DANISH EMISSION INVENTORY FOR AGRICULTURE

Inventories 1985 - 2009

NERI Technical Report no. 810 2011

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
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Data sheet

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Abstract: By regulations given in international conventions Denmark is obliged to work out an annual emission inventory and document the methodology. The National Environmental Research Institute (NERI) at Aarhus University (AU) in Denmark is responsible for calculating and reporting the emissions. This report contains a description of the emissions from the agricultural sector from 1985 to 2009. Furthermore, the report includes a detailed description of methods and data used to calculate the emissions, which is based on national methodologies as well as international guidelines. For the Danish emissions calculations and data management an Integrated Database model for Agricultural emissions (IDA) is used. The emission from the agricultural sector includes emission of the greenhouse gases methane (CH_4), nitrous oxide (N_2O), ammonia (NH_3), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and other pollutants related to the field burning of agricultural residue such as NO_x, CO_2, CO, SO_2, heavy metals, dioxin and PAH. The ammonia emission from 1985 to 2009 has decreased from 119 300 tonnes of NH_3 to 73 800 tonnes NH_3, corresponding to a 38 % reduction. The emission of greenhouse gases has decreased by 25 % from 12.9 M tonnes CO_2 equivalents to 9.6 M tonnes CO_2 equivalents from 1985 to 2009. Improvements in feed efficiency and utilisation of nitrogen in livestock manure are the most important reasons for the reduction of both the ammonia and greenhouse gas emissions.

Keywords: Agriculture, emission, ammonia, methane, nitrous oxide, particulate matter, greenhouse gas, inventory, Denmark

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Preface

On behalf of the Ministry of the Environment and the Ministry of Climate and Energy, the National Environmental Research Institute at Aarhus University is responsible for the calculation and reporting of the Danish national emission inventory to EU directives, the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Economic Commission for Europe Convention on Long Range Transboundary Air Pollution (UNECE CLRTAP). This documentation report for agricultural emissions has been externally reviewed as a key part of the general national inventory QA/QC plan.

The report has been reviewed by Nicholas J. Hutchings from the Faculty of Agricultural Sciences, Aarhus University and by Johnny M. Andersen from the Faculty of Life Sciences, University of Copenhagen.

Summary

Regulations in international conventions oblige Denmark to prepare annual emission inventories and document the methodologies used to calculate emissions. The responsibility for preparing the emissions inventory for agriculture is in Denmark undertaken by the National Environmental Research Institute (NERI), Aarhus University. Chapter 2 contains a description of the emissions from the agricultural sector from 1985 to 2009. This report is an updated version of NERI Research Notes no. 231 published in 2006. The following chapters of the report include a detailed description of methods and data used to calculate the emissions.

The emissions from the agricultural sector include the greenhouse gases: methane (CH_4) and nitrous oxide (N_2O) as well as the air pollutants: ammonia (NH_3), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and other pollutants specifically related to the field burning of agricultural residues such as Nitrogen oxide (NO_x), Carbon dioxide (CO_2), Carbonmonoxid (CO), Sulphur dioxide (SO_2), heavy metals, dioxin and PAH.

The emission calculation is based on an Integrated Database model for Agricultural emissions (IDA). The model covers all aspects of the agricultural inputs and estimates both greenhouse gases and air pollutants. The largest contribution to agricultural emissions originates from livestock production and most of the input data are sourced from Statistics Denmark and from the Faculty of Agricultural Sciences, Aarhus University. These data cover, e.g., the extent of the livestock production, land use, Danish standards for feed consumption and excretion. Furthermore, the estimation of nitrogen from leaching and runoff is based on data collected in connection with the Danish Action Plans for the Aquatic Environment. The emission inventory reflects the actual conditions for the Danish agricultural production. In cases where no Danish data are available, default values recommended by the Intergovernmental Panel on Climate Change (IPCC) and the European Monitoring and Evaluation Programme (EMEP) are used.

Approximately 97 % of the total NH_3 emission originates from the agricultural sector as does approximately 16 % of total greenhouse gas emission.

The NH_3 emission from 1985 to 2009 has decreased from 98 300 tonnes of NH_3-N to 60 800 tonnes NH_3-N, corresponding to a reduction of approximately 38 %. Converted to NH_3, the 2009 emission is an estimated 73 800 tonnes NH_3. Most of this NH_3 emission is related to livestock manure and of this the emission from pigs and cattle contributed, respectively with, 44 % and 36 %.

The emission of greenhouse gases in 2009 is estimated at 9.6 million tonnes CO_2 equivalents, a reduction of 25 % from the 1985 figure of

12.9 million tonnes CO_2 equivalents and a reduction of 22 % since 1990, which is the base year of the Kyoto protocol.

The emission of CH_4 is primarily related to cattle and pig production, which contributed 75 % and 20 % to the agricultural greenhouse gas emissions, respectively. The CH_4 emission in 2009 is estimated to 195 gigagram (Gg), or given in CO_2 equivalents as 4.1 million tonnes.

The emission of N_2O primarily originates from transformation of nitrogen compounds in agricultural fields. The main sources are related to the use of livestock manure, synthetic fertiliser and nitrogen leaching and run-off. The emission of N_2O in 2009 is estimated at 17.9 Gg, corresponding to 5.6 million tonnes CO_2 equivalents.

Biogas plants that process animal slurry reduce the emission of CH_4 and N_2O. A methodology to estimate the emission reductions are not yet provided in the IPCC guidelines. The calculation of a lower emission from biogas treated slurry is based on the amount of treated slurry and the content of volatile solids and nitrogen. In 2009 approximately 8 % of all slurry was treated in biogas plants and the lower emission of greenhouse gases as a consequence of biogas treated slurry has result in a lower emission of 0.04 million tonnes CO_2 equivalents.

Improvements in feed efficiency, use of low emission technologies, the utilisation of nitrogen in livestock manure and a significant decrease in the consumption of synthetic fertiliser are the most important explanations for the reduction of NH_3. This development has furthermore resulted in a significant reduction of N_2O emission, which is the main reason for a considerable fall in the total greenhouse gas. There has been a fall in CH_4 emissions as a consequence of a reduction in the number of cattle. However, this trend is partially counteracted by changes in animal housing towards more slurry-based systems.

Sammenfatning

Hvert år opgøres bidraget af ammoniak og drivhusgasser fra Danmark. I forbindelse med en række internationale konventioner har Danmark, udover opgørelsen af emissionerne, også forpligtet sig til at dokumentere hvorledes emissionerne opgøres. Denne rapport er en opdatering af DMU-arbejdsrapport nr. 231 publiceret i 2006. Rapporten omfatter derfor dels en opgørelse, og dels en beskrivelse af metoden for beregning af landbrugets emissioner af drivhusgasserne: metan (CH_4) og lattergas (N_2O), luftforureningskomponenterne: ammoniak (NH_3), partikler (PM), non-metan VOC´er (NMVOC) og andre stoffer der er relateret til afbrænding af afgrøderester fra landbruget, som kvælstofilte (NO_x), kuldioxid (CO_2), kulilte (CO), svovldioxid (SO_2), tungmetaller, dioxiner og PAH. Opgørelsen omfatter perioden fra 1985 til 2009.

Landbrugets emissioner er beregnet på grundlag af en databasebaseret model kaldet IDA - Integrated Database model for Agricultural emissions. Størstedelen af emissionerne er relateret til husdyrproduktionen og langt de fleste inputdata er hentet fra Danmarks Statistik og det Jordbrugsvidenskabelige Fakultet ved Aarhus Universitet. Disse data omfatter bl.a. omfanget af husdyrproduktionen, arealanvendelse, normdata for foderindtag og dyrenes nitrogenudskillelse via gødningen, som er nogle af de vigtigste parametre for emissionsberegningen. Endvidere er beregningen for udvaskning af kvælstof til vandmiljøet baseret på beregninger foretaget i forbindelse med vandmiljøplanerne. Emissionsopgørelsen tager således højde for de faktiske forhold der gør sig gældende for den danske landbrugsproduktion. For de områder hvor der ikke forefindes nationale data anvendes anbefalede værdier fra The Intergovernmental Panel on Climate Change (IPCC) og The European Monitoring and Evaluation Programme (EMEP).

Langt størstedelen af den samlede NH_3-emission svarende til ca. 97 %, kan henføres til landbrugssektoren, mens ca. 16 % af den total drivhusgasemission stammer fra landbruget.

NH_3-emissionen sker i forbindelse med omsætningen af N. Størstedelen af emissionen kommer fra husdyrgødning, hvor svin og kvæg i 2009 bidrager med henholdsvis 43 % og 36 %. Emissionen fra 1985 til 2009 er faldet fra 98.300 tons NH_3-N til 60.800 tons NH_3-N svarende til en reduktion på 38 %. Omregnet til NH_3 svarer emissionen i 2009 til 73.800 tons NH_3.

Den samlede emission af drivhusgasser fra landbrugssektoren i 2009 er 9,6 mio. tons CO_2-ækvivalenter. I perioden fra 1985 er emissionen faldet fra 12,9 mio. tons CO_2-ækvivalenter, hvilket svarer til en samlet reduktion på 25 %. Siden 1990, som er Kyotoprotokollens basisår, er emissionen reduceret med 22%.

Emissionen af CH_4 stammer primært fra kvæg (75 %) og svin (20 %). Den samlede emission af CH_4 er opgjort til 195 gigagram (Gg) i 2009 svarende til 4,1 mio. tons CO_2-ækvivalenter.

Som for NH_3's vedkommende, er emissionen af N_2O knyttet til omsætningen af kvælstof. De største bidragsydere er emissionen fra handels- og husdyrgødning samt fra kvælstofudvaskningen fra landbrugsjorden. Den samlede emission i 2009 er opgjort til 17,9 Gg N_2O, svarende til 5,6 mio. tons CO_2-ækvivalenter.

Anvendelse af husdyrgødning i biogasanlæg reducerer emissionen af CH_4 og N_2O. Metoden for hvordan dette skal opgøres, er ikke beskrevet i guidelines - udarbejdet af IPCC - hvorfor den reducerede emission er opgjort på baggrund af danske antagelser. I 2009 behandles ca. 8 % af den samlede mængde gylle i biogasanlæg. Det forventes at der fra biogasbehandlet gylle forekommer en lavere emission af drivhusgasser, hvilket er beregnet til at udgøre 0,04 mio. tons CO_2-ækvivalenter.

