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Data sheet

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Abstract:	The report estimates the ammonia emission from Denmark until 2025. The estimate is based on expected development in animal husbandry, development in feeding efficacy, ammonia reducing technologies and manure handling. Denmark has in relation to the Convention on Long-Range Transboundary Air Pollution accepted to reduce the emission to 56,700 tonnes NH_3-N/year in 2010. The analysis in the thematic strategic scenario 2020 primarily suggested a Danish emission ceiling for ammonia at 51,000 tonnes NH_3-N/year in 2020 - this emission is excluding emission from crops and ammonia treated straw. The current projection indicates that Denmark can comply with its emission ceiling in 2010 and are furthermore below the current thematic strategy scenario 2020. It is expected that Denmark will reduce its ammonia emission (excl. emission from crops and ammonia treated straw) from approximately 60,800 tonnes NH_3-N/year in 2005 to 53,600 tonnes NH_3-N/year in 2010 and further to 44,800 tonnes NH_3-N/year in 2020. The overall Danish reduction from 1990 to 2025 is thus expected to be 52%.

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Preface

The National Environmental Research Institute (NERI) is responsible for the preparation and reporting of the annual emissions to the air, among this the ammonia emission from the agricultural sector. In accordance with international conventions Denmark is committed to reduce the ammonia emission to 69,000 tonnes NH_3 in 2010. This emission ceiling for Denmark is formulated in both the Gothenburg Protocol under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the EU NEC Directive – National Emission Ceiling (Directive 2001/81/EC).

The objective of this project financed by the Danish Environmental Protection Agency is to describe the expected development in the ammonia emission from the agricultural sector until 2025.

The projection includes all implemented and planned measures such as the Action Plan for the Aquatic Environment III (VMPIII), the European Common Agricultural Policy Reform (CAP) and a newly launched law on animal husbandry in Denmark (Law No. 1572 – December 20, 2006). Furthermore, expected technological developments are taken into account. A stricter environmental requirement, especially in relation to expansion of livestock farming is expected to result in the implementation of various technical measures to reduce the ammonia emission.

Ongoing revision of the Danish ammonia emission inventory system and emission factors is presently underway, with conversion from a total N-based system to a TAN-based system (Total Ammoniacal Nitrogen). Although the revision is not yet complete, the major effects on the emission estimates are included in this projection in order to give a more comprehensive picture of the future ammonia emission inventory.

The developments in the projections have been followed by a steering committee:

Ulrik Torp, The Danish Environmental Protection Agency; Johnny M. Andersen, Danish Agriculture; Nicholas Hutchings, Faculty of Agricultural Science – University of Aarhus; Sophie Winter, Danish Forest and Nature Agency; Niels Lundgaard, Danish Agricultural Advisory Centre; Ellis Sommer, The Danish Plant Directorate; and Brian H. Jacobsen, Institute of Food and Resource Economics.

Summary

Emission of ammonia to the atmosphere is responsible for acidification of soil and water and increased eutrophication in natural habitats. Approximately 97% of the emission is related to animal husbandry, primarily in the agricultural sector, but also includes private horse ownership as well as use of fertiliser, incl. sludge and the emission from crops. The remaining 3% is from the industry and from transport. In the inventories previously reported, the Danish ammonia emission showed reduction from 109,900 tonnes NH_3-N/year to 80,400 tonnes NH_3-N/year from 1990 to 2004. This decrease was primarily due to an increased utilisation of nitrogen in animal feedstuffs, as well as a reduced number of cattle and changed manure application techniques.

Denmark has ratified the 1999 protocol to Abate Acidification, Eutrophication and Ground-level Ozone under Convention on Long-Range Transboundary Air Pollution and accepted the target to reduce the emission to 56,800 tonnes NH_3-N by 2010. The same obligation is contained in the EU-Directive on National Emission Ceilings (2001/81/EC). This ceiling includes all sources except the emission from crops and ammonia-treated straw.

The emission to 2025 is projected in this report. Due to new research carried out in Denmark, e.g. in connection with the Action Plan for the Aquatic Environment III (VMPIII) research programme, a revision of the current ammonia inventory model is required. The current model overestimated especially the emission from manure application.

A new inventory model for ammonia will be developed in 2007. For the purpose of this projection a preliminary model has therefore been developed and the results are assumed to be close to the outcome of the final model. In the existing model, for example, the total Nitrogen (N) content in manure is used to estimate the ammonia emission. The new model will be TAN based (Total Ammoniacal Nitrogen). Total ammoniacal nitrogen is the part of nitrogen that is volatile. This change is required in order to implement the foreseen effect of new ammonia-reducing technologies in the inventory methodology.

In the projection, developments in animal husbandry, stable types, manure application methods, ammonia-reducing technologies and investment in biogas plants are all taken into account. Implementation is primarily based on expectations relating to the effect of a new animal husbandry law, which is in force by January 1, 2007 (Law No. 1572 – December 20, 2006). However, there is a high degree of uncertainty included in the projection, as it is difficult to estimate which technologies will be used, to what extend and where. The effect of manure burning is not included in the projection. Burning of the solid fraction of manure from cattle and pigs is expected to have very little effect on the ammonia emission, whereas burning of poultry litter may have a greater effect.

The new projection estimates that the current ammonia inventory overestimates the ammonia emission by approximately 5,300 tonnes NH_3-

N/year in 2004. The main reason is an over-estimation of the ammonia emission coefficient for manure application during spring.

The preliminary model estimates an emission of 72,200 tonnes NH_3-N/year in 2005, which represents a reduction of 35% since 1990. In 2010 an emission of 64,700 tonnes/year is expected. Up until 2025, a further reduction to 53,200 tonnes/year is expected. These figures include the emission from growing crops.

Emissions that are included in the National Emission Ceiling are estimated to 53,600 tonnes in 2010. Consequently, Denmark is expected to fulfil its reduction commitments for ammonia. The main reasons behind this are improved feed utilisation, a further reduction in the number of cattle, increased manure injection and investment in new ammonia-reducing technologies in stables and manure storage.

The Clean Air For Europe (CAFE) programme has worked out a policy emission scenario - the thematic strategy scenario 2020 (Amann et al. 2005), as a basis for outlining a strategy towards cleaner air in Europe, including revision of the NEC Directive. Analysis of the thematic strategy scenario 2020 suggests a Danish ammonia emission ceiling for 2020 to 51,000 tonnes NH_3-N. The current Danish projected emission for 2020 is estimated to 44,800 tonnes NH_3 and is thus below the value in the Thematic Strategy scenario. However, it has to be pointed out that negotiations concerning the emission ceiling 2020 is presently taking place. The final proposal for the Danish emission ceiling 2020 is therefore still unknown.

Table A Projected ammonia emission from 1990 to 2025 calculated with the preliminary emission model, tonnes NH_3-N/year.

	1990	2000	2005	2010	2015	2020	2025
Animal manure	80,400	60,700	53,800	46,700	40,400	38,300	36,400
Fertilisers	8,700	5,600	4,500	4,300	4,000	3,900	3,700
Crops	13,000	11,500	11,400	11,100	10,900	10,700	10,500
Ammonia-treated straw	8,400	2,000	0	0	0	0	0
Sludge	100	100	100	100	100	0	0
Field burning	0	0	0	0	0	0	0
Industry	400	500	500	500	500	500	500
Transport	100	1,800	2,000	2,000	2,000	2,000	2,000
Total	111,100	82,100	72,200	64,700	57,900	55,400	53,200
Relative development	100	74	65	58	52	50	48
According to the NEC directive	89,700	68,600	60,800	53,600	47,000	44,800	42,700
NEC (National Emission Ceiling)				56,800		51,000	

Sammenfatning

Ammoniakudslip til luften er medvirkende til forsuring af jord og vand samt næringsstoftilførsel til naturarealerne. Ca. 97 % af ammoniakudslippet stammer fra landbrugets husdyrhold, gødningsforbrug, plantedyrkning samt husdyrhold uden for landbruget, mens de resterende 3 % stammer fra trafikken og fabriksanlæg. I de tidligere afrapporterede opgørelser er ammoniakudslippet reduceret fra 109.900 tons ammoniak i 1990 til 80.400 tons i 2004. Dette skyldes primært forbedret foderudnyttelse hos svin, færre antal kvæg og ændrede udbringningsmetoder for husdyrgødning.

Danmark har ratificeret protokollen om forsuring, eutrofiering og jordnær ozon under konventionen om langtrækkende grænseoverskridende luftforurening og derved forpligtet sig til at reducere emissionen til 56.800 tons NH_3-N i 2010. Den samme forpligtelse er indeholdt i EU-direktivet om nationale emissionslofter (2001/81/EF). Dette emissionsloft omfatter alle ammoniakkilder undtagen udslip fra afgrøder og ammoniakbehandlet halm.

Udslippet af ammoniak frem til 2025 er estimeret i denne rapport. På baggrund af ny viden, bl.a. opnået i forbindelse med forskning gennemført under VMPIII forskningsprogrammet, skal den nuværende beregningsmodel revideres. Den nuværende model har især vist sig at overestimere ammoniakfordampningen fra udbragt husdyrgødning.

En ny model til beregning af ammoniakemission vil først være færdigudviklet med udgangen af 2007. Til brug for fremskrivningen er der derfor udarbejdet en foreløbig model, som forventes at ligge tæt på den endelige model. I den eksisterende model er ammoniakfordampningen beregnet på grundlag af husdyrgødningens totalindhold af kvælstof, hvorimod den nye model bygger på indholdet af ammoniak og ammonium (TAN), som er den del af kvælstoffet der fordamper. Den nye model gør det muligt at beregne effekten af især ammoniakreducerende teknologiske tiltag.

I fremskrivningen er der taget hensyn til udviklingen i husdyrholdet, staldtyper, udbringningsmetoder og udviklingen i ammoniakreducerende teknologi samt af bygningen af biogasanlæg. Implementering af ammoniakreducerende teknologi er i fremskrivningen baseret på forventninger til effekten af den nye husdyrlov (Lov nr. 1572 af 20. december 2006), som opstiller krav om implementering af ammoniakreducerende tiltag ved udvidelser, samt generelle tiltag omkring udbringning. Der er imidlertid stor usikkerhed om hvor hurtigt og hvilken teknologi der implementeres. Effekten af en evt. afbrænding af husdyrgødning er ikke indarbejdet. En evt. forbrænding af kvæg- og svinegødning forventes kun at have en lille effekt på den samlede ammoniakfordampning, men afbrænding af fjerkrægødning kan have en større effekt.

