from poultry houses, BAT is to use a combination of the techniques given below:

	Technique [1]	Applicability
a	Store solid manure on a solid impermeable floor equipped with a draining system	Generally applicable
b	Select a storage facility with a sufficient capacity to hold the manure between periods in which application to land is not possible	Generally applicable
c	Position the location for storage taking into account the general wind direction and/or adopt measures that can serve as windscreens	Generally applicable
d	Reduce the ratio between the surface area and volume of the manure stack	Generally applicable
e	Covering solid manure stacks	Applicable to solid manures that are stored in heaps which are not added to on a frequent basis
f	Store manure in a barn	Applicable to new and existing farms where sufficient space on the farmyard is available. For existing farms, attention must be paid to the availability of impermeable floors
g	Use a concrete silo for storage	The applicability to existing farms may be limited by constraints associated with the requirements for proper planning and construction of the silo (i.e. space availability, distance from the animal houses). Applicable in cases when a storage capacity to cover several months is required
([1]) A description of the techniques is given in Section 5.6.3.1.		

5.3.5 On-farm processing of poultry manure

45. In order to improve the quality of poultry manure for its use as fertiliser, BAT is to process the manure by applying one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Composting of solid manure	Generally applicable. Where emission reduction measures are required for the composting process (i.e. for reducing odour emissions), the applicability may be restricted to large poultry farms
b	Co-composting of manure with green residues	Applicable to new and existing farms
c	Composting of manure with a biological inoculum	Applicable to new and existing farms
([1]) A description of the techniques is given in Section 5.6.4.		

5.3.6 On-farm treatment of poultry manure

46. In order to reduce the potential for gaseous emissions from poultry manure and to make its use easier as fertiliser, BAT is to treat the manure by applying one or a combination of the techniques given below:

	Technique ([1])	Applicability
a	Use of manure additives	Generally applicable
b	Combustion of poultry litter as a fuel	Applicable to new and existing farms
([1]) A description of the techniques is given in Section 5.6.5.		

5.3.7 Emissions from landspreading of poultry manure

5.3.7.1 Landspreading of solid manure from poultry housing systems

47. In order to prevent or reduce ammonia and other nitrogen compound emissions from the application of solid manure to land, BAT is use all the techniques given below (in addition to the general techniques listed under BAT 10):

	Technique ([1])	Applicability
a	Use of a suitable spreading technique: • Rotaspreader • Rear discharge spreader • Dual-purpose spreader	Generally applicable
b	Incorporation of manure into land within four hours after spreading	Not applicable to grassland
([1]) A description of the techniques is given in Section 5.6.6.1.		

5.3.8 Emissions from the whole production process for poultry rearing

48. In order to prevent or reduce ammonia emissions from the whole production process for the rearing of poultry, BAT is to use a combination of techniques that can achieve an overall reduction efficiency for ammonia emissions of at least XX % for broilers and XX % for laying hens.

DESCRIPTION OF TECHNIQUES

5.4 General techniques for the intensive rearing of poultry or pigs

5.4.1 Nutritional management

5.4.1.1 Techniques for reducing nitrogen excretion

Technique	Description
Use of a balanced diet with an optimum feed conversion rate based on net energy, low crude protein content and digestible amino acids	Reduces the amount of nitrogen eliminated through urine, from undigested or catabolised nitrogen, by applying a low protein level in the feed and improving the efficiency of protein synthesis in the animal
Phase feeding with a diet formulation adapted to the specific requirements for the production period	2 to 5 feeds with different diet formulations, depending on the animal weight or growing phase. The feed mix matches the animal requirements in terms of energy, amino acids and minerals
Addition of controlled amounts of essential amino acids to a low crude protein diet	A certain amount of crude protein coming from protein-rich feedstuffs is substituted with amino acids from industrial production (e.g. L-lysine, methionine, threonine, tryptophan, valine). The addition can be done through a single phase or a multiphase feeding regime. Since different levels of crude protein may be needed in different climatic areas, due to a reduction of animal heat associated with a low crude protein diet, the environmental benefits of this technique may be most favourable in the Mediterranean climatic area
Use of feed additives that improve animal growth and promote higher performance in feed conversion	Feed additives such as enzymes (xylanases, glucanases, proteases, non starch polysaccharides, etc.), probiotics, phytogenic additives, organic acids (benzoic acid), enhance the animal performance by improving the digestion of nutrients and the utilisation of feed. Consequently, animals achieve higher growth rates, and a reduced amount of proteins is excreted. The expected environmental benefits of some additives (i.e. probiotics) are more significant for certain animal categories (i.e. sows)

5.4.1.2 Techniques for reducing phosphorus excretion

Technique	Description
Phase feeding with a diet formulation adapted to the specific equirements for the production period	2 to 5 feeds with different diet formulations depending on the animal weight or growing phase. The feed consists of a mix matching the animal requirements in terms of energy, amino acids and minerals
Addition of phytase to the diet	Allows the release of phosphorus contained in the feed ingredients of plant origin, making it available for digestion, and thus reducing the amount of phosphorus required from feed supplements. A reduction of mineral phosphorous requires a parallel reduction of calcium in order to maintain growth and bone mineralisation at a proper level
Use of highly digestible inorganic phosphates for a partial replacement of conventional sources of phosphorus in the feed	An increased rate of highly digestible inorganic phosphates allows reducing the total amount of phosphorous in the feed formulation, which presents variable digestibility

5.5 Techniques for the pig sector

5.5.1 Housing systems

5.5.1.1 Techniques for reducing the emitting manure surface

Technique	Description
Fully-slatted floor with vacuum system for slurry removal	Slurry is discharged from the pit by opening a valve in the main slurry pipe; a slight vacuum develops and allows the removal. The emptying frequency depends on the capacity of the pit
Partly-slatted floors with vacuum system for slurry removal	Slurry is discharged from the pit by opening a valve in the main slurry pipe; a slight vacuum develops and allows the removal. Manure channels are reduced in proportion to the amount of solid floor composing the system. The emptying frequency depends on the capacity of the pit
Partly-slatted floors with slanted walls in the manure channel	The section of the slurry channel presents a V section with the point of discharge at the bottom. The slope and smooth surfaces facilitate the slurry discharge. Manure removal is carried out at least twice a week
Partly-slatted floors or fully-slatted flat decks with a scraper	The flat deck consists of a slatted concrete part (defecating area) and a solid concrete part (laying area) with a slope towards the slats. In the collecting part (pit underneath), urine can drain directly to a collection pit through a drain in the bottom of the manure channel. From the pit, solid manure is removed outside very frequently by a scraper
Partly-slatted pens with convex floor and separated manure and water channels	Manure and water channels are built at the opposite sides of the solid concrete floor, allowing keeping the two flows separated. The manure channel can be built with flashed gutters or slanted walls which are normally flushed twice a day. The slats quickly release the manure to the channel, limiting the manure surface in the channel
Partly-slatted floors with slurry V-shaped manure belts	V-shaved manure belts roll inside the manure channels covering the whole surface, so that all faeces and urine are dropped on them. Belts are run at least twice a day to separately carry urine and faeces from the animal house to closed manure storage. Belts are made of plastic (polypropylene or polyethylene)
Partly-slatted floor with reduced manure pit	The pit is equipped with triangular slats and has a width of about 0.6 m, resulting in a reduced manure surface area. In the narrow pit, urine and faeces fall in the back of the stall improving cleanliness
Frequent slurry removal by flushing	A very frequent removal (once or twice per day) of the slurry is performed by flushing the channels with the liquid fraction of the slurry (dry matter higher than 5 %). Different procedures/tools are used for reducing the expose manure surface and to achieve a natural drainage of urine (liquid fraction of the slurry); including small plastic or metal gutters placed over the surface of the manure channels, plastic tubes under each slat, permanent slurry layer in channels underneath the slatted floors, etc.

Technique	Description
Kennel or hut housing on partly-slatted floors	The systems present differentiated functional areas, one solid concrete for laying (about 60 % of total area) and another perforated for eating and walking. A small emitting manure pit is located under the slatted area. Straw is used on the solid concrete floor, preventing the floor from getting dirty, and the laying area is covered, allowing keeping a room temperature lower than normal
Solid concrete floor with full litter	A fully concrete floor almost completely covered with a layer of straw or other lignocellulosic material that absorbs urine and incorporates faeces. Solid manure is frequently removed to prevent the litter from becoming moist. Manure is removed daily by a scraper. Separate functional areas can be organised into bedding, feeding, walking, defecating, with the aim of encouraging the natural defecating of the sows, resulting in reduced ammonia emissions
Solid concrete floors with littered external alley	A small door allows the pig to go out to defecate in an external alley with a concrete littered (with straw) floor. The manure falls into a channel from where it is scraped once a day and removed to a solid manure heap. Underneath the manure heap, the liquid that drains is collected in a suitable basin
Litter-based pens with feeding/lying boxes on solid floor	Sows are kept in a pen divided into two functional areas, the main one littered and a series of feeding/laying cubicles over a solid floor. Manure is captured in the straw (litter), which is regularly supplied and replaced
Pens for weaning pigs with partly-slatted floors	Pens may be fitted with a sloped floor to one slatted section or with convex floor and slat (metal or plastic) at both sides with two manure channels. Manure is drained through a pipe; the channels are usually drained at intervals of 6 – 8 weeks after the removal of each group of pigs
Pens or flat decks with fully-slatted floors and concrete sloped underground floor	A very smooth sloped surface is placed under the slatted floors in order to allow the urine to drain continuously and the slurry to move towards the central pit. Frequent or continuous emptying of the central slurry channels is performed. At the end of the weaning period, dry faeces are easily removed by water jets
Manure collection in water	The manure is collected in the cleaning water that is kept in the manure channel and refilled up to a level of 120 – 150 mm. In a fully-slatted floor system, slats are triangular iron/metal elements, except around the feeding through (plastic slats). In partly-slatted floors, slats can be at one side of the sloped solid pavement or at both sides of a central convex solid floor. Slanted channel walls are optional. After each breeding round, the manure channel is emptied
Stall housing with partly-slatted floors	Fully ventilated housing system with a daily slurry vacuum removal. Individual pens of around 4.3 m^2 have stalls which allow temporary corralling of sows. The laying area may be partially continuous solid floor. Slats are made of plastic, metal or concrete. Piglets are provided with a levelled, heated nest. The crate may be designed to lift while the sow is standing and lower when the sow lies down in order to prevent piglets getting underneath the sow
Crates with fully-slatted floors and a combination of water and manure channels	The sow is kept in a fixed placed with a specific defecating area. The manure pit is split up into a wide water channel at the front and a small manure channel at the back, with e reduced manure surface. The front channel is partly filled with water

Technique	Description
Crates with fully or partly-slatted floors and manure pan	A prefabricated pan is placed under the slatted floor; its dimension needs to encompass the entire slatted area. The pen is deepest at one end with a slope of at least 3º towards a central slurry channel; the manure discharges when its level reaches 12 cm. If a water channel exists, the pan can be subdivided into a water section and a manure section
Littered pens with or without a yard	Pens are equipped with separate functional areas: a bedded lying area, walking and dung areas with slatted or perforated floors and an eating area on a solid floor. Piglets are provided with a littered and covered nest and an optional non-littered yard. Slurry is frequently removed from under the slatted floor. Solid manure is manually removed from the solid floor areas on a daily basis

5.5.1.2 Techniques for cooling the manure surface

Technique	Description
Partly-slatted floors with slurry cooling	A reduction of the slurry temperature is achieved by installing a cooling system placed above the concrete floor or cast into the floor. The system consists of pipes in which a refrigerating liquid is circulated. The pipes are connected to a heat exchange device (pump or plate) to recover energy that may be used for heating other parts of the farm. The channels need to be scraped or flushed frequently (e.g. on a daily basis)
Partly-slatted floors with manure surface cooling fins	A number of plastic fins, connected to each other and to the slurry channel, are placed in the pit to float over the manure. Groundwater is generally used as coolant. The system may be equipped with a heat pump exchanger to recover heat for other uses (e.g. floor heating systems)

5.5.1.3 Techniques for reducing aerial emissions within pig housing

Technique	Description
Fogging	Water is sprayed by nozzles at high pressure to produce fine droplets that absorb heat and fall by gravity to the floor, moistening dust particles that become heavy enough to drop as well. Evaporation takes place very quickly so that walls and animals are not wet
Treat odorous compounds by atomisation of capturing and reacting agents (brumisation)	Specific hydrosoluble compounds are dispersed in a mist through diffusion devices operating at high pressure. Their molecular structure allows to capture odorant molecules, inactivate them and eventually transform them into stable and non-odorant forms, with a consequent acceleration of odorous pollutants biodegradation
Use of floating balls in the manure channel	High-density polyethylene balls are left to float on the surface of the manure channels below the slatted floors. Balls are half-filled with water and their axis changes when faeces are dropped from the slatted floor. Currently (2013), the technique is used in combination with a diet containing 1 % benzoic acid

5.5.1.4 Techniques for treating air emissions from pig housing

Technique	Description
Wet acid scrubber	The air flow (in part or in total) of the housing system is forced through a filter (e.g. packed wall) where an acid liquid (e.g. sulphuric acid or hydrochloric acid) is trickled
Bioscrubber (or biotrickling filter)	A packed tower filter with inert packing material which is normally maintained continuously wet by sprinkling water. Air pollutants are absorbed in the liquid phase and subsequently degraded by microorganisms settling on the filter elements
Biofilter	The exhaust air is led through a filter bed of organic material, such as root wood or wood chips, coarse bark, compost or peat. The filter material is always kept moist by intermittent sprinkling of the surface. Dust particles and odorous air compounds are absorbed by the wet film and are oxidised or degraded by micro-organisms living on the moisturised bedding material
Two-stage scrubber of combined wet acid scrubber and bioscrubber	A scrubber consisting of a series of two steps aimed at removing different air pollutants, including dust and ammonia. The first stage (wet chemical scrubber) is combined with a biologically active water scrubber (second stage)
Three-stage scrubber of combined water scrubber, wet chemical scrubber and biofilter	A scrubber consisting of a series of three steps aimed at removing different air pollutants, including dust and ammonia. In general, a first stage consisting of a water scrubber is combined with a second stage (wet acid scrubber), followed by a biofilter (third stage)

5.5.2 Manure storage in pig farms

5.5.2.1 Techniques for reducing emissions from slurry tanks

Technique	Description
Use of stable tanks able to withstand mechanical, chemical and thermal influences	Underground or above-ground tanks can be constructed in suck a way that the risk of leakage of the liquid fraction can be minimised. Appropriate concrete mixtures and, in many cases, lining to concrete tank walls or impermeable layers to steel sheets are applied
Reduce the ratio between surface area and volume of the slurry tank	In order to reduce the exposed slurry surface a proper SA/V ratio should be chosen. For rectangular slurry stores, the proportion of height and surface area should be equivalent to 1: 30 – 50. Side walls of the slurry store may be increased in height in order to achieve a more favourable SA/V ratio
Use of slurry tank with a sufficient capacity that allows operating at a lower level of fill	The capacity of the slurry store should be sufficient until further manure treatment or application is carried out. With a lower level of fill, the freeboard of the store provides a wind shielding effect
Emptying the slurry tanks in spring before the warm season for reducing the quantity of stored slurry	At higher temperatures, gaseous emissions increase; therefore, the least possible quantity of slurry should be stored during summer
Perform the discharge of slurry in open storage containers as close as possible to the base of the containers	The practice involves infilling below the liquid surface level, operating the pumps for homogenisation and circulation of slurry at favourable wind conditions and keeping the stirring of slurry to a minimum (before emptying the slurry tank)
Covering slurry stores	Covering applied to reduce the evaporation rates from the slurry surface
Rigid cover	A cover made of concrete, fibreglass panel or polyester sheets with a flat deck or conical shape. It should be well sealed and 'tight' to minimise air exchange and to prevent rain and snow from entering
Flexible covers	
Tent cover	A cover with a central supporting pole and spokes radiating from the tip. A fabric membrane is spread over the spokes and tied to a rim-bracing. Non-covered openings are kept to a minimum
Dome-shaped cover	A cover with a curved structural frame installed over round stores with the use of steel components and bolted joints
Cover tended flat	A cover consisting of a flexible and self-supporting composite material held by plugs on a metal structure
Swollen cover	A cover made of PVC fabric supported by an inflatable pocket that floats over the slurry. The fabric is fixed by guy rope to a peripheral metal structure
Floating covers	
Natural crust	A crust layer is formed spontaneously on the surface of a slurry that has a sufficient dry matter (DM) content (>2 %).
Straw and/or high dry matter content manure	Straw is added to the slurry and a straw-induced crust is formed. It generally works well for DM >4 – 5 %
Plastic pellets	Polystyrene balls are used to cover the slurry surface. A regular replacement of deteriorated elements and a refill for uncovered spots are necessary
Peat and light bulk materials	Materials such as LECA, perlite, zeolite are added to the slurry surface to form a crust. The addition should be renewed after each stirring
Rapeseed oil and grains	Generation of a floating, biodegradable cover on the slurry
Floating flexible covers	Canvas or plastic floating covers rest directly on the slurry surface. Floats and tubes are installed to keep the cover in place, while maintaining a void beneath the cover

Technique		Description
	Geometrical plastic tiles	Hexagonal plastic bricks "automatically" distribute on the slurry surface. Depending on the geometry of the tank, about 95 % of the surface can be covered

5.5.2.2 Techniques for reducing emissions from earth-banked slurry storages

Technique		Description
Use of a suitable slurry storage that ensure protection of the soil underneath		The soil used to construct the earth–banked store should ensure stability and low permeability (high clay content). Geomembrane liners (i.e. double-layered plastic geomembrane) with leakage control are applied. A minimum allowance for freeboard is also necessary
Keep to a minimum the stirring of slurry		A low evaporation rate can be maintained if the stirring of slurry is done only before emptying the slurry storage for the homogenisation of the suspended matter
Covering the earth-banked slurry storage by means of flexible and/or floating covers		The use of covers reduce the evaporation rates from the slurry surface
	Flexible plastic sheets	Impermeable UV-stabilised plastic sheets (e.g. HDPE) are secured at the bank tops and supported on floats. The covers can also be fitted with collection piping for gases that develop on the covered surface
	Natural crust	A crust layer is formed spontaneously on the surface of the slurry that has a sufficient dry matter (DM) content (>2 %).
	Straw and/or high dry matter content manure	Chopped straw is added to the slurry and a straw-induced crust is formed. It generally works well for DM >4 – 5 %.
	Light bulk materials	Materials such as LECA, perlite, zeolite are added to the slurry surface to form a crust. The addition should be renewed after each stirring
	Floating flexible covers	Plastic floating covers (blankets and films) rest directly on the slurry surface reducing the release of gases from slurry
	Geometrical plastic tiles	Hexagonal plastic bricks "automatically" distribute on the slurry surface. Depending on the geometry of the tank, about 95 % of the surface can be covered

5.5.2.3 Techniques for reducing emissions from storage of solid manure

Technique	Description
Store solid manure on a solid impermeable floor equipped with a draining system	A solid impermeable floor prevents leakages to soil and groundwater. The storage is equipped with a draining system connected to a pit for collection of liquid fractions and any run-off caused by rainfall
Select a storage facility with a sufficient capacity to hold the manure between periods in which the application to land is not possible	The periods when manure application to land is allowed depend on the local climatic conditions; thus, requiring a suitable capacity of the storage area
Position the location for storage taking into account the general wind direction and/or adopt measures that can serve as windscreens	The stripping effect of wind may be reduced by natural barriers such as trees, walls (wood, bricks or concrete) that can be erected to surround storage heaps, with the opening of the storage on the lee side of the prevailing wind direction
Reduce the ratio between surface area and volume of the manure stack (SA/V)	In order to reduce the exposed manure surface, a proper SA/V ratio should be chosen

Technique	Description
Covering the solid manure stacks	Materials such as peat, sawdust, wood chips or UV-stabilised plastic covers may be used to reduce the evaporation of ammonia and prevent the run-off of rainwater
Use a concrete silo for storage	A foundation slab of water-impermeable concrete with walls on three sides and roofing over the manure platform. The floor has an inclination of 2 % towards a front drain gutter or elevated edges. Fluids are collected into a pit

5.5.3 Techniques for on-farm manure processing

Technique	Description
Mechanical separation of pig slurry: 1. Screw press and auger separator 2. Decanter-centrifuge separator	1. Slurry is pumped into a separator directly or through a funnel with the aid of a vibration unit. Solids are conveyed by a screw auger towards the mouthpiece of the separator. Pressed and dry manure solids are discharged. 2. The slurry enters the decanter centrifuge, which then rotates at high speed. The solid particles of the slurry are hurled to the edge of the centrifuge and removed by a scraper
Mechanical separation of slurry combined with biological treatment (with or without nitrification-denitrification)	The solid fraction of manure is removed by sieving, sedimentation or centrifuge. The liquid is pumped through an aeration tank or basin, where it remains for 2 to 3 weeks. In the basin, microorganisms (activated sludge) transform organic matter into mainly CO_2 and H_2O. The liquid residue is captured in a storage basin to concentrate it further and can be used as a fertiliser
Aerobic digestion (aeration) of liquid manure	Stored slurry is aerated by means of aerating pumps that blow air into the mass. The aerator can be submerged or floating and usually work intermittently
Composting of solid manure	A controlled aerobic fermentation is performed producing a more stable final product than the initial matter. Oxygenation is done mostly by reversing the windrows (reversal) or by forced ventilation of the heaps
Anaerobic treatment of manure in a lagoon system	Manure settles in the lagoon into two layers (solid or sludge and liquid) and then undergoes anaerobic respiration with the conversion of organic compounds into CO_2 and methane. A final aerobic stage may be applied before the resulting fluid fraction can be applied to soil, sent to a treatment facility, or discharged
Anaerobic treatment of manure in a biogas installation	Anaerobic microorganisms decompose the organic matter contained in the slurry in a closed reactor in the absence of oxygen. Biogas is produced and collected to serve a heat generation system. A stabilised residue (digestate) that could be applied to land as a soil conditioner and a source of nutrient is produced
Drying of manure: 1. Evaporation and drying of manure with a heat exchanger and dryer 2. Drying of manure by belt dryer	1. The manure is ground, mixed and heated up to 100 °C by means of a heat exchanger; then, it is dried and compressed. Any water vapour that is formed is compressed with a resulting increase in temperature (up to 110 °C) and then used in the heat exchanger. 2. The solid fraction obtained from slurry separation processes is dried by means of a belt through which warm air flows. In drying chambers, one or several transport belts are arranged one above the other, each downloading matter to the one below. When the material is downloaded to the lower belt, it is mixed and homogenised