De væsentligste forklaringer på reduktionen af NH_3, er en forbedring i fodereffektivitet, en bedre udnyttelse af kvælstofindholdet i husdyrgødningen, anvendelse af emissionsreducerende teknologier og på baggrund heraf, et markant fald i anvendelsen af kvælstof i handelsgødning. Denne udvikling har samtidig betydet et markant fald i N_2O-emissionen, hvilket er den væsentligste årsag til reduktion i den samlede udledning af drivhusgasser fra landbruget. Der er sket en reduktion i CH_4-emissionen fra fordøjelsesprocessen som en konsekvens af faldet i antallet af kvæg. Dog er denne reduktion delvis modvirket af en omlægning i staldtyper fra systemer med fast gødning til flere gyllebaserede systemer, som medvirker til en øget emission fra håndteringen af husdyrgødning.

1 Introduction

As a signatory to international conventions Denmark is under obligation to prepare annual emission inventories for a range of pollutants. For agriculture, the relevant emissions to be calculated are ammonia (NH_3), the greenhouse gases (GHG): methane (CH_4) and nitrous oxide (N_2O) as well as the indirect greenhouse gases: non-methane volatile organic compounds (NMVOC), particulate matter (PM) and a series of other pollutants related to the burning of crop residues on fields. The National Environmental Research Institute (NERI) under Aarhus University is responsible for calculating emissions and reporting the annual emission inventory. Most of the calculations are based on data collected from Statistics Denmark and the Faculty of Agricultural Sciences, Aarhus University (DJF). In addition to the reporting of emission data, Denmark is obliged by the conventions to document the calculation methodology. This report, therefore, includes both a review of the emissions for the period 1985–2009 and a description of the methodology on which calculation of emissions is based.

The 1999 Gothenburg Protocol, under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP), and the EU's NEC Directive on national emission ceilings (2001/81/EC) commit Denmark to reduce NH_3 emissions from all sectors to 69 000 tonnes NH_3 by 2010 at the latest. In 2009, 97 % of the total NH_3 emission in Denmark came from the agricultural sector, the remainder from the energy sector and industrial processes. It is important to point out, that the Danish emission inventory reported under the NEC directive does not include the emission of NH_3 from crops, or from NH_3 treated straw.

Denmark has ratified the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC). This commits Denmark to reduce the emission of greenhouse gases, measured in CO_2 equivalents, by 21 % from the level in the base year to the annual average in the first commitment period (2008-2012). In 2009, the agricultural sector contributed 16 % to the total emission of greenhouse gases in Denmark, measured in CO_2 equivalents. The relatively large contribution is due to the emission of CH_4 and N_2O from the sector. These gases have a higher global warming effect than CO_2. Measured in GWP (Global Warming Potential), the effects of CH_4 and N_2O are, respectively, 21 and 310 times stronger than that of CO_2 (IPCC, 1997).

The IPCC has developed guidance documents on how greenhouse gas emissions should be calculated. The two documents currently used under the UNFCCC is the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) hereafter the IPCC Guidelines and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) hereafter the IPCC GPG. The guidelines are prepared for use in all countries based on a division of different climatic regions into different geographic locations. The guidelines, however, do not always represent the best method at the level of the individual country due to the different national circumstances. The IPCC, therefore, advocates the use, as far as possible, of national figures where data are available.

A good basis for calculating the emissions from the agricultural sector for Denmark is by making use of the extensive databases generated when (a) calculating the normative values for feed consumption and nitrogen excretion associated with livestock husbandry (Poulsen, 2010; Poulsen et al., 2001; Poulsen & Kristensen, 1997; Laursen, 1994), (b) estimating the nitrogen content in crops (Kristensen & Kristensen, 2002; Kyllingsbæk, 2000; Høgh-Jensen et al., 1998) and (c) estimating nitrogen leaching (Børgesen & Grant, 2003).

Generally, the IPCC Guidelines are based on livestock numbers in order to be comparable with international statistics. For livestock from which meat is produced, the Danish normative calculations are based on the number of livestock produced. The Danish normative values are used to calculate an emission which is based on actual levels of production in the Danish agricultural sector.

Agricultural emissions are calculated in an integrated national model complex (Integrated Database model of Agricultural emissions, IDA) as recommended in the IPCC Guidelines. This means that the calculation of emissions of NH_3, greenhouse gases and other pollutants have the same foundation, i.e. the number of livestock, the distribution of types of livestock housing, fertiliser type, land use, etc. Changes in the emission of NH_3 will therefore have a direct effect on emissions of N_2O.

The emission inventory is continuously being improved with the availability of new knowledge. This means that over time changes will be made to reflect changes in both emission factors and in the methodology in the IPCC Guidelines and in the national inventories. In the emission inventory, the aim is to use national data as far as possible. This sets high requirements for the documentation of data, especially in areas where the method used and the national data differ significantly from the IPCC's recommended standard values.

This report is an updated version of NERI Research Notes (Mikkelsen et al., 2006). The report starts with an introductory overview of emissions in the period from 1985 to 2009, describing the changes in agricultural activities that have influenced the emissions. Thereafter, the IDA model used to calculate the emissions is described and a detailed description is provided on how the emissions for the individual pollutants are calculated.

2 Trends in agricultural emissions 1985-2009

This chapter describes the development in the agricultural emissions of air pollutions and greenhouse gases from 1985 to 2009. The first group includes pollutants involved in air pollution, i.e. ammonia (NH_3), nitrogen oxides (NO_x), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and other air pollutants (SO_2, CO, heavy metals, PAH and dioxin), which all have to be reported under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). Emissions of other air pollutants are only related to the field burning of agricultural residues. The second group includes the direct greenhouse gases, which have to be reported to the Kyoto Protocol under the Climate Convention, i.e. methane (CH_4) and nitrous oxide (N_2O). Pollutants that have an indirect effect on greenhouse emissions, i.e. NMVOC and nitrogen oxides (NO_x) from growing crops, carbon monoxide (CO) and sulphur dioxide (SO_2) from field burning, have to be estimated and reported to both the UNFCCC and the CLRTAP. Table 2.1 gives an overview of the conventions, the required report format and which pollutants they cover.

Table 2.1 Overview of conventions and pollutants.

Convention	Report format	Pollutants
The United Nations Framework Convention on Climate Change (UNFCCC). Including the Kyoto Protocol.	Data: CRF (Common Reporting Format) Report: NIR (National Inventory Report)	Direct greenhouse gases; CH_4, N_2O, CO_2[1] Indirect greenhouse gases; NMVOC, NO_x, CO, SO_2[1]
The UNECE Convention on Long-Range Transboundary Air Pollution Convention. Including 8 protocols.	Data: NFR (Nomenclature For Reporting) Report: IIR (Informative Inventory Report)	Main Pollutants (NH_3, NO_x NMVOC) Particulate Matter (TSP, PM_{10}, $PM_{2.5}$) Other pollutants (CO, SO_2) Priority metals (Pb, Cd, Hg) Other metals (As, Cr, Cu, Ni, Se, Zn) PAH (benzo(a)pyrene, benzo(b)fluoranthene, benzo-(k)fluoranthene, Indeno(1,2,3-cd)pyrene) Dioxin (PCDD/-F)
EU's Directive on national emission ceilings (NECD) (2001/81/EC)	NFR (Nomenclature For Reporting)	NH_3 (excl. emission from crops and NH3 treated straw) NMVOC, NO_x, SO_2

[1] In the present CRF format it is not possible to report CO_2 and SO_2 from field burning of agricultural residues. However, the CO_2 emission from field burning is seen as CO_2 neutral.

It must be noted that CO_2 removals/emissions from agricultural soils are not included in the emission inventory for the agricultural sector. According to the IPCC guidelines this removal/emission should be included in the LULUCF sector (Land-Use, Land-Use Change and Forestry) (Gyldenkærne et al., 2005). The same comment applies to the emission related to agricultural machinery (tractors, harvesters and other non-road machinery), emissions are reported in the energy sector.

It should also be noted that the agricultural emissions include two non-agricultural activities, i.e. emissions from horses in riding schools and from synthetic fertiliser used in parks, golf courses and sports grounds. These emission sources cover approximately 1 % of the total agricultural emissions.

2.1 Air pollutants

2.1.1 NH_3

Approximately 97 % originates from the agricultural sector and the remainder from the energy sector and industrial processes. Most of the NH_3 emissions from agricultural activities relate to livestock production, the remaining 15 % - 20 % from the use of synthetic fertiliser, growing crops, NH_3 treated straw, the field burning of agricultural residues and sewage sludge applied to fields as fertiliser.

Figure 2.1 shows the emissions partitioned into the different sources. The emission of NH_3 from the agricultural sector decreased from 98 Gg NH_3-N in 1985 to 61 Gg NH_3-N in 2009, which corresponds to a 38 % reduction.

The significant decrease in NH_3 emissions is a consequence of an active national environmental policy over the last 20 years. A string of measures have been introduced by action plans to prevent the loss of nitrogen from agriculture to the aquatic environment, for example the NPO (Nitrogen, phosphor, organic matter) Action Plan (1986), Action Plans for the Aquatic Environment (1987, 1998, 2004), the Action Plan for Sustainable Agriculture (1991) and the Ammonia Action Plan (2001). These measures have brought about a decrease in animal nitrogen excretion, improvement in use of nitrogen in manure and a fall in the use of synthetic fertiliser, all of which have helped reduce the overall NH_3 emission significantly.

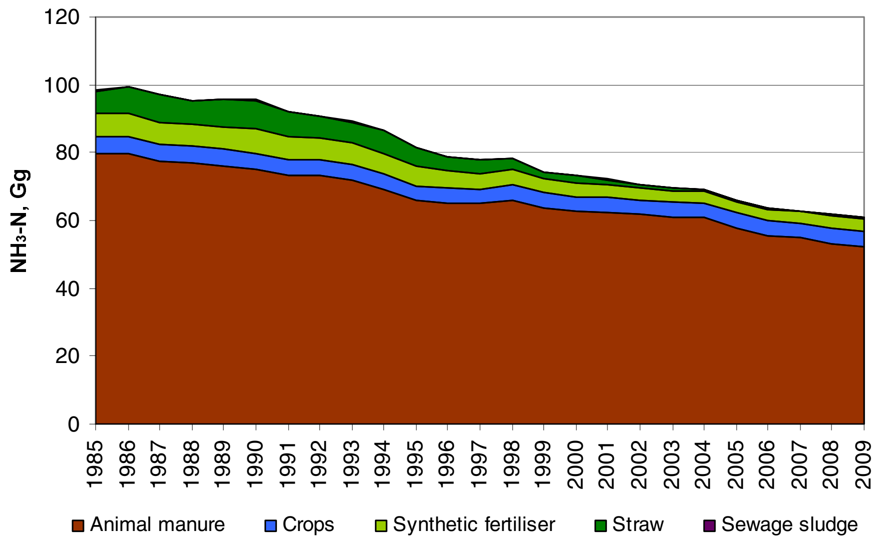

Figure 2.1 NH_3-N emissions in the agricultural sector, 1985 to 2009. Straw includes NH_3 treated straw and field burning of agricultural residues.