Den foreløbige model anslår at ammoniakemissionen er overestimeret med ca. 5.300 tons NH_3-N i 2004. Hovedparten af denne overestimering

skyldes en overestimering af ammoniakfordampningskoefficienten for udbragt husdyrgødning i foråret.

Med den udviklede model forventes en emission på 72.200 tons NH_3-N i 2005, hvilket er en reduktion på 35 % siden 1990. Frem til 2025 forventes en yderligere fald i ammoniakfordampningen, således at der i 2025 forventes en fordampning på ca. 53.200 tons NH_3-N, svarende til en 52%-reduktion siden 1990. I 2010 forventes en fordampning på 64.700 tons NH_3-N. Af dette indgår 53.600 tons i emissionsloftet. Målsætningen i Gøteborg-protokollen forventes derfor opfyldt.

En væsentlig årsag til reduktionen er en forventet bedre foderudnyttelse i svinesektoren, et faldende antal malkekøer, øget brug af gyllenedfældning og ammoniakreducerende tiltag i staldbygninger og gødningslagre.

CAFE programmet (The Clean Air For Europe) har udarbejdet et politisk emissions scenario 2020 – det tematiske strategi scenario 2020, som indgår i arbejdet omkring revidering af NEC direktivet (Amann et al. 2005). I scenariet er der for Danmark angivet en foreløbig målsætning på 62.000 tons NH_3 eller 51.000 tons NH_3-N. Denne fremskrivning viser, at emissionen i 2020 med nuværende tiltag vil være mindre end foreslået i det tematiske strategi scenario 2020. Det skal understreges at det danske emissionsloft for 2020 på nuværende tidspunkt er til forhandling og derfor er det endelige resultat endnu ikke kendt

Tabel A Estimeret ammoniakemission fra 1990 til 2025 beregnet med en foreløbig model, tons NH_3-N/år.

	1990	2000	2005	2010	2015	2020	2025
Husdyrgødning	80,400	60,700	53,800	46,700	40,400	38,300	36,400
Handelsgødning	8,700	5,600	4,500	4,300	4,000	3,900	3,700
Afgrøder	13,000	11,500	11,400	11,100	10,900	10,700	10,500
Ammoniakbehandlet halm	8,400	2,000	0	0	0	0	0
Slam	100	100	100	100	100	0	0
Halmafbrænding	0	0	0	0	0	0	0
Industri	400	500	500	500	500	500	500
Transport	100	1,800	2,000	2,000	2,000	2,000	2,000
I alt	111,100	82,100	72,200	64,700	57,900	55,400	53,200
Relativ udvikling	100	74	65	58	52	50	48
Ifølge NEC direktivet	89,700	68,600	60,800	53,600	47,000	44,800	42,700
NEC (det nationale emissionsloft)				56,800		51,000	

1 Introduction

The main part of the Danish ammonia emission, corresponding to 97%, comes from the agricultural sector as well as some small sectors such as horses from riding schools and use of fertilisers in private gardens. The remaining 3% is related to the transport sector and industrial processes.

80% of the emission from the agricultural sector stems from animal manure and the ways in which it is handled. 6.5% comes from losses involved in the application of mineral fertilisers and 12% stems from the cultivation of crops. Emissions from crops are, unlike in most other countries, included in the Danish inventory, although they are not included in the ammonia emission ceiling. Technically, it is difficult to reduce the emission from mineral fertilisers further without increasing incorporation of the fertiliser into the soil, because almost all mineral fertiliser applied in Denmark has low emission rates. Therefore this report focuses on the total amount of N in animal manure and how it is handled.

From 1985 to 2004 the emission of ammonia from the agricultural sector decreased from 133,100 tonnes NH_3 to 94,800 tonnes NH_3, which corresponds to a 29% reduction (Figure 1). This development is due to the active national environmental policy over the past twenty years, including the effect of the various Danish action plans for the aquatic environment and the Action Plan for Reducing the Ammonia Emission, as well as improved management practices especially in pig production. A series of environmental policy measures to prevent loss of nitrogen from agriculture to the aquatic environment has been introduced. The measures include improved utilisation of nitrogen in husbandry manure, stricter requirements with regard to storing and application of husbandry manure, increased area with winter green fields to 'catch' nitrogen, as well as ceilings with regard to livestock per hectare and maximum nitrogen application rates in cultivation of agricultural crops. The result of these measures is a decrease in N-excretion and NH_3 emission per animal produced, which has reduced the overall emission of ammonia.

As mentioned above, the main part - nearly 80% - of the emission from the agricultural sector relates to livestock production.

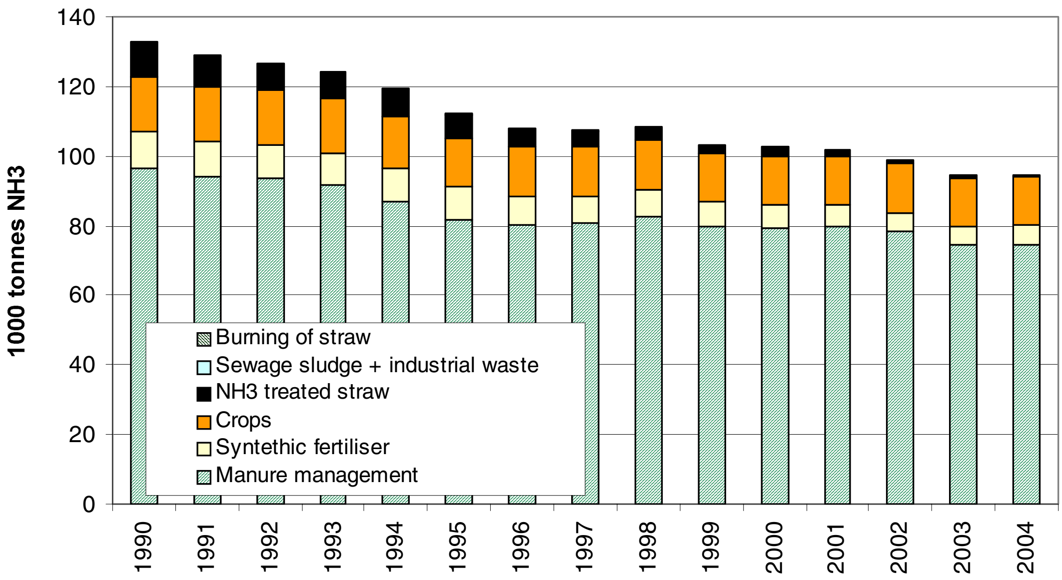

Figure 1 NH_3 emission 1990-2004

In the Gothenburg Protocol under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the EU NEC Directive – National Emission Ceiling (Directive 2001/81/EC), Denmark has committed itself to a maximum ammonia emission of 69,000 tonnes NH_3 or 56,800 tonnes of NH_3-N in 2010. This emission ceiling excludes the emission from crops and ammonia-treated straw. All emission sources except these two are included in the Danish emission inventory. In 2004 the total Danish ammonia emission including emission from traffic and industrial processes, but without emission from crops and ammonia-treated straw, is estimated to 68,500 tonnes NH_3-N.

The projection is an update of the ammonia emission projection in 2002 (Illerup et al. 2002). New emission data, especially for ammonia-reducing technologies, have become available and been implemented in the model, as well as new emission factors for manure application in the field. Several of these data are based on the amount of Total Ammoniacal Nitrogen (TAN) in the manure. The basic emission model (DIEMA) has therefore undergone major changes to include both Total-N emission factors and TAN emission factors. These changes were necessary in order to incorporate the most recent knowledge on emission factors from ammonia-reducing technologies and from field application of manure. The TAN-based model is a prototype that has to be validated further before it can be used in the official Danish ammonia inventory. The official Danish ammonia emission inventory for ammonia in 2004 will therefore be based on the early version of the total-N model; hence, there will be discrepancies between this projection and the officially reported emission for 2004. It is expected that a validated TAN-based model will be available by the end of 2007.

In the projection, effects of the VMPIII are taken into account, as well as expectations to the outcome of the CAP reform in 2004 and a newly launched Danish political decision aiming to further reduce the ammonia emission (Law No. 1572 – December 20, 2006).

The overall effect of the new law is:

- A general requirement for farms undergoing expansion of a reduction 15% in 2007 and 20% in 2008 in relation to the best available stable system for all farms above 75 (LU) livestock units (35 dairy cows incl. heifers, or a pig production of 225 sows, incl. weaners, or a production of 2,700 slaughter pigs).
- Expansion of farms within a buffer zone of 300 metres from ammonia-sensitive habitat areas must not increase the overall ammonia emission.
- Expansion outside the buffer zone but in the vicinity of ammonia-sensitive areas should entail reduction of the ammonia loss per area unit to an agreed extent.
- A general requirement from 2011 a manure injection within 1,000 metres of sensitive areas.

The new law is an issue for political debate in 2006 and is planned to come into force in 2007.

The Danish landscape is fragmented with ammonia-sensitive areas scattered throughout the agricultural farming area. As a consequence many farms with fields within 1,000 metres from sensitive areas will be affected. Calculations have shown that approximately 7% of the agricultural area is within a buffer zone of 250 metres from sensitive areas.

Due to the very rapid structural development in Danish agriculture it is expected that 90% of all livestock will have been subject to the regulation under the new law by 2015. In the near future, there will be a high demand for ammonia-reducing technologies.

Ammonia emission reduction technologies implemented in stables to date, have not been considered in the national inventory due to the small proportion of stables operating with these technologies as well as a lack of official emission factors reported. In this projection expectations from the main producers and importers for the near future are included. In the longer term the expectation from the background material for the new law (http://www.skovognatur.dk/Emne/Landbrug/udrednings_vejledningsrapporter.htm) will be used to estimate possible investments in buildings and technology. For example, it is estimated that farmers with pigs not housed according to Best Available Technique (BAT) will have to invest in ammonia-reducing technologies, and 30 per cent of these will select slurry acidification as a measure, with the remaining 70 per cent choosing to invest in air-cleaning technologies. For dairy cows the most important investment in connection with new building is likely to be flooring with drainage.

Biogasification of slurry has an effect on the ammonia emission from field application of the slurry. This has not been included in previous projections due to lack of emission data. Data are now available and the effect is included in the projection, but no recalculations in the historical data have been made.