5.5.4 Techniques for the on-farm treatment of manure

Technique	Description
Slurry acidification	Sulphuric acid is added to the slurry tank in order to lower the pH to 5.5, followed by aeration and homogenisation. Part of the treated slurry is pumped back to the storage pit under the housing floors in order to reduce ammonia volatilisation. The treatment system is fully automated
Ammonia stripping	Ammonia in a gaseous form is separated from the liquid slurry fraction obtained from manure separation by air or steam stripping. The gaseous flow (air or steam) is passed through a column counter-current to the liquid. Stripped air is washed in sulphuric acid solution to produce ammonium salt. In steam stripping, the output gas is condensed to an ammonia water solution
Use of manure additives	Chemical and biological compounds are added to manure to change its characteristics and properties. The resulting effects may include: manure flowing, elimination of superficial crusts, reduction of soluble and suspended solids, reduction of the stratification of manure, neutralisation of volatile compounds, etc. Different additives are used including: 1. Masking agents for covering odours 2. Blocking agents for neutralising volatile compounds 3. Microbiological agents for degrading organic substances 4. Absorbing agents with large chemical surface for absorbing odours 5. Chemical additives with specific properties such as: pH control, oxidising agents, precipitating agents, electron acceptors

5.5.5 Techniques for landspreading of manure

5.5.5.1 Techniques for landspreading of solid manure

Technique	Description
Use of a suitable spreading technique	The selection of the spreading technique should be based on the type and condition of soil (depth, stone content, wetness, etc.); topography (slope, size of the field, evenness of the ground); manure type and composition, crop type and growth stage
1. Rotaspreader	A discharge spreader with a rotor that throws the solid manure out to the side when it spins
2. Rear discharge spreader	A trailer body fitted with a moving floor or other mechanism which delivers solid manure to the rear of the spreader. The spreading mechanism can have either vertical or horizontal beaters and, in some cases, spinning discs
3. Dual-purpose spreader	A side discharge spreader with an open top V-shaped body capable of handling both slurry and solid manure
Incorporation of manure into land within 4 hours from spreading	Incorporation of manure applied on the soil surface is done by either ploughing or other shallow cultivation equipment, such as discs or cultivators, depending on the soil type and conditions. Manure is completely buried under the soil

5.5.5.2 Techniques for landspreading of liquid manure (slurry)

Technique	Description
Use of a suitable spreading technique:	The selection of the spreading technique should be based on the type and condition of soil (depth, stone content, wetness, etc.); topography (slope, size of the field, evenness of the ground); manure type and composition, crop type and growth stage
1. Dilute slurry irrigators	Irrigation systems such as rain guns, boom-mounted splash plates, pulse-jet and rotary boom systems are used to landspread dilute slurry with less than 2 % dry matter content. The clarified fraction of mechanically separated slurry can be mixed with irrigation waters and distributed by irrigation systems such as pivots and mechanical wings
2. Pulse jet irrigators	A hose is mounted on a rotating arm and delivers a pulse of slurry or dirty water every 30 – 90 seconds around in a circle with a radius of about 60 m. About 100 litres of liquid are gradually pumped into a pressure accumulator tank and are discharged when the pressure reaches a pre-set level. Then, the pressure tank refills, the nozzle moves round and the next pulse is discharged
3. Band spreader (trailing hose or trailing shoe)	Plastic or rubber hoses hang from a 12 – 28 meters wide bar mounted onto the slurry trailer, at a distance of 30 – 50 cm to each other. The hoses trail over the soil surface and release slurry directly in 5 – 10 cm wide parallel bands
4. Injector (open slot)	Cutting discs or steel knives from a harrow tine are used to cut slots in the soil forming grooves into which slurry is deposited. The injected slurry is fully or partially located below the soil surface at a depth of 3 – 8 cm and grooves will normally be open after slurry application
5. Deep injector (closed slot)	Cultivators with sharp S-shaped spring tines or disc harrows are used to loosen the soil and deposit the slurry into it, before the soil again closes the groove with press wheels or rollers fitted behind the injection tines or discs
Incorporation of manure into land within 4 hours from spreading	Incorporation of manure applied on the soil surface is done by either ploughing or other shallow cultivation equipment, such as discs or cultivators, depending on the soil type and conditions. Manure is completely buried under the soil

5.5.6 Techniques for energy use in pig rearing

Technique	Description
Minimisation of thermal losses while adapting heating and ventilation to the physiological needs of the pigs	An optimised and balanced management of heating and ventilation obtained through automation and minimisation of the air flow, taking into account the needs for a fresh air supply, sufficient air humidity, and removal of undesirable air pollutants for animal welfare
Insulation of the houses walls, floors and ceilings	The interposition of insulation material between the internal and external environment limits excessive cooling and heating of the housing system, resulting in energy savings. Insulation material that repels moisture should be used, as humidity is a major cause of insulating material deterioration
Use of wood and other biomass fired boilers for heating up water	The boiler fired with biomass heats up water through an exchanger. Hot water is then circulated in the building (e.g. by means of fins, hot plates)
Replacement of low efficiency light bulbs with more energy-efficient lighting	Conventional tungsten light bulbs can be replaced with fluorescent, sodium, LED lights, being more energy efficient. They can be used in combination with devices to adjust the frequency of micro flashes, dimmers to adjust artificial lighting, proximity sensors or room entry switches
Use of energy-saving fans and optimised ventilation system	Fans with lowest possible specific power consumption (low-speed units) allow using less energy; however, they can only be used if the ventilation system exhibits a low resistance. Ventilation systems can be designed to operate so that the flow resistance is kept as low as possible by adopting short air ducts, avoiding sudden changes into air duct cross-sections, removing any dust deposit in the ventilation systems and on the fans, and avoiding rain protection covers above the discharge points
Use of heat exchangers for warming up water. The following systems may be applied: 1. air-air 2. air-water 3. air-ground	In the air-air and air-water exchanger, heat is recovered from the exhaust air extracted from the housing system that otherwise would be lost in the outdoor environment. In the air-ground exchanger, the combination of the two characteristic heat variations in soils is used. On one side, the thermal variation of soil horizons decreases with depth and on the other side the deep soil average temperatures are negatively correlated to the seasonal temperatures. This means that the air-ground heat exchangers can produce heat in the cold season and keep relatively cool in summer
Use of heat pumps for heat recovery in air-air or air-water circuits	Heat is recovered from various media (water, slurry, ground, air, etc.) and transferred to a fluid circulated in a sealed circuit, transforming it from a liquid to a gaseous state. The heat is used to produce sanitary water or to feed a heating system or a cooling system. Geothermal energy, heat from scrubbing water, from biological reactors or engine exhausts may be used in the system. The technique is often coupled with slurry cooling

5.6 Techniques for the poultry sector

5.6.1 Housing systems

5.6.1.1 Housing systems for laying hens

Technique	Description
Enriched cages with one or two manure removals per week	Cages are built with sloping floors and are made of welded wire mesh or plastic slats. Cages are equipped with fixtures for feeding, drinking egg collection, manure removal. Additional equipment includes perches, nest boxes, litter areas, claw shortening devices. The cages are arranged on three or more tiers. Belts are placed under the cages for manure removal. The collecting belt may be aerated by an air stream for drying the manure
Small groups of hens in enriched cages with one manure removal per week	The cages are tiered vertically in four or more rows. Compared with the standard enriched cages, the technique employs larger surface area per animal, higher cages and more defined areas with litter and nests. Manure belts are placed under the cages for a frequent manure removal. Manure drying can be performed by means of pipes placed above or along the belts, blowing air over the droppings
Deep litter with deep pit and manure belt or scraper	At least one-third of the total house floor is partly covered with litter (e.g. sand, wood shavings, straw). The remaining floor area is slatted. A deep pit is situated under the slatted area. Feeding and drinking fixtures are located over the slatted area, while the bedding area is on solid floor with litter. Additional structures may be present inside or outside the house, such as verandas and free-court ranges. Manure is removed by scrapers (periodically) or by belts (once a week for dried manure, twice a week without drying)
Deep litter with forced air manure drying	The deep litter system (see above for description) is combined with manure drying by means of forced ventilation applied through tubes that blow air (e.g. at 17 – 20 ºC) over the manure stored under the slatted floor
Deep litter with perforated floor and forced drying	The deep litter system (see above for description) is equipped with a perforated floor placed underneath the manure which allows for forced air blowing from below in order to dry the manure
Aviary with manure belt with or without veranda and forecourt free range	Aviaries are divided into different functional areas for feeding and drinking, egg laying, scratching and resting. The available indoor usable surface area is increased by means of elevated slatted floors combined with stacks. The slatted area ranges between 30 and 35 % up to 55 and 60 % of the total available floor area. The remaining floor is typically littered. The system can be combined with verandas with or without free-court ranges. Manure is collected on belts and removed twice a week for belts without ventilation or once a week when drying is carried out on the belt by ventilation
Aviary with underfloor manure drying	Aviaries are built with a deep pit, at least 70 cm deep where manure is stored for the whole egg-laying period (13 – 15 months). A ventilation outlet circulates heated air in the manure pit to dry the droppings. A crust forms on top of the manure reducing the degradation of urea to ammonia and its volatilisation from the manure

Technique	Description
Use of an external tunnel for manure drying	The manure is removed daily by belts that convey it outdoors to a dedicated closed structure, containing a series of perforated overlapping belts that form the tunnel. Warm air is blown through the belts, drying the manure in about three days. The incoming manure is sent to the top of the tiered belt system and dropped down from the end of a belt to a lower belt. The tunnel is ventilated with air extracted from the hens house

5.6.1.2 Housing systems for broilers

Technique	Description
Litter-based system with circulating fans	Vertical shafts with ventilators hang from the ceiling. At the bottom of the shaft (at a maximum of 1.2 m above the manure); a special device directs the warm air from the roof horizontally over the litter. Circulating fans homogenise the air flow
Litter-based system with circulating fans and heat exchanger	Incoming air is warmed up in a heat exchanger by using the heat recovered from indoor air. Ventilators distribute homogeneously the warm air over the litter
Litter-based system with (equally spread) recirculated air by indoor fans and heaters	The house is heated by a combination of ventilators and heaters placed at about 1.5 m from the floor. The air is warmed up by thermal heat exchange with hot water produced by indirect-fired thermal heater using propane or natural gas, or by central heating. The heater is provided with equipment to direct the air horizontally over the litter
Tiered floor system with bedding on manure belt and forced air drying	A multi-floor system on tiers equipped with manure belts with bedding on. Corridors for ventilation are left between the rows of tiers. Air enters through one corridor and is directed to the bedding material (litter) on the manure belt. A pressure drop is generated by the ventilators, forcing the air to exit through the other corridor. Litter is removed at the time of removing the flock. The system is generally used in combination with the patio system, where the first growing phase is carried out
Patio system for hatching and growing broiler chicks for a limited time	A multi-tiered system composed of two rows containing several levels where the young broiler is housed. Incubated eggs are placed in the patio system and the resulting young chicks are reared on manure belts with litter on, which are also used to transport them out of the house. The system is equipped with light, heating and ventilation with an even distribution of fresh air to all the layers. Heat, removal from the bottom of the broilers can be provided by an air flow underneath the litter belt. The system is generally used in combination with a second stage, such as a tiered floor system (see above) or a traditional housing system for broilers
Use of biological additives in the litter	Complexes of microorganisms containing lactobacillus and bacillus, mixture of bacteria and mushrooms are added over the litter at the beginning of the breeding period, resulting in a drier, low-emitting litter

5.6.1.3 Housing systems for ducks

Technique	Description
Solid floor with full litter, manure removal at the end of the rearing cycle	The litter on solid floor absorbs urine and faeces that are removed at the end of the cycle. The housing system can be equipped with natural or forced ventilation. Depending on the type of rearing cycle (all-in, all-out or two separate ages), the space per animal may vary between 0.07 m^2/ap and 0.2 m^2/ap
Littered floor combined with partly-slatted floor, manure removal at the end of the rearing cycle	About 25 % of the surface is covered with a slatted floor. The litter on the solid floor is topped up every day. Manure is completely removed at the end of the "all-in, all-out" cycle
Fully-slatted floor with variable frequency for manure removal	Slats cover the pit where the manure is stored and evacuated to the external store. Manure removal can be done in different ways: 1. At the and of the whole rearing cycle 2. By permanent gravitating flow to an external store 3. By scraping with variable frequencies to an external store

5.6.1.4 Housing systems for turkeys

Technique	Description
Solid floor with full litter, forced ventilation and manure removal at the end of the rearing cycle	The building is closed and well insulated, and equipped with forced ventilation. The solid floor is covered with litter (wood shavings or straw). Manure is removed at the end of the cycle
Solid floor with full litter, natural ventilation and manure removal at the end of the rearing cycle	The building is naturally ventilated with insulated floor and roof and deep litter (e.g. chopped straw). Litter is added upon necessity. Manure is removed at the end of the fattening cycle

5.6.1.5 Techniques for reducing aerial emissions within poultry housing

Technique	Description
Fogging	Water is sprayed by nozzles at high pressure to produce fine droplets that absorb heat and fall by gravity to the floor, moistening dust particles that become heavy enough to drop as well. Evaporation takes place very quickly so that walls and animals are not wet
Ionisation	An electrostatic field is created in the house to produce negative ions. Circulating airborne dust particles are charged by free negative ions; particles are collected on the floor and to room surfaces by gravitational force and electrostatic field attraction
Oil Spraying	Pure rapeseed oil is sprayed by nozzles inside the house. Circulating dust particles are bound to the oil drops and collected in the bedding or litter. A thin layer of rapeseed oil is applied on the bedding to prevent dust emissions
Treat odorous compounds by atomisation of capturing and reacting agents (brumisation)	Specific hydrosoluble compounds are dispersed in a mist through diffusion devices operating at high pressure. Their molecular structure allows to capture odorant molecules, inactivate them and eventually transform them into stable and non-odorant forms, with the consequent acceleration of odorous pollutants biodegradation
Use of biological additives in the litter	Complexes of microorganisms containing lactobacillus and bacillus, and a mixture of bacteria and mushrooms are added over the litter at the beginning of the breeding period, resulting in a drier, low-emitting litter

5.6.1.6 Techniques for treating air emissions from poultry housing

Technique	Description
Dry filter	The air extracted from the house is blown against a screen made of multi-layered plastic placed in front of the end wall ventilator. The passing air is subject to strong changes of direction causing the separation of particles through centrifugal force. Dust is collected in V-shaped filter pockets
Water trap	The exhaust air from the house is directed by ventilation fans down onto a water bath (15 cm deep pit containing water) where dust particles get soaked. The flow is then redirected 180 degrees upward. The water level is refilled regularly to compensate for evaporation
Water scrubber	The exhaust air from the housing is blown through a packed filter medium by transverse flow. Water is continuously sprayed on the packing material. Dust is removed and settles down in the water tank which is emptied before refilling
Wet acid scrubber	The air flow (in part or in total) of the housing system is forced through a filter (e.g. packed wall) where an acid liquid (e.g. sulphuric acid or hydrochloric acid) is trickled
Bioscrubber or biotrickling filter	A packed tower filter with inert packing material which is normally maintained continuously wet by sprinkling water. Air pollutants are absorbed in the liquid phase and subsequently degraded by microorganisms settling on the filter elements
Biofilter	The exhaust air is led through a filter bed of organic material, such as root wood or wood chips, coarse bark, compost or peat. The filter material is always kept moist by intermittent sprinkling of the surface. Dust particles and odorous air compounds are absorbed by the wet film and are oxidised or degraded by micro-organisms living on the moisturised bedding material
Two-stage scrubber of combined wet acid scrubber and bioscrubber	A scrubber consisting of a series of two steps aimed at removing different air pollutants, including dust and ammonia. The first stage (wet scrubber) is combined with a biologically active water scrubber (second stage)
Three-stage scrubber of combined water scrubber, wet acid scrubber and biofilter	A scrubber consisting of a series of three steps aimed at removing different air pollutants, including dust and ammonia. In general, a first stage consisting of a water scrubber is combined with a second stage (wet acid scrubber), followed by a biofilter (third stage)

5.6.2 Techniques for energy use in the rearing of poultry rearing

Technique	Description
Minimisation of thermal losses while adapting heating and ventilation to the physiological needs of the poultry	An optimised and balanced management of heating and ventilation obtained through automation and minimisation of the air flow, taking into account the needs for fresh air supply, sufficient air humidity, and removal of undesirable air pollutants for animal welfare
Insulation of the houses walls, floors and ceilings	The interposition of insulation material between the internal and external environment limits excessive cooling and heating of the housing system, resulting in energy savings. Insulation material that repels moisture should be used, as humidity is a major cause of insulating material deterioration
Use of wood and other biomass, including bedding material and poultry litter, to fire boilers for heating up water	The boiler fired with biomass heats up water through an exchanger. Hot water is then circulated in the building (e.g. by means of underfloor piping)
Use of heat-reflecting membranes	Walls and ceiling are lined on the indoor side with laminated plastic foils to seal off poultry housing from air leakage and humidity. More than 96 % of infrared energy can be blocked from the outside, and indoor energy is not radiated away from the membrane surface. The electric power for lighting can be reduced
Replacement of low efficiency light bulbs with more energy-efficient lighting (e.g. LED lights)	Conventional tungsten light bulbs can be replaced with other type of lights that are more energy efficient, in particular LED lights. They can be used in combination with devices to adjust the frequency of micro flashes, dimmers to adjust artificial lighting, proximity sensors or room entry switches
Use of energy-saving fans and optimised ventilation system	Fans with lowest possible specific power consumption (low-speed units) allow using less energy; however, they can only be used if the ventilation system exhibits a low resistance. Ventilation systems can be designed to operate so that the flow resistance is kept as low as possible by adopting short air ducts, avoiding sudden changes into air duct cross-sections, removing any dust deposit in the ventilation systems and on the fans, avoiding rain protection covers above the discharge points
Use of heat exchangers for warming up water. The following systems may be applied: • air-air • air-water • air-ground	In the air-air and air-water exchanger, heat is recovered from the exhaust air extracted from the housing system that otherwise would be lost in the outdoor environment. In the air-ground exchanger, the combination of the two characteristic heat variations in soils is used. On one side, the thermal variation of soil horizons decrease with depth and on the other side the deep soil average temperatures are negatively correlated to the seasonal temperatures. This means that the air-ground heat exchangers can produce heat in the cold season and keep relatively cool in summer
Heat recovery with heated and cooled littered floor (combideck system)	Two closed water circuits are connected by a heat pump. One circuit is installed below the floor and the other is built at a deeper level for storing the excess heat or to return it to the poultry house when needed. The heat pump connects the two water circuits. At the beginning of the rearing cycle, chicks are heated with the stored heat; during the second rearing cycle, birds produce an excess of heat that is preserved in the storing circuit while cooling down the floor

Technique	Description
Combustion of poultry litter as a fuel	Poultry litter is automatically fed from the storage into a combustion chamber. The hot flue-gases leaving the chamber go through a heat exchanger in which water is heated. The heated water is used in the rearing houses; the remaining ash can be used as a fertiliser

5.6.3 Manure storage in poultry farms

5.6.3.1 Techniques for reducing emissions from the storage of solid manure

Technique	Description
Store solid manure on a solid impermeable floor equipped with a draining system	A solid impermeable floor prevents leakages to soil and groundwater. The storage is equipped with a draining system connected to a pit for collection of liquid fractions and any run-off caused by rainfall
Select a storage facility with a sufficient capacity to hold the manure between periods in which the application to land is not possible	The periods when manure application to land is allowed depend on the local climatic conditions; thus, requiring a suitable capacity of the storage area
Position the location for storage taking into account the general wind direction and/or adopt measures that can serve as windscreens	The stripping effect of wind may be reduced by natural barriers such as trees, walls (wood, bricks or concrete) that can be erected to surround storage heaps, with the opening of the storage on the lee side of the prevailing wind direction
Reduce the ratio between surface area and volume of the manure stack (SA/V)	In order to reduce the exposed manure surface a proper SA/V ratio should be chosen
Covering the solid manure stacks	Materials such as peat, sawdust, wood chips or UV-stabilised plastic covers may be used to reduce the evaporation of ammonia and prevent the run-off of rainwater
Store manure in a barn	The barn is usually a simple construction with an impermeable floor and a roof, equipped with ventilation openings and an access door for transport. Poultry manure is transported by belts or front-end loaders from the poultry house to the barn where it can be stored for a long period of time
Use a concrete silo for storage	A foundation slab of water-impermeable concrete with walls on three sides and roofing over the manure platform. The floor has an inclination of 2 % towards a front drain gutter or elevated edges. Fluids are collected into a pit

5.6.4 Techniques for on-farm manure processing

Technique	Description
Composting of solid manure	A controlled aerobic fermentation is performed producing a more stable final product than the initial matter. Oxygenation is done mostly by reversing the windrows (reversal) or by forced ventilation of the heaps
Co-composting of manure with green residues	Substances of plant origin (e.g. crashed woody residues, pine bark) are added to the poultry manure to raise the carbon content. In general, the ratio of excreta to green residue is from 1/1 to 2/1 for woody residues and 3/1 for pine bark. A dilution effect of the nitrogen load by 30 % to 60 % can be achieved. Green residues can be pre-composted before their use
Composting of manure with a biological inoculum	Microorganisms (aerobe-anaerobe type) are used to degrade the organic matter. The bacterial inoculum is a combination of wild strain bacteria (bacillus, lactobacillus). The reduction of nitrogen load varies according to the origin of the manure, the type of litter and the housing system applied (deep litter, removal with belts)
Combustion of poultry litter as a fuel	Poultry litter is automatically fed from the storage into a combustion chamber. The hot flue-gases leaving the chamber go through a heat exchanger in which water is heated. The heated water is used in the rearing houses; the remaining ash can be used as a fertiliser

5.6.5 Techniques for the on-farm treatment of manure

Technique	Description
Use of manure additives	Chemical and biological compounds are added to the manure to change its characteristics and properties. The resulting effects may include: manure flowing, elimination of superficial crusts, reduction of soluble and suspended solids, reduction of the stratification of manure, neutralise volatile compounds, etc. Different additives are used including: 6. Masking agents for covering odours 7. Blocking agents for neutralising volatile compounds 8. Microbiological agents for degrading organic substances 9. Absorbing agents with large chemical surface for absorbing odours 10. Chemical additives with specific properties such as: pH control, oxidising agents, precipitating agents, electron acceptors
Combustion of poultry litter as a fuel	Poultry litter is automatically fed from the storage into a combustion chamber. The hot flue-gases leaving the chamber go through a heat exchanger in which water is heated. The heated water is used in the rearing houses; the remaining ash can be used as a fertiliser

5.6.6 Techniques for the landspreading of manure

5.6.6.1 Techniques for the landspreading of solid manure

Technique	Description
Use of a suitable spreading technique	The selection of the spreading technique should be based on the type and condition of soil (depth, stone content, wetness, etc.), topography (slope, size of the field, evenness of the ground), manure type and composition, crop type and growth stage
• Rotaspreader	A discharge spreader with a rotor that throws the solid manure out to the side when it spins
• Rear discharge spreader	A trailer body fitted with a moving floor or other mechanism which delivers solid manure to the rear of the spreader. The spreading mechanism can have either vertical or horizontal beaters and, in some cases, spinning discs
• Dual-purpose spreader	A side discharge spreader with an open top V-shaped body capable of handling both slurry and solid manure
Incorporation of manure into land within 4 hours from spreading	Incorporation of manure applied on the soil surface is done by either ploughing or other shallow cultivation equipment, such as discs or cultivators, depending on the soil type and conditions. Manure is completely buried under the soil

6 EMERGING TECHNIQUES

6.1 Microbial inducted nitrification of ammonium

Principle
Pens are provided with a fully-slatted floor and a shallow manure pit (0.60 m depth) underneath, from which the manure is removed at least once a month. Ammonia content is reduced by regularly applying a specifically selected strain of microorganisms to the manure which transforms ammonium to nitrate.