The total NH_3 emission is strongly correlated to a decrease in the emission from livestock production. 'Straw' includes both emissions from NH_3 treated straw and from field burning of agricultural residues. As a result of livestock regulations (BEK, 2002) NH_3 treatment of straw was banned from 1 August 2004. Field burning of agricultural residues has been prohibited in Denmark since 1990 (BEK, 1991) and may only take place in connection with the production of grass seeds on fields with repeated production and in cases of wet or broken bales of straw.

It is important to highlight the difference between the NH_3 emission expressed in nitrogen NH_3-N and that expressed in total NH_3. The conversion factor is 17/14, corresponding to the difference in the molecular mass. In appendix A, the trend for NH_3 emission from 1985 to 2009 from different sources is expressed in both NH_3-N and NH_3.

NH_3 emission from animal manure

In 2009, animal manure contributed approximately 86 % to the total NH_3 emission from agriculture. From 1985 the emission from animal manure has decreased by 38 %. There are several reasons for this decrease.

Figure 2.2 shows the annual NH_3 emissions from the main livestock categories. Most of the emission from manure originates from the production of cattle and pigs. In 1985 approximately 45 % of the emission came from cattle and 45 % from pigs. In 2009, the contribution from cattle had decreased to 36 %. The percentages of the emission from fur farming and poultry production have increased, while that from pigs is nearly unaltered (43%).

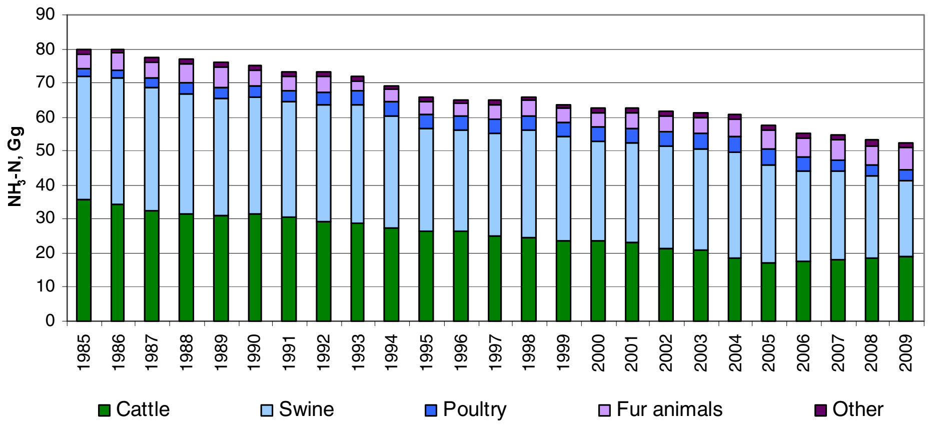

Figure 2.2 NH_3-N emissions from animal manure contributed by the different livestock categories. Other includes horses, sheep, goats and deer.

It is noteworthy that the overall emission from pigs has decreased by 38 % despite a considerable increase in pork production from 14.7 million produced fattening pigs in 1985 to 20.9 million in 2009. One of the most important reasons for this is the improvement in feed efficiency. In 1985, the nitrogen excretion for a fattening pig was an estimated 5.09 kg N (Poulsen & Kristensen, 1997). In 2009, that figures were considerably lower at 2.94 kg N per fattening pig produced (Poulsen, 2010). Due to the large contribution from the pig production, the lower level of N-excretion has a significant influence on total agricultural emissions.

The other causes of the significant decrease in the NH_3 emission since 1985 have to be mentioned. Figure 2.3 shows the different sources, i.e. from manure handling in animal housing, manure storage, application to fields and from grazing animals. Most of the emission reduction comes from manure applications to fields. A further emission reduction from manure storage is evident from 2005, which is due to the requirement to cover manure heaps in the field.

Regarding the field application of animal manure, considerable changes have taken place in manure management. From the beginning of the 1990s slurry has increasingly been spread using trailing hoses. From the late 1990s the practice of slurry injection or mechanical incorporation into the soil has increased. For 2009 it is estimated that as much as 63 % for cattle and 28% for swine is applied using injection/incorporation techniques (Birkmose, 2009). This development is a consequence of a ban on broad spreading from 1 August 2003 (BEK, 2002), but it is also a consequence of the general requirement to improve the utilisation of nitrogen in the manure - e.g. requirements to a larger part of the nitrogen in manure has to be included in the farmers nitrogen accounting. This has forced farmers to consider the manure as a resource instead of a waste product.

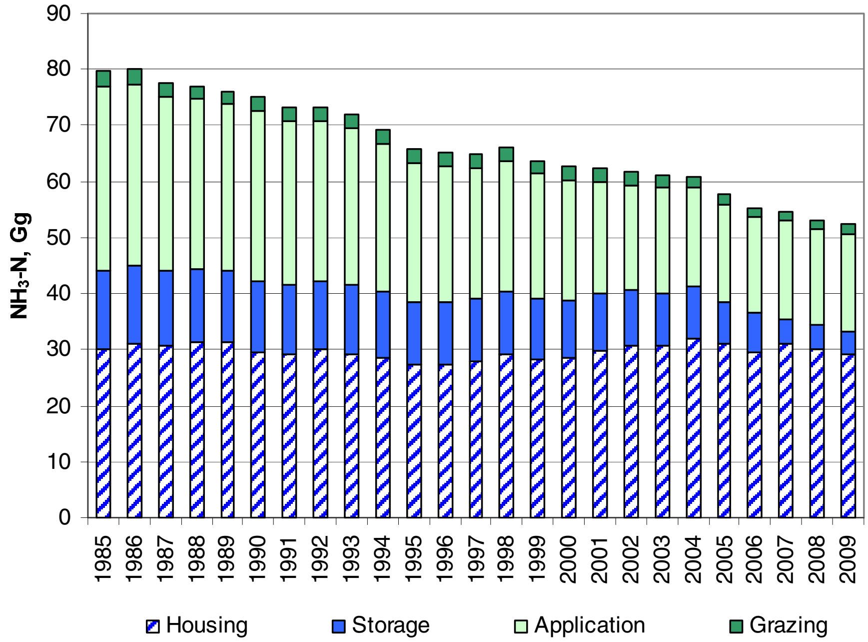

Figure 2.3 NH_3-N emissions from animal manure, 1985 to 2009.

The effort to further reduction of the NH_3 emission could be achieved by focusing on the possibilities of emission reduction technologies in animal hosing.

NH_3 emissions from agricultural soils

In 2009, NH_3 emission related to the agricultural soils contributed 15 % to total agricultural emissions, this mainly stems from the use of synthetic fertiliser and from growing crops. Figure 2.4 shows the emission from synthetic fertiliser, crops and sewage sludge from 1985-2009.

The Danish inventory includes the emission from growing crops, although no methodological guidance is provided regarding this emission source. The reason for the inclusion of these emissions in the Danish emission inventory is that studies have demonstrated that growing crops can emit NH_3 (Schjoerring & Mattsson, 2001). It is uncertain how much NH_3 is emitted from crops under different geographic and climatic conditions. Denmark does not report NH_3 from crops under the NECD, because it was not included in the Danish inventory at the time when emission ceilings were negotiated and because no methodological guidance is available in the EMEP/EEA Guidebook.

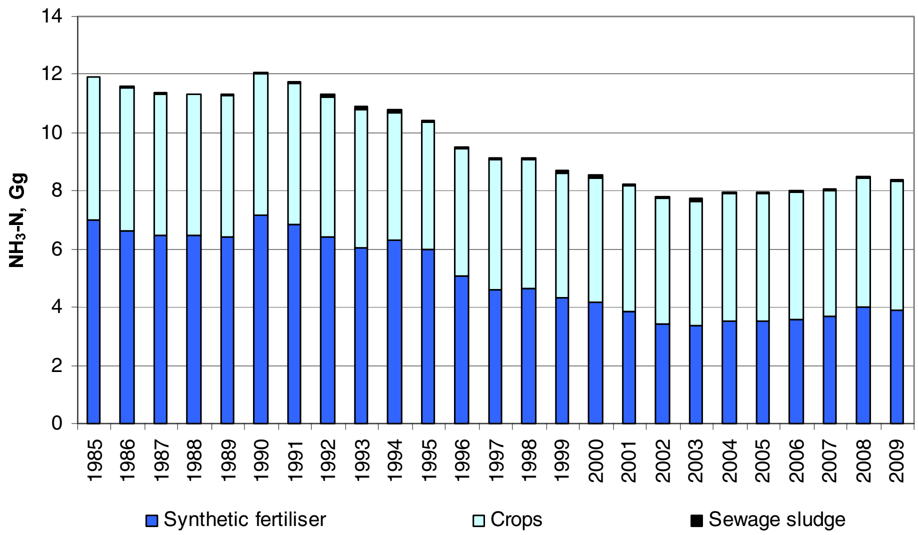

Figure 2.4 NH_3-N emission from synthetic fertiliser, crops and sewage sludge, 1985-2009.

Due to the requirement to improve the utilisation of nitrogen in animal manure, the use of synthetic fertilisers has decreased dramatically. The amount of nitrogen applied to soils from synthetic fertilisers in 2009 is almost halved compared with the amount in 1985. The emission from growing crops also follows a downward trend due to a reduction in the agricultural area.

2.1.2 PM

Farmers and livestock have an increased risk developing lung and respiratory diseases through breathing in small particles. Emission of PM originates from livestock housing, field operations such as soil cultivation and harvesting, and the field burning of agricultural residues. There are currently no estimates of emissions from field operations. When resources are available, the emissions will be calculated and reported as part of the emission inventory.

The PM emissions from the agricultural sector mainly consist of larger particles. In the reporting under CLRTAP particulate matter is reported as the total suspended particles (TSP), PM_{10} and $PM_{2.5}$ (Particulate matter with diameter less than 10 µm and less than 2.5 µm). TSP emission from the agricultural sector contributes 27 % to the national TSP emission in 2009 and the emission shares for PM_{10} and $PM_{2.5}$ are only 17 % and 4 % respectively. Most of this comes from animal production. The emission from the field burning of agricultural residues, contributes less than 1 % to the agricultural emission.

Figure 2.5 shows the TSP emission from livestock from 1985 to 2009. Since 1985, the emission has varied by ±5 %, which is mainly due to changes in the production of pigs. The changes in the total emission for each livestock category mainly reflect the changes in the number of animals, but are also effected by the distribution of subcategories and changes in housing type.