The Habitat Directive and the Water Framework Directive will no doubt have an influence on agriculture, especially near vulnerable areas. One of the possible outcomes is to move production units out of the areas and buffer zones around protected habitats to reduce ammonia deposition in the local area. However, this will not have any effect on the overall ammonia emission.

The projected developments have been discussed with experts from the Danish Institute of Agricultural Science, Danish Agricultural Advisory Service, the Danish Research Institute of Food Economics, The National Committee for Pig Production and producers of stable and manure handling equipment.

2 Assumptions

This chapter gives a brief description of the assumptions behind the projection.

- It is assumed that the average livestock feed efficacy level in 2015 corresponds with the level for the present-day efficacy of the 25% best farms for both dairy and pig farms. From 2015 to 2025 a slight increase in feeding efficacy is incorporated in the projection.
- For dairy cows, an increase in milk yield of 180 kg milk per cow per year from 2003-2015 is expected. From 2015-2025 a lower growth rate of 100 kg milk per cow per year is assumed. The milk quota is expected to remain unaltered until 2006, at which point an increase of 1.5 % in the milk quota is expected. From 2006 to 2025 milk production is expected to remain at a constant level.
- N-excretion from dairy cattle is expected to increase from 132.8 kg N per cow in 2004 to 139.3 kg N per cow in 2015 and 150.1 kg N in 2025 due to an increased milk yield and a slightly increased feed efficacy (O. Aaes, Danish Agricultural Advisory Centre, pers. com. 2006).
- Due to the recent constraints within Danish pig production the number of sows has been constant at 1.15 M sows since 2002. No further increase in the number of sows in Denmark is expected in the basic scenario, but due to an increased productivity of 0.3 piglets per sow per year the number of pigs produced will continue to increase. Until 2010 an increase in the export of piglets is expected. This will reduce the number of fatteners produced in Denmark in the short term and the related ammonia emission. In 2005 a production of 24.0 M pigs is estimated. In 2025 the estimated production is 28.8 M pigs.
- N-excretion from slaughter pigs is assumed to be reduced from 3.17 kg N per produced pig in 2004 to 2.70 kg N in 2015 and 2.60 in 2025 (Poulsen et al. 2004, P. Tybirk, The National Committee for Pig Production, personal communication, pers. com. 2005).
- The production of broilers is expected to continue at the same level as today, i.e. about 135 M per year, despite current strong competition from foreign products and low market prices.
- The production of turkeys has decreased within the past year. No major increase in production is expected in the future.
- 93% of pig slurry and 79% of cattle slurry was applied in spring 2005. No major seasonal changes are expected. 15% of the pig slurry and 59% of the cattle slurry was injected into the soil in 2004 (Danish Agriculture, 2004a). The low figure for pig farms is due to a high share of winter green crops where application takes place as hose trailing in growing crops. In 2015 50% of the pig slurry and 75% of the cattle slurry is expected to be injected (T. S. Birkmose, Danish Agricultural Advisory Centre, pers. com. 2005). From 2015 and onwards these percentages are expected to be kept at a constant level.
- The level of implementing ammonia-reducing technologies in stables is restricted to the expectations of the main producers and importers for the next two years. From 2010 new technologies are included to a limited extent (see Section 7 for further details).
- Subsidies for building new biogas plants are restricted to a total energy production of 8 PJ according to the Danish action plan on en-

ergy. This is twice as much as today. However, it may be difficult to find suitable locations and financial investors. Hence, only a 30% increase is expected until 2010 and no further increase in gasification is projected.

- The agricultural area is assumed to decrease by approximately 230,000 ha from 2003 to 2025 – corresponding to 8%. This relates to 30,000 ha of afforestation and establishment of wetlands as planned in VMPIII.

2.1 Calculation methodology

The methodology has been changed in a small number of areas in relation to the annual ammonia emission inventory. Preliminary results from the ongoing revision of the Danish ammonia emission inventory from a total-N based system to TAN (Total Ammoniacal Nitrogen (ammonia and ammonium), are taken into consideration (N.J. Hutchings, Faculty of Agricultural Science – University of Aarhus, pers. com. 2006). For ammonia emission from buildings and storage only minor changes are expected because the new applied emission factors in many cases yield the same ammonia emission as the old system.

As the principles of the two systems are more or less the same, please see Mikkelsen et al. (2004) for a more complete description.

The emission is calculated as the sum of activities (ai) multiplied by the implied emission factor (IEF) for each activity, i.

$$E_{total} = \sum a_i \bullet IEF_i$$

The emissions from the agricultural sector are calculated in a comprehensive agricultural model complex called DIEMA (Danish Integrated Emission Model for Agriculture). This model is very detailed and is used to cover emissions of ammonia, particulate matter and greenhouse gases from the agricultural sector. Figure 2 shows the unit that relates to the ammonia emission.

The ammonia emission related to the livestock production includes about 30 different livestock categories depending on livestock category, weight class and age. Each of these subcategories are subdivided according to stable type and manure type, which results in about 100 combinations of subcategories and stable types (Table 2.1). The emission is calculated from each of these subcategories and then aggregated to main livestock categories.

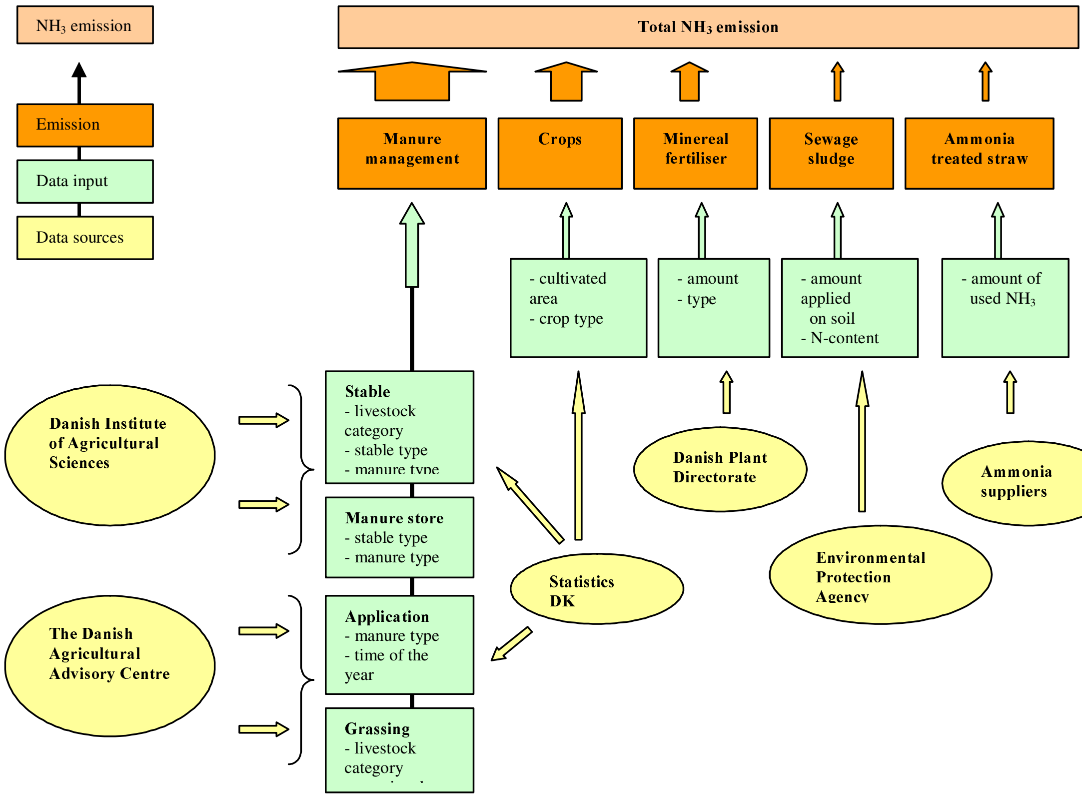

Figure 2.1 DIEMA – NH_3 unit (Danish Integrated Emission Model for Agriculture).

Table 2.1 Livestock categories and subcategories.

Animal categories	Includes	No. of subcategories in DIEMA (animal type/stable system)
Dairy Cattle[1]	Dairy Cattle (large breed and Jersey)	9
Non-dairy Cattle[1]	Calves, heifers, bulls, suckling cattle (large breed and Jersey)	40
Sheep	Lambs	1
Goats	Kids	1
Horses	200 kg, 400 kg, 600 kg, 800 kg	4
Swine	Sows, piglets, slaughter pigs	33
Poultry	Hens, pullet, broilers, turkey, geese, duck	24
Other	Fur farming	5
	Sewage sludge	-

[1] For all cattle subcategories, distinction is made between large breed and Jersey cattle

3 Cultivated area

The agricultural area covers about two thirds of the total land area in Denmark. The general structural development, the focus on nature restoration, environmental considerations and growth in urban areas have all resulted in a continued decrease in the agricultural area. The trend from 1990–2004 shows that the cultivated area has decreased by approximately 140,000 ha, corresponding to 0.35% per year. This development is expected to continue until 2025. In 2004-2015 the cultivated area will decrease by a further 30,000 ha as a consequence of measures included in the third Action Plan for the Aquatic Environment, due to expansion of the forest area, and establishment of wetlands and buffer zones. It is assumed that most of these developments will take place in the agricultural areas. Thus, the cultivated area is expected to decrease from 2,589,000 ha in 2005 to 2,518,000 ha in 2015 and 2,431,000 ha in 2025.

Table 3.1 Cultivated area 1990-2025 (Statistics Denmark and own calculations (*))

Cultivated area	1990	2000	2005	2010*	2015*	2020*	2025*
1000 ha	2,788	2,647	2 ,589	2,576	2,518	2,475	2,431

The Danish ammonia emission inventory takes the emission from crops into account, even though this emission source is not included in the emission ceiling.

In the projection no considerable changes in either the distribution of crop type or set-a-side area are expected. The situation with regard to land use is assumed to be similar to that in 2003 – 77% cash crops, 8% grass/clover in rotation, 7% permanent grass and 8% set-a-side.

4 Livestock production

4.1 Cattle production

Denmark is a milk producing country with a relatively small herd of beef cattle. Hence the national milk quota has a large influence on the number of cattle compared with countries with a large beef cattle herd. The CAP reform in 2005 is assumed to have a minor influence on the Danish milk production (Jacobsen et al. 2003). The EU milk quota is fixed until 2013, but will increase by 1.5% from 2006. A further liberalisation of the world market for meat and milk products may affect the Danish production level because of high Danish productions costs. However, due to skilled Danish farmers and a high technology based agricultural production, milk production is expected to continue at the same level until 2025.