Description
Pens are fully-slatted floored. The shallow manure pit underneath the floor has a maximum depth of 0.60 m. The manure is removed from to an external storage at least once a month in order to reduce the residence time of the manure in the manure pit. As the concentration of nutritional elements decreases, the microbial activity will also decrease. By reducing the residence time, the manure in the channel is mainly 'fresh' manure which contains the necessary nutrients for the microorganisms. Hence the microbial activity is stimulated and ensures a rapid transformation of ammonium to nitrate.

A layer of manure of at least 10 cm must remain at any time in the manure pit to ensure that fresh manure immediately comes in contact with the microorganisms. To ensure the continuity of the microbial activity, the manure is inoculated with a new batch of specific microorganisms at least once a year. Use of antibiotics or detergents needs to be avoided. During disinfection, a fogger may be used to prevent liquid chemicals from leaking into the manure pit.

The manure that is removed to the external storage also contains a large amount of the ammonia-reducing microorganisms which suppress the formation of ammonia and the metabolism of other microorganisms in the manure storage.

Necessary provisions have to be made to ensure the required and correct dosing of the manure additive (e.g. automated dosage system with continuous registration).

Measurements to determine the ammonia abatement efficiency of the system are ongoing.

References
[275, BE Flanders 2010]

6.2 Winching and tilting plateaus in a partially littered and partially slatted housing for laying hens

Principle

Hens are unabled to scratch in the manure, hence a natural crust can build up to slow ammonia evaporation.

Description

At least two plateaus that can be winched and tilted are installed. Plateaus allow the animals to scratch and to learn how to fly (depending on the type of barn in use for the laying period).

A littered area of minimum 1/3 and maximum ½ of the total house surface is provided. The slatted floor is situated underneath the plateaus. Water and feeding provisions are located above the slatted floor area. A maximum of 16.6 animals may be reared (600 cm²/animal).

The manure is stored underneath the slatted floor area until removal at the end of the production cycle.

Preliminary measurements indicate a reduction of ammonia emissions by more than 50 % compared to a traditional floor housing systems. Further determination of the actual emission of the system are ongoing.

References

[275, BE Flanders 2010]

6.3 Fertilisation planning

Nitrogen (N) leaching from livestock manures happens especially as percolation through soil layers when it is applied on fields in an imprecise way, not being based on norms and fertiliser planning, or when manure is distributed to bare soils or where the nutrients are not taken up by the crops. Phosphorus (P) is lost to the environment via run-off and leaching, largely for the same reasons as mentioned for N, but in close connection to soil erosion mechanisms and the P content of the soils.

Hence, phosphorus and nitrogen fertilisations need to be balanced with the crop requirements for plant nutrients.

In the Baltic region, the over-fertilisation for phosphorus has been studied and interesting innovations have emerged under experiment in that region [Best Available Technologies for Manure Treatment for intensive rearing of pigs in Baltic Sea Region EU Member States, Baltic2020].

The presence of manure standards is a prerequisite for the efficient use of phosphorus and nitrogen norms at a large scale. Manure standards are official references that describe as a minimum, the amount of livestock manure produced per animal per year or per produced animal, and the composition of that manure as a dry matter percentage and as content of nitrogen, phosphorus and potassium.

6.3.1 Phosphorus fertilisation norms

In Sweden and Estonia, phosphorus norms are determined as a maximum allowed flat rate of phosphorus fertilisation, while Finland and Germany have taken a more developed regulation into use. Phosphorus fertiliser norms in Denmark, Lithuania, Latvia and Poland are recommendations only. Official norms are built into the legislation, while recommended norms are just advisory.

The recommended norms are normally more advanced than the official flat rate norms, as in Latvia and Denmark, where the phosphorus fertiliser norm for a field depends on a complete series of parameters: crop, yield level, previous permanent grasslands, soil type, pH, soil analysis, soil incorporated green manure from previous crops, the after effect of livestock manure from the previous two years, and the balance in the soil (if fertilisation from the previous years was not following the norms).

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6.3.2 P-index

The purpose of a P-index is to assess the risk of the release of phosphorus to surface waters. The index is a tool to help conservation planners, landowners and land users to evaluate the current risk of P reaching surface waters from a specific site, and to determine the factors which dominate the risk due to P transportation to surface waters. A regionally developed P-index methodology would be preferred, as the relevance of the parameters as well as the associated phosphorus loss risk varies between regions and countries.

The P-index may also assist landowners and land users in making management decisions to reduce the associated risk. It is not a simple phosphorus content score, but it has an erosion component, which considers shell and rill erosion, P enrichment, total soil P, filter strip, sediment delivery, distance to a stream, and the long term biotic availability of particulate P in surface water ecosystems.

The index is a formula, which is calculated annually after the specific parameters for the given field have been determined. The formula may consider run-off components based on soil tests, rate time and the method of P application, as well as internal drainage components based on the presence of tiles, water flow to tile lines, surface water recharge to subsurface flow, and soil tests.

Practical examples

Denmark: a P-index has been developed by researchers and tested in practice in cooperation with the farm advisory service with positive results. The index tool is web-based, consisting of pre-calculated P-index maps covering the entire Denmark as well as P mitigation planning tools. The major challenges to face before its implementation at farm level are the lack of data (mainly on soil P status), and the need for additional validation of the model. The interface to the user requires some practice for its interpretation.

Finland: researchers have built sound experience and competence in assessing risks for P losses and their mechanisms through modelling and research on erosion. Nevertheless, no P-index has been developed yet.

Germany: two tools have been developed and introduced as official regulations in 2010: the 'risk maps associated with compulsory use of cultivation practices' and the 'P-balance calculation'. These P-measures are not the same as a P-index, but with their focusing on the P-balance, they are more advanced than a mere P-norm.

Norway: a P-index has been developed which is used voluntary by farmers and their advisers. It is simple and effective in its structure, has an introductory presentation via a web tool and has been proven in practical use. Farmers and their advisers can test the effects on the P-index calculation of different management practices.

Sweden: a P-index has been developed and tested in practice, but it was not yet implemented in agricultural practices. The large amount of baseline data and the individual software that is required discouraged the practical implementation of the system at farm level. On the other hand, the existing Swedish regulation of maximum animal density in combination with the flat-rate P-norm is acknowledged within the research community as a very effective way to avoid high P surpluses.

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~~**Practical examples**~~

~~Denmark: research and pilot tests have been carried out. This has not been implemented in practice.~~

~~Sweden: a Swedish model for P index exists, developed at Swedish University of Agricultural Services (SLU). It is tested in pilot cases but is not yet implemented in practice.~~

~~Germany: regulation is in force concerning the risk of erosion and corresponding P discharge. Starting in July 2010 the farmer has to carry out field-specific risk assessment. Parts of the field are categorised as at risk of erosion levels (CC-water 1, CC-water 2, CC-wind). Category-dependent usage restrictions are defined.~~

6.4 Separation treatments

6.4.1 Multi-step biological and chemical manure treatment

Description

The initial stage of the process is biological, where the system is filled with the designed microbial growth. During aerobic biological treatment, liquid manure is changed to an odourless form and organic molecules are changed to a form where they are easy to precipitate and separate.

Most of the solid fraction containing phosphorus is collected in a first treatment chamber, screw pressed and is eventually used as concentrated phosphorus fertiliser. The ammonia formed during aeration is collected and saturated with water or acid. The biological treatment is followed by a N reduction with a stripping procedure in a series. After the stripping procedure, the slurry is deprived of N and P slurry and can be directly spread or sprinkled onto a field or further fractionated. Fractionation is when organic matter is precipitated by the addition of a small amount of ferric sulphate. After both processes, the end products are NH_3, separated phosphorus fertiliser, organic matter and water.

Source: [224, Finland 2010]

Figure 6.1: Scheme of slurry treatment system installed on a farm

Achieved environmental benefits

The final product is completely odourless and considerably reduced of pathogenic organisms.

Cross-media effects

The demand of resources is about 4.33 kWh of energy and 0.05 kg of ferric sulphate per tonne of treated manure.

Operational data

Tests are still in progress. Reported data are summarised in Table 6.1

Table 6.1: Characteristics of the manure before and after separation with the multi-step biological and chemical manure treatment

	Dry matter (%)	Total N (kg/ t)	NH_4-N P (kg/t)	Total P (kg/t)	Soluble P (kg/t)	Total C (kg/t)
Input	4.1	2.7	1.8	0.39	0.28	10.2
Separated slurry	2.0	1.2	1.0	0.16	0.10	2.8
Source: [224, Finland 2010]						

Applicability
No restriction is seen for the on-farm application of either existing or new installations.

Economics
Depending on the size and the system, costs of installation may vary from EUR 150 000 to EUR 200 000 per tonne. With an expected lifespan of 15 years and 5 % amortisation, the annualised investment costs would set at around EUR 18 330 per tonne of manure.

Driving force for implementation
Separation reduces the costs of manure storage, transport and application, which are key factors in intensive livestock areas where the field nutrient balances need to be taken into consideration.

Reference literature
[224, Finland 2010]

6.4.2 Phosphorus separation by calcium-sulphate based precipitation product

Description
Gypsum and magnesium oxide -based precipitate is mixed with slurry (2 – 6 kg per slurry tonne depending on the dry matter content of the slurry). Initially dissolved P is precipitated into Ca- and Mg-salts and settles with fibrous P to the bottom of the slurry storage. The fractions can be pumped out separately, the liquid fraction being rich in N and K, and the sediment fraction being rich in P.

Achieved environmental benefits
The separation provides an improvement in the slurry handling properties aimed at a more focused balance of phosphorus fertilisation. According to the preliminary results, the precipitation decreases the ammonia evaporation.

Cross-media effects
Compared to the untreated slurry, the fractionation application requires little extra work and few extra chemicals.

Operational data
Depending on slurry temperature fractionation and sedimentation of P (phosphorus) will take a time from 3 days to 3 weeks.

Only conventional farm-machinery is needed. The precipitate is handled in 600 – 700 kg bags and can be applied with a tractor lifter and mixed with the propeller mixer. Both fractions are pumped out of the tank with transfer pump to be transported and spread with conventional spreading equipment.

Applicability
No restriction.

Economics
No particular investment is needed, only raw material costs will be afforded.

Driving force for implementation
The liquid fraction is usually spread at farms nearby, and the fibrous fraction can be transported at reasonable costs and spread on more distant fields with lower phosphorus content.

Reference literature
[225, Finland 2010]

6.4.3 Slurry separation with acidification and ozone treatment

Description
This technique is an improvement of the manure acidification technique dealt with in Section 4.12.9.

The slurry is pumped from the houses ~~stables~~ to a process tank (an intermediate buffer tank is also used) where three treatments are carried out: a separation via a chemical and mechanical process, on odour treatment via an ozone process and an ammonia binding via pH regulation.

After the fibre fraction is separated, only the liquid fraction is used to refill the barn pits to reduce odour and ammonia evaporation under the grates. As in the acidification technique, part of this liquid is back-pumped in the house and the rest is stored.

This combined technique allows farmers to meet by a wide margin the ammonia and odour standards they need to respect when expanding their farm.

Achieved environmental benefits
The most significant environmental benefit is a drastic reduction of the odour from the slurry. The result is a better working and living environment for the farmer, the animals and the surroundings of the farm.

Hydrogen sulphide, bacteria and hormones are eliminated or inactivated.

The advantages of the separation are added allowing for a better control of the transportation costs and of the nutrient distribution when landspreading. Preliminary research indicated that weekly treatment of the slurry results in a 40 percent reduction in odour emissions.

Economics
The ozone treatment system is only available as an addition to a slurry acidification unit. To the main investment for installing the acidification unit with the relative piping and controlling devices (EUR 200 000), an extra investment of EUR 150 000 is needed.

The operating costs per tonne of slurry refer to 5 kg of concentrated sulphuric acid, to 7.75 kWh of electrical power and to 70 g of dry polymer for the separation treatment.

The maintainance service costs approximately EUR 2 000 a year.

The total operating cost amounts therefore to EUR 3 – 4 per tonnes of treated manure.

Reference literature
[230, Denmark 2010]

6.4.4 Electrolysis/electrocoagulation

Description
Aluminium and iron electrodes are placed in the liquid to be treated to cause three different effects.

- Oxidation. By electrolysis of water, reactive oxygen is created that oxidises material in suspension and leads to the degradation of different organic complexes.
- Flotation. After electrolysis hydrogen forms small bubbles rising to the surface while carrying joined particles previously suspended.
- Flocculation. The anode releases Al and Fe ions releasing. Both metals contribute to the formation of flakes. Catalytic nitrate reduction is induced by including copper/palladium catalyst. Part of the nitrate is converted into ammonium through an unwanted side reaction.

Another possibility is to work with an excess of ferrous iron in the presence of copper as catalyst.

Achieved environmental benefits
The removal of suspended solids and to some extent of N and P compounds. Conversion of nitrite (NO_2) to N_2 may occur.

Operational data
Table 6.2 provides an overview of the characteristics of the matter deriving from pig slurry before and after the treatment.

Table 6.2: Summary levels before and after treatment of pig slurry by electrocoagulation

Parameter	Concentration in pig slurry (mg/l)	Concentration in the solid fraction (mg/kg)	Concentration in the effluent (mg/l)
COD	68 700	84 200	1 053
BOD	8 120	10 400	449
Total N	4 650	1 258	478
N-ammonium	3 630	981	538
Total P	4 970	2.52	0.85
Ca			16
Mg			43
K			734
Pb	0.41	5.6	<0.02
Cd	0.17	6.5	<0.01
Cr	0.09	12	<0.05
Cu	48	98	<0.02
Ni	0.49	<2	0.10
Hg	<0.001	<0.1	<0.001
Zn	67	154	<0.02
Source: [256, Lemmens et al. 2006]			

Economics
The price that has been reported includes the separation and electrocoagulation/flotation, and is about EUR 12/m³ dung.

Example plants
The only system currently operational in Flanders is a mobile system of a German company.

Reference literature
[256, Lemmens et al. 2006]

6.5 Land application of diluted clarified slurry using drip lines

Description
After the separation treatment of slurry, the liquid fraction is rich in ammonia nitrogen that can be used with significantly greater efficiency than the nitrogen from unprocessed slurry.

The liquid fraction of digested pig slurry can be distributed onto crops using drip lines, mixing it with irrigation water. Drip line system is fed by pumps supplying a mixture of about one part slurry to three parts water. Disc filtration is performed after mixing.

Achieved environmental benefits
The utilisation of nitrogen by plants is highly efficient. The low water consumption is implicit in the irrigation method.

Operational data
The system has been tested on maize placed in rows 0.7 m apart from one another, each drip line being positioned between alternate rows and thus 1.4 m from one another. The mixture that was used had 0.31 % of dry matter and 0.05 % of NH_4 content.

Comparisons with the traditional band spreading technique were made and report that the same maize yields can be obtained but that the uptake efficiency for the nitrogen distributed in the slurry/water mix is significantly more efficient.

Minimal emissions were measured, varying from 0.003 to 0.013 kg of ammonia per applied m^3.

Drawbacks still remain in the operational implementation of this system, requiring the setting up of the slurry separation and distribution equipment, the maintenance of the pump and filter and rodent control. Drip lines are foreseen to be replaced annually.

Cost estimations result in EUR 840/ha for the annualised investment plus the annual running costs.

Reference literature
[240, Italy 2010] [241, Italy 2010]

6.6 Litter-less flooring system

Information was received of the development of innovative flooring equipment for commercial broiler houses that is intended to reduce ammonia emissions. It must be recalled that the Council Directive 2007/43/EC laying down minimum rules for the protection of chickens kept for meat production provides at paragraph 3 of Annex I that all chickens shall have permanent access to litter which is dry and friable on the surface.

Description

The principle is rearing broilers with significantly reduced bedding on a ventilated plenum floor that reduces ammonia production ~~little or no bedding on plastic floor that is regularly cleaned.~~ It subsequently can improve performances and can be cleaned in accordance with current industry practices.

The system consists of two piece-layer ~~layers of neutral pH~~ polymer flooring with an air plenum in between. The top layer is perforated and held by conic structures of the lower layer, to allow the downward wicking of moisture from poultry faeces, which will result in a much dryer manure.

Achieved environmental benefits

The system was intended to reduce ammonia production and emissions by attempting to have accelerated drying of the manure ~~and thus eliminate the need for litter. Absence of litter allows for a drastic reduction of circulating dust and the inhibition of darkling beetle populations which eliminates a major disease vector from the growing cycle.~~ The accelerated drying in combination with an inert polymer allows for the manure to maintain an acidic pH which leads to a drastic reduction (quasi-elimination) of ammonia and darkling beetle populations (a major disease vector). As a result of the indoor environmental improvements, animals can perform more efficiently.

Development

It seems that ammonia reductions are primarily a consequence of the control of the manure pH. A series of experiments were undertaken at the University of Maryland (US) during five years. Results indicated that while the technique and design were ~~was~~ improved, better results for ~~mortality and~~ feed efficiency were obtained. ~~As a result of the cooler temperature that seems to be obtainable at the floor level, ammonia reductions are possible. Occurrence of footpad lesions is still under improvement.~~

No cost or availability have been reported to date for the European market.

Reference literature

[369, Harter-Dennis 2010]

6.7 Photocatalytic titanium dioxide (TiO_2) coating paints

Titanium dioxide (TiO_2) is used in industrial applications to abate pollutant emissions into the atmosphere.

Through photocatalytic oxidation, TiO_2 can degrade ammonia in water solutions and in the atmosphere leading to the production of N_2, or N_2O or NO and water along one of the three following main paths:

1. $2\ NH_3 + 1.5\ O_2 = N_2 + 3\ H_2O$
2. $2\ NH_3 + 2\ O_2 = N_2O + 3\ H_2O$
3. $2\ NH_3 + 2.5\ O_2 = 2\ NO + 3\ H_2O$.

Photocatalysis is an accelerated photoreaction produced by a catalytic substance which accelerates the chemical transformation of a substrate, without undergoing any transformation itself.

Description
TiO_2 catalytic paint can be used for coating walls of pig houses to abate the indoor content of ammonia and its release in the outdoor environment.

Cross-media effects
In the Safety Data Sheet available from producers, it is reported that paints have no negative effect on animal and operator health.

Products are tested for the possibility of releasing GHG through the photocatalytic reaction.

Achieved environmental benefits
Fields experiments tested the differences of ammonia concentration between houses painted with conventional paint and painted with TiO_2 paint.

The average daily concentration of ammonia was lower for the TiO_2 paint treatment by 1.65 mg/m^3.The reduction effect of the paint treatment was hence of 30.50 %.

GHG measurements were lower in houses painted with TiO_2 paints: CO_2 by 10.80 %, N_2O by 4.24 % and CH_4 by 15.29 %.

Economics
The cost for treating a surface of 150 m^2 with TiO_2 paint at 70 g/m^2 is EUR 126. The cost for abated kilogram of ammonia is hence estimated to be around EUR 3.1.

Reference literature
[286, Guarino et al. 2008]

6.8 Sequential feeding in poultry

Description
Sequential feeding is a cyclic feeding programme of two feeds, one high-protein-low energy and one high energy-low-protein, during one or several days.

Its principle is to allow a great flexibility in the diet formulation to reduce the feed costs. The nutritional balance that is provided during the growth cycle is no different than in standard feeding, so sequential feeding gives the possibility to use a wide spectrum of raw feed, including those which are difficult to incorporate into traditional feed formulae. [281, France 2010]

It was found that a strong interaction exists between feed composition and its physic composition (colour and energy content) and that birds may learn to recognize the types of feed and therefore to select for a preferential ingestion. These aspects are not completely clear but it seems clear that growth performances are not affected. [446, Bouvarel et al. 2007]

It also seems that the practice tends to increase the animal activity hence to decrease the incidence of locomotive disorders. Animals would spend more time pecking less attractive feed.

Sequential feeding allows the disjunction of calcium supply from that of phosphorus. Therefore it should be possible to adjust the phosphorus intake and its release.