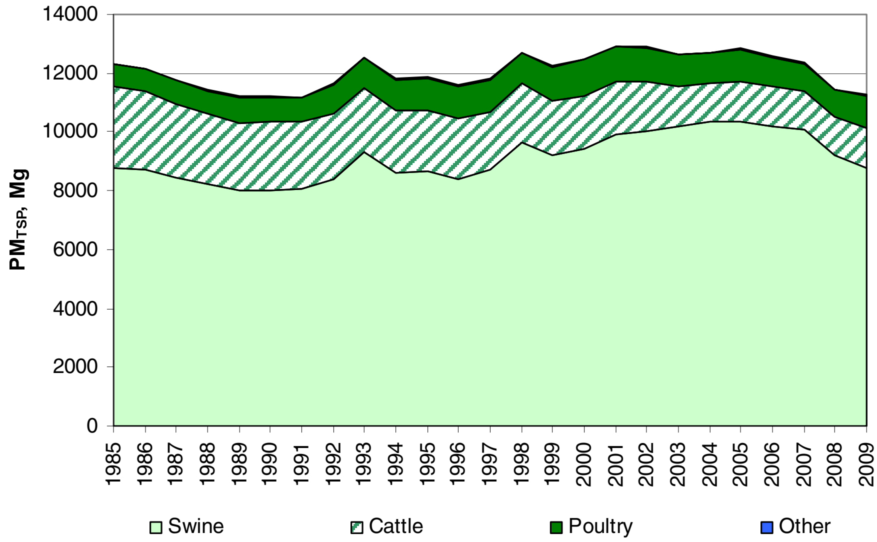

Figure 2.5 Emission of total suspended particles (TSP) from the agricultural sector, 1985 to 2009. Other includes horses, sheep, goats and field burning of agricultural residue.

2.1.3 NMVOC

Non-Methane Volatile Organic Compounds (NMVOC) is included in the reporting requirements for emission inventories under both CLRTAP and UNFCCC. The reason for including NMVOC in the reporting requirements to the UNFCCC is that NMVOC are considered an indirect greenhouse gas. NMVOC contribute to the formation of tropospheric ozone, therefore it is included in the reporting requirements under CLRTAP.

An estimate of the emission from field burning of agricultural residues and from growing crops and grass is included in the emission inventory. Agriculture contributed 2.20 Gg NMVOC in 2009, corresponding to 2 % of the national NMVOC emission. From 1985 the emission has decreased mainly due to the ban on field burning. Since 1990 a small decrease in emission has occurred due to a decrease in the farmed area.

2.1.4 Other air pollutants

Other air pollutants include NO_x, CO, SO_2, heavy metals, dioxin and PAH and these are estimated from the field burning of agricultural residues. In 2009 NO_x, CO, SO_2, heavy metals and dioxin from field burning contributed less than 1 % to the total national emission, while PAH contributed around 2 %. From 1989 to 1990 all emissions decrease significantly due to the banning of field burning.

Emissions related to the energy consumption from agricultural plants and machinery, such as tractors, harvesters, etc., are not included in the agricultural sector. These are included in the energy sector.

2.2 Greenhouse gases

Table 2.2 shows the development in greenhouse gas emissions calculated in CO_2 equivalents. The overall emission in 1985 are estimated to 12 887 Gg, decreasing to 9 637 Gg in 2009, corresponding to a 25 % reduction. Since 1990, the base year of the Kyoto Protocol for CH_4 and N_2O, the emission has been reduced by 22 %. N_2O has the highest global warming potential of the two gases and is the largest contributor to the overall agricultural emission of greenhouse gases. CO_2 is estimated for field burning of agricultural residues, but it is not reported in the CRF because this is not possible in the present format. The CO_2 emission from field burning is considered biogenic and would therefore not count in the national total, but would only be reported as a memo item, which is also the case for CO_2 emissions from combustion of biomass in the energy sector.

Table 2.2 Development in the emission of greenhouse gases, 1985-2009, measured in Gg CO_2 equivalents.

	1 985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
CH_4	4 708	4 584	4 370	4 250	4 207	4 226	4 242	4 229	4 308	4 199	4 186	4 186	4 080
N_2O	8 179	8 079	7 999	7 909	7 993	8 181	7 987	7 767	7 620	7 594	7 275	6 730	6702
Total	12 887	12 663	12 369	12 159	12 200	12 407	12 229	11 996	11 928	11 793	11 461	10 917	10 782

Continued

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4	4 115	3 975	3 982	4 104	4 050	4 015	3 946	3 907	3 883	4 028	4 017	4 090
N_2O	6 935	6 634	6 358	6 175	6 093	5 679	5 876	5 804	5 650	5 741	5 811	5 547
Total	11 050	10 609	10 340	10 279	10 143	9 695	9 822	9 711	9 533	9 769	9 828	9 637

2.2.1 CH_4

The CH_4 emission primarily originates from livestock digestive processes, with a smaller contribution from animal manure particularly slurry. Field burning of agricultural residues is also included as a source of emission, but contributes less than 1 % to total agricultural CH_4 emissions.

The trend in CH_4 emissions from 1985 to 2009 is presented in figure 2.6 and shows a reduction from 224 Gg CH_4 to 195 Gg CH_4 in 2009, corresponding to 13 %. From 1985 to 2009 the emission from enteric fermentation has decreased mainly due to a decrease in the number of cattle. A contrasting development has taken place in emission from manure management. Structural changes in the sector have led to a move towards the use of slurry-based housing systems, which have a higher emission factor than systems with solid manure.

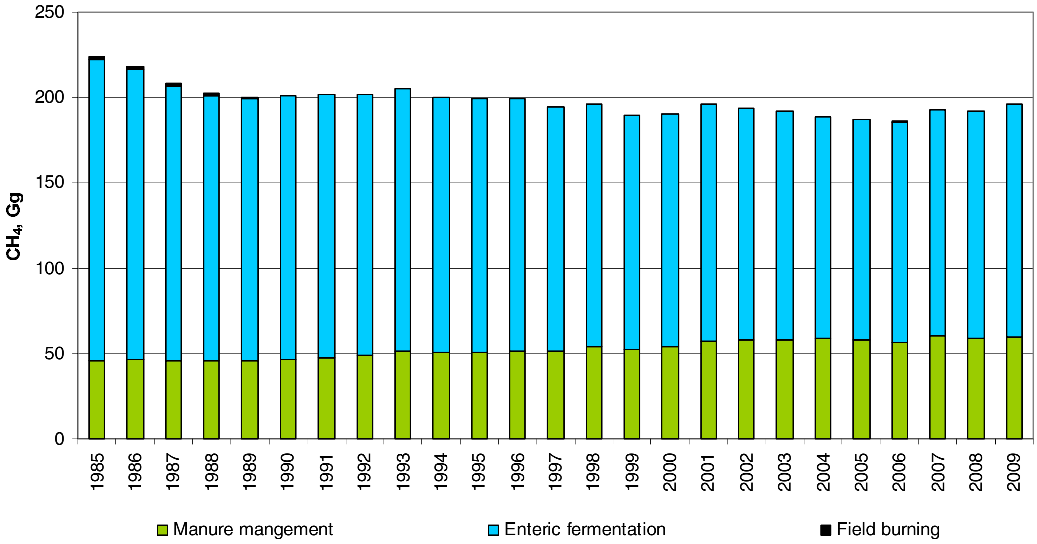

Figure 2.6 CH_4 emission 1985-2009, Gg CH_4 per year.

In 2009 approximately 8 % of slurry was treated in biogas plants. The biogas treatment has a lower emission of CH_4 and N_2O, which is included in the emission inventory. In 2009 the biogas treatment has lowered the CH_4 emission with 1.11 Gg CH_4, which corresponds to 0.6 % of the total CH_4 emission from the agricultural sector.

2.2.2 N_2O

The emission of N_2O takes place in the chemical transformation of nitrogen and is therefore closely linked with the nitrogen cycle. There is a direct link between the estimation of the NH_3 emission and the estimation of the N_2O emission.

Figure 2.7 presents the trend in the emissions of N_2O in the period 1985 to 2009 and reveals that the emission has decreased from 26.4 Gg N_2O to 17.9 Gg N_2O, which corresponds to a 32 % reduction.

N_2O is produced from a range of different sources, which are presented in figure 2.7. The largest sources are animal manure and synthetic fertilisers applied to soil, and nitrogen leaching and run-off. The reduction in total N_2O emissions is strongly related to a significant decrease in emissions from the use of synthetic fertiliser and in nitrogen leaching and run-off. This development is primarily a consequence of an improved utilisation of nitrogen in animal manure.

Despite the increasing production of pigs and poultry, the total amount of excreted nitrogen in manure has decreased by 15 % from 1985 to 2009, which is due to an improved feed efficiency, especially for fattening pigs. A decrease in the total amount of nitrogen also means a decrease in N_2O emissions. Another reason for reduction is the change from previous, more traditional, tethering systems with solid manure to a slurry-based system, because the N_2O emission is lower for liquid manure than for solid manure.

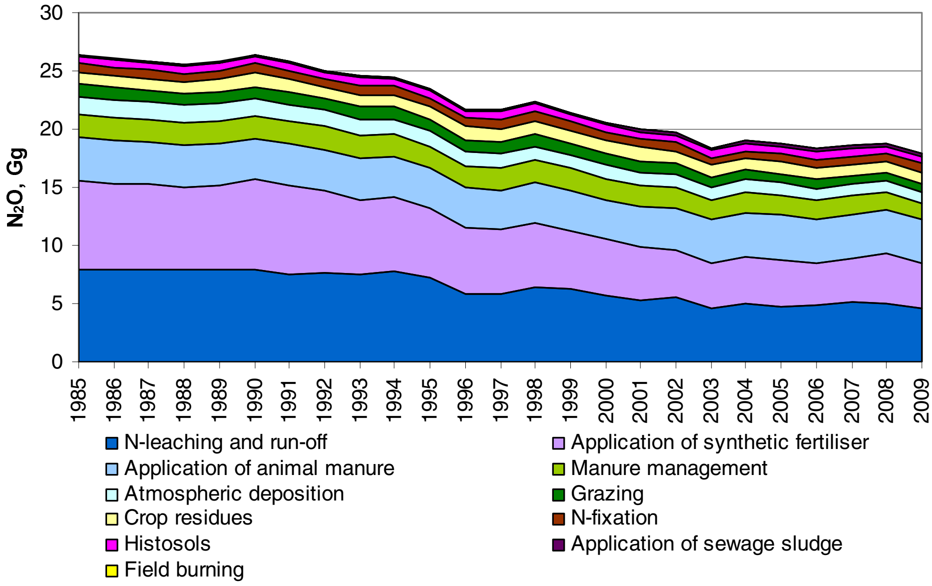

Figure 2.7 Emission of N_2O according to source, 1985-2009.

As mentioned in the section for CH_4, the biogas treatment of slurry also has an effect of lower N_2O emission. Investigations indicate that biogas treated slurry applied on soil has a lower N_2O emission. For 2009, the biogas treated slurry lowered the N_2O with 0.05 Gg, which corresponds to a 4 % reduction of the N_2O emission from manure management in 2009.