Due to increasing milk yields per cow the number of dairy cattle will decrease. Recent years have shown a yield increase of 150-200 litres per dairy cow per year. This is expected to continue in the future. Until 2015 an increase of 180 kg milk per cow per year is expected. From 2015-2025 a lower rate is expected, corresponding to an increase of 100 kg milk per cow per year. Table 4.1 provides the expected average milk yield and number of cattle until 2025 based on the assumptions mentioned above.

As a consequence of the CAP reform and the Danish implementation of a partial withdrawal of bull premium subsidies, the production of suckling cows is expected to decrease by 15% until 2010 (Jacobsen et al, 2003). From 2010 a further decrease may be possible. However, as a result of the Habitat Directive and the Water Framework Directive, a demand for grazing areas to protect nature areas will increase in the future. Thus, the production level of suckling cattle is assumed to remain unaltered from 2010-2025.

Table 4.1 Expected development in milk yield and cattle production (Statistics Denmark and own calculations (*)

	1990	2000	2005	2010*	2015*	2020*	2025*
Milk yield							
(kg milk/cow/yr)	6,200	7,300	8,200	9,200	10,100	10,600	11,100
No. of cattle (1000 heads)							
Dairy cattle	753	636	558	516	470	449	428
Other cattle	1,399	1,108	888	880	802	766	730
Suckling cattle	87	125	98	95	95	95	95
Cattle, total	2,239	1,868	1,544	1,492	1,367	1,310	1,253

The number of calves, heifers and bulls are expected to decrease proportionally with the reduction in dairy cattle. The new technology allowing the genetic screening of sex in calves could influence the number of heifer and bulls produced in the future. However, it is assessed that these screening possibilities would only have a minor influence on the total emission as bulls contribute with just 10% of the total emission from cattle.

Table 4.2 N-excretion for dairy cattle (Aes 2005)

N-excretion (kg N/cow/yr)	2000	2005	2010*	2015*	2020*	2025*
Large breed	128.0	134.5	135.2	139.3	143.7	150.1
Jersey	105.8	111.1	112.0	116.0	120.3	126.4

4.1.1 Cattle, N-excretion

An increase in milk yield normally follows an increase in fodder consumption and produces a higher ammonia emission per cow. However, this can be compensated with improvements in fodder efficacy.

The Faculty of Agricultural Science, University of Aarhus, has made a projection of the potential for reducing nitrogen excretion based on research results and future progress (Poulsen et al., 2004). Depending on the development of milk yield and fodder composition, the interval of N-excretion in 2010 is expected to be 118 – 136 kg N per dairy cow. In 2015 the average milk production of 10,600 kg per cow is assumed. Combined with an expectation of an average level in fodder efficacy corresponding to the 25% best farmers today (fodder efficacy of 89% and albuminoidal-content of 128 g per fodder unit), it is possible to reduce the N-excretion in 2015 to 127,1 kg N per dairy cow (P. Lund, Faculty of Agricultural Science – University of Aarhus, pers. com. 2005). The N-excretion rate, however, is likely to differ from this in practice. Ole Aaes (Danish Agricultural Advisory Centre, pers. com. 2006) has estimated N-excretion to 139.3 kg N for large breeds in 2015 as a more appropriate figure, taking into account increased feed efficacy (Table 4.2). The figures in Table 4.2 may be overestimated but are used in the projection, because the actual excretion rates from 2000 to 2005 have shown a steady increase and no signs of reduction.

For other cattle no changes in N-excretion rates are foreseen.

4.1.2 Cattle – allocation of stable type

In 2003 6% of dairy cattle are estimated to be tethered in production systems with solid manure. This system is expected to become outdated within 3-4 years. In the future most dairy cattle will be placed in loose-housing systems with slurry-based systems, with only a small fraction still being housed in deep litter systems. The fraction on deep litter is assumed to decrease slightly after this point. Drained floors with low emission rates in loose-housing systems with dairy cattle are expected to increase rapidly so that 60% of the dairy cattle will be housed on this flooring type in 2025.

In the future bulls and beef cattle are expected to be raised in loose holdings on deep litter.

4.2 Pig production

The future Danish pig production is much more unpredictable than the production in the dairy sector. The Danish pig production has increased by 2.0% per year since 1990. More than 80% of the production is exported. This is a result of efficient Danish pig breeders, high sanitary standards and high dollar exchanges rates.

The Danish Research Institute of Food Economics (Jacobsen et al. 2003) has, in a study, used an increase in the Danish pig production of 1.3% per year from 2001-2010. A recent study on the effect of the CAP reform indicates an increase in the EU pig production of 1.5%, which makes the Danish estimates plausible. The projection from the European Environment Agency (EEA) does not give figures for the individual member states.

During the last three years there have been a constant number of sows at 1.15 M in Denmark. However, the production of fatteners has increased due to an increased productivity per sow. During the last three years the export of weaners has increased rapidly. In 2004 the export of weaners was estimated to 1.9 M head (The Danish Pig Meat Industry, 2005). An export of nearly 4.0 M piglets is expected in 2006. In 2010 the projected export is 5 M head of weaners per year. 12.5% of these are assumed to be exported at 7 kg/head (F. Udesen, The Danish Pig Meat Industry, pers. com. 2006).

The combination of strict Danish environmental requirements, high prices on agricultural land for manure application, slow administrative procedures, high Danish labour costs, the recent low dollar/EURO exchange rates and no immediate indication for higher exchange rates, combined with high export ratios to low world market prices outside the EU, have led to stagnation in the Danish production of fatteners. The long-term consequences for Danish pig production in this context are difficult to estimate, but the short-term effect is an immediate decrease in the production of fatteners in Denmark. In 2005 the number of pigs slaughtered in Denmark decreased by 2.5% compared with 2004; however, the average slaughter weight increased by 2.7%. As a result the total meat production increased slightly, giving an almost unaltered ammonia emission.

The increasing export of weaners to the Netherlands, Germany and Poland for fattening is explained by difficulties in obtaining building licences. Increasing requirements in relation to environmental and nature considerations, e.g. VMPIII, the expected new regulation on agricultural farms, the Habitat Directive and the Water Framework Directive can further restrain the development of the pig production. The expansion of pig production, especially near vulnerable areas, will be met with increasing demands in relation to maintenance or reduction in the levels of odour and the ammonia emission itself. Altogether this will reduce the number of slaughter pigs produced in Denmark in the near future. High labour costs in Danish slaughterhouses compared with other European countries are leading to higher export of fattened pigs for slaughter abroad. The export of fattened pigs is included in the current projection estimates because the production takes place in Denmark.

Table 4.3 Pig production 1990-2025, Basic scenario (Statistics Denmark, 2003 and own calculations (*)).

	1990	2000	2001	2005	2010*	2015*	2020*	2025*
Sows (M)	0.9	1.1	1.15	1.15	1.15	1.15	1.15	1.15
Number of weaners exported				5.0	5.0	5.0	5.0	5.0
Produced no. of slaughter pigs per year (M)	15.9*	22.7*	23.1*	24.0*	25.3	26.8	28.3	29.8
Live slaughter weight	98	100	100	102	103	104	104.5	105

In the basic scenario a constant number of 1.15 M sows is estimated to 2025 (Table 4.3), and an increase in the export of weaners is estimated to 5 M in 2010. Of this export, 12.5% is assumed to be exported at 7 kg/head and the remaining at 30 kg/head. The improved genetic development and management in the pig production results in more piglets produced per sow. Based on the development over the previous ten years, an increase of 0.3 piglets per sow per year until 2025 is assumed. This corresponds to an average production of 26.8 piglets per sow in 2015 and 29.8 in 2025.

Table 4.3 shows the key figures for pig production from 1990 and the excepted development until 2025 in the basic scenario. The level in 2015 corresponds to the average production of the 25% best farmers in 2004, which by the National Committee for Pig Production is expected to be the average production for all pig farmers in 2015 (Hansen et al. 2005, Udesen et al. 2005). The average live weight of slaughter pigs is assumed to increase from 100 kg in 2001 to 104 kg in 2015 and 105 kg in 2025.

It should be noted that the number of slaughter pigs produced includes all pigs that contribute to the ammonia emission by way of manure – e.g. discarded and dead pigs are included.

4.2.1 Pig, N-excretion

Studies by the Danish Institute of Agricultural Science and the National Committee for Pig Production show possibilities with regard to further reduction in N-excretion by means of improvements in fodder efficacy – reducing the content of protein and adding essential amino acids.

The potential reduction in N-excretion can be expressed by the difference between the most and the least effective farmers. In 2004 the level of N-excretion for the best farmers was 2.6 – 2.7 kg N per slaughter pig of 30 to 102 kg live weight produced (Tybirk, P., The Danish Pig Meat Industry, pers. com. 2006). The National Committee for Pig Production expects an excretion level of 2.6 kg N as the average production in 2015 (Hansen et al., 2005). The expectation from the Faculty of Agricultural Science (University of Aarhus) is an N-excretion of 2.9 kg N in 2010 (Poulsen et al., 2004). Based on these assumptions an N-excretion of 2.7 kg N per produced slaughter pig in 2015 and 2.6 kg N in 2025 is assumed.

Table 4.4 N-excretion for sows and slaughter pigs (Poulsen et al. 2001 and own calculations(*))

N-excretion (kg N/ produced pig/yr)	2000	2005[1]	2010*	2015*	2020*	2025*
Sows	26.39	27.2	26.38	25.81	25.17	24.52
Slaughter pigs[2]	3.13	3.19	2.93	2.70	2.65	2.60
Piglets	0.64	0.63	0.56	0.55	0.55	0.55

[1] Normative figures 2004 (DJF 2005)

[2] The increase from 2000 to 2004 is due to an increase in the slaughter weight from 100 to 102 kg.

Poulsen et al. (2004) assume that for sows it is possible to reduce the N-excretion per sow from 27.2 kg N per sow in 2004 to 21.1 kg N per sow in 2010. This is a very high reduction, which may not be achieved. During the last four years (2000 to 2004) the average N-excretion has increased from 26.39 kg per sow per year to 27.2 kg. Due to the increased number of piglets per sow and an expected increase in feed productivity, an overall decrease of 5% in N-excretion is assumed from 2004 to 2015, and a further 5% from 2015-2025 (Table 4.4). This gives an N-excretion per sow in 2015 of 25.81 kg N per sow per year. For piglets a reduction from 0.58 kg N/pig to 0.55 kg N/pig is assumed (Danish Agriculture 2004b).