Reference literature
Bouvarel I. et al., Septièmes Journées de la Recherche Avicole, Tours, 28 et 29 mars 2007
Bizeray D., Leterrier C., Constantin P., Picard M., Faure J.M., Poult. Sci. 2002 Dec vol. 81 no. 12 1798-1806

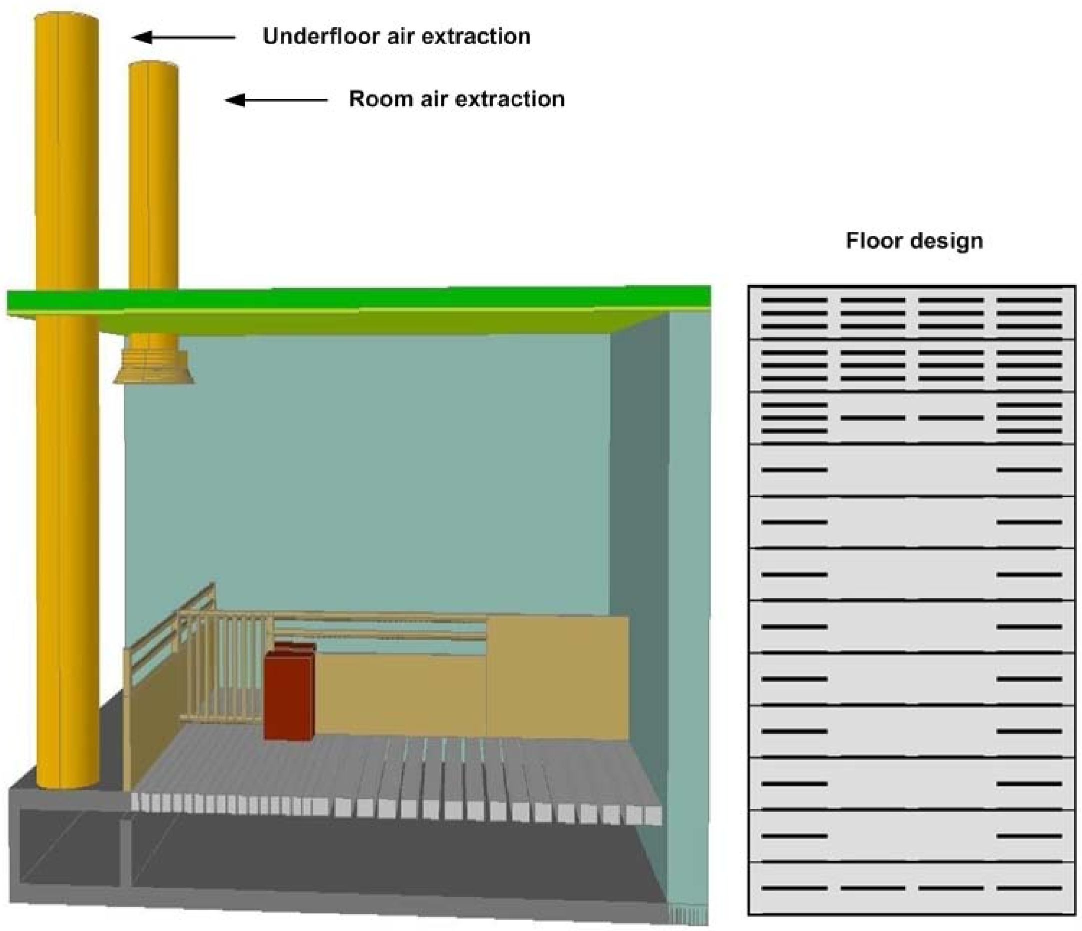
6.9 Air cleaning of pit ventilation exhausts in pig housing

The ideas that underpin this group of techniques are to create cost-efficient solutions to reduce ammonia and odour emissions from pig production units and to improve the indoor air quality. Pre-condition for this solution is the possibility of applying partial air cleaning (see Section 4.9.7) to the housing exhaust air that consists of cleaning the exhaust collected from the pits only. It is assumed that by cleaning around 20 % of the maximum ventilation capacity of a house with an air scrubber with 95 % ammonia reduction efficiency, more than 65 % of the ammonia that is emitted indoor (from manure and animals) would be captured by the air cleaning system and not lost in the air.

6.9.1 Air cleaning of underfloor ventilation in fully-slatted floors with slurry systems

Description

The room is equipped with separate exhaust outlet for the room air and the underfloor pit air. Only the exhaust air extracted from underfloor is cleaned by an air cleaning system (e.g. wet scrubber). A reduced opening design is used for the floor that allows 0.054 m^2 of open area per pig place. These features are described in Figure 6.2.



Source: [489, Pedersen et al. 2010]

Figure 6.2: Layout of the ventilation system (left) and of the floor design (right)

Achievable environmental benefits
An experimental study conducted on this system has shown that a partial pit ventilation rate of only 10 m^3/hour per pig can collect considerable amounts of pollutants for their subsequent cleaning. Around 70 % of the ammonia, 50 % per cent of the odour and 90 % of the hydrogen sulphide can be saved from being emitted in the environment in comparison with the system with only room extraction (see Table 6.3).

Table 6.3: Odour, hydrogen sulphide and ammonia concentrations and emissions measured at a pit ventilation rate of 20 m3/h per pig (32 pigs per pen)

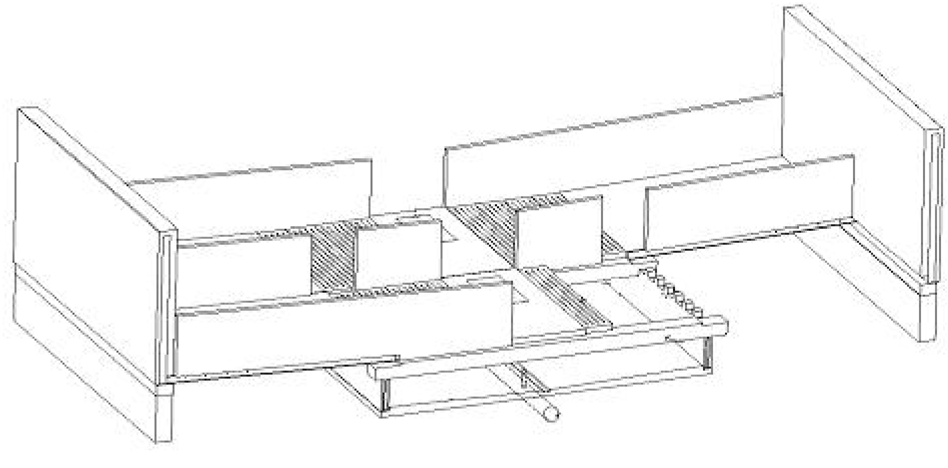
	Control	Experiment 1		Experiment 2	
Measurement	**Room**	**Pit**	**Room**	**Pit**	**Room**
Ventilation rate, m^3/h/pig	53	20	43	19	39
Odour concentration, OU_E/m^3	360	820	140	910	170
Odour emission, OU_E/s per 1 000 kg	80	64	22	71	27
H2S-concentration, ppb	197	505	70	475	30
H_2S-emission, mg H_2S/h per pig	4.3	3.8	1.1	4.0	0.4
	Control	**Experiment 1**		**Experiment 2**	
Measurement	**Room**	**Pit**	**Room**	**Pit**	**Room**
Ventilation rate, m3/h per pig	50	22	33	18	31
NH3-concentration, ppm	7.4	14	1.5	18	1.1
NH_3-emission, g NH_3-N/h per pig	7.3	5.2	1.0	6.4	1.1
Source: [489, Pedersen et al. 2010]					

It is expected that cleaning by an air cleaner with 95 % efficiency of ammonia reduction the air extracted from the pit at 20 m^3/hour per pig (20 % of maximum capacity), a 65 % ammonia reduction can be achieved on a year-round basis. Similar results can be achieved by cleaning only 10 % of maximum ventilation by connecting the air cleaner to a highly efficient pit ventilation system instead of cleaning air from a room exhaust.

The technique is under development for a full-scale implementation. Attention is placed onto the design of a central pit ventilation system to ensure uniform pit ventilation and the dimensioning of a partial pit ventilation with an efficient air cleaner to create a cost-efficient solution.

6.9.2 Air cleaning of underfloor ventilation in partially slatted floors with scraper and urine separation

Description
The design of this house (Perstrup system) features pens with partially slatted floor, sloped manure channel with a gutter for urine drainage and partial air evacuation from the manure channel through the solid part of the pen floor (see Figure 6.3). The room is equipped with separate exhaust outlet for the room air and the underfloor pit air.



Source: [490, Pedersen et al. 2011]

Figure 6.3: Drawing of the partially slatted floored Perstrup pig pens

Straw is daily brought to pens for an amount of 70 g/pig per day that does not clog the slots in the slatted floor.

Faeces are collected in a scraped manure channel having a 3 % slope down to a gutter for urine drainage.

Productions are not affected by the solution whilst room ammonia concentrations are very low (below 0.5 ppm), also compared with the concentrations in the exhaust air beneath the slats that are more than 10 times higher.

The frequent scraping does not have additive effect to that of the underfloor ventilation on ammonia and odour contrentrations in the room.

Significant parameters for this technique are shown in Table 6.4.

Table 6.4: Measured parameters for air cleaning of underfloor ventilation in partially slatted floors with scraper and urine separation

Parameter	**Room air**		**Underfloor air**	
	ventilation rate m^3/hour	Concentration	ventilation rate, m^3/hour	Concentration
Ammonia	9 200	0.3 ppm	20 500	5.5 ppm
Odour	11 600	381-589 OU_E/m^3	22 300	913 OU_E/m^3
Source: [490, Pedersen et al. 2011]				

7 CONCLUDING REMARKS

The EIPPCB will update and finalise this section for the final Draft of this document.

8 GLOSSARY

This glossary is meant to facilitate the understanding of the information contained in this document. The definitions of terms in this glossary are not legal definitions (even if some of them may coincide with definitions given in European legislations), they are meant to help the reader understand some key terms in the context of their use in the specific sector covered by this document.

This glossary is divided up into the following sections:

I. ISO country codes
II. Units
III. Chemical elements
IV. Chemical formulae commonly used in this document
V. Acronyms and technical definitions

I. ISO country codes

ISO code	Country
***Member States* (*)**	
BE	Belgium
BG	Bulgaria
CZ	Czech Republic
DK	Denmark
DE	Germany
EE	Estonia
IE	Ireland
EL	Greece
ES	Spain
FR	France
IT	Italy
CY	Cyprus
LV	Latvia
LT	Lithuania
LU	Luxembourg
HU	Hungary
MT	Malta
NL	Netherlands
AT	Austria
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
FI	Finland
SE	Sweden
UK	United Kingdom
(*) The protocol order of the Member States is based on the alphabetical order of their geographical names in the original language(s).	

II. Units

Numbers in this document are written using the '.' character (period) as the decimal separator and the space as the separator for thousands (e.g. 12 345 678.9).

Term	Meaning
°C	degree Celsius
bar	bar (1.013 bar = 100 kPa or 1 atm)
Cfu	colony-forming unit
cm	centimetre
d	Day
db(A) or dbA	A-weighted decibels
g	gram
h	hour
ha	hectare (1 ha = 10^4 m^2)
J	Joule
K	kelvin (0 °C = 273.15 K)
kcal	kilocalorie (1 kcal = 4.19 kJ)
kg	kilogram (1 kg = 1 000 g)
kJ	kilojoule (1 kJ = 0.24 kcal)
kWh	kilowatt-hour (1 kWh = 3 600 kJ = 3.6 MJ)
l	Litre
L_{Aeq}	Equivalent continuous A-weighted sound pressure level
LU	Livestock unit= 500 kg live weight
m	Metre
m^2	square metre
m^3	cubic metre
mA	Milliampere
mg	milligram (1 mg = 10^{-3} g)
min	Minute
MJ	megajoule (1 MJ = 1 000 kJ = 10^6 J)
mm	millimetre (1 mm = 10^{-3} m)
MWh	megawatt hour
OU_e	European odour unit
Pa	pascal (1 Pa = 1 N/m^2)
ppm	Parts per million (1 ppm = 10^{-6})
rpm	Round per minute
s	Second
psi	pound per square inch
T	metric tonne (1 000 kg or 10^6 g)
t/yr	tonnes per year
U	Enzyme unit
V	Volt
vol- %	percentage by volume (also % v/v)
W	Watt (1 W = 1 J/s)
wt- %	percentage by weight (also % w/w)
Yr	Year

III. Chemical elements

Symbol	Name	Symbol	Name
Al	Aluminium	N	Nitrogen
As	Arsenic	Nd	Neodymium
C	Carbon	Pb	Lead
Ca	Calcium	Pd	Palladium
Cd	Cadmium	Pm	Promethium
Co	Cobalt	Ra	Radium
Cu	Copper	Rf	Rutherfordium
F	Fluorine	Sb	Antimony
Fe	Iron	Sc	Scandium
H	Hydrogen	Ta	Tantalum
Hg	Mercury	Te	Tellurium
I	Iodine	Ti	Titanium
K	Potassium	U	Uranium
Li	Lithium	Xe	Xenon
Mg	Magnesium	Zr	Zirconium

IV. Chemical formulae commonly used in this document

Chemical formula	Name
H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
NaOH	Sodium hydroxide. Also called caustic soda
NH_4-N	Ammonium (calculated as N)
NO_2-N	Nitrite (calculated as N)
NO_3-N	Nitrate (calculated as N
NO_X	The sum of nitric (or nitrogen) oxide (NO) and nitrogen dioxide (NO_2) expressed as NO_2
SO_X	The sum of sulphur dioxide (SO_2) ans sulphur trioxide (SO_3) expressed as SO_2

V. Acronyms and definitions

Definitions are mostly in line with the 'RAMIRAN Glossary of terms on manure management 2011'.

AA	Amino Acid
Absorption	a volume process in which one substance permeates another.
AC	alternating current
Acid	proton donor – a substance that more or less readily gives off hydrogen ions in a water solution.
Acidification	adding acid to a substance to achieve acidic properties.
ACNV	automatically controlled natural ventilation.
ADEME	Agence de l'Environnement et de la Maîtrise l'Énergie.
ADG	Average Daily Gain. Increase in weight of animals
Adsorption	a surface process in which one substance adheres to a surface.
AEL	associated emission levels or the emission levels associated with the best available techniques as defined in Article 3(12) of the industrial emissions Directive.
Aeration	a process by which air is introduced to increase the oxygen concentration in liquids.
Aerobic	adjective that means 'requiring air', where 'air' usually means oxygen
Aerobic processes	biological processes that occur in the presence of oxygen.
Ammoniacal nitrogen	nitrogen present as ammonia and ammonium ion in liquid effluents.

Anaerobic	adjective that means ‘without air’, where ‘air’ usually means oxygen.
Anaerobic processes	biological processes that occur in the absence of oxygen and other electron accepting substances except carbon dioxide/carbonate.
Animal place or head (ap)	unit referring to one animal in production.
Annual capital cost	an equal or uniform payment made each year over the useful life of the proposed technique.
Anode	An anode is an electrode through which electric current flows into a polarized electrical device. The polarity can be positive or negative.
Antibiotic	a substance that kills bacteria or slows their growth.
Antimicrobial	a substance that kills or inhibits the growth of microorganisms such as bacteria, fungi, or protozoans.
ap	animal place. Also see 'bird place'
Application rate	the ratio between manure volume, and the available hectares for landspreading.
Bactericide	a substance that kills bacteria.
BAT	best available techniques.
BAT-AEL	emission levels associated with the best available techniques as defined in Article 3(12) of the industrial emissions Directive.
Battery cages	cages to contain rearing birds that are arranged in tiers, more or less overlaying, arranged in long rows
Benefits	used in this document synonymously with ‘advantages’ to mean the positive or negative environmental effects considered to be due to the implementation of a technique or other environmental measure.
Bird place	synonym of 'animal place' in poultry rearing
Biochemicals	chemicals that are naturally occurring or identical to naturally-occurring substances.
Biodegradability	a measure of the ability of an organic substance to be biologically oxidised by bacteria. It is measured by BOD tests.
BOD	biochemical oxygen demand – the quantity of dissolved oxygen required by microorganisms in order to decompose organic matter. The unit of measurement is mg O2/l.
BOD_5	biological oxygen demand within 5 days
Breeding Sow	female pig individual destined to reproduction (see Sow)
BSE	bovine spongiform encephalopathy.
Cathode	a cathode is an electrode through which electric current flows out of a polarized electrical device. The polarity can be positive or negative.
Cation	a positively charged ion – an ion that is attracted towards the cathode in electrochemical reactions.
CEEP	Centre Européen d’Etude des Polyphosphates.
Cfu	colony forming unit
CHP	combined heat and power (co-generation).
COD	chemical oxygen demand indicating the amount of chemically oxidisable organic matter in waste waters (normally referring to analysis with dichromate oxidation) according to ISO 15705:2002.
Deep litter	Faeces or droppings and urine mixed with large amounts of bedding (e.g. straw, sawdust, wood shavings) and accumulated over a certain time on the floors of buildings housing any type of livestock or poultry.~~the amount of straw absorbing urine.~~
DEFRA	Department for Environment, Food and Rural Affairs (for England and Wales).
Denitrification	biological process by which nitrite is converted to nitrogen and other gaseous end products.
Description	technical description of the technique.
Dessication	process of becoming completely dried out; as in consumption of groundwater in excess of the natural supply.
DG	Directorate General (of the European Commission).
Digestate	solid residue after anaerobic digestion.
Direct measurements	specific quantitative determination of the emitted compounds at the source.

Discharge	physical release of a pollutant through a defined outlet, i.e. channelled, system, e.g. sewer, stack, vent, curbing area, outfall.
DM	dry matter.
DM %	dry matter percentage
Drake	Male duck
Drainage	manner in which the waters of an area exist and move, including surface streams and groundwater pathways. A collective term for all concentrated and diffuse water flows.
Droppings	Waste voided by poultry.
Dry matter Percentage	the ratio between the initial weight of a defined substance and the final (constant) weight, obtained after a defined drying procedure.
Dung	Faeces from mammalian livestock
EC	European Commission.
ECE	Economic Commission for Europe.
Economics	information on costs (investment and operating) and any possible savings (e.g. reduced raw material or energy consumption, waste charges) or revenues including details on how these have been calculated/estimated. Economic information relevant to new build and retrofit to existing installations will be included. This should allow for identifying, where possible, the overall economic impact of the technique.
Ecosystem	community of organisms and their immediate physical, chemical and biological environment.
Efficiency	a measure of the effectiveness of a technique to achieve a particular result. In some cases, it may be expressed as a ratio of input to output.
Effluent	a physical fluid (air or water together with contaminants) forming emissions.
EIPPCB	European Integrated Pollution Prevention and Control Bureau.
Electrode	a conductor by which an electric current enters or leaves an electrolyte in an electrochemical reaction (or an electric arc or a vacuum tube) (see also: anode and cathode).
Electrolysis	a process that decomposes a chemical compound or produces a new compound by the action of an electrical current.
Emission	(from the IED Directive 2010/75/EU). The direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into the air, water or land.
Emission and consumption levels associated with the use of BAT	see: BAT-AEL.
Emissions factor	the estimated average emissions rate of a given pollutant for a given source, relative to units of activity.
EMS	environmental management system.
End-of-pipe technique	a technique that reduces final emissions or consumptions by some additional process but does not change the fundamental operation of the core process. Synonyms: secondary technique, abatement technique
EOP	end-of-pipe
EPA	Environmental Protection Agency.
ESF	electronic sow feeder. Self feeding device. A computer aided gestating sow feeding system for loose housing.
EU	European Union.
EU-15	Member States of the European Union before 1 May 2004.
EU-25	Member States of the European Union from 1 May 2004 until 31 December 2006.
EU-27	Member States of the European Union from 1 January 2007.
European odour unit	that amount of odorant that, when evaporated into one cubic metre of neutral gas at standard conditions, elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one ‘reference odour mass’ evaporated in one cubic metre of neutral gas at standard conditions (see also: OU_e).

Eutrophication	the pollution of a body of water by sewage, fertilisers washed from the land, and industrial wastes (inorganic nitrates and phosphates). These compounds stimulate the growth of algae, reducing the oxygen content in the water, and so killing animals with a high oxygen requirement.
Excreta	Waste expelled from the body: faeces plus urine
Exhaust air	air stream (waste gas) from an installation contaminated with gaseous components, normally with low concentrations.
External dunging area	a fully-slatted alley, covered with a roof, about 1 m wide, with the slurry pit underneath, alongside the pig house, to which the pigs can exit from the indoor through openings. The indoor room can have solid concrete floor or partially slatted floor.
FAO	Food and Agricultural Organisation of the UN.
Fattening Pig:	pig reared for producing meat during the Fattening period
Fattening period	period from after weaning to slaughter. It may be divided into the periods: • post-weaning period: from 4–6 weeks of age up to 20–30 kg LW • growing period: from 20–30 kg up to around 60 kg LW • finishing period: from around 60 kg to slaughter
Farm size	number of animals that can be reared at full capacity
Farrowing Sow	breeding sow around the times of parturition (see Sow)
FCR	Feed conversion rate
Feed Additives	Substances, micro-organisms or preparations, other than feed material and premixtures, which are intentionally added to feed or water in order to perform, in particular, one or more of the functions mentioned in Article 5(3) of Regulation (EC) No 1831/2003. See • Nutritional additives • Zootechnical additives
Feed conversion ratio	the ratio expressing the amount of feed (kg) needed for 1 kg growth of live weight. In Finland, the ratio expresses the amount of feed per kg of slaughter weight.
Finisher	see fattening
Finishing	see fattening
Flocculant	substance that causes suspended particles to aggregate or clump.
Flocculation	agglomeration of destabilized particles into microfloc and after into bulky floccules which can be settled called floc.
Flue-gas	off-gas that exits to the atmosphere via a flue, which is a pipe or channel for conveying exhaust gases from a fireplace, oven, furnace, boiler or steam generator.
Forecourt	Free outdoor space in full light, for exercise.
FSF	Fully-slatted floor
Functional areas	areas of living space that are dedicated to feeding, drinking and resting or exercising due to the presence of specific equipment
FYM ~~**Fym**~~	Farm yard manure
Gestating Sow	pregnant breeding sow during gestation (see Sow)
GHG	greenhouse gases.
Gilt	female pig growing up until reproductive stage
Global warming	greenhouse effect – the shortwave solar radiation passes through the Earth's atmosphere but after being reradiated by its surface as infrared radiation, some of it is absorbed by gases in the atmosphere causing a rise in temperature (known as global warming).
Good practice	approach which provides a good framework to the given activity. It does not preclude other approaches which may be more appropriate for a given requirement.