3 Description of the model IDA

A comprehensive model complex called "Integrated Database model for Agricultural emissions" (IDA) is used to store input data and to calculate the agricultural emissions. The emission calculation includes greenhouse gases, NH_3, PM, NMVOC and other pollutants related to the field burning of agricultural residues, namely NO_x, CO_2, CO, SO_2, heavy metals, dioxin and PAH.

3.1 Methodology

The main principle in the estimation of the emission is an activity, a, multiplied with an emission factor, EF, set for each activity. The overall emission is calculated as the sum of the emissions from all activities, see Equation 3.1.

$$E_{total} = \sum a \bullet EF \qquad \text{(Eq. 3.1)}$$

Activity data for reporting in the agricultural sector could be, e.g. the number of cattle. The activity data for estimating emissions in the database is typically disaggregated into several different subcategories, which for cattle, for example, are dairy cattle, calves, heifers, bulls and suckling cattle and again divided into different breeds and weight classes.

The emissions are estimated on the basis of international guidelines. The emission calculations for the greenhouses gases are in accordance with the methods in the IPCC Guidelines (IPCC, 1997 and IPCC, 2000). The calculation of air pollutant emissions are in accordance with the methodologies described in the EMEP/EEA Guidebook (EMEP/EEA, 2009). National values and methodology approach are used where these better reflect the Danish agricultural conditions.

3.2 Data references – sources of information

Data input for emission calculations are collected, evaluated and discussed in collaboration with a range of different institutions involved in agricultural research and administration. The organisations include, for example, Statistics Denmark, the Faculty of Agricultural Sciences at Aarhus University, the Danish Agricultural Advisory Service, the Danish Environmental Protection Agency and the Danish Plant Directorate.

Table 3.1 provides an overview of the various institutions and organisations who contribute national data in connection with the preparation of the agricultural emissions inventory.

Table 3.1 Organisations contributing input data to the preparation of the emissions inventory.

References	Link	Abbreviation	Data / information
National Environmental Research Institute, Aarhus University	www.dmu.dk	NERI	- data collecting - emission calculations - quality assurance & quality control - reporting
Statistics Denmark – Agricultural Statistics	www.dst.dk	DSt	- livestock production - milk yield - slaughtering data - land use - crop production - crop yield - export of live animal - poultry
Faculty of Agricultural Sciences, Aarhus University	www.agrsci.dk	DJF	- N-excretion - feeding situation - animal growth - N-fixing crops - crop residue - N-leaching/runoff - NH_3 emission factor
The Danish Agricultural Advisory Service	www.lr.dk	DAAS	- housing type (until 2004) - grazing situation - manure application time and methods - estimation of extent of field burning of agricultural residue
Danish Environmental Protection Agency	www.mst.dk	EPA	- sewage sludge used as fertiliser - industrial waste used as fertiliser
The Danish Plant Directorate	www.pdir.dk	PD	- synthetic fertiliser (consumption and type) - housing type (from 2005) - sewage sludge used as fertiliser (from 2005 based on The Register for fertiliza-tion)
The Danish Energy Agency	www.ens.dk	DEA	- manure treated in biogas plants

3.3 Integrated database model for agricultural emissions

The **I**ntegrated **D**atabase for **A**gricultural emissions (IDA) model complex is designed in a relational database system (MS Access). Input data are stored in tables in one database called IDA_Backend and the calculations are carried out as queries in another linked database called IDA.

Most emissions relate to livestock production, which basically is based on information on the number of animals, the distribution of animals according to housing type and, finally, information on feed consumption and excretion.

IDA operates with 38 different livestock categories, according to livestock type, weight class and age. These categories are subdivided into different housing types and manure types, which results in around 200 different combinations of livestock subcategories and housing/manure types (Table 3.2). For each of these combinations, information on e.g. feed intake, digestibility, nitrogen excretion and CH_4 conversion factors is attached. The emission is calculated from each of these subcategories and then aggregated to the main livestock categories.

Table 3.2 Livestock categories and subcategories.

Main livestock categories	Subcategories	Number of subcategories divided into housing type and manure type system
Dairy cattle[1]	Dairy Cattle	34
Non-dairy cattle[1]	Calves (<½ yr), heifers, bulls, suckling cattle	120
Sheep	Including lambs	1
Goats	Including kids (meet, dairy and mohair)	3
Horses	Up to 200 kg, 200-400 kg, 400-800 kg, >800 kg	4
Pigs	Sows, weaners, fattening pigs	32
Poultry	Hens, pullets, broilers, turkeys, geese,ducks, ostriches, pheasants	42
Other	Mink, fitchew, foxes, finraccoon, deer	7

1) For all subcategories, large breeds and jersey cattle are separately identified.

Data are collected from the organisations mentioned above (Table 3.1) and processed and prepared for import to the database. This step is done in spreadsheets. The data are imported and stored in the database called "IDA-backend" which also stores the emission factors for all pollutants. All emission calculations are done in IDA, which is linked to IDA-backend. This means that calculations of pollutants all use the same data on number of animals, crop area, amount of synthetic fertiliser, etc. The calculated emissions and additional information are uploaded to the CRF and NFR templates via a conversion database. An overview of the data process is shown in figure 3.1.

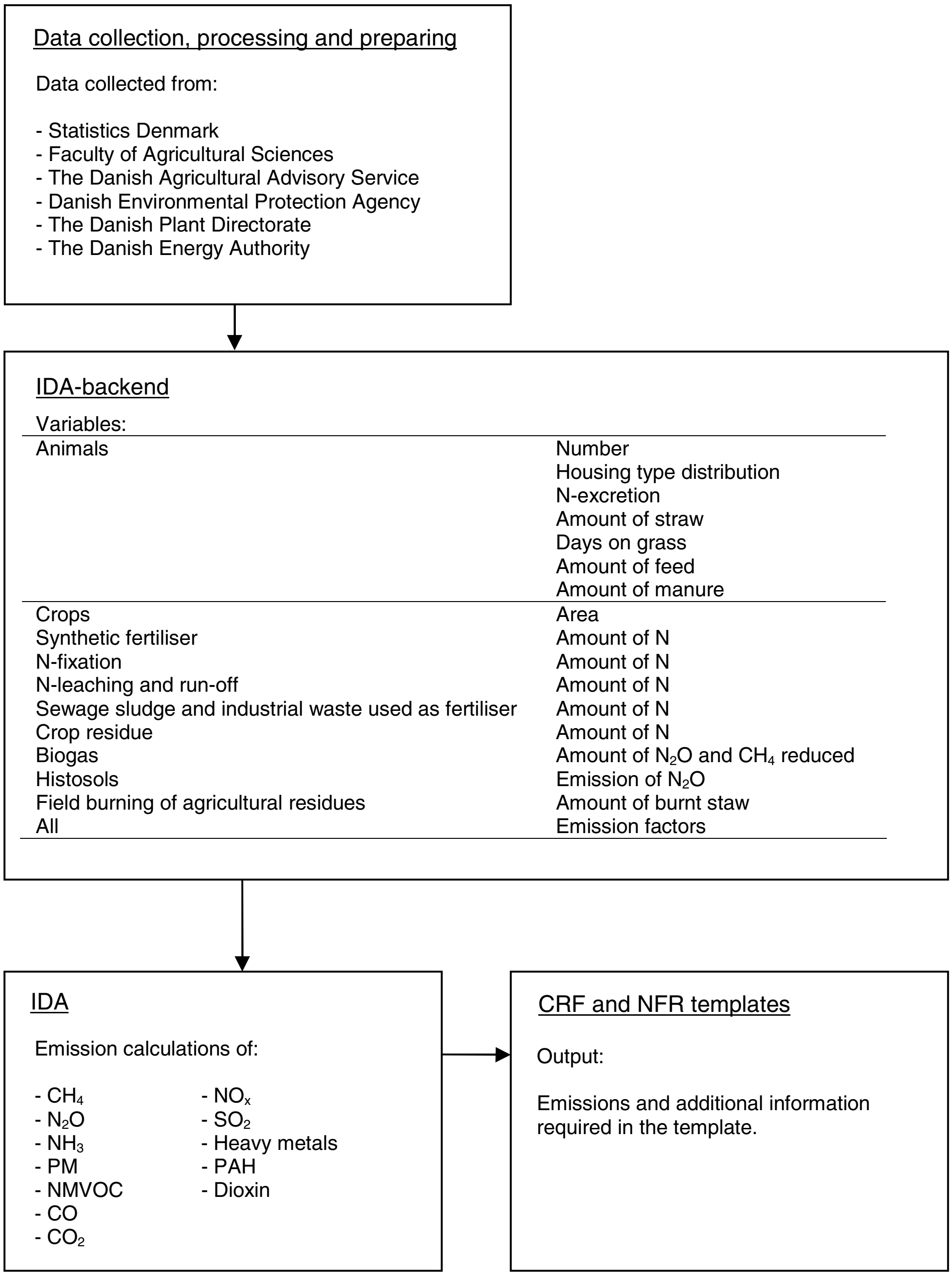

Figure 3.1 Overview of the data process for calculation of agricultural emissions.

4 Livestock population data

In 2009 livestock production was the main source of the agricultural emissions, contributing 87 % of the NH_3 emission and approximately 65 % of the greenhouse gas emission. To calculate the agricultural emission, a series of input data is used. Some values are obtained as default values from guidelines and some are estimated based on national values, which closer reflect the Danish agricultural conditions. Table 4.1 lists the most important national variables, and shows that some variables are used to calculate both NH_3 and greenhouse gas emissions. These variables (number of animals, distribution of housing types and estimated days on pasture and in housing) are described in this chapter. The remaining variables are included in the relevant pollutant chapters.

Table 4.1 Pollutants and variables.

Pollutants	National variables
NH_3, N_2O, CH_4	- No. of animal
	- Housing type/manure type
	- Days in housing and on pasture
NH_3, N_2O	- N-excretion
NH_3	- Conditions for storage and application of manure on agricultural soil
CH_4	- Feed intake (amount and composition)
	- Manure excretion (amount, content of dry matter and volatile solids)

4.1 Livestock population

Livestock production figures are primarily based on the agricultural census from Statistics Denmark (DSt), see appendix B for numbers of livestock 1985-2009. The emissions from fattening pigs and poultry are based on slaughter data.

DSt does not include farms smaller than 5 ha, therefore approximate numbers for horses, goats and sheep have been added to the numbers published by DSt. This procedure is in agreement with the Danish Agricultural Advisory Service (DAAS). The largest difference in animal numbers is for horses. In the agricultural census for 2009 the number of horses is estimated at approximately 60 000. Including horses on small farms and riding schools, however, the number rises to approximately 190 000 (Clausen, E., 2008). Data on the number of sheep and goats are based on the Central Livestock Register (CHR), which is the central register of farms and farm animals of the Ministry of Food, Agriculture and Fisheries.