4.2.2 Pig – allocation of stable type

Today 70% of all sows and almost all weaners and fattening pigs are on slatted floors. No major changes are expected for sows and weaners. An EU directive (Directive 91/630/EEC) on animal welfare states that fully slatted stables are to be phased out. The stable type will probably be replaced with drained floors. The emission factor for drained floors is only slightly lower than for fully slatted and hence it has only little influence on the emission. The ammonia emission factor from partly slatted floors is half that for fully slatted flooring.

Farrowing houses and weaning stables have a need for heating. The heat may be taken from other stable sections with heat surplus where it has a cooling effect that lowers the ammonia emission from the stable. It is expected that within the next 10 years 25% of gestation stables will have this technology. Grøn (2005) has estimated that 50% will have this technology in 2015, but this figure is assumed to be too optimistic.

The main driving forces are the energy prices and the heating needs in the other sections, thus the heating may also be provided by straw or other biomass products produced on the farm. Cooling is a BAT technology (Best Available Technology). Cooling is claimed to reduce the ammonia emission by 30% if the system is used throughout the year (DAAC 2005), e.g. also in periods where there is no need for heating in the farrowing sections. In the projection it is assumed that cooling is used for 50% of the year in the whole gestation unit. According to Poulsen et al. (2001) 2/3 of the excretion from sows is from the gestation units. If the whole gestation stable is established with cooling systems, the overall effect of cooling will be a reduction in the emission from stables with sows of 10% compared with stables with no cooling system (2/3 of manure production * 0.5 * 0.3 = 0.10). This value should be further validated.

4.2.3 Poultry

The Danish broiler production in 2005 is approximately 180 M kg per year or equivalent to 130-135 M produced broilers. No significant changes have been seen for the last five years. Jacobsen et al. (2003) assume an increase of 1.7% per year from 2001-2010 for all poultry as a whole. This rate seems to be too high considering that the broiler production over the past five years has been stagnant, and so has the egg production. The production has been influenced by the outbreak of Newcastle disease, increasing competition from the Far East and cheaper imported eggs. The Danish Poultry Council expects an unaltered production in the future (Jensen, H.B., Pers. comm. 2006), and this expectation is used in the projection.

For hens and pullets an increase of 0.8% and 0.7% per year, respectively, is assumed until 2010 (Jensen, H.B., The Danish Poultry Council, pers. com. 2006). A slower growth rate (half) is assumed from 2010-2025.

The production of turkeys has ceased in the last two years with limited production taking place in the existing buildings and export of live turkeys for slaughter in Germany. It is not expected that a competitive increase in the production will take place in Denmark in the future.

Other poultry such as ducks and geese are of minor importance for the total ammonia emission and no significant changes are foreseen.

The development in N-excretion rates has remained unaltered for poultry in recent years, indicating that it may be difficult to bring about reductions by changes in fodder composition (Poulsen et al., 2004). No future changes in the N-excretion for poultry are expected in the projection.

For broilers no changes in stable type are assumed. In connection with egg layers, caged hens are not allowed and these will probably be replaced with hens in welfare cages. Due to this change, no major changes in the emission factors are foreseen.

4.3 Other

Denmark is one of the market leaders in the production of fur from mink. In total there are approximately 2.5 M female mink in 2004 producing 12.6 M furs.

In accordance with the prognosis performed by Jacobsen et al. (2003) the production of mink is expected to increase by 1.5% per year from 2004-2010. From 2010-2025 a lower growth rate of 0.5% per year is assumed. The number of mink is estimated to 2.7 M in 2015.

Sheep and goats are of minor importance in Denmark. It is assumed that the number of sheep and goats will increase slightly. The number of horses is estimated to 155,000 in 2004 and this includes horses on small farms and in riding schools. The number of horses is assumed to increase to 167,000 in 2015.

4.4 Storage

Today, by law all slurry tanks have to be covered either with solid covering or natural crusting.

The new law indicates that all slurry tanks built after 1 January 2007 within 300 metres of neighbours and ammonia sensitive areas are required to be established with solid covering (concrete or tent) unless acidification of the slurry takes place. It is difficult to estimate the effect of this regulation, because in many cases it is possible to establish new slurry tanks in the field, more than 300 metres away from sensitive nature. The emission factor from covered slurry tanks is 50% of that of tanks with natural crusting. The lower emission from the storage will increase the nitrogen content in the manure and consequently increase the emission from manure application. The overall effect of the requirements for solid covering on the ammonia emission may, therefore, be difficult to estimate, and may even be limited. The total ammonia emission from liquid storage in 2004 has been estimated to 3,624 tonne NH_3-N. The maximum effect of solid covering can then be estimated to approximately 1,800 tonnes NH_3-N/year. In the projection it is assumed that 25% of the storage capacity will have solid cover in 2015 with 50% in 2025.

4.5 Application of manure

In 2004 the ammonia emission from manure application is estimated to 19,800 tonnes NH_3-N, which is equivalent to 25% of the total ammonia emission. The total amount of N applied to the field is estimated to 200,900 tonnes N giving an overall emission rate from manure application of 9.9%.

The methodology for estimating the ammonia emission in the national inventories is based on the amount of total N applied to the field independently of origin of animal type but at different times of the year. This model has some drawbacks, because it does not take into account differences in ammonium content between animal types and changes in the ammonium content in the manure due to the changed feeding strategies. However, the methodology and its time resolution have shown a very high correlation between the estimated temporal emission and the measured ammonia air concentrations (Gyldenkærne et al., 2005, Ambelas Skjøth et al., 2004). This indicates that the temporal distribution in the methodology is very good. However, it is not possible, from the verification, to validate the absolute emission in quantitative terms. In a joint European project (Sogaard et al. 2002) several research institutes pooled the ammonia emission data they had from manure application and made a regression model, which takes into account differences in application method (www.alfam.dk). The model is based on the ammonia content of the manure in contrast to the model currently used. The Faculty of Agricultural Science (University of Aarhus), who is responsible for the model development, is planning to change the emission factors used in the national emission estimates in 2007.

There is a large deviation between the model currently used and the ALFAM model (Andersen et al., 2005). Especially the emission estimates for manure application in the month of May have been over-estimated in the current model. Andersen et al. (2005) estimated a difference between the two models of 6,000 tonnes per year. Because the ongoing work with the changes to the model has not yet been validated and because it will have a significant influence on the ammonia emission estimates, a simplified version of the new model has been developed for this projection.

Figure 4.1 shows the approximate old emission rates for slurry used in crops while they are growing (solid line, converted to per cent of ammonia content) and the new approximate estimates for pig and cattle slurry based on ALFAM. As can be seen the expected new emission factors are approximately 50% of that produced by the former model. For slurry application on bare soil only minor changes in the emission rates are expected.

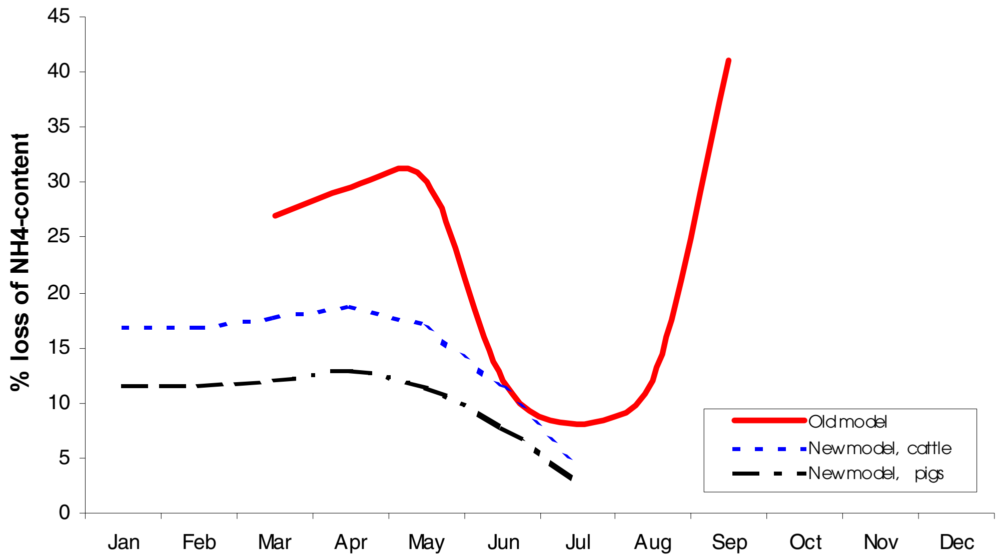

Figure 4.1 The old and new estimates for ammonia emission from slurry application in growing crops. Ammonia loss is given in % of TAN applied.

In the case of slurry application on bare soil in spring and autumn (primary August), the new emission factors are expected to increase compared to the emission factor used in the previous inventory.

For solid manure a 10 per cent increase in the emission factors is expected with the conversion to a TAN-based system.

4.5.1 Application time and methods 2004 to 2025

In the former version of DIEMA there is no difference in the emission factor between cattle and pig manure. The emission factors used in the earlier version can be found in Mikkelsen et al. (2004). An analysis made by Danish Agriculture in 2004 (Danish Agriculture, 2004a) showed that 79% of cattle slurry was applied in spring and for pig slurry, 93%. 54% of cattle slurry and only 15% of pig slurry was injected. The share of injected cattle slurry is expected to increase to 75% in 2015 and for pig slurry the proportion is 50% (Birkmose, T.S., Danish Agricultural Advisory Centre, pers. com. 2005). This is mainly due to the structural development in Danish agriculture towards larger farms with the potential of buying more efficiently developed injection technologies. Other reasons for this development are the increasing political requirements, e.g. in 2011 all manure applied to bare soil and grassland will have to be injected. The current low share of injected pig slurry is explained by the high specialisation rate in Danish agriculture and the high demand for winter annual crops, not leaving much room for bare soil application. Incorporation in cereal crops while they are growing is not economically feasible with the current technology and economical situation.

In Table 4.5 and 4.6 the estimated emission factors for different times of the year are shown in relation to application methods. The emission factors are estimated from the ALFAM model (Appendix 1) and from Sommer and Hansen (2004). Furthermore, the assumed distribution of the different application methods and timing of the year in 2004, 2010 and 2015 are provided. For 2016 to 2025 the same application pattern as in 2015 is assumed.