Gross human apparent consumption:	Quantities of products made available for human consumption in all forms: quantities consumed without further processing and quantities supplied by the distributive trades and the food (processing) industry. It is a derived statistic obtained from supply balance sheets and calculated as: (commercial production + estimated own account production for self consumption + imports + opening stocks) – (exports + usage input for processed food + seed + feed + non-food usage + wastage + closing stocks)
Groundwater	part of subsurface water in the zone of saturation. Distinct from surface water.
Group	The animals that are able interact with one another form a ‘group’
GRP	glass fibre-reinforced plastic
HDPE	high density polyethylene
Heavy metals	technical literature and 1998 Aarhus Protocol on Heavy Metals describes these as metals with a density greater than 4.5 g/ml. By this definition, most chemical elements are heavy metals.
Hen egg production	term used to indicate the production of chicken eggs as opposed to ~~to distinguish from~~ other egg laying poultry species (e.g. ducks)
HM	heavy metals.
IED Directive	Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (Integrated Pollution Prevention and Control).
IEF	Information Exchange Forum (informal consultation body in the framework of the IPPC Directive).
Immission	occurrence and level of polluting substance, odour or noise in the environment.
IMPEL	European Union Network for the Implementation and Enforcement of Environmental Law.
InfoMil	the Dutch information centre for environmental licensing.
Inspection	process consisting of surveys, checks, controls and validations in an industrial unit, carried out by authorities or by internal or external experts, in order to analyse and assess procedures, operating modes, operating conditions of the process and the related equipment, mechanical integrity, level of performance, and the records and results obtained by the industrial operator.
IPCC	Intergovernmental Panel on Climate Change.
IPPC	Integrated pollution prevention and control.
IPPC Directive	Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (IPPC Directive), which replaces Directive 96/61/EC.
IRPP	Intensive Rearing of Poultry and Pigs
ISO	International Organisation for Standardization.
JRC	Joint Research Centre.
Lactating Sow	breeding sow that is kept in the same facility where has delivered nursing the newborn until their weaning (see Sow)
LCA	life cycle assessment.
Leachate	solution obtained by leaching, e.g. water that has percolated through soil containing soluble substances and that contains certain amounts of these substances in solution.
Leaching	passage of a solvent through a porous or crushed material in order to extract components from the liquid phase. For example, gold can be extracted by heap leaching of a porous ore or pulverised tailings. Other methods are tank leaching of ore, concentrates or tailings and in-situ leaching.
LECA	light expanded clay aggregate
Leakage	gaseous or liquid spills out of system/equipment due to system/equipment failure.
Litter, poultry litter	Droppings mixed with a layer of, for example sawdust or wood shavings, on the floors of buildings housing poultry
LW	Live Weight

Manure, livestock manure	Usually a mixture of faeces and urine with or without bedding material, depending on the type of animal housing system.
Manure application	the activity of spreading manure or slurry onto land (unless otherwise stated).
Manure treatment	all potential ways of processing manure, including manure application
Market penetration	Measure of the extent of a product's sales volume relative to the total sales volume of all competing products, expressed as a percentage.
Mating Sow	breeding sow that is ready to accept a male (boar) for reproduction (see Sow)
Measure	Technique or combination of techniques.
Measured value	the result of a measurement.
Measurement	set of operations for determining the value of a quantity.
Measuring system	complete set of measuring instruments and other equipment, including all operating procedures used for carrying out specified measurements.
Mesophilic	organisms for which the optimum temperature for growth is within the range of 20 – 45 °C.
Method of measurement	logical sequence of operations, described genetically, used to carry out measurements.
MS	Member State of the European Union.
Muck	A colloquial term for livestock manure, most commonly solid manure
Mucking out	A colloquial term for removing manure, usually solid manure such as farmyard manure from a building housing livestock
N	normal – refers to volume of gases under normal conditions with a temperature of 0 °C and pressure of 1 atmosphere (101.3 kPa).
N	Nitrogen element, atomic number 7
Neutralisation	raising the pH of acidic solutions or lowering the pH of alkaline solutions to neutral pH (pH 7).
Nitrification	biological process by which ammonia is converted first to nitrite and then to nitrate.
Nitrogen (ammoniacal)	nitrogen present as ammonia and ammonium ion in liquid effluents.
Nutritional Additives	The following functional groups are included, as per Regulation (EC) No 1831/2003: (a) vitamins, pro-vitamins and chemically well-defined substances having similar effect; (b) compounds of trace elements; (c) amino acids, their salts and analogues; (d) urea and its derivatives.
Nitrogren (total)	organic nitrogen, ammonia, nitrite and nitrate.
NVZ	nitrate vulnerable zone.
Odour concentration	the number of odour units in a cubic metre of gas at standard conditions.
OU_e	European odour unit
Parameter	measurable magnitude representing the main features of a statistical group.
Particulate matter	dust. All material that is solid at the point of measurement (synonymous: dust). Total particulate matter refers to all inorganic and organic solid, and liquid materials (droplets and aerosols) that may be present in the flue-gas.
PE	polyethylene (polythene).
PE-LD	polyethylene, low density.
Pesticide	biological, physical or chemical agent used to kill pests. In practice, the term pesticide is often applied only to chemical agents.
PET	polyethylene terephthalate.
PM_x	particulate matter with an aerodynamic diameter less than or equal to a nominal *x* micrometres. Check air quality directive.
Pollutant	individual substance or group of substances which can harm or affect the environment.
Power	the term power refers to electrical energy, e.g. generation/power plant/power output. Energy is expressed in J (joule). Power in W (watt) 1 W = 1 J/s.
Poult	Young fowl (any species)
Pullet	Young hen of the domestic fowl (less than one year old)

PSF	Partly-slatted floor
Quality of data	The Technical Working Group decided to classify provided data into categories depending on the nature of the figure: • D: measured data based on statistical analysis • E: expert judgement based on few measurement results • M: modelled figures (e.g. results of N-flow processing) • A: expert judgement based on conclusion by analogy
Recovery	defined by the EC Waste Framework Directive as any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.
Recycling	defined by the EC Waste Framework Directive as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes.
Re-use	defined by the EC Waste Framework Directive as any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.
Reference conditions	conditions that are specified, e.g. in connection with operating a process, collecting samples.
Replacement sows	sows that replace sows in the breeding herd to maintain the required genetic material
RPM	(1) respirable particulate matter; (2) rotations per minute.
Run-off	part of the precipitation and snowmelt that does not infiltrate but moves as overland flow.
Slurries	consist of excreta produced by livestock whilst in a yard or building mixed with rainwater and wash-water and, in some cases, waste bedding and feed. Slurries can generally be pumped or discharged by gravity.
Solid manures	include farmyard manure (FYM) ~~and~~ comprised of material from covered straw yards, excreta containing a lot of straw, or solids from mechanical slurry separators. Solid manure can generally be stacked.
Sow	technical term for the female pig from the beginning of the first service period, or from the first moment of the first gestation. This includes replacement sows (gilts). Sow categories may be the following: • waiting sow: breeding sow after parturition awaiting for the heat before insemination, dry sow • mating sow: breeding sow that is ready to accept a male (boar) for reproduction • gestating sow: pregnant breeding sow during gestation • farrowing sow: breeding sow around the times of parturition • lactating sow: breeding sow that is kept in the same facility where has delivered nursing the newborn until their weaning
Stag	male turkey.
Stocking density	number of animals per surface area (m^2 or km^2).
TAN	Total available nitrogen
Techniques (from the IED Directive)	shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.
UBA	Umweltbundesamt – Federal Environmen Agency, i.e. from Germany and Austria.
UN ECE	United Nations Economic Commission for Europe.
UNEP	United Nations Environment Programme.
Underground deep pit	Storage volume of manure that is collected for long periods.
USDA	United States Department of Agriculture.
UV	ultraviolet.
Veranda	littered space adjacent to the housing, with roof and open side wall in full light, usually in chicken, especially laying hens.
VROM	Dutch Ministry of Housing, Spatial Planning and Environment.
Waiting Sow	breeding sow after parturition awaiting for the heat before insemination (see Sow)

Weaner	a pig during the post-weaning phase of fattening. Pigs kept separate from the sow after weaning at a live weight of around 7 kg up to approximately 25 – 30 kg.
WID	Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (Waste Incineration Directive).
Zootechnical additives	The following functional groups are included, as per Regulation (EC) No 1831/2003: (a) digestibility enhancers: substances which, when fed to animals, increase the digestibility of the diet, throughaction on target feed materials; (b) gut flora stabilisers: micro-organisms or other chemically defined substances, which, when fed to animals, have a positive effect on the gut flora; (c) substances which favourably affect the environment; (d) other zootechnical additives.

9 ANNEXES

9.1 Animal species and livestock units (LU)

In the evaluation of the environmental impact of intensive livestock farms the term “place” may lead to confusion. A place can be considered equal to one animal, but there is a difference in the extent of environmental effects from keeping different kinds of animals belonging to the same species but different kinds and stages of production. For example hens, broilers, ducks and turkeys all belong to the species “poultry“, but environmental effects of installations with these kinds of animals and the same number of places are considerably different. In addition it makes a difference whether young animals are reared or older animals are fattened.

To overcome these problems, animal places can be expressed in terms of animal masses (Livestock Units - LU, 1 LU = 500 kg animal mass), as environmental effects depend strongly on the average animal mass during a production period. Animal masses equate approximately with manure production and emissions. They may be defined as the time-integrated average animal mass over a production period or cycle on the basis of the animal-specific growth-function, which is available for every kind of animal (Table 9.1). This enables different kinds (breeding, fattening) and stages (weaning, growing-finishing) of production, housing periods and changing production processes to be taken into consideration.

Table 9.1: Animal species expressed in livestock units [39, Germany 2001]

Animal species	Animal mass (LU)
Pigs	
- boar or pregnant sows	0.3
- sows with piglets (≤ 10 kg)	0.4
- sows with piglets (≤ 20 kg)	0.5
- rearing of piglets (7 – 35 kg)	0.03
- young sows (30 – 90 kg)	0.12
- fattening pigs (20 – 105 kg)	0.13
- fattening pigs (35 – 120 kg)	0.16
Poultry	
- laying hens (average mass 2 kg)	0.004
- laying hens (average mass 1.7 kg)	0.0034
- young hens (average mass 1.1 kg)	0.0022
- broiler (fattening period 25 days, average mass 0.41 kg)	0.0008
- broiler (fattening period 36 days, average mass 0.7 kg)	0.0014
- young ducks (average mass 0.65 kg)	0.0013
- ducks (average mass 1.1 kg)	0.0022
- ducks (average mass 1.9 kg)	0.0038
- rearing of turkeys (average mass 1.1 kg)	0.0022
- turkeys (hens, average mass 3.9 kg)	0.0079
- turkeys (male, average mass 8.2 kg)	0.0164

Animal production	**Average live animal mass in LU/animal**
Pigs	
Fattening pigs (25 kg to 110 kg)	0.13
Fattening pigs (25 kg to 115 kg)	0.14
Fattening pigs (25 kg to 120 kg)	0.15
Early-pregnant and non-pregnant sows, boars (150 kg)	0.30
Sows with piglets (up to 10 kg)	0.40
Sows with piglets (up to 14 kg)	0.45
Sows with piglets (up to 18 kg)	0.50
Rearing piglets (up to 15 kg)	0.02
Rearing piglets (up to 25 kg)	0.03
Rearing piglets (up to 30 kg)	0.04
Young sows (up to 90 kg)	0.12
Poultry	
Laying hens	0.0034
Young hen rearing (until the 18th week)	0.0014
Fattening broilers (up to 35 days)	0.0015
Fattening broilers (up to 42 days)	0.0020
Fattening broilers (up to 49 days)	0.0024
Duck rearing (Pekin ducks)	0.0013
Duck fattening (Pekin ducks)	0.0038
Flying duck rearing	0.0012
Flying duck fattening	0.0050
Turkey rearing	0.0022
Turkey fattening, hens	0.0125
Turkey fattening, cocks	0.0222
Turkey fattening (mixed males and females)	0.016

9.2 References to European legislation

Intensive pig and poultry farms have the potential, if not properly managed and controlled, to lead to deterioration in the environment and to cause environmental pollution. The potential pollutants range from direct to accidental emissions to water, soil and air as well as the waste generated and to a lesser extent noise emissions. There is a comprehensive body of EU legislation designed to reduce and avoid pollution from various sectors. The legislation is generally aimed at protecting water, air, soil and the environment rather than limiting emissions from the various sources. There is also legislation on animal health and welfare that must be taken into consideration.

Many European directives directly or indirectly impose requirements on agricultural activities and they can be found, for example, on the following web pages:

- http://europa.eu.int/eur-lex/en/lif/ind/en_analytical_index_15.html
- http://europa.eu.int/comm/environment/agriculture/index.htm
- http://europa.eu.int/comm/food/index_en.html

9.3 National legislation of European Member States

In the national legislation of individual Member States a large number of European directives and their requirements are translated into emission limit values, quality standards and measures at national or farm level. Regulation of agricultural activities at farm level is fairly recent. In some countries general binding rules are applied, but the licensing of an individual farm is common practice in very few Member States.

This Annex presents an overview of some of the national environmental legislation that is currently applied to intensive farming installations.

Austria

Controlled emissions of waste water to surface water are regulated for intensive livestock farming. Discharge of slurry or liquid manure into surface water is not allowed [15, Austria, 1997; 14, BGB1.II 349/97, 1997].

Odour emissions from intensive livestock installations are regulated and will affect for the spatial planning of installations. The required distance between a farm building and an odour sensitive object is calculated by including a number of factors:

- an odour factor associated with the type of animal and its production phase
- a ventilation factor, combining the ventilation technique, air speed and position of emission point
- a factor associated with the manure removal system
- a factor associated with the type of feed system
- a meteorological factor representing the characteristics of the surrounding area, such as hills and mountains, and the effect on speed and direction of the wind
- a factor representing the purpose (use) of the surrounding area. [76, BMU, 1995]

Belgium

A national environmental action plan forms the framework for the legislation on intensive livestock. Within this framework, plans for ammonia reduction have been developed.

In Flanders, VLAREM is the Flemish regulation concerning environmental licensing including activities such as intensive livestock farming; it follows the definition in the IPPC Directive. Vlarem contains general and sectoral requirements for the operation of installations. For intensive livestock installations the sectoral requirements concern regulation for the construction of housing and manure storage, and the treatment of manure.

Flanders is the most important region for intensive livestock farming with a concentration of animals per hectare comparable with the Netherlands. A decree concerning protection of the environment against contamination by manure has been issued, requiring low-emission application of manure. The task is to reduce the excess of minerals and to achieve for nitrate the quality standard of 50 mg NO_3 per litre of ground- or surface water. Belgium has to reduce ammonia emissions by 31 %. Flanders has to apply to the national ammonia reduction programme and has to reduce 42.4 % of the national ammonia emissions and Wallonia 1.2 %.

A mixture of measures is proposed: measures at the source, such as feed measures (25 %), application of manure to appropriate soils or after previous treatment to achieve the required ratio (25 %) and further elimination by end-of-pipe measures without causing cross-media problems (50 %) [8, Technologisch Instituut, 1999].
Emissions to air are regulated in the VLAREM in terms of ammonia from housing and manure storage, emissions of dust from other storage equipment and manure drying facilities and emissions of NH_3, NO_x and H_2S from on-farm incineration installations [39, Vito, 1999].
Planning of pig farms with respect to odour emissions assesses both the existing and future situation, using a system that rates the applied housing system and the number of animals in it or the installation to store manure. The rating is linked to the required minimum distance between the farm (or the emitting installation) and the nearest residential area, nature reserve or other sensitive object. For poultry the same system applies, combining housing design and manure storage facility with the number of bird places [39, Vito, 1999].

Denmark

All commercial livestock farms in Denmark, including pig farms, are subject to a wide range of demands as to manure handling systems in the housing facilities, storing facilities as well as the location of the production units.

Pig houses and similar facilities, e.g. outside yards, have to be laid out so that ground water and surface water do not run off. Flooring and manure channels have to be made of materials which are difficult for moisture to penetrate. At the same time there must be a discharge system. In practice, this means that all pig houses have cast concrete flooring.

Manure stores, i.e. manure pits, liquid manure stores and slurry silos as well as silage storing facilities, are subject to demands similar to those relating to housing facilities as the farmers have to see to it that no run-off occurs to the surroundings. Simultaneously, storage capacities must be large enough to comply with the rules concerning the spreading and utilisation of nutrients. For pig farms this normally means 9 months' storage capacity.

The location of commercial livestock farms in Denmark is subject to a number of restrictions. Generally, commercial livestock farming is not allowed in urban zones and summerhouse areas. Farms located in rural zones have to comply with a number of restrictions as to distance to neighbours, urban zone etc. These distances increase with increasing production volume. By way of example, pig farms with more than 120 LUs have to be located at least 300 m from urban zone. The distance applying to farms with less than 120 LUs is 100 m.

The purpose of these demands as to distance is to reduce the nuisances of neighbours, meaning that mainly nuisances in the form of odour and noise are to be reduced. For farms who are exempt from the general rules concerning distance the municipality may tighten the demands for livestock farming and layout of housing facilities, manure stores etc.

Livestock farms with more than 250 LUs (more than 210 LUs for broilers) are subject to special demands. These farms have to be approved in accordance with the Environmental Protection Act and in this connection an environmental impact assessment (EIA) has to be made before establishing or extending the premises.

The EIA rules imply a broader appraisal of the location and layout of the production facilities in relation to landscape, cultural history and biology compared to the environmental approval. The EIA rules are basically not to a tightening of the environmental control measures but the pollution from the farm is appraised together with other impacts on the environment. All this is done in one procedure where the county provides a special annex to the regional plan with an EIA statement and simultaneously the municipality works out an environmental approval. [87, Denmark, 2000]

Germany
[154, Germany, 2001]

Germany reported a large number of laws, decrees and administrative and technical guidelines that are related to the operation of an intensive livestock farm.

To control environmental problems related to livestock farming, in Germany activities such as the construction, enlargement or substantial alteration and operation of livestock building installations (e.g. housings, manure stores) require a permission. The term "substantial alteration" includes the change of utilisation (e.g. keeping pigs instead of cattle), the change of ventilation or manure removal system (e.g. slurry instead of manure) or any other alteration that might have serious impact on the environment. Approval depends on the location, type and number of animals kept and the environmental impact. With respect to the environmental impact, odour nuisance is the key issue.

Dependent on the type and number of animals kept, either an approval according to the Federal Building Code (Baugesetzbuch - BauGB) by the district authorities or according to the Federal Emission and Ambient Pollution Control Act (Bundes-Immissionsschutzgesetz - BImSchG) by the state intermediate authorities (regional government) or the district authorities is required. The latter is more strictly and obligate for farms with more than e.g. 750 sows and 2000 fattening pigs. Participation of public is possible. Capacity figures are laid down in the Fourth Ordinance Implementing the Federal Emission and Ambient Pollution Control Act – On Installations Requiring Permission – 4 BImSchV. This ordinance has been amended in March 1997 according to EC Directive (96/61/EC) on Integrated Pollution Prevention and Control (IPPC). Besides these figures IPPC is not yet transposed into national law.

In addition facilities for storing slurry with a capacity of 2500 m^3 or more are subject to permission according to BImSchG by the way of a simplified procedure without participation of public.

During permitting procedures authorities will check whether the farmer has met crucial obligations according to the BImSchG. Additionally establishment and operation must not conflict with any other provision under public law (e.g. water resources protection, nature conservation, building law) and labour protection concerns. If prerequisites are given, there is a legal obligation to grant the permission.

In the case of a permitting procedure according to the BImSchG application according to the Federal Building Code is included. Application forms include in particular general information on design and operation and a detailed description of the project (e.g. type and number of animals, housing systems and management of the livestock, amount of livestock wastes to be stored), the project and ground plans, evidence of proper structural engineering, a calculation of cost, a description of the sewerage system, information on type and quantity of emissions, and of location and dimension of sources. Measures to reduce emissions and to avoid environmental effects must be specified. Usually an assessment of odour immissions is carried out. Referring to livestock waste management, amount and composition (nitrogen content) of manure and slurry have to be estimated and a detailed inventory of agricultural land for manure application including cadastral maps is necessary. Type of soil must be indicated.

During the permitting procedure the enforcement authority will involve other authorities, e.g. for nature conservation, for preservation of historical monuments, for air pollution control and for the prevention of water pollution. Their statements get part of the permission. Not only other involved authorities must be informed, but also the public if serious effects on the environment are expected to arise. Documents must be open to the public. A meeting must be summoned to give public opportunity to discuss the project. Statements of authorities and public shall be taken into account when deciding upon approval. This permitting procedure lasts regularly 4 - 6 months, in some (problematic) cases up to one year and more.

Permitting according to BImSchG is very extensive, but it provides legal certainty. For the neighbours have the opportunity to take care for their interests during the permitting procedure, nobody has the right to request cessation of operation of an animal husbandry with a private prosecution subsequent if the permission has become final. Even if somebody is prejudiced by immissions, he may only insist on measures that are necessary to prevent effects. If such measures are technically not feasible according to the state of the art or economically not viable, compensation may only be claimed for the actual damage suffered.

Cost of permitting procedures (charges, preparation of documents for application) amount up to 1 % of expenses (EUR 3000 – 8000). Extra cost can be expected if an expert´s report is required, e.g. for the prognosis and assessment of odour immissions (EUR 2000 – 5000). When an environmental impact assessment is required, the cost of permission might increase to up to EUR 15000. Although there are detailed regulations, requirements during permitting procedures will differ from federal state to state for they are responsible for enforcement.

Legislation with respect to the emissions to air

Installations subject to permission according to BImSchG shall be constructed and operated in such a way that:

- they do not involve harmful effects on the environment or other hazards, considerable disadvantages and considerable nuisance to the general public and the neighbourhood (principle of protection). Referring to animal husbandry neighbourhood must be safe from odour nuisance. A safety distance between a certain livestock building and the next dwelling house usually guarantees this. In addition, poultry farms must keep this distance towards woodlands. These distances are recognised as immission standards
- precautions are taken to prevent harmful effects on the environment, in particular by such emission control measures as are appropriate according to the state of the art (Stand der Technik). According to the precautionary principle harmful emissions must be reduced by technical means below a certain limit. Limits depend on the hazardousness of the emissions, the technical feasibilities and the economic efficiency. In this context, odour emissions are usually regarded as less serious. In practice, if distances as mentioned above are too short and if environment is likely to be affected by the emissions, an assessment is necessary. Probably supplementary measures to reduce emissions and immissions must be taken
- waste is avoided, unless provision is made for its orderly and safe re-use and recycling, or if such avoidance and re-use or recycling is technically not feasible or not reasonable, is disposed without impairing the public welfare. Storing and application of manure is concerned by this regulation. Manure is not classified as waste, as long as its application complies with the Fertiliser Act (Düngemittelgesetz) and the Fertilisation Ordinance (Düngeverordnung) respectively. The latter is based on the Council Directive (91/676/EEC) of 12 December 1991 concerning the Protection of Waters against Pollution Caused by Nitrates from Agricultural Sources. Manure shall be applied according to site conditions and the demand of the plants in order to reduce nitrate leaching and run-off. For this reason the amount of manure applied to land each year shall not exceed 170 kg N/ha. A storing capacity of 6 months or more is obligatory. By technical and/or organisational measures ammonia emissions should be reduced (e.g. by band spreader, ploughing instantly after spreading or waiting with spreading for favourable weather conditions). Maximum losses of ammonia from slurry should not exceed 20 % during application. Further regulations concern the duty to estimate fertiliser demand of the land and to draw up a balance of nutrients. Additional regulations may include the duty to keep a minimum distance to surface waters, nature reserves or settlements while spreading. States are authorised to regulate application in detail by administrative rules.

During the permitting procedure authorities will check whether a project complies with obligations described above. For large-scale farms subject to permission according to BImSchG corresponding requirements (distance regulation, technical requirements) are laid down in the First General Administrative Guideline Pertaining to the Federal Emission and Ambient Pollution Control Act – Technical Instructions on Air Pollution Control (Technische Anleitung zur Reinhaltung der Luft – TA Luft). In addition, special guidelines on odour abatement in livestock farming published by the Association of German Engineers (VDI) (VDI 3471 - Emission Control Livestock Management Pigs, VDI 3472 - Emission Control Livestock Management Hens) describe livestock farming techniques in general, the sources of odour emissions, feasibilities to reduce emissions and immissions and a method for odour assessment in form of a minimum distance regulation as well. Those guidelines are accepted by the authorities and courts as so-called "anticipated expertise", because experts from various fields of knowledge worked together and established them.