The inventory furthermore includes emissions from deer, ostrich and pheasants, which are not included in DSt. Data on the number of deer and ostrich are based on the CHR, while the number for pheasants is based on the expert judgement of NERI (Noer, 2009) and the pheasant breeding association (Stenkjær, 2009).

The normative figures for feed intake and N-excretion are for some livestock categories, e.g. dairy cattle and sows, given for a year animal, which means the average number of animals, present within the year. This corresponds to the definition of annual average population (AAP) in the EMEP/EEA Guidebook (EMEP/EEA, 2009). For other livestock categories such as bull calves, bulls, weaners, fattening pigs, pullets and heifers (1985-2002), the normative figures are given per animal produced.

Below follows a description of the how livestock production is calculated for each animal category.

4.1.1 Cattle

Cattle are divided into six main categories and for each of these categories distinction is made between large breeds and Jersey cattle (Table 4.2). The categories are dairy cattle, bull calves and heifer calves, bulls more than 6 months destined for slaughter, heifers more than 6 months to be used for breeding purposes, and suckling cattle. The categories are further divided into different housing systems and manure types.

Data regarding the distinction between large breed and Jersey cattle were, until 2000, collected via special calculations from DSt. From 2001 the figures on Jersey cattle have been provided by DAAS, and are based on registrations from yield control exercises covering approximately 90 % of dairy cattle.

Table 4.2 Main categories of cattle.

	Proportion of Jersey cattle (%) in the total cattle population 2009[1]
Dairy cattle	12.9
Heifer calves, 0 - 6 months	10.3
Heifers, 6 months to calving	9.1
Bull calves, 0-6 months	2.7
Bulls, 6 months to slaughter age	4.3
Suckling cattle	0

[1] Source: Flagstad, 2010.

In order to calculate the emission, the number of animals has to be quantified for each of the categories.

Dairy cattle

The annual average population of dairy cattle is based on DSt.

Heifers

The number of heifers is calculated by two different methodologies, which is due to a change in the Danish Normative System in 2003. This change in the calculation has no impact on emissions.

From 1985 to 2002, the normative figures for N-excretion are given per animal produced, which is described in Mikkelsen et al. (2006). From 2003 and onwards the normative figures are changed so the values of feed intake and N-excretion represent AAP (annual average population), which are based on the number of animals reported by DSt.

Calculation of the number of heifer calves produced (< ½ year) per year:

a) $no_L = no_{DSt} \cdot (1 - J)$ (Eq. 4.1a)

b) $no_J = no_{DSt} \cdot J$ (Eq. 4.1b)

Example for 2009:

$$no_L = 150\,782 \cdot (1 - 0.103) = 135\,251$$

where: no_{DSt} = number of heifers <½ year given by DSt
no_L = number of large breed heifers <½ year
no_J = number of Jersey heifers <½ year
J = fraction of Jersey heifers

Bulls

The normative figures from DJF represent feed intake and N-excretion per animal produced. The number of animals produced is converted based on the number provided by DSt.

Number of total bulls and bull calves produced

Bulls are slaughtered, on average, after 382 days which means that the overall production time is ½ year + 200 days. When calculating the annual production of bull calves (<½ year), the population from DSt is multiplied by 365/182.5 and for bulls >½ year the sum is multiplied by 365/200, as follows:

Number of bull calves and bulls produced per year:

$$no = no_{DSt} \cdot \frac{356}{T}$$ (Eq. 4.2)

where: no = number of bulls/bull calves
no_{DSt} = number of bulls/bull calves given by DSt
T = production time in days (up to ½ year = 182.5 and more than ½ year = 200)

Example from 2009:

$$no_{<½} = 117\,478 \cdot (365/182.5) \cong 234\,956$$

$$no_{>½} = 145\,183 \cdot (365/200) \cong 264\,959$$

Distribution between large breed and Jersey

An average slaughter weight for large breed cattle and Jersey cattle of 440 kg and 328 kg, respectively, is assumed in the normative figures (Poulsen et al., 2001).

The number of bulls from suckling cattle is counted under the category of bull calves, large breed. It is assumed that the allocation between dairy cattle and suckling cattle is approximately the same for bull and for bull calves. This fraction of suckling cattle has been nearly unaltered at 16 % for the last ten years, but are fallen to 14.5% in 2009.

The number of bulls/bull calves from suckling cattle is estimated. For the remaining part of cattle the distribution between large breed and Jersey is estimated by using the percentage for Jersey cattle given in Table 4.2.

Equation 4.3:

$$Frac = no_{S,\,DSt}/(no_{D,\,DSt} + no_{S,\,DSt}) \quad \text{(Eq. 4.3)}$$

where: Frac = fraction of suckling cattle
$no_{S,\,DSt}$ = number of suckling cattle given by DSt
$no_{D,\,DSt}$ = number of dairy cattle given by DSt

Calculation for 2009:

The number of respectively large breed and Jersey bulls and bull calves produced is calculated as follows:

Equation 4.4 a) and b):

a) $$no_{B,L} = (no_B - no_B \cdot Frac) \cdot (1 - J) + (no_B \cdot Frac) \quad \text{(Eq. 4.4a)}$$

b) $$no_{B,J} = (no_B - no_B \cdot Frac) \cdot J \quad \text{(Eq. 4.4b)}$$

where: $no_{B,\,L}$ = number of large breed bulls produced
no_B = number of bulls produced
$no_{B,\,J}$ = number of Jersey breed bulls produced
Frac = fraction of suckling cattle
J = percent of Jersey bulls

Calculation example for 2009:

Table 4.3 Number of bulls, 2009.

	Number of animals, DSt	No. of bulls/bull valves produced	Fraction of suckling cattle	No. of bulls produced	
				Large breed	Jersey
Bull calves < ½ year	117 478	234 956	0.145	229 534	5 422
Bulls > ½ year	145 183	264 959	0.145	255 221	9 738

Suckling cattle

The number for suckling cattle is provided by DSt.

4.1.2 Pigs

There are three different main pig categories: sows (including piglets up to 7.3 kg), weaners (7.3 to 32 kg) and fattening pigs (32 to 107 kg).

Sows

The number for sows is provided by DSt. Sows include pregnant sows, suckling sows and barren sows.

Weaners and fattening pigs

The normative figures for feed intake and N-excretion for fattening pigs and weaners are provided per pig produced, therefore the emission calculation has been based on the number of animals produced.

The production of both weaners and fattening pigs is mainly based on data on slaughter provided by DSt. Discared animal during the slaughtering process and export of living animals is taken into account. The calculated emission from weaners and fattening pigs also include the emission related to bredding of boars and barren.

The number of fattening pigs is based on the total meat production divided wiht an average slaughter weight based on the normative figures, which in 2009 was provided to 82 kg (Poulsen, 2010).

Number of fattening pigs produced:

$$no = (\frac{AM}{AS}) + Ex_{fattening} + Ex_{breeding} \quad \text{(Eq. 4.5)}$$

where:

no	= number of fattening pigs
AM	= amount of meat produced, kg
AS	= average slaughter weight, kg per produced animal
$Ex_{fattening}$	= export of living fattening pigs, 1000 s
$Ex_{bredding}$	= export of living animals for breeding, 1000 s

Example from 2009:

$$no_{2009} = (\frac{1\,639\ M\ kg}{82\ kg}) + (856 + 17) = 20\,866\,000 \Rightarrow 20.9\ million$$

Numbe of weaners is calculated as the the number of fattening pigs plus the number of exported lving weaners, which has increased significantly in the last five years from 1.9 million in 2004 to 7.0 million in 2009.

Number of weaners produced:

$$no = no_{fattening} + no_{exported} \quad \text{(Eq. 4.6)}$$

where: no = number of weaners, weight 7-32 kg
$no_{fattening}$ = total number of produced fattening pigs
$no_{exported}$ = number of exported living weaners

Example for 2009:

$$no_{2009} = 20.9\,\text{million} + 7.0\,\text{million} = 27.9\,\text{million}$$

The normative feed intake and excretion values for fattening pigs are in 2009 based on a 107 kg live weight, equivalent to 82 kg slaughter weight (Poulsen, 2010). Slaugthering data is as mentioned based on Statistics Denmark. Information on dischared animal is based on data from DAKA, which is a cooperative society owned by 16 members and these members represent most of the Danish meat industry. In 2009, the total meat production is estimated at 1 639 million kg meat and the number of living animal exported are 7.9 million (Table 4.4).

Table 4.4 Backgrounddata for estimating number of produced fatteing pigs and weaners, 2009.

Fattening pigs to slaughter (million kg meat)	
Delivered to slaughterhouse	1 570
Slaughtered for the producer at slaughterhouse	0,2
Slaughtered at home	1,9
Discarded during the production process	5,7
Transfer to sow unit (million kg meat)	
Gilt to slaugther	0,5
Bredding period of boars	0,9
Breeding period of barren sows	43,3
Total meat production from pigs, million kg meat	1 639
Export of living animals (1000 s)	
Fattening pigs	856
Animals for breeding	17
Weaners	7 042
No of produced animal (1000 s)	
No. of produced fattening pigs	20 866
No. of produced weaners	27 908

Table 4.5 shows the figures for the number of pigs other than sows reported by DSt, compared to the calculated number of weaners and fattening pigs produced per year. The emission calculations are based on number of produced pigs.

Table 4.5 Number of weaners and fattening pigs, 2009.

	No. of animal, DSt	No. of produced pigs 1000s
Pigs (other than sows)	12 369	
Fattening pigs (32-107 kg)		20 866
Weaners (7.5-32 kg)		27 908

4.1.3 Poultry

For poultry, the production is based on the number of animals slaughtered. Mortality during the breeding process and export is taken into account.

For poultry, there are four main categories: laying hens, broilers, turkeys and other poultry (geese, ducks, pheasants and ostrich).

Laying hens

The category of laying hens includes hens and pullets. The normative figures for hens are based on average annual hens (units of 100). Five main production forms are distinguished between – free-range, organic, barn and battery as well as production of hens for brooding. The distribution between the different production forms is estimated on the basis of the number of eggs weighed as part of the efficiency control, which includes approximately 33 % of the eggs produced (Jensen, 2008) – see Table 4.6.

Hens

The population of hens for 2009, according to DSt, is 4.19 million, of which the number of average annual brood hens is approximately 1.07 million (Jensen, 2008). The remaining non-brood hens (3.12 million in 2009) fall into the six different categories according to the different production forms. The number of hens within each category is calculated as follows:

$$no_h = (no_{DSt} - no_{BE}) \cdot (P/100) \qquad \text{(Eq. 4.7)}$$

where: no_h = number of hens within a given production form

no_{DSt} = number of hens given by DSt

no_{BE} = number of brood hens

P = percent distribution of the production form

Below is an example calculation of the number of free-range hens in 2009 (100s):

$$no_h = (32\,797 - 10\,672) \cdot (7/100) = 154$$

The category of battery hens is furthermore divided into three different housing systems according to the differences in the handling of manure. These categories are termed manure houses, manure tanks and manure cellar.