The annual average emission factor (Table 4.7) for cattle slurry with the new model is 10.4% of TAN in 2004. This average emission factor is expected to be reduced to 10.1% in 2015. For pig slurry the values are 11.8% in 2004 and 10.9% in 2015. The reductions are mainly due to increased injection of slurry and only to a lesser extent to changed seasonal patterns. For solid manure major changes are foreseen, because a faster incorporation into the soil is expected. Solid manure covers only a small amount of the manure (6-8%). The effect of slurry acidification also affects the ammonia emission from manure application. The expected increase in acidification is included in the overall emission factor from manure application.

For manure from horses, sheep, goats, poultry and mink emission data and application data from cattle are used.

The change from the total-N to the TAN-based system generally lowers the emission from slurry and increases the emission from solid manure.

Table 4.5 Emission factors for cattle slurry and solid cattle manure (% of TAN) and the distribution of application in per cent.

Manure type	Method	Crop	Time	Incorporation	Emission, % of TAN	Application, %		
						2004	2010	2015
Liquid	Injection	-	Winter-spring	-	1.9	34	39	40
		+	Winter-spring	-	15.9	8	14	19
		-/+	Summer-autumn	-	15.9	11	13	15
	Trailing-hose	-	Winter-spring	< 6 hours	10	10	5	5
		-/+	Winter-spring	No	19.6	25	19	15
		+	Spring-summer	No	19.6	3	3	2
		+	Summer-autumn	No	19.6	4	4	2
		-	Summer-autumn	< 6 hours	12	5	3	2
Solid	Broad-spread	-	Winter-spring	< 6 hours	27.9	56	63	65
		-	Winter-spring	> 6 hours	39.0	14	8	0
		+	Winter-spring	No	64.5	11	4	0
		-	Summer-autumn	< 6 hours	16.5	19	25	35

Table 4.6 Emission factors for pig slurry and solid pig manure (% of TAN) and the distribution of application in per cent.

Manure type	Method	Crop	Time	Incorporation	Emission, % of TAN	Application, %		
						2004	2010	2015
Liquid	Injection	-	Winter-spring	-	1.3	13	15	15
		+	Winter-spring	-	9.6	0	14	27
		+	Summer-autumn	-	9.6	2	3	3
	Trailing-hose	-	Winter-spring	< 6 hours	6.9	15	6	5
		-/+	Winter-spring	No	13.5	60	54	43
		+	Spring-summer	No	13.5	3	3	3
		+	Summer-autumn	No	13.5	3	3	3
		-	Summer-autumn	< 6 hours	8.3	3	2	1
Solid	Broad-spread	-	Winter-spring	< 6 hours	27.9	56	63	65
		-	Winter-spring	> 6 hours	39.0	14	8	0
		-	Winter-spring	No	64.5	11	4	0
		-	Summer-autumn	< 6 hours	16.5	15	25	35
		-	Summer-autumn	No	64.5	4	0	0

Table 4.7 Annual average emission factor for cattle and pig manure (% of TAN) in 2004, 2010 and 2015 with the new model. For 2015 to 2025 the same emission factors as in 2015 are used.

		Average emission factor		
		2004	2010	2015
Cattle	Slurry	10.4	10.3	10.1
	Solid	18.2	15.3	13.8
Pigs	Slurry	11.8	11.7	10.9
	Solid	16.5	14.8	14.0

5 Mineral fertiliser

The total consumption of mineral fertiliser depends on the nitrogen content in manure, requirements for nitrogen utilisation in manure and the size of the area under cultivation. Since 1985 the use of mineral fertiliser has been halved and this trend is expected to continue.

5.1 Nitrogen utilisation

With reference to the Danish action plan for the aquatic environment (VMPIII) and the object of reducing nitrogen leaching by 13% before 2015 compared to 2003, it will probably be necessary to implement further requirements with regard to the utilisation of nitrogen in manure of a further 4.5-5% per cent. In this project is it assumed that:

- the nitrogen utilisation in slurry from fur farming will increase from 60% to 70% in 2005.
- implementation of further 2.5 per cent from 2009 takes place.
- implementation of further 2 per cent from 2012 takes place.

Table 5.1 shows the percentage of nitrogen, which is to be incorporated in the nitrogen accounts from 2012.

5.2 Consumption of mineral fertiliser

The consumption of mineral fertiliser depends on the amount of nitrogen in the manure that has to be incorporated in the farmers' nitrogen accounts (N ab storage). Because no major changes are expected in crop type distribution and the maximum N application rate in the future, an average application rate of 140 N per ha is used to estimate the future consumption of mineral fertilisers. The estimated consumption is estimated as the total area multiplied by 140 kg N minus N reported in the nitrogen accounts.

Table 5.1 Utilisation rates for nitrogen in manure from 2012.

	Solid	Liquid	Slurry	Deep litter
Horses	65 %	65 %	65 %	45 %
Cattle	65 %	65 %	75 %	45 %
Sheep and goats	65 %	65 %	65 %	45 %
Pigs	65 %	65 %	80 %	45 %
Poultry	65 %	65 %	65 %	45 %
Fur farming	65 %	65 %	75 %	45 %

Table 5.2 The consumption of mineral fertiliser 2003-2025 (Statistics Denmark, own calculation (*)).

	2004	2010*	2015*	2020*	2025*
			M tonnes N		
N in manure (N ab animal)	271*	238	220	223	237
N in nitrogen accounts	134*	141	136	137	146
N in mineral fertiliser	207	204	202	194	180

6 Other emission sources

6.1 Other agricultural sources

Today half of the sewage sludge produced is deposited on agricultural soil. The amount of sewage sludge applied to soil decreased from 112 M kg sludge (dry matter) to 81 M kg in 2004. A further decrease to 60 M kg in 2015 and 55 M kg in 2020 is assumed.

Ammonia is used to conserve straw used for fodder. A ban on ammonia treatment of straw was formulated in the Ammonia Action Plan and became effective from 1 August 2006 (BEK nr. 815 af 20/07/2004).

The ammonia emission from both the sewage sludge applied to agricultural fields and emission from ammonia-treated straw has a minor effect on the total emission – approximately 1%.

6.2 Traffic

Traffic accounts for 2,000 tonnes NH_3-N in 2004 or 3% of the total Danish ammonia emission. The ammonia is formed in the catalytic converters in cars. Due to improved catalyst technology no change in the total amount emitted is foreseen, despite expectations of an increased number of cars.

6.3 Other point sources

Other point sources from industrial processes, e.g. production of glass wool, catalysts and fertiliser are, in 2004, estimated to 500 tonnes NH_3-N. No changes in these emissions are foreseen.

7 Technologies which affect the ammonia emission

The new animal husbandry law (Law No. 1572 – December 20, 2006) is expected to have an effect on the number of farms investing in ammonia emission reduction technologies. According to the political agreement the ammonia emission is required to be reduced by 15% in 2007 and 20% in 2008 compared with 2003-levels. These targets cannot be reached without large investments in new stable types and in ammonia-reducing technologies. In the following a short description of the different technologies is provided as well as the expected implementation rates. In the background paper for the new law three scenarios for ammonia reduction have been discussed, each of which involving introduction of a certain number of ammonia-reducing technologies. In this projection a medium-tech scenario is used.

7.1 Principles

Animal manure contains organic bound nitrogen (mostly in faeces) and inorganic nitrogen as ammonium (in poultry: uric acid). Ammonium (NH_4+) in animal manure is a waste product from the protein turnover in the body. Ammonium is excreted as urine by the kidneys. In an aquatic solution NH_4+ is in equilibrium with NH_3. In an aquatic solution NH_3 evaporates but not the NH_4+. When NH_3 evaporates, more NH_3 will be formed, which again evaporates, and so on.

The equilibrium state depends on the pH of the solution. At low pH the major part of the nitrogen is in the form of NH_4+. At high pH the major part is NH_3. At pH 9.25 (the pKa-value) half of the nitrogen is represented by NH_3 and the other half by NH_4+. How fast the evaporation takes place depends on the temperature and the air speed above the solution. The lowest NH_3 evaporation is therefore obtained as a combination of a small amount of excreted TAN, low pH values in the manure, a minimum wet surface area from where the evaporation can take place (e.g. slats, driving paths, slurry canals, slurry tanks, surface area during application in the field, etc.) as well as low temperatures and low air speed over the wet areas.

In principle ammonium-reducing technologies represent attempts to reduce the pH in the manure to secure:

- that the nitrogen is in NH_4+ form (slurry acidification, air cleaners – here only sulphuric acid (H_2SO_4) is used as acidifier)
- reduction of the surface where manure is deposited and stored (partly slatted floors, floor scrapers)
- lowering of the temperature of the slurry until better controlled storage conditions are possible (slurry cooling)
- reducing the air speed over the surface (in slurry canals and slurry tanks with crust)

7.2 Technologies

The following provides a short description of the principles of the most widely known technologies available today. A more detailed description can be found on the homepages of the different producers and on www.vmp3.dk.

7.2.1 Cleaning of the air output

Air cleaning can be carried out by replacing the existing ventilation system with new ventilators where the air passes through an aquatic suspension with sulphuric acid (Landscentret 2002, Landscentret 2005). In a water bath the NH_3 is reduced to NH_4+ and collected in the water (ScanAirclean, www.scanairclean.dk). The efficacy of these systems is generally high (up to 90%). In practice the overall efficacy is lower (approx. 60%) because some air escapes without having been cleaned. Moreover, these systems only have limited effect on odour. In new stables it is possible to built central channels that collect the air to achieve a higher efficacy. The latter principle is used in the air cleaners from SKOV (www.skov.dk). In the SKOV central canal system the air passes through a membrane where the NH_3-concentration in the air emitted from the plant is reduced to 2 ppm $NH_{3,}$ which under average conditions in Danish pig stables gives a 70% reduction of ammonia (Danske Slagterier 2004).

Air cleaning is only relevant in pig and poultry stables as cattle stables often are open barns with natural ventilation.

By the end of 2005 approximately 30 units with 125 livestock units (LU) each will be in operation in Denmark. Consulting producers and importers foresees an increased demand in the years to come. By the end of 2008, 180 units are estimated to be in operation. In a medium-tech scenario this number is expected to increase until 2025 with 112 units with 125 LU/year; 104 units for slaughter pig and sow stables, and 8 units for poultry farms. In 2025 it is projected that approximately 50% of the pig and broiler production will be using the new air cleaning system.