Distance regulations

Odour

Both TA Luft and VDI Guidelines prescribe a distance regulation to avoid odour nuisance. Regulation of the TA Luft is based on VDI Guidelines. But in contrast to VDI Guidelines the minimum distance is only a function of the number of animal places and distances are valid only between livestock units and dwelling houses under optimal emission and dispersion conditions. It is not given special attention neither to the fact that the neigbourhood in villages has to tolerate higher levels of nuisance compared to residential areas nor that emissions from pig breeding are only half of that from fattening pigs. In addition natural ventilated housing systems are not considered. Though distance regulation has been established with odour in mind, it applies for the distance of poultry housings to woodlands too. If distances are too short, waste gas should be treated in biofilters or bioscrubbers. For these installations are almost too costly, a special odour assessment is conducted.

The distance regulation of VDI Guidelines allows a more detailed assessment than that of the TA Luft. It proved successful in practice in thousands of cases. The distance is determined in three steps:

1. Calculation of the average animal masses (livestock units LU, 1 LU = 500 kg; e.g. pigs 0.12 LU) corresponding to the number of animals kept. If there are different kinds of animals on a farm, animal masses can be multiplied by an animal-specific odour-equivalent factor (e.g. feq = 0.5 for sows, 0.17 for cattle, 0.39 for turkeys and 0.94 for ducks). This factor is a function of the animal-specific odour emissions referred to fattening pigs (feq = 1).
2. A point system is used to rate the emission potential of various livestock parameters such as manure removal and storage, ventilation system and other criteria (feeding, slurry storage capacity, influences by the site). Parameters leading to lower emissions are rated better than those causing higher emissions. The maximum rate is 100 points.
3. From a distance diagram the minimum distance between the livestock farm and the neighbourhood can be read.

Technical requirements in practice

Besides a distance regulation TA Luft prescribes technical requirements for livestock farming installations. These are the same as the preconditions for the use of the distance regulations of VDI Guidelines. The following measures shall usually be applied:

- animal housings should be as clean and dry as possible. This affords especially a high standard of hygiene, to use always enough bedding of high quality, the regular removal of manure, no overstocking and sufficient ventilation
- the ventilation system should be designed according to the German Standard on "Thermal insulation for closed livestock buildings; Thermal insulation and ventilation; Principles for planning and design" (DIN 18910) to guarantee an air exchange rate suitable to the animal needs. Naturally ventilated housings are not affected by this requirement
- if slurry is drained-off the housings, provisions have to be made to prevent noxious gas and odour migration
- manure is to be stored on a liquid-tight concrete base. In the case of a slurry system, the area where the tanker is filled should be liquid-tight. In both cases precipitation should be collected and drained-off in appropriately closed collection tanks to avoid water pollution
- slurry should be stored outside the housings only in closed tanks or equivalent measures to reduce emissions must be taken
- a storing capacity of 6 months is prescribed. A smaller capacity is sufficient if slurry is treated (e.g. aerobic treatment by composting, forced drying or anaerobic digestion).

There is sometimes discussion about the term “equivalent measures to reduce emissions“ from storing tanks. In practice besides concrete or light construction roofs floating covers consisting of natural floating crusts, of straw, burnt clay pellets and plastic are used. The build up of an artificial floating cover is supported by mixing chopped straw (7 kg/m^2 surface area) into the slurry. Several investigations revealed, that even with floating covers made of straw emissions can be reduced up to 90 %. For this reason floating covers made of straw are not only equivalent to closed tanks but also most cost effective. Annual cost are about 30 % - 50 % lower than for covers made of clay pellets or plastic and 60 - 70 % lower than for light construction roofs.

Water conservation regulations

When discussing the water legislation requirements, it is necessary to differentiate between the requirements in dependency of:

- the site of operation affecting the structural condition of animal housings and slurry stores
- the livestock management, especially in areas which are sensitive referring to management of water resources, such as water conservation areas and medicinal spring conservation areas or areas subjected to flooding.

The legislation governing the environment in Europe which is essentially codified in directives and which includes the laws governing water is only partly regulated uniformly in the individual states in Germany's federal legal system. The states are authorised to fill in details of the system of standards under federal law, which is largely designed as a skeleton law, so that different requirements may be made of agricultural livestock production in the individual federal states.

Water conservation in regulations under federal law

On the federal level the Water Resources Management Act (WHG) contains both rules on the nature of facilities for storing and filling liquid manure, slurry and silage effluents (§ 19 g WHG) and the obligation to apply the due care necessary according to the circumstances to prevent pollution of the water or any other negative change in its properties when implementing measures which can be connected with effects on a water body (§ 1 a WHG). In water conservation areas it may additionally be necessary, for reasons of precautionary averting of danger, to prohibit certain actions or to declare them only allowable to a restricted extent when bodies of water are to be protected against negative influences in the interest of currently existing or future public water supplies, or when rain-washing or discharge of fertilisers into bodies of water are to be prevented (§ 19 WHG).

In addition, in facility permit procedures for large-scale livestock and poultry management operations, the Federal Emission and Ambient Pollution Control Act (BImSchG) stipulates that these facilities are to be constructed and operated in such a fashion that wastes - which also include slurry, liquid manure and silage effluents - are properly and safely utilised (§ 5 BImSchG). Details of this proper utilisation are governed in the Fertiliser Act (§ 1 a) and in the Fertilisation Ordinance issued on the basis of the Fertiliser Act, which are detailed below.

Regulations under state law

The requirements under federal law are set out in more concrete terms at the level of state law.
Thus the obligation contained in § 19 g WHG to construct and maintain facilities for storing and filling liquid manure, slurry and silage effluents in such a manner that bodies of water are protected in the best possible manner against pollution is specified in detail in orders decreed by the states. These orders, which are similar in principle but which differ in detail, are based on the fundamental requirements that facilities must be tight, stable and sufficiently resistant to thermal, mechanical and chemical incidents. Leaks and any spillage of water-hazardous substances must be identified quickly and reliably. The generally recognised rules of the art for the construction of slurry tanks and fermenting silos are contained in the German Standard on "Silage and liquid manure containers" (DIN 11622), which is valid on a federal basis. General requirements made of collecting and filling facilities include:

- pipes must be made of corrosion-resistant material. The return line from the storage tank to the preliminary pit or the pumping station must be equipped with two gate valves for safe shut-off. One of these should be a quick-acting gate valve
- gate valves and pumps must be easily accessible. They are to be arranged over a water-impermeable area
- pits, ducts and channels must be constructed in a fashion impermeable to water
- places at which liquid manure or slurry are filled into containers must be paved in a fashion impermeable to water. Rainwater is to be discharged into the preliminary pit, liquid manure pit or the pumping station of the filling facility
- facilities for storing solid manure are to be equipped with a tight and water-impermeable bottom plate. In order to discharge the liquid manure, the bottom plate is to be contained at the side and be protected against the penetration of surface water from the surrounding terrain
- if it is not possible to discharge the liquid manure into an existing liquid manure or slurry pit, it must be collected separately
- the capacity of the facilities must be adjusted to the requirements of the relevant farm unit and of water conservation. The capacity must be greater than the capacity necessary during the longest period in which application on agricultural land is prohibited, unless it can be proven to the competent administrative authority that the quantity exceeding the stated capacity will be disposed of in an environmentally sound fashion. Proper agricultural use or spreading of the contents must be assured. In the case of open tanks, a minimum freeboard and a safety margin for rainfall must be maintained at each place
- facilities in water conservation areas and medicinal spring conservation areas must be additionally equipped with a leak identification device.

However, there are deviations between the states regarding e.g. the determination of the necessary storage capacity. For instance in the case of slurry channels, consideration ranges from crediting of the complete volume as storage space to complete disregard of the channel volume. Different leak identification systems apply for monitoring tightness. For instance, in some states soil samples, in others ground water examinations are necessary in addition to a visual inspection. These different requirements lead in part to substantial differences in costs for farms, without objective construction-specific justifications for this applying in all cases.

Special regulations in protected water grounds

In areas requiring special protection such as water conservation areas and medicinal spring conservation areas, livestock production is subjected to far reaching restrictions. Thus on the one hand requirements extending beyond the general state of the art apply for the structural condition of storage tanks. Buried liquid manure reservoirs in water conservation areas without sufficient covering layers are just as inadmissible (Higher Administrative Court Lüneburg, ZfW 93, 117) as buried reservoirs with sealing strips made of plastic (Higher Administrative Court Lüneburg, ZfW 97, 249). In the area covered and the inner protected zone, facilities for storing and filling liquid manure, slurry and silage effluents and for storing solid manure are generally prohibited completely, and in the extended protected zone they are only admissible if equipped with special leak identification devices.

In some rules governing conservation areas, grazing is also forbidden in the inner protected zone and there is a ban on spreading non-hygiene-treated slurry in the inner and extended protected zones.

Since such restrictions on land use lead to substantial extra economic burdens for the farms affected, in 1987 the legislator included a rule in the Water Resources Management Act (§ 19 Para. 4 WHG) according to which reasonable compensation is to be paid for the economic disadvantages caused by the more stringent requirements. The rule reflects the 'burden-sharing' principle which applies in environmental legislation alongside the 'polluter-must-pay' principle, according to which the rules issued in the interest of the general public for protection of bodies of water may not be solely for the account of an occupational group particularly affected by them. The nature and extent of the obligation to pay compensation vary widely in part in the state water legislation. However, the ban on water-hazardous storing of fertiliser or field silage with fermentation juices, as well as the ban on spreading liquid manure or on nitrogen fertilisation outside the growth period, do not represent higher burdens for farm units which give rise to compulsory compensation, since these bans apply generally and not only in conservation areas. The extra construction costs for slurry and farmyard manure storage resulting on the basis of water conservation orders do not lead to a claim for financial compensation either, since only the direct agricultural use is covered by the obligation to pay compensation under § 19 Para. 4 WHG, but not non-recurrent construction conditions (Federal High Court of Justice, NJW 1998, 2450 ff.).

Fertilisation and waste management law

German law on fertilisation limits the quantities of farm and secondary resource fertilisers which may be spread, on the basis of the nutrient content of fertilisers. When secondary resources are utilised, for instance fermentation residues from agricultural co-fermentation (simultaneous fermentation of farm manures of animal origin with organic wastes), the provisions of the German Organic Waste Ordinance (Bioabfallverordnung, BioAbfV) also come into play in addition to the fertiliser regulations.

The following survey provides an overview of the statutory provisions to be observed in the spreading of solid organic manure and secondary resource fertilisers.

Waste management law

Due to the German Waste Management Act of September 27, 1994 (Gesetz zur Vermeidung, Verwertung und Beseitigung von Abfällen) a new set of regulations in waste management law and related areas of the law was provided.

Article 1 contains the German Closed-Loop Materials and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz, KrW-/AbfG), which makes it mandatory to promote the closed-loop management approach, so as to conserve natural resources and ensure the environmentally sound disposal of waste. The KrW-/AbfG confers delegated powers to issue an array of statutory ordinances (Arts. 7 and 8; sub-statutory regulations 1996, BioAbfV 1998).

Article 4 covers the simultaneously required amendments to the German fertilisers legislation: the 1999 Fertiliser Ordinance (Düngemittel-verordnung), the 1996 Fertilisation Ordinance (Düngeverordnung), and the 1998 Sewage Sludge Compensation Fund Ordinance (Klärschlamm-Entschädigungsfondsverordnung).

Where farm manures are utilised exclusively, the provisions of waste management law only come into play when application is carried out contrary to the provisions of the Fertiliser Ordinance, i.e. not carried out with regard for the appropriateness of the site and the nutrient needs of the crops, but with the primary purpose of disposing of farm manure. Waste management law also has a bearing on the biological treatment and agricultural utilisation of mixtures of farm manures and organic waste, such as arise in the form of process residues from agricultural co-fermentation facilities.

The Ordinance on the Recycling of Organic Wastes on Agricultural, Silvicultural and Horticultural Soils (BioAbfV) regulates the agricultural, silvicultural and horticultural utilisation of organic wastes (including those mixed with farm manures). Annex 1 of the BioAbfV lists the organic waste materials that may be treated in a biogas plant. Furthermore the responsible waste authority may permit additional materials if they are suitable for biological treatment and agricultural utilisation.
The BioAbfV also details the obligatory documentation to be obtained by facility operators (e.g. hygiene clearance, low pollutant content). The quantity of organic waste which may be landspread per hectare within a three-year period is limited and depends on soil heavy metal content. A soil analysis for heavy metals and pH value is to be carried out prior to first spreading. Repeat spreading of organic wastes is prohibited if levels in the soil are found to exceed the limits prescribed in the Ordinance.

Fertiliser law

The Fertiliser Act specifies that fertilisers may only be applied in line with agricultural 'good practice' (Art. 1a: gute fachliche Praxis). This entails criteria for fertilisation including adjusting the type, quantity and timing of nutrient applications according to the needs of the crops and the soil, taking account of the nutrients and organic matter available in the soil and the site and cultivation conditions. The nutrient needs of crops are determined by their potential yields in the given site and cultivation conditions and the produce quality standards expected (Art. 1a, para 2).

The permitted fertilisers are regulated in Article 2, under which fertilisers may only be put into circulation if they correspond to a fertiliser type permitted by statutory provision. According to the Ordinance on Good Practice in Fertilisation (Verordnung über die Grundsätze der guten fachlichen Praxis beim Düngen – Düngeverordnung) Fertilisers are to be spread at times and in quantities that allow crops to take maximum advantage of the nutrients, and in a way ensuring that in cultivation nutrient losses and associated harmful inputs into water resources are prevented to the greatest possible extent. Nitrogenous fertilisers may only be applied so as to make the nutrients they contain available to plants essentially during the growing season and in quantities corresponding to their needs. Any direct inputs into surface water are to be avoided by maintaining an adequate safety distance, among other measures. Nitrogenous fertilisers may only be spread when the soil is receptive to them. A soil is not receptive when it is waterlogged, frozen solid or has a heavy covering of snow.

To calculate the quantity of nitrogenous fertilisers to be spread, the principles of establishing the fertilisation requirements are to be observed. This entails taking into account:

- the nutrients needed by particular crops to attain their expected yields and quality given the site and cultivation conditions
- the quantities of nutrients available in the soil and additional quantities of nutrients likely to become available to the crops during the growing season
- nutrient fixation.

In the case of farm manures of animal origin, taking account of the other principles of the Ordinance, the average application per holding should not exceed 210 kg total nitrogen per hectare per year on grassland, and 170 kg total nitrogen per hectare on arable land (net values, i.e. after deduction of permitted storage and spreading losses); set-aside land must be excluded for the purposes of calculating the average for the holding. Furthermore farm manures of animal origin which are high in phosphates or potassium may only be spread up to the level of the net phosphate or potassium uptake of the crop, taking into account the expected yield and quality, and only if no harmful impact on water resources is anticipated.

In line with the Ordinance, nitrogen inputs following harvest, in autumn or in early winter, on fallow fields which are not to be cultivated until the spring, are not normally permitted. The Fertiliser Ordinance (Düngemittelverordnung) regulates the licensing and putting into circulation of fertilisers. Where the intention is to put into circulation fermentation residues containing organic wastes (even without charge) these must correspond to a permitted type of secondary resource fertiliser. In this regard, restrictions must be observed pertaining to the permitted feedstock substances for producing secondary resource fertilisers, e.g. in this case no rendered animal fat, food wastes etc. may be included in the fermentation process.
Under the German Soil Protection Act (Bundesbodenschutzgesetz, BBodSchG) agricultural use of the soil must be in accordance with agricultural 'good practice', i.e. soil must be worked and soil structure maintained or improved appropriately given the climate and the site, soil compaction must be avoided (as far as possible) and soil erosion prevented by site-appropriate utilisation.
Animal welfare and animal diseases law

~~The Animal Welfare Act (Tierschutzgesetz) constitutes the central provision regarding animal welfare in Germany. The Act is based on ethical animal welfare and aims at protecting animals from pain, suffering or harm. The Act applies to all animals, irrespective of their uses, i.e. to productive livestock, to domestic animals as well as to laboratory animals. It regulates the keeping of these animals as well as their use.~~

~~Source: [154, Germany, 2001] with reference to:~~

- ~~Grimm, E., Kypke, J., Martin, I., Krause, K.-H. (1999): German Regulations on Air Pollution Control in Animal Production. In: Regulation of animal production in Europe. KTBL-Arbeitspapier 270, Darmstadt, 234-242~~
- ~~Schepers, W., Martin, I., Grimm, E. (2000): Bau- und umweltrechtliche Rahmenbedingungen. In: Zukunftsweisende Stallanlagen. KTBL-Schrift 397, 11-33~~
- ~~Nies, V., Hackeschmidt, A. (1999): Water Conservation Regulations in Germany – Differences between the Federal States and Impacts on Livestock Production. In: Regulation of animal production in Europe. KTBL-Arbeitspapier 270, Darmstadt, 129-132~~
- ~~KTBL e.V. (Hrsg.): Bau- und umweltrechtliche Rahmenbedingungen der Veredelungsproduktion. KTBL-Arbeitspapier 265, Darmstadt 1998~~
- ~~Bauförderung Landwirtschaft e.V. (Hrsg.): Hilfestellung bei Genehmigungsverfahren für Tierhaltungen. Baubrief Landwirtschaft 38, Landwirtschaftsverlag Münster-Hiltrup 1998~~
- ~~Schwabenbauer, K. (1999): Animal Welfare Provisions and their Practical Application in Germany. In: Regulation of animal production in Europe. KTBL-Arbeitspapier 270, Darmstadt, 90-92~~
- ~~InfoService Tierproduktion (IST): Network on information about laws and permitting relevant for agricultural building projects – Informationsnetzwerk zu Rechts- und Genehmigungsfragen bei landwirtschaftlichen Bauvorhaben; http://www.ist-netz.de~~

~~**Greece**~~

~~Greek legislation for intensive farming is primarily concerned with the protection of water resources. Limited storage in earth “tanks” is allowed if the soil is not porous. The re-use of treated waste waters is allowed (1) for land application only if they have $BOD_5 \leq 1200$ mg/l, and (2) for disposal to carry out surface waters only if they have $BOD_5 \leq 40$ mg/l. Application is allowed in combination with the substitution of chemical fertilisers.~~

~~**Finland**~~

~~The Environmental Protection Act (86/2000) and other legislation based on this document came into effect on 1 March 2000. The new Act repealed the Acts on Air Protection and Noise Prevention, Environmental Permit Procedures Act and the decrees based on these as well as on the Decree on Preventive Measures in Water Protection. Various acts, such as the Water, Waste, Adjoining Properties and Health Protection Acts were amended. Water rights courts were closed, and most of their duties were transferred to the environmental permit authority established on 1 March 2000. The harmonisation of the environmental protection legislation lays the foundations for the integrated study of environmental damages.~~

~~The environmental permit for livestock stables concerns the keeping of animals in production buildings. Livestock stables comprise the storage of manure produced by the animals as well as processing and storage of feed in connection with the production buildings. Manure spreading and arable farming are not subject to licence. However, the surface area available for manure spreading is taken into consideration in the permit procedure.~~
~~At the moment, there are no spatial planning regulations or guidelines concerning odour.~~

~~A government decree on preventing the passing of agricultural nitrates into bodies of water applies Council Directive 91/676. It concerns all agricultural activities and imposes requirements for storage time of manure, for manure stores, the time of spreading of fertilisers (i.e. manures) and the amounts allowed [26, Finland 2001].~~

~~**Ireland**~~

~~IPPC legislation under the Environmental Protection Agency Act (1992) introduced a licensing system controlling emissions from pig and poultry installations in an integrated manner.~~

~~One of the most generally applied approaches to ensure that odour is not a nuisance is to use a setback approach, which means that units are not allowed within a specified distance of residences or odour sensitive locations. These distances may be measured based on an odour dispersion model. Limit criteria in terms of odour units are set.~~

[61, EPA, 1997]

The Netherlands

The Netherlands has high densities of pigs and poultry. Much attention is therefore paid to the application of manure and contamination of soil and groundwater, as well as the emission of ammonia and odour. A permitting system as operated under the responsibility of the local governments (municipality) is currently in use. Stricter rules will apply in the coming years. Although standards are applied equally to all farmers, stricter requirements will apply in the south and the east of the country where most of the ammonia-emitting farming is.

The Dutch government has adopted a policy in three stages to reduce the mineral losses to the environment. This programme is now in its third stage. The objective is to achieve an acceptable level of nitrogen and phosphate losses to the environment. One of the tools to achieve this is the use of a Minerals Accounting System, which allows a better understanding of mineral input and output on a livestock installation [85, Oele, 1999].

Emissions to air from manure application are regulated by the Use of Livestock Manure Decree obliging the use of low-emission application techniques [21, VROM, 1998].

Planning regulations allow manure application only during autumn and winter, which means that requiring sufficient storage capacity is needed. Manure storage built after 1 June 1987 has to be covered.

Ammonia emissions, mainly from housing, are reduced by obligatory use of certain types of housing (Green Label housing units). Under a government inspection scheme, systems can qualify for a Green Label. Farmers with Green Label housing are exempt for a certain period of time from new ammonia reduction measures to encourage them to invest in low-emission housing. Developments in housing techniques and increasing knowledge will head to stricter animal housing requirements.

For regulation of odour emissions and spatial planning, a complicated model is applied that categorises sensitive objects around a farm or a number of farms and identifies their distance from the point of emission. For each farm, a ratio of the number of animals housed and the number of animals allowed (considering legislation and given the local circumstances) is calculated. Per sensitive object The relative individual contributions to the odour nuisance of all farms are aggregated and should not exceed a certain value for each sensitive object. If they do, measures must be taken, including reduction of stocking density [24, VROM/LNV, 1996].

Noise standards for intensive livestock farms are set on an individual basis and laid down in the environmental permit for a farm. The Dutch Environmental Management Act and the Dutch Noise Nuisance Act form the basis for setting of noise standards in the permit. New intensive livestock farms will have to comply with the noise level defined for the area. Use can be made of an instrument called 'zoning' where a number of different agricultural and industrial activities take place in the same area. The noise 'zone' combines the noise emissions of all activities in that area.

Extension of existing farms must take place within the existing limits set in the permit. Any additional noise associated with the extension of farming activities will have to be compensated by reduction measures (e.g. insulation) or relocation of activities.

Portugal

In Portugal, there is no specific legislation for protection of waters caused by nitrates from agricultural origin. In the same way, it was published the "Code of Good Practices for Protection of Water against Pollution by Nitrates of Agricultural Origin". Apart from this "Code" there is specific legislation for the designated NVZs and respective associated Action Programme Rules.

A specific decree sets emission limit values for discharges of waste water to surface water from pig installations, expressed in terms of BOD_5 and TSS. There is no similar decree for poultry installations. The emissions of other substances (e.g. N, P and heavy metals) via waste water are regulated through separate decrees, either for discharges to surface water, or to agricultural soil. The emission of heavy metals to agricultural soil via application of slurries and/or manure are regulated through again another decree
Air emissions are regulated by limiting the emissions of NO_x (as mg $N0_2$), VOC (as mg C), H_2S and dust. Noise is regulated for both sectors in a general way by limiting the immission to 5 dB during day-time

and 3 dB during night-time, compared with the background noise. New regulations also uses another criterion, based on maximum noise exposure.