Table 4.6 Distribution of hens in different categories in 2009. (100s).

	No of hens given in DSt, 100s	Pct. distribution on production forms	Number of hens 100s
Hens - total (population DSt)	32797		
- of which egg layers for brooding	10672		10672
- of which egg layers	22125	100	
Free-range		6	1328
Organic		15	3319
Barn		19	4204
Battery, manure cellar		31	6859
Battery, slurry tank		5	1106
Battery, manure shed		24	5310
Total number of hens			32797

Pullets

The normative figure for pullets is based on the production of 100 pullets. The production time for pullets is between 112 and 119 days depending on production form (Poulsen et al., 2001), which corresponds to approximately three production cycles during the year (365/112 = 3.3, 365/119 = 3.1). Pullets for production of consumption egg have a 112 days production time while pullets for brooding eggs have 119 days production time. Annual production is determined using the population figure provided by DSt (chickens for breeding) multiplied by the production cycle.

The total number of pullets produced during the year is divided into three main production forms – consumption (net), consumption (floor) and pullets used for brooding eggs. The multiplication factor related to the percentage distribution of the three different production forms is based on information from the Danish Poultry Meat Association (Jensen, 2008) – see Table 4.7.

Calculation of the total number of pullets produced:

$$no_{pu} = no_{DSt} \cdot \frac{365}{T} \cdot (P/100) \qquad \text{(Eq. 4.8)}$$

where: no_{pu} = number of pullets within a given production form

no_{DSt} = number of pullets given by DSt

T = production time, days

P = percent distribution of the production form

Below is, as an example, the calculation of the number of pullets produced for consumption, net production (units - 100), for 2009:

$$no_{pu} = 10\,916 \cdot \frac{365}{112} \cdot (5/100) = 1779$$

Table 4.7 Calculation of the number of pullets produced in 2009.100s.

	No. of pullets given in DSt 100s	Distribution on production forms	Production time	Production runs per year	Number of pullets produced per year 100s
		%	days		
Pullets - total (population DSt)	10 916	100			
Consumption, net		5	112	3.259	1 779
Consumption, floor		69	112	3.259	24 546
Egg brooding, floor		26	119	3.067	8 705
Number of pullets produced in 2009					35 030

Broilers, turkeys, ducks and geese

Numbers of broilers, turkeys, ducks and geese are based on the number of animals produced. The calculation of production is based on slaughter data from DSt. Export of animals, farmers' private consumption of animals, deaths occurring in the production process are all taken into account.

Data on both export of live broilers, ducks, geese and turkeys and the farmers private consumption have been obtained from DSt.

Calculation method to estimate poultry production:

$$no_{po} = no_{DS} + no_{PC} + no_{E}$$ (Eq. 4.9)

where: no_{po} = number of the given category of poultry (broilers, ducks, geese or turkeys)
no_{DS} = number of animals delivered to slaughter
no_{PC} = number of animals slaughtered at home for private consumption
no_{E} = number of live animals exported

Example for the number of broilers produced in 2009 (in 1 000s):

$$no_{po} = 100\,132 + 500 + 8\,719 = 109\,351$$

The calculated number of broilers, turkeys, ducks and geese produced is compared in Table 4.8 with the figures for the number of average annual animals reported by DSt. The number of average annual animals represents the number of housing places.

Table 4.8 Number of broilers, turkeys, ducks and geese, 2009.

	No. of animal, DSt	No. of produced animals 1000s
Broilers	14 787	109 351
Turkeys	165	1 176
Ducks	208	827
Geese	10	20

Pheasants and ostrich

DSt has no data on the number of pheasants and ostrich produced. The number of pheasants is based on expert judgement by NERI (Noer, H., 2009) and the pheasant breeding association and is estimated at 1 062 500 in each of the years 1985-2009. Pheasants are bred for hunting and this is estimated to have been unaltered in the period. The number of ostrich is based on information obtained from the Central Livestock Register (CHR), which is the central register for farm data of the Ministry of Food, Agriculture and Fisheries, (see Table 4.9). The production of ostrich in Denmark started in 1993 and the number of ostrich from 1985 to 1992 has therefore been set at zero.

Table 4.9 Number of ostrich 1985 to 2009.

	1985-1992	1993	1994	1995	1996	1997	1998	1999	2000
Ostrich	0	1 111	2 222	3 333	4 444	5 556	6 667	7 778	8 889
Continued									
	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ostrich	10 000	6 579	4 782	4 153	3 661	3 661	569	461	358

4.1.4 Horses

There are four different weight classes for horses: small ponies up to 200 kg, lighter breeds – 200-400 kg, medium-weight breeds –400–800 kg and large breeds – over 800 kg. DAAS estimates that the distribution in these groups is 25, 34, 38 and 3 %, respectively.

The figures from DSt only includes horses on farms larger than 5 ha. However, a study of pets undertaken by DSt has indicated that a significant number of horses are found on smaller hobby farms and riding schools that are below 5 ha. The total number of horses in the inventory is based on the horse breeding register managed by DAAS.

In 2009, 57 981 horses were listed by DSt, as opposed to 177 500 according to DAAS figures. In 2000 DAAS has estimated the number of horses to 150 000. The number is interpolated between 2000 and 2008. Number of horses in 2009 is based on a new judgement from DAAS, which shows a fall in number of horses. Table 4.10 shows the number of horses registered by, respectively, DSt and DAAS.

Table 4.10 Number of horses 1985 to 2008 (thousands).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
DSt[1]	32	30	33	34	35	38	32	28	20	18	18	20
DAAS[2]	140	139	138	137	136	135	137	138	140	141	143	144

Continued

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
DSt[1]	39	38	40	40	43	38	43	39	54	53	53	60
DAAS[2]	146	147	149	150	155	160	165	170	175	180	178	165

[1] agricultural units > 5 ha.

[2] Total number of horses incl. horses on small farms and riding schools.

4.1.5 Sheep, goats and deer

The normative figures for sheep and goats are based on average annual breeding ewes/goats including lambs and kids. It is expected that a number of sheep and goats are to be found on farms smaller than 5 ha and that the actual number is, therefore, higher than that reported by DSt. Therefore, data on the number of sheep and goats are based on the Central Livestock Register (CHR).

The production of deer is included in the Danish inventory and covers animals bred for meat on farms (in enclosures) and not deer in the wild. No data on the number of deer is available from DSt, thus the number of deer is based on CHR.

4.1.6 Fur animals

The production of fur animals is calculated as the population of mink, fitchew, foxes and finraccoon as stated by DSt.

4.2 Housing system

For each livestock category, the number of animals is divided into a range of different housing systems. The housing system is a determinant factor for how the animal manure is handled and therefore decisive for the distribution into liquid and solid manure systems.

No systematic record of the distribution of the different housing types exists until 2004. Therefore, the distribution form 1985 to 2004 is based on expert judgement. For cattle and pigs, the distribution is based on information from Rasmussen (2003) and Lundgaard (2003). The distribution of housing systems for fur animals is obtained from Risager (2003). The housing distribution for poultry is determined on the basis of efficiency controls by the Danish Poultry Meat Association (Jensen, 2008). From 2005 onwards, the distribution of the different housing types is based on information from the Danish Plant Directorate (PD) on farm nitrogen budgets, which farmers, by law have to submit annually.

appendix C presents the distribution of the different housing types for all livestock categories. Table 4.11 and Table 4.12 show the estimated distribution of housing types from 1985 to 2009 for dairy cattle and fattening pigs, the two most important livestock categories.

The structural development in the agricultural sector has influenced the change in housing types. New housing facilities have been built and most of the tethered housings have been replaced by larger loose-housing facilities. In 1985, 85 % of the dairy cattle were kept in tethered stalls and in 2009 this had been reduced to 12 %. In the case of fattening pigs, many solid floor systems have been replaced by a system with slatted floors. The consequence of this development is that, more of the animal manure is handled as slurry.

Table 4.11 Dairy cattle distributed on main housing types.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Housing type						%							
Tethered housing	85	84	83	82	80	79	78	77	75	74	73	72	66
Loose-housing with beds	14	15	15	16	17	18	18	19	20	21	21	22	26
Deep litter	1	1	2	2	3	3	4	4	5	5	6	6	8

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Housing type						%						
Tethered housing	60	60	46	40	35	26	22	26	26	17	14	12
Loose-housing with beds	30	30	43	49	54	63	67	66	66	76	79	82
Deep litter	10	10	11	11	11	11	11	8	8	7	6	6

Table 4.12 Fattening pigs distributed on main housing types.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Housing type						%							
Fully slatted floor	29	33	38	42	47	51	56	60	60	60	60	60	60
Partly slatted floor	30	29	27	26	24	23	21	20	21	23	24	25	26
Solid floor	40	36	33	29	26	22	19	15	14	12	11	9	8
Deep litter	1	2	2	3	3	4	4	5	5	5	5	6	6

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Housing type						%						
Fully slatted floor	60	60	58	57	56	55	53	49	49	52	52	53
Partly slatted floor	28	29	31	33	34	35	38	38	38	39	41	42
Solid floor	6	5	5	4	4	4	3	7	7	4	3	2
Deep litter	6	6	6	6	6	6	6	6	6	5	4	3

4.3 Number of days in housing and on pasture

A proportion of the manure from dairy cattle, heifers, suckling cows, sheep, goats, horses and deer is deposited on the field during grazing. It is assumed that on average 5 % of the manure from dairy cows is excreted directly onto the field during grazing in 2009, which translates to 18 days on pasture. The equivalent estimate for suckling cows is 224 days, with 132 days for heifers, 183 days for horses, 265 days for sheep and goats and 365 for deer (Poulsen et al., 2001), Table 4.13.

The number of grazing days for dairy cattle and heifers has decreased in the period 2002-2009 due to the structural development towards larger farms. Appendix D shows the number of days on pasture for all years (1985-2009) and for all livestock categories.

It should be stressed that there is uncertainty attached to these evaluations and the calculations given should be considered as the best possible estimate with the current availability of data.

Table 4.13 Number of grazing days corresponding to the proportion of N in manure deposited on the field during grazing.