7.2.2 Slurry acidification

In slurry acidification units 93% sulphuric acid (H_2SO_4) is added to the raw slurry in a small storage tank. pH is then reduced typically from 7.5-8.5 to pH 5.5. Approximately 4-6 kg H_2SO_4 is used per tonne slurry. At pH 5.5 only 3% of the TAN is in the form of NH_3 and the remaining appears as NH_4+. The change in pH is almost permanent and hence the ammonia emission during storage and field application is low too. In existing Danish units the acidified slurry is used to flush the slurry canals in the stables in order to reduce the pH in slurry inside the stables. This lowers the emission from the stables. Overall, acidification reduces the ammonia emission by 55-60%. However, acidification, changes the structure of the slurry, making it more difficult to form a natural crust, which may increase the ammonia emission from storage. This is not included in the projection since it is mandatory either to have a solid cover or a crust on the slurry tanks. The plant uptake of nitrogen from acidified slurry may be higher than the uptake from raw slurry. This is probably due to the changed slurry structure. In the calculation of the consumption of mineral fertiliser, an increased utilisation rate in acidified slurry is not taken into account.

Acidification may take place in slurry-based systems in both cattle and pig stables as well as in slurry-based systems with mink.

In Denmark there is only one producer of slurry acidification systems, namely Infarm A/S. According to Infarm A/S, 30 units of approximately 300 LU each will be installed by the end of 2005. This number is expected to increase by 15 units in both 2007 and 2008. From 2014 and onwards an increase of 40 units of 300 LU each year is assumed in a medium-tech scenario. The assumed distribution between animal types is eight units in sow stables, 15 in slaughter pig stables, 15 in dairy cattle and two in mink farms. In 2025 it is projected that 26% of all slaughter pig stables will be equipped with acidification systems; the number is 12% for sow stables and 13% for cattle stables.

7.2.3 Slurry separation

Slurry separation into a solid and fluid fraction takes place on some farms in an attempt to reduce the phosphorous surplus at farm level. Approximately 80% of the nitrogen is found in the fluid fraction and 20% in the solid (Sørensen, 2003; Hinge, 2005). For pig slurry, approximately 80% of the nitrogen in the fluid fraction is TAN (Sørensen, 2003, Hansen et al. 2004) and the level in cattle slurry is approximately 67 %.

Separation may not have an effect on the emission from storage. However, formation of a crust is impeded; hence, until further notice the ammonia emission factor is doubled compared with untreated slurry (from 3% to 6% of TAN). The separated fluid fraction infiltrates faster in soil after application, leading to a lower ammonia emission (Sørensen, 2003; Hansen, 2004). This is estimated to 76% of the emission from untreated slurry.

The ammonia loss from the solid fraction during storage is assumed to be 3% of TAN (Hansen et al., 2004).

Today there is no market for the solid fraction from separated slurry other than as input to biogas plants.

No figures are available on the current amount of separated slurry in Denmark, although it may be limited. In the projection it is assumed that up to 1.8 % of the slurry will be separated in the future. Because the solid fraction only contains a small amount of TAN, the influence on the ammonia emission from the solid manure in the overall emission is limited.

7.2.4 Biogas plants

Biogas plants are built as both farm units and joint enterprises. Today biogas plants are very complicated. To achieve the optimum output of the resources and project management, it is expected that future biogas plants primarily will be large-scale joint enterprises. The following description comprises, therefore, only large enterprises where the slurry/deep litter/separated manure is transported in pipelines each day, or once or twice a week in lorries. Some plants receive both raw slurry and the solid fraction after slurry separation to increase the overall efficacy. After treatment in the biogas plants the manure is returned to the farmers. To increase the overall output, input of solid manure or the solid fraction from slurry separation may be added at the plants.

Until now the residual after gasification are returned to the farmers. The ongoing revision of the husbandry manure regulations will probably make it possible to burn the solid fraction after gasification in local incineration power plants to obtain energy.

Biogas treatment has several impacts on the ammonia emission (Sommer 1997). Storage conditions are changed; the first step in the biogas treatment is a hygienisation of the slurry at 70°C, which increases the ammonia emission. In this process some of the ammonia evaporates and may be collected by air strippers. The collected ammonia may be returned to the farmers in the returned slurry or sold to industry. Here, it is assumed that all ammonia is returned to the slurry and back to the farms. After treatment in the fermentation unit the slurry has a higher pH value, around 8.1 to 8.5, which may increase the ammonia evaporation during storage. This is taken into account for slurry returned to the farmers by increasing the volatilisation rate from treated slurry from three per cent to six per cent of TAN (Sommer, 2004).

After gasification, the slurry is more fluid and infiltrates faster into the soil. This is not incorporated in the existing inventory. The emission from slurry, which has undergone gasification, is estimated to be 80% of that from untreated slurry (Hansen et al., 2004). This value is higher than separated slurry due to the higher pH value in the slurry treated at the plant.

The amount of slurry treated in biogas plants in 2004 has been estimated to 1.8 M tonnes slurry. 55% is from pigs and the remaining is from cattle (Tafdrup, S., Energistyrelsen, pers. com., 2005). No figures on the amount of the solid fraction from slurry separation input to the biogas plants are available.

Two large biogas plants are approved for construction at the moment (Bornholm and Ærø). The two plants are planned to be operational in 2006 and 2007, respectively. A large plant is planned in Maabjerg, Jutland. This plant is planned to be operational by the end of 2008 with a capacity of 25,000 LU. All the plants are planning to increase the biogas production by addition of the solid fraction from slurry separation.

It is difficult to give an estimate of future developments for manure treated in biogas plants. The energy policy strategy (Energi, 2004) will give economic subsidies to an annual production of up to eight PJ. This represents an approximate doubling of the capacity today. Several barriers, including the economy and location of the plants, will hinder expansion and it may be questionable whether a doubling will take place by 2010. In the projection, an increase of 30% in the amount of slurry digested in biogas plants is assumed, equivalent to the capacity of the three planned plants. After this, no further increase is assumed. Adding solid separated slurry fractions or deep litter into biogas plants may be common practice to increase the energy yield. These fractions may contain limited TAN nitrogen and the ammonia emission will alter. However, this is not taken into account in the projection.

7.2.5 Manure burning

The ongoing revision of the husbandry manure regulations is likely to legally allow burning of manure for energy production. This could be of interest to farms with limited access to land for manure application, e.g. pig farms in areas dominated by intensive husbandry and for solid poultry manure. Raw slurry is not assumed to represent a source because of its high water content, whereas the solid fraction after slurry separation or the separated fraction after gasification may be burned. The effect on the ammonia emission from burning the solid fraction after slurry separation is expected only to have limited effect on the ammonia emission, as the major part of the nitrogen is organically bound. The largest impact on the ammonia emission, therefore, comes from the burning of poultry litter, which has a high nitrogen content. As long as the burning of poultry manure is not allowed and no incineration plants are built, no estimates for the future will be made. The total ammonia emission from poultry litter in storage and from application is estimated to 1,300 tonnes NH_3-N/year in 2004.

The solid fraction after gasification in biogas plants contains a small amount of nitrogen that is lost when incinerated. This is not taken into account in the projections, as it is assumed to have very little overall effect on the total ammonia emission, and furthermore it is assumed that it will be counteracted by a higher consumption of mineral fertiliser.

8 Results/Conclusion

The current emission model used in the official reporting is under revision, converting from use of a totally nitrogen-based model to a TAN-based model. New knowledge on emission factors for animal manure obtained in recent years has confirmed the need for the revision. It is estimated that the currently used model over-estimates the official ammonia emission bound organically by approx. 5-6,000 tonnes NH_3-N/year. The official estimates are expected to be most biased in the current period. This is due to the fact that the bias mainly concerns manure application with trailing hoses in spring and this application method is at its maximum right now. At present 93% of pig slurry is applied in spring and no further increase is expected. This method of application is expected to decrease in the future and it will be replaced by a higher proportion of manure injection. The ammonia emission from other sources than animal manure will not be changed in the current revision.

By the end of 2007 an updated inventory model will be available. For the purpose of this projection, however, a preliminary model has been developed. Some elements are still missing, but the major expected changes have been incorporated.

In Figure 8.1 the previous reported ammonia emission from animal husbandry from 1985 to 2004 is shown as well as the estimated ammonia emission with the preliminary model until 2005. The official reported ammonia emission from animal husbandry in 2004 is estimated to 61,600 tonnes of NH_3-N. The prototype model estimates the emission from animal husbandry in 2004 to 56,000 tonnes NH_3-N, or 5,600 tonnes less than the official figure. The major reasons are the changed emission factors from manure application, incorporation of new emission factors from already installed technologies and, to a lesser extent, implementation of a new method to calculate the pig production. The ammonia emission from different sources is given in Appendix 1.

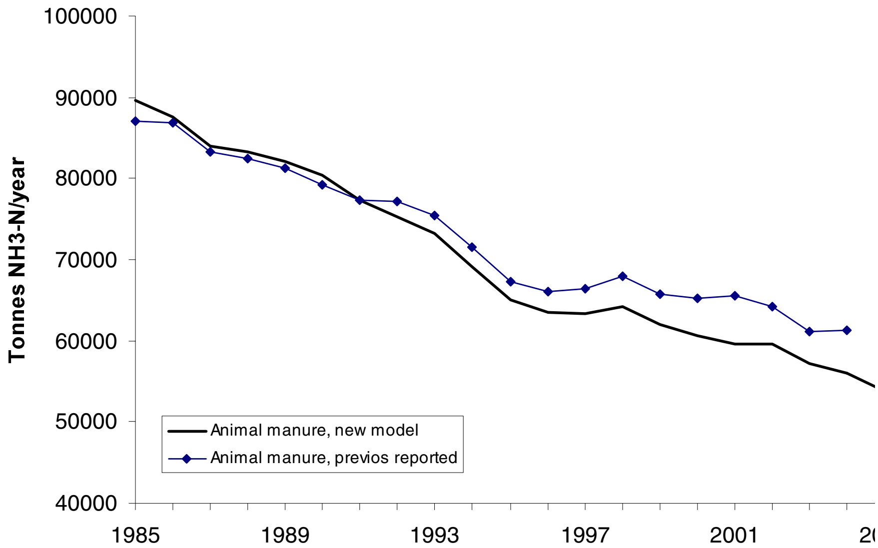

Figure 8.1 Previously reported emission and new preliminary estimates for 1985 to 2005 from animal husbandry.