Several decrees lay down rules for the operation of pig farms. The most recent one is Decree Law Nº 163/97 with rules on the registration, authorisation, classification, designation and operation of pig farms. Similar laws exist for poultry farming.

Spain

In Spain, Royal Decree 324/2000, adopts an integrated approach to the sanitary and environmental aspects of pig production. By means of this Royal Decree, minimum sanitary distances from sensitive objects such as other pig units, residential areas, public thoroughfare, etc. are fixed. These distances are linked to the number of LU in the installation. In addition, this is the first Royal Decree that fixes the maximum capacity of pig production units.

United Kingdom

Currently there is no 'permitting' of farms in the UK, although this will change with the implementation of IPPC for large pig and poultry installations. In the Nitrate Vulnerable Zones, farmers must comply with the mandatory Action Programme Rules. There is no national legislation concerning landspreading except in NVZs. Guidelines and information on manure planning for farmers in NVZs has been issued.

On a more general basis, a large number of rules are listed in Codes of Practice, which have been issued to inform the farmer about measures to take to reduce emissions to water and soil. Emissions to surface water can be allowed under a 'discharge consent' with appropriate conditions (volume and emission limit levels) attached. Legislation makes it an offence to knowingly pollute surface or groundwater.

Reduction of emissions to air of odour and dark smoke are described in the Air Code [43, MAFF, 1998]. There are no emission controls on ammonia.

There are regulations dealing with planning consents. Planning permission is required for new or extended livestock buildings and slurry or manure storage facilities within 400 metres of any protected building such as houses and schools etc.

9.2 Examples of phase feeding programmes

Feeding programmes that are applied are reported in the following sections.

9.2.1 Phase feeding in the UK

Examples of feeding programmes in use in the UK for different animal productions [293, UK 2010] [294, UK 2010] [295, UK 2010] [296, UK 2010] [297, UK 2010] [298, UK 2010] [299, UK 2010] [308, UK 2010] [309, UK 2010] [310, UK 2010] [311, UK 2010]

Cage Layers	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Weeks	*16 – 28*	*29 – 40*	*41 – 55*	*56 – 70*	*71 –*
Crude protein %	16 – 18	16.5 – 19	16 – 18	15 – 17	13 – 16
Amino acids %	0.7 – 1	0.85 – 1	0.7 – 0.9	0.7 – 0.8	0.6 – 0.75
Total calcium %	2 – 4	3.5 – 4	3.6 – 4.2	3.8 – 4.4	3.8 – 4.4
Total phosphorus %	0.4 – 0.55	0.4 – 0.5	0.4 – 0.55	0.4 – 0.55	0.38 – 0.5
Total copper %	10 – 20	10 – 25	10 – 20	10 – 20	10 – 20
Total zinc %	40 – 100	40 – 100	40 – 100	40 – 100	40 – 100
Phytase %	0.018	0.018	0.018	0.018	0.018
NSP enzymes %	0.01	0.01	0.01	0.01	0.01

Pullet	Phase 1	Phase 2	Phase 3
Weeks	*0 – 6*	*7 – 12*	*13 – 16*
Crude protein %	19 – 21	18 – 19	15 – 17
Amino acids %	0.9 – 1.1	0.8 – 0.95	0.65 – 0.8
Total calcium %	0.9 – 1.2	0.9 – 1.2	0.9 – 1.2
Total phosphorus %	0.5 – 0.6	0.5 – 0.6	0.4 – 0.55
Total copper %	10 – 25	10 – 25	10 – 25
Total zinc %	40 – 80	40 – 80	40 – 80
Phytase %	0.018	0.018	0.018
NSP enzymes %	0.01	0.01	0.01

Layers on free range	Phase 1	Phase 2	Phase 3
Crude protein %	17.5	17	15.5
Amino acids %	0.88	0.84	0.76
Total calcium %	3.8	3.9	4.05
Total phosphorus %	0.475	0.451	0.403
Total copper %	15	15	15
Total zinc %	70	70	70
Phytase %	120	120	120
NSP enzymes %	500	500	500

Pullets (free range laying)	Phase 1	Phase 2	Phase 3
Crude protein %	19	16.5	15.5
Amino acids %	1	.08	0.7
Total calcium %	0.95 – 1	0.95 – 1	0.95 – 1
Total phosphorus %	0.741	0.76	0.76
Total copper %	15	15	15
Total zinc %	70	70	70
Phytase %	0	0	0
NSP enzymes %	500	500	500

Light broiler (2, 25 – 2, 45 kg)	Phase 1	Phase 2	Phase 3	Phase 4
Days	*0 – 10*	*11 – 20*	*21 – 33*	*34 – 40*
Crude protein %	22 – 23	20 – 22	18 – 19.5	18 – 19.5
Amino acids %	1.3 – 1.5	1.2 – 1.4	1.15 – 1.3	1 – 1.2
Total calcium %	0.9 – 1	0.75 – 0.9	0.65 – 0.85	0.65 – 0.85
Total phosphorus %	0.5 – 0.6	0.45 – 0.55	0.4 – 0.48	0.4 – 0.48
Total copper %	15 – 25	15 – 25	15 – 25	15 – 25
Total zinc %	60 – 90	60 – 90	50 – 80	50 – 80
Phytase %			0.015 – 0.03	0.03 – 0.03

Heavy broiler (3 kg)	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Days	*1 – 8*	*9 – 13*	*14 – 27/37*	*28 – 45/38 – 55*	*46 – 49/56 – 59*
Crude protein %	23.3	20.7	19.7	17.8	17.7
Amino acids %					
Total calcium %	1	0.74	0.74	0.69	0.64
Total phosphorus %	0.78	0.58	0.58	0.52	0.46
Total copper %	0.00001				
Total zinc %		0.03	0.03	0.03	0.03
Phytase %					
Inorganic phosphorus %	2.05	1.03	1.02	0.82	0.47
NSP enzymes %	0.03	0.03	0.03	0.03	0.03

Turkey	Phase 1	Phase 2	Phase 3	Phase 4
Weeks	*0 – 2*	*3 – 6*	*7 – 12*	*13 – 20*
Crude protein %	25 – 28	23 – 26	20 – 23	17 – 21
Amino acids %	1.6 – 1.8	1.4 – 1.7	1.3 – 1.5	1 – 1.3
Total calcium %	1.2 – 1.4	1 – 1.4	0.9 – 1.2	0.75 – 1
Total phosphorus %	0.7 – 0.9	0.65 – 0.85	0.6 – 0.7	0.55 – 0.65
Total copper %	15 – 25	15 – 25	15 – 25	15 – 25
Total zinc %	60 – 100	60 – 100	60 – 100	60 – 100
Phytase %	0.03	0.03	0.03	0.03
NSP enzymes %	0.015 – 0.03	0.015 – 0.03	0.015 – 0.03	0.015 – 0.03

Sows	Phase 1	Phase 2
Crude protein %	15 – 20	12 – 15
Amino acids %	0.8 – 1.1	0.5 – 0.6
Total calcium %	0.55 – 0.75	0.75 – 0.9
Total phosphorus %	0.55 – 0.75	0.55 – 0.75
Total copper %	25	25
Total zinc %	100 – 150	100 – 150
Phytase %	0.1	0.1
Inorganic phosphorus %	0.7	0.7

Weaners	Phase 1	Phase 2	Phase 3
Crude protein %	20 – 24	19 – 23	18 – 21
Amino acids %	1.6 – 1.7	1.4 – 1.6	1.2 – 1.4
Total calcium %	0.55 – 0.75	0.6 – 0.75	0.6 – 0.75
Total phosphorus %	0.55 – 0.75	0.55 – 0.75	0.55 – 0.75
Total copper %	170	170	17
Total zinc %	150 – 2 650	150 – 2 650	150
Phytase %	0.1	0.1	0.1
Inorganic phosphorus %	0.7	0.7	0.7

Fatteners 5 phases	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Crude protein %	21 – 23	19 – 22	18 – 22	17 – 20	16 – 19
Amino acids %	1.4 – 1.7	1.3 – 1.5	1.2 – 1.45	1 – 1.25	0.8 – 1.1
Total calcium %	0.6 – 1	0.6 – 1	0.7 – 0.9	0.7 – 1	0.65 – 1
Total phosphorus %	0.6 – 0.8	0.6 – 0.75	0.6 – 0.7	0.6 – 0.7	0.55 – 0.65
Total copper %	170	170	170	25	25
Total zinc %	150	150	150	150	150
Phytase %			0.01	0.01	

Fatteners 2 phases	Phase 1	Phase 2
Crude protein %	17 – 20	16 – 19
Amino acids %	1 – 1.2	0.9 – 1.2
Total calcium %	0.6 – 0.75	0.6 – 0.75
Total phosphorus %	0.55 – 0.75	0.55 – 0.75
Total copper %	25	25
Total zinc %	150	150
Phytase %	– 0.1	– 0.1
Inorganic phosphorus %	– 0.7	– 0.7

9.2.2 Phase feeding in Germany

Examples of feeding programmes in use in germany for different animal productions
[326, Germany 2010] [327, Germany 2010]

Sows	Phase 1	Phase 2
Period (Days of pregnancy ~~Weight~~)	1 – 84	85 – 115
Net energy MJ ME/kg	11, 8 – 12, 2	11, 8 – 12, 2
Crude protein %	12 – 14	12 – 16
Amino acids %	0.5 – 0.7	0.6 – 0.8
Total calcium %	0.55 – 0.65	0.56 – 0.75
Total phosphorus %	0.4 – 0.55	0.45 – 0.55
Total copper %	0.0008 – 0.001	0.0008 – 0.001
Total zinc %	0.005 – 0.008	0.005 – 0.008
Phytase FTU ~~%~~	500 ~~0.005 – 0.015~~	500 ~~0.005 – 0.015~~
Inorganic phosphorus %	0.1 – 0.2	0.1 – 0.2

Weaners	Phase 1	Phase 2
Period (Weight)	8 – 20 kg	21 – 30 kg
Net energy MJ ME/kg	13.4	13.8 – 13.0
Crude protein %	18	17 – 18
Amino acids %	1.25	1.1 – 1.2
Total calcium %	0.75	0.65 – 0.8
Total phosphorus %	0.55	0.42 – 0.55
Total copper %	0.002	0.0006 – 0.017
Total zinc %	0.008	0.007 – 0.01
Phytase %	0.01	0.005 – 0.015
Inorganic phosphorus %	0.15	0.1 – 0.2
Benzoic acid %		
NSP enzymes %		

Fatteners 2 phases	Phase 1	Phase 2
Period (days)	25 – 60 kg	60 – 110 kg
Net energy MJ ME/kg	13.0 – 13.4	13.0 – 13.4
Crude protein %	17	14
Amino acids %	1.05	0.9 – 1.05
Total calcium %	0.7	0.6 – 0.75
Total phosphorus %	0.58	0.4 – 0.45
Total copper %	0.001	0.0005 – 0.0015
Total zinc %	0.005	0.006
Phytase %	0.01	0.005 – 0.015
Inorganic phosphorus %	0.15	0.1 – 0.2

Fatteners 5 phases	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Period (Weight)	30 – 40 kg	40 – 60 kg	60 – 80 kg	80 – 100 kg	100 – 110 kg
Net energy MJ ME/kg	13.4				12.8
Crude protein %	16.5 – 18	16.5 – 17.5	15.5 – 17	14 – 16	12.9 – 15
Amino acids %	0.95 – 1.15	0.9 – 1.05	0.85 – 1.05	1	0.85
Total calcium %	0.65 – 0.75	0.6 – 0.75	0.7	0.6	0.6
Total phosphorus %	0.42 – 0.6	0.45 – 0.55	0.4 – 0.5	0.4 – 0.5	0.45
Total copper %	0.0005 – 0.0015	0.0005 – 0.0015	0.0004 – 0.0015	0.0004 – 0.0015	0.0004 – 0.0015
Total zinc %	0.006	0.006	0.006	0.006	0.006
Phytase %	0.005 – 0.015	0.005 – 0.015	0.005 – 0.015	0.005 – 0.015	0.005 – 0.015
Inorganic phosphorus %	0.1 – 0.2	0.15	0.1 – 0.2	0.1 – 0.2	0.1 – 0.2

Cage Layers	Phase 1	Phase 2	Phase 3
Net energy MJ ME/kg	11.6 – 12.1	11.4	11 – 11.4
Crude protein %	18	17	16.5
Amino acids %	0.4	0.35	0.35
Total calcium %	0.38	3.8	4.1
Total phosphorus %	0.55	0.45	0.45
Total copper %	0.0005	0.0005	0.0005
Total zinc %	0.0044	0.0044	0.0044
Phytase %	300	300	300

Pullets	Phase 1	Phase 2	Phase 3	Phase 4
Period	1 – 3 weeks	4 – 8 weeks	9 – 15/16 weeks	16/17 week
Net energy MJ ME/kg	12	11.4	11 – 11.4	11.2 – 11.4
Crude protein %	20 – 21	18 – 18.5	14.5 – 16	16 – 17.5
Amino acids %	0.4 – 0.48	0.37 – 0.42	0.31 – 0.39	0.34 – 0.37
Total calcium %	0.95 – 1.05	0.95 – 1	0.9 – 0.92	2 – 2.25
Total phosphorus %	0.75 – 0.75	0.7 – 0.7	0, 58	0.65 – 0.65
Total copper %	0.0006 – 0.00062	0.0006 – 0.00062	0.0006 – 0.00062	0.0006 – 0.00062
Total zinc %	0.0044 – 0.006	0.0044 – 0.006	0.0039 – 0.004	0.004 – 0.0044
Phytase %	250 – 750	250 – 750	250 – 750	205 – 750

Broiler	Phase 1	Phase 2	Phase 3
Period (days)	0 – 10	11 – 27	28 – 35
Net energy MJ ME/kg	12.2 – 12.6	13.0 – 13.4	13.2 – 13.8
Crude protein %	20 – 23	20 – 22	18 – 21
Amino acids %	0.45 – 0.6	0.45 – 0.55	0.45 – 0.52
Total calcium %	0.85 – 1.2	0.8 – 1.2	0.7 – 1.2
Total phosphorus %	0.65 – 0.7	0.55 – 0.7	0.5 – 0.7
Total copper %	0.0004 – 0.0008	0.0004 – 0.0008	0.00062 – 0.0008
Total zinc %	0.004 – 0.005	0.004 – 0.0044	0.002 – 0.007
Phytase %	250 – 1 000	250 – 750	250 – 750

Ducks	Phase 1	Phase 2
Period	1 – 3 weeks	4 – 7 weeks
Net energy MJ ME/kg	11.40 – 12.34	12.20 – 12.97
Crude protein %	20 – 23.75	18 – 18
Amino acids %	0.4 – 0.48	0.4 – 0.45
Total calcium %	0.8 – 1.2	0.7 – 0.8
Total phosphorus %	0.65 – 0.85	0.6 – 0.7
Total copper %	0.00045 – 0.00045	0.00045 – 0.00062
Total zinc %	0.004 – 0.0055	0.004 – 0.0055
Phytase %	250 – 1 000	250 – 1 000

Turkey Starter	Phase 1	Phase 2
Period (Weeks)	1 – 2	3 – 5
Net energy MJ ME/kg	male 11.2 – 11.8.	male 11.5 – 12.1
Crude protein %	27.5 – 29.5	26 – 27.5
Amino acids %	0.17 – 0.171	0.152 – 0.162
Total calcium %	1.3 – 1.4	1.1 – 1.5
Total phosphorus %	0.8 – 1	0.8 – 1
Total copper %	0.0008 – 0.001	0.0008 – 0.001
Total zinc %	0.005 – 0.0065	0.004 – 0.005
Phytase %	250 – 1 000	250 – 1 000
NB: Regardless of sex, turkeys are raised together for the first and second phase of growth, which extend over the first 4 – 5 weeks until full feathering of the young turkey.		

Turkey MALE	Phase 1	Phase 2	Phase 3	Phase 4
Period (Weeks)	5 – 8	9 – 12	13 – 16	> 17
Net energy MJ ME/kg	11.8 – 12.3	12.3 – 12.8	12.8 – 13.2	13.2 – 13.6
Crude protein %	24 – 24.5	20 – 21	18 – 18	14 – 16
Amino acids %	1.35 – 1.45	1.25 – 1.28	1 – 1	0.8 – 0.85
Total calcium %	0.8 – 1.4	0.75 – 1.2	0.7 – 1.1	0.65 – 1
Total phosphorus %	0.6 – 0.82	0.55 – 0.55	0.5 – 0.7	0.45 – 0.65
Total copper %	0.0005 – 0.001	0.0006 – 0.001	6 – 10	0.0006 – 0.001
Total zinc %	0.004 – 0.006	0.003 – 0.004	30 – 40	0.003 – 0.004
Phytase %	250 – 1 000	250 – 1 000	250 – 1 000	250 – 1 000

Turkey FEMALE	Phase 1	Phase 2	Phase 3
Period (Weeks)	5 – 6/8 – 9	9 – 10/12 – 13	13 – 14/16 – 17
Net energy MJ ME/kg	12.3 – 13.8	12.8 – 13.2	13.2 – 13.6
Crude protein %	23 – 24.4	20 – 21	18 – 18.5
Amino acids %	1.4 – 1.45	1.22 – 1.25	1 – 1.1
Total calcium %	0.8 – 1.2	0.75 – 1.2	0.7 – 1.1
Total phosphorus %	0.55 – 0.8	0.55 – 0.55	0.5 – 0.75
Total copper %	0.0008 – 0.001	0.0008 – 0.001	0.0008 – 0.001
Total zinc %	0.005 – 0.0065	0.004 – 0.005	0.004 – 0.005
Phytase %	250 – 1 000	250 – 1 000	250 – 1 000

9.3 Examples of emission limit values and manure spreading limits in Member States

The following tables show the estimated average emission values and the tolerated spreading limits applied to pig and poultry farms in the environmental permits of Belgium.

Type of crop	P_2O_5	Total N	N from animal and other manure	N from chemical fertiliser
Grassland	130	500	250	350
Maize	100	275	250	150
Crop with low N demand	100	125	125	100
Other crops	100	275	200	200

Table 9.2: Maximum tolerated limits to organic N- and P_2O_5 application (kg/ha) by landspreading of manure in Flanders from 1-1-2003
[8, Technologisch Instituut, 1999]

Type of crop	P_2O_5	Total N	N from animal and other manure	N from chemical fertiliser
Grassland	100	350	170	250
Maize	100	275	170	150
Crop with low N demand	80	125	125	70
Other crops	100	275	170	170

Table 9.3: Maximum tolerated limits to organic N and P_2O_5 application (kg/ha) by landspreading of manure in Flanders in sensitive zones concerning water
[8, Technologisch Instituut, 1999]

Parameter	Emission limit value (mg/Nm^3) 1)
Emission of dust particles from grinding, drying or cooling of mineral manure (dry gas)	75
Emission in flue gas of on-farm incineration installations	NH_3 50 H_2S 5 NO_x 200
1) mg/Nm^3 with 0 °C, pressure 101.3 kPa	

Table 9.4: Examples of emission limit values for certain on-farm activities
[39, Vito, 1999]

9.4 Example of protocol for monitoring of ammonia emissions from housing systems

In Europe, data on the consumption and emissions of intensive livestock farms are collected in different ways. It is not always clear under what circumstances data have been collected; where many factors account for the variation in the observed levels.

In the Netherlands, a protocol has been developed to measure emissions of NH_3 from housing systems for all production species to allow comparison of the emissions of alternative housing techniques. The protocol standardises the factors thought to be relevant for emission variation, such as indoor climate, feed and occupancy rate [63, Commissie van Deskundigen, 1999].

For poultry and pig housing, several factors have been summarised in Table 9.5 and Table 9.6.

Factor	Layers	Broilers	Turkeys 1)	Ducks	Guinea fowl
Housing (cm^2)	450 – 600	20/m^2	2000 – 2500	6 – 8/m^2	20/m^2
Minimum indoor temp. (ºC)	20 – 25	35 – 20	26 – 15	34 – 12	35 – 20
Feed	see text	see text	see text	see text	See text
Production (kg)	see text	1.825 in 43 days	18 in 20 wk (m.) 9 in 16 wk (f.)	2.95 in 47 days	1.5 in in 43 days
Health (loss %)	<5	<10	<10	<5	<10
Minimum number per unit	750	1000	250	400	1000
Measuring periods	2	2	2	2	2
Correction factor	61/63	6/8	21/23	47/56	6/8
1) (m) = male; (f) = female					

Table 9.5: Examples of factors to include in the measurement of emissions from poultry housing [63, Commissie van Deskundigen, 1999]

The indoor temperature is very important and is lowered with increasing weight. With the exception of layers, the temperature is maintained at a constant level, the temperatures mentioned in the Table are the maximum to the minimum temperatures for a production period.

With respect to feed it is important to consider the nutrients (raw proteins), the cation/anion balance and the effects on the emissions of urea, and to exclude feed additives that may affect the pH of urine. Water is given ad lib, except for layers, where water can be rationed.

To assess the emission levels, a comparable growth rate is important: hence the given estimated end weight and the associated growing periods. For layers, egg production and egg quality must be recorded to enable adjustment if needed.

There should be two periods of measuring, with one period in summer when emission levels are potentially at their highest. In the calculation the emissions have to be adjusted for periods of empty housing between two production periods, also called occupancy rate, which for layers is about 3 % and for broilers can be up to 25 % of the time. The average measured emission over two periods per animal per day multiplied by the correction factor and 365 gives the emission per animal place per year.

For pigs a similar protocol can be applied. The factors and their values are summarised in Table 9.6.

Factor	Mating/ gestating sows	Farrowing sows	Weaners	Finishers
Housing (m^2)	2.25	4.0	0.4	variable
Indoor climate (ºC)	15	see text	see text	see text

Feed	see text	see text	see text	see text
Production (kg)	NA	NA	8 – 11 to 23 – 27 (350 g/day)	23 – 27 to 80 – 90 (700 g/day)
Health (loss %)	NA	NA	<5	<5
Minimum number in group	20	6	30	50
Measuring periods	2	2	2	
Correction factor	100/105	100/110	100/110	110/110
n.a. not applicable				

Table 9.6: Example of factors to include in the measurement of emissions from pig housing

The slatted surface area per finisher is not constant but increases with increasing weight. Each minimum surface requirement is associated with a minimum surface requirement for the unslatted part. The surface requirements increase from 0.4 m^2 (0.12 unslatted) at 30 kg to 1.3 m^2 (0.40 unslatted) for animals above 110 kg.

The indoor temperature should be kept at a minimum which varies with age and production stage. The higher the weight the lower the temperature. The minimum temperature of the thermo-neutral zone is applied, except for finishers, where the minimum temperature is at maximum 2 ºC lower than the minimum temperature of the thermo-neutral zone.

With respect to feed it is important to consider the nutrients (raw proteins), cation/anion balance and the effects on the emissions of urea, and to exclude feed additives that may affect the pH of urine.

For finishers it must be noted that average growth per day and the finisher weight apply to the most common finishing practice in the EU. If finishers are grown to 160 kg of live weight before slaughter, the average daily growth will be different and may affect the emission level.

For finishers, there should be two measuring periods also with one period in summer at the moment of potentially elevated emission levels.

In the calculation the emissions have to be compensated for periods of empty housing between two production periods. Except for weaners this is assumed to be 10 % of the total production time. The average measured emission over two periods per animal per day, multiplied by the correction factor and 365 gives the emission per animal place per year.

9.5 Example of calculation of costs associated with the application of emission reduction techniques

The scope of this annex is limited to describing an approach that can be used for calculating the cost of individual techniques proposed under the framework of the IPPC Directive. The approach described relates to the 'unit' cost of techniques; it has also been adopted by UNECE for part of the process of calculating the compliance costs of reducing ammonia emissions from livestock production

This annex further implies that for this approach to be adopted, all techniques to be considered in the determination of BAT should be presented with the required technical and financial data as listed in the tables. As regards the cost data that are needed for assessment of BAT in a general sense, this annex can therefore be considered a proposal for a future updating of this BREF.

This annex is largely based on work done by DEFRA, UK, in turn based on work by an expert-group within the TWG on cost assessment and BAT [557, MAFF 2000] ~~[216, UK, 2002]~~

Methodology

This section comprises the following topic areas:

- overview
- type of measure
- calculation of 'unit' costs.

Overview

The calculation of unit cost requires a clear understanding of:

- the proposed technique to be introduced to reduce emissions
- the whole range of systems of production and management that are found on relevant farms
- the impact that the introduction of the technique will have on farm production and management systems in both physical and financial terms as well as in terms of costs and benefits.

the calculation will result in an annual cost, which may comprise an allowance for capital expenditure amortised over the life of the investment.

Once calculated, these costs can be used in:

- the calculation of the cost of individual, or a combination of, techniques per kilogram of pollutant abated
- the determination of general BAT
- the relationship between the costs of BAT implementation and the economic viability or profitability of the intensive poultry and pigs ~~livestock~~ industry
- the cost to the industry of compliance.

Categories of technique

Techniques applicable to the intensive poultry and pigs ~~livestock~~ sector may be categorised as follows:

- feed
- housing
- manure storage
- treatment of manure
- application of manure to land.

(Note: 'Manure' may be liquid slurry or solid manure)

A technique should be identified under one of the above categories, and according to livestock category affected; for example, laying hens or breeding pigs. The categories are subsequently used to identify how 'unit' costs should be calculated.

Calculation of Unit Costs

Unit costs are the annual increase in costs that a typical farmer will bear as a result of introducing a technique. The general approach to the calculation of unit costs is as follows:

- define the physical and husbandry changes resulting from implementation of the abatement technique based on a thorough understanding of current farming systems
- for each technique identify those areas where cost or performance changes will be associated with the introduction of that technique
- in all cases, only those costs directly associated with the technique should be considered
- additional costs associated with any technical enhancements should be ignored.

The category that techniques fall into will determine the physical units that are used to define the population or quantities of manure, and form the basis of subsequent calculations. The relationship can be seen in the following table.

Table 9.7: ‘Units’ used for assessing costs

Category	‘Units’	Details
Feed	per head	Per head of livestock
Housing	places	Building capacity
Manure storage, treatment and land application	m^3 or tonnes	Liquid slurry (including dilution) and solid manure (including bedding)

Unit costs should be calculated according to the general approach described below:

- current costs should be used for all calculations
- capital expenditure, after deducting any grants, should be annualised over the economic life of the investment
- annual running costs should be added to the annualised cost of capital
- changes in performance have a cost and should be taken into account as part of the annual costs
- this total sum is divided by the annual throughput to determine the ‘unit cost’. The throughput should be described using the ‘units’ shown in Table 9.7.

The approach is detailed in the following sections.

Capital Costs

Capital expenditure needs to be assessed under the headings shown in Table 9.8.

Table 9.8: Capital expenditure considerations

Primary consideration	Notes
Capital for fixed equipment [1)] or machinery [2)].	Use national costs. If these are unavailable use international costs including delivery cost and convert the cost to national currency at the appropriate rate
Labour cost of installation.	Use contract charges if these are normal. If farm staff are normally used to install the conversion, employed staff should be costed at typical hourly rates. Farmers’ input should be charged at the opportunity cost.
Grants	Subtract the value of capital grants available to farmers.
Note 1): Fixed equipment includes buildings, conversions of buildings, feed storage bins, or manure storage. Note 2): Machinery includes feed distribution augers, field equipment for manure application or equipment for manure treatment.	

Annual Costs

The annual cost associated with the introduction of a technique needs to be assessed in the following steps.

Table 9.9: Annual cost considerations

Step	Consideration	Notes
A	Annualised cost of capital should be calculated over the life of the investment.	Use standard formula. The term will depend on the economic life. Conversions need to take account of remaining life of original facility. See Appendix 1.
B	Repairs associated with the investment should be calculated.	See Appendix 2.
C	Changes in labour costs.	Additional hours 5 cost per hour.
D	Fuel and energy costs.	Additional power requirements may need to be taken into account. See Appendix 2.
E	Changes in livestock performance.	Changes in diets or housing can affect performance, with cost implications. See Appendix 3.
F	Cost savings and production benefits.	In certain cases the introduction of techniques will result in the saving of costs for the farmer. These should be taken into account only when they are the direct result of the measure. The avoidance of fines for pollution should be excluded from any costed benefits for these purposes.

<u>Worked examples in the UK</u>

Liquid manure application by soil injection

Basis for the costs:

1. the costs are based on the purchase of an injector attachment for fitting to either the slurry tanker or the tractor. The capital cost of such equipment is EUR 10 000
2. additional tractor power of about 35 kW is needed compared to surface application
3. work rates of about 14 m^3 per hour may be achieved compared to 17 m^3 (2½ loads per hour of 7 m^3) per hour using a tanker and splash plate system. This is based on a 6 minute discharge for a splash plate operation being extended to 12 minutes when injecting
4. annual throughput 2000 m^3
5. capital cost amortised over 5 years at 8.5 %
6. emission reduction: e.g. reduction of ammonia emission expressed in mg NH_3/Nm^3.

Table 9.10: Additional costs incurred with liquid manure application by soil injection in the UK

Step	Consideration	Calculation	Total (EUR/yr)
		Use formula given at Appendix 1 and shown below.	
A	Annual Cost of Capital	C 5 $(r(1+r)^n)/((1+r)^n – 1)$ C = EUR 10 000 r = 8.5 % inserted into formula as 0.085 n = 5 years EUR 10 000 5 $(0.085(1+0.085)^5)/((1+0.085)^5 – 1)$	**2 540**
B	Repairs	At 5 % of capital cost of injector (EUR 10 000).	**500**
C	Changes in labour costs	Slower application rates (2 000m^3 ÷ 14 m^3/hr less 2 000m^3 ÷ 17 m^3/hr) = 25 hours times EUR 12 per hour	**300**
D	Fuel and energy costs.	Additional tractor costs - 35 kW for 2 000m^3 ÷ 14 m^3/hr = 143 hrs at 10 litres per hour at EUR 0.35 per litre	**500**
E	Changes in livestock performance.	Not applicable	**0**
F	Cost savings and production benefits.	Not included, although there may be better use of manure nitrogen	**0**
	Total extra annual costs		**3 840**
	Total extra cost per m^3 based on an annual throughput of 2 000 m^3		**1.92**

Solid manure incorporation by ploughing (example calculation without capital expenditure)

Basis for the costs:

1. contractors will need to be used to incorporate solid manure in many situations, as employed labour and machinery will be fully utilised on other tasks
2. the method of incorporation will normally be by ploughing
3. there will be a marginal cost saving, as this operation (ploughing) will not need to be carried out by farm staff at a later time
4. manure spread up to the equivalent of 250 kg total N per hectare per year.

Table 9.11: Additional costs incurred in solid manure incorporation by ploughing in the UK

Step	Consideration	Calculation	Total (EUR/ha)
A	Annual cost of capital	Not applicable	**0**
B	Repairs	Not applicable	**0**
C	Changes in labour costs	Employment of a contractor to carry out ploughing	**65**
D	Fuel and energy costs.	Not applicable (included in contractor charge)	**0**
E	Changes in livestock performance.	Not applicable	**0**
F	Cost savings and production benefits.	Savings in farmer's own marginal machinery costs	**10**
	Total extra annual costs		**55**
	Extra cost per tonne of manure:		**EUR/tonne**
	Pig manure applied at 36 tonnes/ha		**1.53**
	Laying hen litter applied at 16.5 tonnes/ha		**3.33**
	Broiler litter applied at 8.5 tonnes/ha		**6.47**

Calculations with changes to a building: 1. air ducts in deep pit poultry housing

Basis for the costs:

1. simple polythene pipe air ducts are installed in the pit under the manure and fan ventilated. The capital cost is EUR 0.32 per bird place
2. such systems have additional running costs of EUR 0.16 per bird place per year (electricity and repairs)
3. the capital costs of the system are amortised over 10 years at 8.5 %.

Table 9.12: Additional costs incurred with changes of a building in the UK

Step	Consideration	Calculation	Total EUR/bird place
A	Annual cost of capital	Cost of pipes and fan	**0.05**
B	Repairs	Additional repair cost	**0.08**
C	Changes in labour costs	Not applicable	**0**
D	Fuel and energy costs.	Additional electricity costs	**0.08**
E	Changes in livestock performance.	Not applicable	**0**
F	Cost savings and production benefits.	Not applicable	**0**
	Total extra annual costs per bird place		**0.21**

Calculations for changes to a building: 2. Metal grid replacement floors in pig buildings

Basis for the costs:

1. capital cost of replacement slats EUR 78 per m^2 *(Tri-bar)* plus EUR 16 installation
2. installation is uncomplicated
3. the cost of capital is amortised over 10 years at 8.5 %. This allows for fitting the slats in existing accommodation, which has a part-expired life
4. cost per pig place is based on a total allowance of 0.63 m^2 per pig place, see below. Of this area normally 25 % or 0.156 m^2 per pig place is slatted in part-slatted accommodation
5. repair costs are considered to be similar to other types of floor.

Table 9.13: Additional costs incurred with metal grid floor replacement in the UK

Step	Consideration	Calculation	Total EUR/pig place
A	Annual cost of capital	Capital cost of EUR 94/m^2 for 0.156 m^2 amortised over 10 years at 8.5 %	**2.23**
B	Repairs	No extra costs	**0**
C	Changes in labour costs	Not applicable	**0**
D	Fuel and energy costs.	Not applicable	**0**
E	Changes in livestock performance.	Not applicable	**0**
F	Cost savings and production benefits.	Not applicable	**0**
	Total extra annual costs per pig place		**2.23**
NB -Data provided by Kirncroft Engineering (U.K.).			

Table 9.14: Finishing pig space requirement in the UK

	Space requirement (m^2)	Weighted average (m^2)
30 – 50 kg	0.4	0.132
50 – 90 kg	0.65	0.436
Subtotal		**!Invalid Character Setting**
Allowance for 90 % occupancy		0.057
Total space requirement		**!Invalid Character Setting**
Data provided by ADAS (U.K.)		

Useful reporting of cost data

A number of issues and presentational factors make assimilation of cost data easier for the reader and could support future assessment.

Any report on costs should contain sufficient information to enable the uninformed reader to follow the logic and calculations. A mixture of explanatory narrative and tables allows the reader to follow the thought processes of the author(s).

In all cases, the sources of data should be identified. Where professional judgement has been used to derive certain figures or assumptions, this should be acknowledged.

It is suggested that a report should contain the following sections and format:

• Introduction	
• Summary	*Text and tables showing unit cost of techniques*
• Cost of technique	*Text and tabular presentation for each technique showing the basis and calculation of the unit cost, drawing on supplementary data contained in appendices*

Appendices

Appendix 1: Calculation of annual charge for capital

Capital expenditure on abatement techniques should be converted to an annual charge. Capital may be for buildings, fixed equipment or machinery. It is important to include only the additional or marginal capital associated with the abatement techniques.

Amortisation should be used to calculate the annual cost of capital. When using this method, an additional allowance for depreciation of the asset should **not** be included in the calculation. Factors derived from appropriate tables can be applied to the capital invested or the standard formula, shown below, can be used.

Formula:

The formula for calculating the annual charge is:

$$C\ 5 \left[\frac{r(1+r)^n}{(1+r)^n - 1} \right]$$

Where: C = capital investment
r = rate of interest expressed as a decimal of 1. For example an interest rate of 6 % is entered in the equation as 0.06.
n = term in years

Rate of interest:

The rate of interest that is applied should reflect that commonly paid by farmers and will vary by country and by investment term. For guidance, the UK calculations are based on finance available to farmers through the Agricultural Mortgage Corporation (AMC). Their interest rates, as at September 2000, for fixed interest loans are quoted below.

Table 9.15: Interest on agricultural mortgage in the UK

Term in years	Fixed interest rates (%)	Annual charge([1]) EUR per EUR 1 000 of capital
5	8.5	254
10	8.5	152
20	8.25	104

([1]) Based on amortisation formula shown above including interest and capital.
Source: AMC. September 2000

Term:

The term will depend on the type of investment and whether it is a new facility or a conversion.

In the case of new facilities the following economic lives are given as a guide. In particular circumstances it may be necessary to vary these figures.

Table 9.16: Economic life of facilities

Type of investment	Economic life in years
Buildings	20
Fixed equipment	10
Machinery	5

In the case of conversions it is necessary to annualise the capital cost over the remaining life of the original facility.

In many cases the facility may have a productive life in excess of the economic life, though it is the economic life that must be used in these calculations.

Appendix 2: Repair and fuel costs

Repairs:

Repair costs associated with any investment will vary greatly. The type of investment, original build quality, operating conditions, age in relation to design life and amount of use all play their part in influencing costs.

The following figures can be used for guidance:

Table 9.17: Repair costs as a percentage of new costs

Type of investment	Annual repair costs as a percentage of new cost
Buildings	0.5 – 2
Fixed Equipment	1 – 3
Tractors	5 – 8
Manure and slurry spreaders	3 – 6

<u>Fuel:</u>

The following general formulae can be used to calculate fuel costs:

Electricity:

Fuel cost = kWh 5 Hours of use 5 Fuel price

Tractor Fuel:

Fuel cost = kWh 5 Fuel consumption per kWh 5 Hours of use 5 Fuel price

Appendix 3: Unit costs - Some detailed considerations

The following detailed factors should be considered in relation to each technique:

<u>Feed:</u>

Changes to diets can be applied to many classes of livestock to reduce ammonia emissions. The following implications need consideration in each case.

Table 9.18: Annual costs to consider in capital costs of feeding systems

Capital costs	Annual costs to consider
Additional feeding systems	Annual charges, repairs and power inputs.
	Changes to carcase value.
	Relative costs of diets.
	Changes to livestock performance and feed consumption.
	Changes in excreta output.
	Changes in labour requirements.

<u>Housing:</u>

For those techniques requiring capital expenditure by farmers, it is necessary to consider the elements in the following table:

Table 9.19: Annual costs to consider in capital costs of housing systems

Capital costs	Annual costs to consider
Changes to housing systems	Annual charges, repairs and power inputs.
	Changes in house capacity.
	Changes in labour requirements.
	Changes in bedding requirements
	Changes to livestock performance and feed consumption.
	Changes in excreta storage capacity in the building.
NB: Capital costs may refer to either the modification of existing facilities or the **additional** costs of replacement facilities. The choice will depend on building condition and suitability for conversion, normally related to age and remaining economic life. Only the additional costs of providing those facilities that relate to the facilities' pollution abatement capabilities should be included.	

Manure storage:

For those techniques requiring capital expenditure by farmers, it is necessary to consider the elements in the following table.

Table 9.20: Annual costs to consider in capital costs of manure storage systems

Capital costs	Annual costs to consider
Additional storage	Annual charge, repair costs.
Permanent covers	Annual charge, repair costs.
	Cost of temporary covers on an annual basis
All covers	Changes in labour requirements.
	Reductions in rainwater dilution.

Application of manure to land:

Table 9.21: Annual costs to consider in capital costs of manure storage systems

Capital costs	Annual costs to consider
Low emission spreaders (compared to splash plate spreaders)	Annual charge, repair costs.
	Changes in tractor power requirement
	Changes in work rates
	Changes in labour requirements.

9.6 Procedure for BAT-assessment of techniques applied on intensive poultry and pig farms

The assessment procedure described in this annex has been developed by a subgroup of the TWG on Intensive Livestock Farming. The primary objective of this annex is to promote a better understanding of the evaluation behind the BAT proposed in Chapter 5.

Each assessment depends on the quantity and quality of the information available. A solution must be developed for comparing techniqueswhere the information is poor or difficult to assess. This will need to cover validation and comparison of the different characteristics of potential reduction techniques.

This BREF document presents, the conclusions of an exchange of information on environmental techniques in the intensive rearing of pigs and poultry. It can be regarded as the first inventory of the available data. Although a large amount of data is available, the information needed to support the decision-making process can still be improved in terms of both the quality and quantity of data.

To allow the assessment to be made in a transparent way, all these data should be presented in a specific format and (even more importantly) should have a high degree of comparability. Therefore, the data should be made available with a clear explanation on how they have been collected, measured and analysed and under what circumstances. Ideally, they should have been collected according to the same protocol and presented with the same level of detail. Comparing sets of data collected in this way promotes an easy understanding of any differences, such as large variations in performance levels, that can be expected in the intensive livestock sectors. These variations may be caused by differences between farming practices and/or by specific regional or local conditions.

Chapter 4 aims to present this kind of information as far as possible for each activity or group of techniques. Where such information is limited or not available expert judgement will play an important role.

The assessment and selection of BAT

Techniques are considered on an individual basis by assessing their emission reduction potential, operability, applicability, the animal welfare, and their associated costs, all in comparison to a reference technique. The approach carried out for the applied assessment consists of the following steps:

13. create an assessment matrix of all the relevant factors for each **group of techniques**
14. identify the reference technique for each **group of techniques**
15. identify the key environmental issues for each **group of techniques**
16. give a qualitative rating (-2, -1, 0, 1 2) for **each technique**, where quantitative data are not available
17. rank **techniques** by their environmental performance in terms of the reduction of, for example, ammonia emissions
18. assess the technical applicability, the operability and the animal welfare aspects of **each technique**
19. assess the environmental cross-media effects caused by **each technique**
20. assess the costs (CAPEX and OPEX)of applying **each technique** in new build and in retrofit situations
21. discuss the qualifications -2 and -1 to see if it is possibly a conditional BAT or to decide that it is a knock-out criterion, for example a technique with -2 on animal welfare can never be BAT
22. identify (conditional) BAT and decide if it is BAT for new and/or for retrofit situations.

Table 9.22 on the next page shows the assessment matrix used to assess housing techniques as used by the TWG in the discussion on BAT for housing systems.

POSSIBLE ECM's	Emission reduction potential (%)	Operability	Applicability	Animal Welfare	N_2O, CH_4 emission	Odours emission	PM10	Energy cons.	Water cons.	Noise	CAPEX (new)	CAPEX (retrofit)	OPEX (Ops & Main & Investment) new	OPEX (Ops & Main & Investment) retrofit
	A	B	C	D	E	F	G	I	J	K	L	M	N	O
Housing with confined movement (2.3.1.2.1)														
FSF/crates and board on a slope (4.6.2.1)	30 %													
FSF/crates, water + manure channel (4.6.2.2)	50 %													
FSF/crates, flush + manure gutters (4.6.2.3)	60 %													
FSF/crates, manure pan (4.6.2.4)	65 %													
FSF/crates, surface cooling fins (4.6.2.5)	70 %													
Partial slatted floors (PSF) + crates (4.6.2.6)	30 %													
PSF/crates and manure scraper (4.6.2.7)	35 %													

Scoring definitions
scores range: -2; -1; 0; 1; 2
a 0 score means equal to reference
a 2 score on emission reduction potential indicates the highest reduction potential
a 2 score on operability means easiest to operate
a 0 score on applicability indicates that the technique is as often used as the reference
a 2 score on animal welfare indicates the highest welfare standard
a 2 score on cross-media indicates no cross-media effects
a 2 score on all CAPEX/OPEX columns indicates lowest costs

Table 9.22: Assessment matrix

In an intermediate meeting with the TWG, the following groups of techniques were assessed using the matrix shown in Table 9.22emission of the reference technique.

The ammonia emission reduction potential of the techniques presented in Chapter 4 are given in units expressed as an absolute emission range and as relative reductions (% against a reference technique). Working with livestock and a large variation in feed formulation, the absolute ammonia emissions from manure, or from housing, etc. will cover a very wide range and make interpretation of absolute levels difficult. Therefore, the use of ammonia reduction levels expressed in percentages has been preferred, particularly for animal housing, manure storage and manure application to land.

Assessment of technical applicability, operability and animal welfare
The applicability of a technique is whether and how often it is used compared to the reference technique. The operability of a technique is affected by factors such as the complexity of a construction and the creation of extra labour. The effects on the welfare of animal are also assessed, again in comparison to the reference technique. As far as possible, these factors have been described in Chapter 4.

Assessment of cross-media effects
The cross-media effects assessed in housing techniques include factors such as N_2O and CH_4 emissions, odour emissions, dust, energy consumption, water consumption and noise.

Assessment of costs
The costs of techniques were not always been reported and, where cost indications were given, factors on which these calculations were based were often not clarified. The number of applications and the number of Member States from which applications are reported then take on more significance in the evaluation.

The costs on housing techniques reported in Chapter 4 are expressed as the extra costs compared to the reference technique. These data are used in the assessment and where these figures were not available, experts from the TWG gave a qualification. The fact that costs are expressed in comparison to the reference housing system presents problems in the assessment in retrofit situations. This is because retrofitting is not only applied on the reference system, but also on other existing housing systems. The costs for retrofitting depend very much on the existing housing system and to compare the extra costs only with the reference system is not realistic in all situations.

Some techniques may incur no extra costs compared to the currently applied reference technique. Obviously, there should be no financial argument not to apply these techniques, but there may be other reasons why such techniques may not be BAT. Where techniques have extra costs, a cost level was identified beyond which it would not be reasonable to expect their application by the sector.

It was very difficult to identify such a standard at a European level, against which the real costs of a technique could be compared. Often, there are other rationale behind the decision-making at the farm level. Also, local, regional or national (financial) incentives may encourage farmers to change their practices. Cost data for applying a reduction technique (as presented in Chapter 4) are often for a specific situation. However, for almost all the techniques that were assessed the meeting was able to agree the qualification of the costs and able to identy the cost level beyond which application by the sector was not considered to be reasonable.

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