The total projected ammonia emission to 2025 is given in Table 8.1. In 2010 a total ammonia emission of 64,000 tonnes NH_3-N/year is projected, with a further decrease by 2025 to 53,200 tonnes/year. The overall reduction from 1990 to 2025 is expected to be 52%.

Table 8.1 Projected ammonia emissions in 1990 to 2025 with the preliminary new emission model (tonnes NH_3-N).

	1990	2000	2005	2010	2015	2020	2025
Animal manure	80,400	60,700	53,800	46,700	40,400	38,300	36,400
Fertilisers	8,700	5,600	4,500	4,300	4,000	3,900	3,700
Crops	13,000	11,500	11,400	11,100	10,900	10,700	10,500
Ammonia-treated straw	8,400	2,000	0	0	0	0	0
Sludge	100	100	100	100	100	0	0
Field burning	0	0	0	0	0	0	0
Industry	400	500	500	500	500	500	500
Transport	100	1,800	2,000	2,000	2,000	2,000	2,000
Total	111,100	82,100	72,200	64,700	57,900	55,400	53,200
Relative development	100	74	65	58	52	50	48
According to the NEC Directive	89,700	68,600	60,800	53,600	47,000	44,800	42,700
NEC (National Emission Ceiling)				56,800		51,000	

The preliminary model for animal manure shows a 33% decrease from 1990 to 2005, from 80,400 tonnes to 53,800 tonnes NH_3-N/year. A further decrease is expected in the future. The projected emission in 2010 is 46,700 tonnes NH_3-N, reducing to 38,300 tonnes in 2020 and 36,400 tonnes in 2025.

The emission from mineral fertiliser is (from 1990 to 2005) reduced by 49% from 8,700 to 4,500 tonnes NH_3-N/year. In the future it is projected to decrease further by 20% to 3,696 tonnes NH_3-N/year in 2025, due to a decrease in agricultural area and an increased demand for utilisation of nitrogen in animal manure.

Ammonia emission from crops is not included in the National Emission Ceiling, although it is included in the Danish inventory. This source is expected to decrease slightly due the decrease in the agricultural area.

The emission from non-agricultural sources has increased from 190 tonnes NH_3-N in 1990 to 2,500 tonnes NH_3-N in 2004. This is mainly due to increased use of cars with catalytic converters and to some extent to inclusion of new stationary point sources in the inventory. No changes in the emissions from non-agricultural sources are expected in the future.

With the current model the total ammonia emission is estimated to 64,700 tonnes NH_3-N/year in 2010. Of this, 53,600 tonnes is included in the National Emission Ceiling for 2010. The National Emission Ceiling for Denmark in 2010 is 56,800 tonnes of NH_3-N. The projection, therefore, estimates that the Danish ceiling will be adhered to without any further action (Figure 8.2).

The Clean Air For Europe (CAFE) programme has worked out a policy emission scenario - the Thematic Strategic scenario 2020 (Amann et al., 2005), as a basis for outlining its strategy towards cleaner air in Europe, including revision of the NEC Directive. The Commissions aim for improvement of mortality effects, reduction of excess nitrogen and acid deposition and reduction of human ozone exposure provided country-specific details on e.g. emission reductions. The analysis of the Thematic Strategic scenario 2020 suggested a Danish ammonia primarily emission ceiling for 2020 to 51,000 tonnes NH_3-N. The current Danish projected emission in 2020, without crops, is estimated to 44,800 tonnes NH_3-N and is below the result from the Thematic Strategic scenario 2020. Based on the ongoing negotiation the final Danish emission ceiling 2020 will be presented and it will indicate if further measures are necessary to comply the emission target.

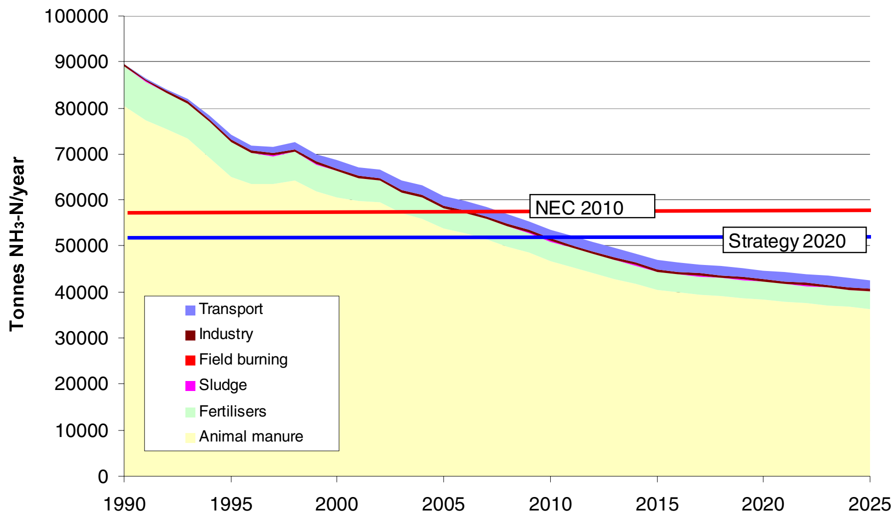

Figure 8.2 Total projected ammonia emission under NEC and the thematic strategy, 1990 to 2025.

Appendix 1

Table A1 Ammonia emission from animal husbandry distributed on sources, 1990 to 2025 [tonnes NH3-N).

	1990	2000	2005	2010	2015	2020	2025
Total emission	80,441	60,699	53,774	46,680	40,404	38,312	36,406
Manure deposited on grass, total	2,422	2,370	2,105	2,069	1,967	1,941	1,898
Horses	231	227	235	245	252	254	255
Cattle	2,080	2,000	1,741	1,722	1,615	1,590	1,548
Sheep and goats	108	79	78	79	80	81	82
Pigs	0	60	45	18	15	11	7
Poultry	3	5	5	4	5	5	5
Manure deposited in stables, total	78,019	58,329	51,669	44,612	38,437	36,371	34,508
Dairy cows	20,929	13,480	9,674	8,721	7,115	6,245	5,159
Other cattle	10,590	6,721	4,725	4,884	4,414	4,321	4,212
Fattening pigs	24,030	17,155	16,470	12,187	9,658	9,022	8,726
Sows	7,953	7,122	7,352	6,691	5,705	5,139	4,691
Piglets	4,156	3,842	3,584	3,238	2,871	3,036	3,179
Sheep	157	109	99	96	94	95	97
Goats	14	13	14	14	14	14	14
Horses	1,015	984	939	934	932	938	943
Egg layers	1,327	1,157	1,212	1,194	1,174	1,187	1,200
Broilers	2,388	3,107	3,083	2,678	2,367	2,105	1,844
Other hens	185	170	142	162	162	165	168
Turkeys	130	302	27	36	35	35	35
Ducks	171	103	111	112	110	110	110
Geese	0	0	0	0	0	0	0
Mink	4,975	4,060	4,214	3,644	3,763	3,935	4,108
Foxes	0	4	23	22	22	22	22

Table A2 Ammonia emission from animal husbandry distributed on main life stock category, 1990 to 2025 [tonnes NH3-N).

	1990	2000	2005	2010	2015	2020	2025
Total emission	80,441	60,699	53,774	46,680	40,404	38,312	36,406
Animal type							
Horses	1,246	1,211	1,174	1,178	1,185	1,192	1,199
Cattle	33,598	22,201	16,140	15,326	13,144	12,157	10,918
Sheep and Goats	280	201	191	189	188	190	193
Pigs	36,139	28,179	27,452	22,135	18,249	17,208	16,604
Poultry	4,204	4,843	4,581	4,187	3,853	3,608	3,362
Fur animals	4,975	4,064	4,237	3,666	3,785	3,957	4,130

Table A3 Ammonia emission from animal husbandry distributed on production process, 1990 to 2025 [tonnes NH3-N).

	1990	2000	2005	2010	2015	2020	2025
Total emission	80,441	60,699	53,774	46,680	40,404	38,312	36,406
Production							
Stable	29,627	27,494	28,137	24,875	22,114	20,410	18,964
Storage	10,198	8,443	8,584	8,159	7,249	7,167	6,991
Manure application	38,193	22,392	14,948	11,578	9,075	8,794	8,553
Grassing	2,422	2,370	2,105	2,069	1,967	1,941	1,898

Table A4 Ammonia emission from animal husbandry distributed on cattle and pigs, 1990 to 2025 [tonnes NH3-N).

	1990	2000	2005	2010	2015	2020	2025
Cattle, total emission	33,598	22,201	16,140	13,639	13,144	12,157	10,918
Stable	6,377	5,890	6,003	5,687	5,527	4,823	4,033
Storage	4,186	3,501	3,089	2,920	2,755	2,701	2,550
Manure application	20,956	10,810	5,306	3,396	3,247	3,043	2,786
Grassing	2,080	2,000	1,741	1,637	1,615	1,590	1,548
Pigs, total emission	36,139	28,179	27,452	19,003	18,249	17,208	16,604
Stable	17,003	15,418	15,406	10,671	10,344	9,338	8,675
Storage	4,610	3,428	4,023	3,359	3,162	3,177	3,194
Manure application	14,527	9,272	7,977	4,957	4,728	4,681	4,727
Grassing	0	60	45	16	15	11	7

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DMU Danmarks Miljøundersøgelser

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Furthermore the website contains a database of publications including scientific articles, reports, conference contributions etc. produced by NERI staff members.

Further information: www.neri.dk

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The report estimates the ammonia emission from Denmark until 2025. The estimate is based on expected development in animal husbandry, development in feeding efficacy, ammonia reducing technologies and manure handling. Denmark has in relation to the Convention on Long-Range Transboundary Air Pollution accepted to reduce the emission to 56,700 tonnes NH_3-N/year in 2010. The analysis in the thematic strategic scenario 2020 primarily suggested a Danish emission ceiling for ammonia at 51,000 tonnes NH_3-N/year in 2020 – this emission is excluding emission from crops and ammonia treated straw. The current projection indicates that Denmark can comply with its emission ceiling in 2010 and are furthermore below the current thematic strategy scenario 2020. It is expected that Denmark will reduce its ammonia emission (excl. emission from crops and ammonia treated straw) from approximately 60,800 tonnes NH_3-N/year in 2005 to 53,600 tonnes NH_3-N/year in 2010 and further to 44,800 tonnes NH_3-N/year in 2020. The overall Danish reduction from 1990 to 2025 is thus expected to be 52%.

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