	2009
Cattle:	
Dairy Cattle	18
Calves and bulls	0
Heifers	132
Suckling Cattle	224
Pigs:	
Sows, weaners and fattening pigs	0
Sows, outdoor	365
Poultry:	
Hens, pullets, broilers, turkeys and ducks	0
Geese, pheasant and ostrich	365
Other:	
Horses	183
Sheep and goats	265
Deer	365
Fur animals	0

5 NH_3 emission

Figure 5.1 shows the NH_3 emissions from different sources in 2009. The emission from the handling of animal manure constitutes 84 % of the total NH_3 emission. The emissions from growing crops and synthetic fertilisers contribute 6 and 7 %, respectively. The remainder comes from grazing animals (3 %) and less than 1 % is from other sources such as sewage sludge and industrial sludge, applied to agricultural land, the field burning of agricultural residues and NH_3 treated straw. Appendix A shows the NH_3 emissions from all sources for the period 1985 – 2009.

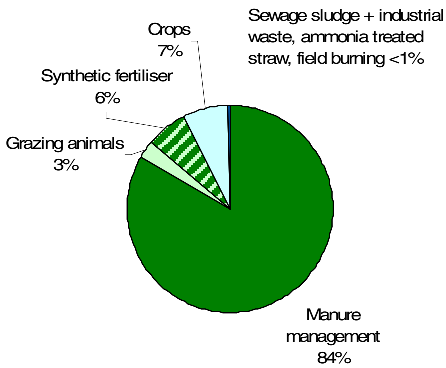

Figure 5.1 NH_3 emissions, 2009.

5.1 Animal manure

5.1.1 Total N and TAN

The emission of NH_3 from manure management is calculated on the basis on nitrogen excreted from livestock. Most of the N excreted that is readily degradable and broken down to NH_4-N is found in the urine. Previously, the emission calculation has been based on the total N content in manure for all manure types. However, the relationship between NH_4-N and total N will not remain constant over time due to changes in feed composition and feed use efficiency.

In order to be able to implement the effect of NH_3-reducing measurements as improvements in feed intake and composition in the emission inventory, it is necessary to calculate the emission based on the Total Ammoniacal Nitrogen (TAN) content, which has been done to the extent possible. From 2007 the calculation of NH_3 emission from liquid manure is based on TAN. For solid manure and deep litter an emission factor for total N is still used.

The normative figures for both total nitrogen excretion and the content of TAN are provided by DJF.

5.1.2 Methodology

The NH_3 emission occurs wherever the manure is exposed to the atmosphere in livestock housings, manure storages, after application of manure to the fields and from the manure deposited by grazing animals. The total NH_3 emission from animal manure is calculated as:

$AM_t = AM_{,H} + AM_{,S} + AM_{,A} + A_{,G}$ (Eq. 5.1)

where:
$AM_{,t}$ = total ammonia emission
$AM_{,H}$ = emission from manure in livestock housing
$AM_{,S}$ = emission from manure storage
$AM_{,A}$ = emission from manure application to fields
$AM_{,G}$ = emission from manure deposited by animals on grass

For each of the elements above, NH_3 losses are calculated for each individual combination of livestock category and housing type. The time the livestock spends indoors and outdoors (grazing), respectively, is taken into account.

a) $AM_{,H} = no \cdot Nex_A \cdot (1-D_G/365) \cdot EF_H$ (Eq. 5.2a)

b) $AM_{,S} = no \cdot Nex_H \cdot (1-D_G/365) \cdot EF_S$ (Eq. 5.2b)

c) $AM_{,A} = no \cdot Nex_S \cdot (1-D_G/365) \cdot EF_A$ (Eq. 5.2c)

d) $AM_{,G} = no \cdot Nex \cdot (D_G/365) \cdot EF_G$ (Eq. 5.2d)

where:
no = number of animals
Nex_A = N excretion from animals, kg head^{-1} yr^{-1}
Nex_H = N excretion in housing unit, kg head^{-1} yr^{-1}
Nex_S = N excretion in storage unit, kg head^{-1} yr^{-1}
D_G = days on grass during the year (see Table 4.13)
EF = emission factor for the given housing unit

The emission calculation for fattening pigs in 2009 housed on fully slatted flooring is shown below as an example, based on normative figures and emission factors given in Table 5.1. In 2009, 20.9 million fattening pigs were produced (Table 4.1.2). Of these, 54 % are housed for 365 days a year in housing systems with fully slatted flooring.

Table 5.1 Normative figures and emission factors for one produced fattening pigs in 2009 (DJF).

Normative figures, kg N pr produced animal			Emission factors, EF, pct NH_3-N of TAN		
TAN ex animal	TAN ex housing	TAN ex storage	Housing unit	Storage	Application
1.96	1.49	1.80	24	2.9	11.22 (slurry)

Calculation of the emission from fattening pigs housed on fully slatted flooring:

$$AM_H = (20\,865\,535 \cdot 0.54) \cdot \frac{1.96}{1\,000} \cdot (1 - \frac{0}{365}) \cdot \frac{24}{100} = 5\,300 \text{ tonnes } NH_3\text{ - N}$$

$$AM_S = (20\,865\,535 \cdot 0.54) \cdot \frac{1.49}{1\,000} \cdot (1 - \frac{0}{365}) \cdot \frac{2.9}{100} = 487 \text{ tonnes } NH_3 \text{ - N}$$

$$AM_A = (20\,865\,535 \cdot 0.54) \cdot \frac{1.80}{1\,000} \cdot (1 - \frac{0}{365}) \cdot \frac{11.22}{100} = 2\,276 \text{ tonnes } NH_3 \text{ - N}$$

$$AM_{total} = 5\,300 + 487 + 2\,276 = 8\,063 \text{ tonnes } NH_3 \text{ - N} \Rightarrow 9\,790 \text{ tonnes } NH_3$$

N-excretion and emissions given in NH_3-N for all main livestock categories are shown in appendix E.

5.1.3 Normative figures for nitrogen in animal manure

The normative values for nitrogen excretion are estimated by FAS based on research results (Laursen, 1994; Poulsen & Kristensen, 1997; Poulsen et al., 2001; Poulsen, 2010). The normative figures are continually adjusted to take account of the changes in feed composition and feed use efficiency. The normative values are since 2002 updated every year. Values for N ex animal are provided in Table 5.1 A-D for the most important livestock categories and in Table 5.2 based on TAN for 2007 to 2009.

For heifer a change in methodology has taken place. From 1985 to 2002 the normative figures for N ex was provided for each produced animal. This has changed form 2003, where the N ex covers N ex per AAP (annual average population – see definition in section 4.1).

For animal categories which N ex is based on produced animal, this is noticed as a footnote in Table 5.1A-D.

Table 5.1 A-D N ex animal, 1985 to 2009, kg pr animal.

A) Cattle, large breed		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Dairy cows	Total N	125.0	127.3	129.5	131.8	134.0	133.0	132.0	131.0	130.0	129.0	128.0	127.8	127.7
Bulls[a]	Total N	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
Heifers[b]	Total N	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2
Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Dairy cows	Total N	127.5	127.3	128.0	128.0	130.0	132.8	134.5	136.3	137.4	140.2	140.6	140.6	
Bulls[a]	Total N	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	
Heifers[b]	Total N	39.2	39.2	39.2	39.2	39.2	39.2	39.2	43.7	48.1	52.6	52.6	52.6	

[a] 6 mth to slaughter. Kg N pr produced animal.

[b] 6 mth to calving.

B) Pigs		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Sows	Total N	31.9	31.2	30.6	29.9	29.3	28.7	28.1	27.5	26.9	26.3	25.7	26.0	26.2
Fattening pigs[c]	Total N	5.09	5.01	4.94	4.86	4.78	4.53	4.28	4.03	3.78	3.53	3.28	3.25	3.21
Weaners[c]	Total N	0.84	0.82	0.79	0.77	0.74	0.73	0.72	0.71	0.7	0.68	0.67	0.67	0.66
Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Sows (incl. piglets)	Total N	26.5	26.6	26.6	27.2	27.2	27.2	27.2	26.5	26.3	26.4	25.8	26.0	
Fattening pigs[c]	Total N	3.18	3.15	3.12	3.12	3.25	3.17	3.19	3.18	3.03	3.1	3.02	2.94	
Weaners[c]	Total N	0.65	0.64	0.64	0.64	0.65	0.58	0.63	0.67	0.51	0.53	0.55	0.51	

[c] pr. produced animal.

C) Poultry		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Battery hens[d]	Total N	61.1	64.6	68.0	71.4	74.9	75.2	75.6	75.9	76.3	76.6	77.0	77.0	77.0
Broilers[e]	Total N	40.7	40.7	48.3	52.2	56.0	55.2	54.4	53.7	52.9	52.1	51.3	51.3	51.3
Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Battery hens[d]	Total N	77.0	76.9	67.1	67.1	67.9	72.5	73.2	77.9	77.9	68.4	69.5	69.5	
Broilers[e]	Total N	51.3	51.3	53.3	53.3	53.6	53.6	58.1	64.3	64.2	65.5	65.5	65.5	

[d] pr. 100 animal. Change in methodology has taken place from N ex per produced hens to N ex per AAP (annual average population – see definition in section 4.1) In this table all years covers N ex per AAP.

[e] pr. 1000 produced animal.

D) Fur animals		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Mink (incl. cubs)	Total N	5.17	5.1	5.03	4.95	4.88	4.83	4.78	4.73	4.69	4.64	4.59	4.59	4.59
Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Mink (incl. cubs)	Total N	4.59	4.59	4.59	4.59	4.59	4.59	5.07	5.36	5.17	5.17	5.28	5.51	

Sources: Laursen (1994), Poulsen & Kristensen (1997), Poulsen et al. (2001), Poulsen (2010).

Table 5.2 TAN ex animal, 2007-2009.

kg pr animal		2007	2008	2009
Cattle				
Dairy cows	TAN	66.7	67.0	65.7
Bulls[a]	TAN	16.1	16.1	16.1
Heifers[b]	TAN	35.84	35.44	35.9
Pigs				
Sows	TAN	19.8	19.2	19.3
Fattening pigs[c]	TAN	2.04	2.03	1.96
Weaners[c]		0.31	0.33	0.31
Fur animals				
Mink	TAN	3.85	3.93	4.11

[a] 6 mth to slaughter. Pr produced animal.

[b] 6 mth to calving.

[c] pr produced animal.

Source: Poulsen (2010).

Appendix E shows the total N-excretion for the different livestock main categories from 1985 to 2009 as well as the NH_3 emission for the different main livestock categories.

5.1.4 Emission factors

Housing unit

The emission factors for housing vary according to the combination of housing and manure type. As an example, the emission factors for cattle housing units are given in Table 5.3 based on values in the report on normative standards (Poulsen et al., 2001, Poulsen, 2010). For emission factors for other livestock types see appendix F.

Table 5.3 NH_3 emission factors for housing units.

Cattle		Urine TAN	Slurry TAN	Solid manure Total N	Deep litter manure Total N
Stable type		Pct. loss of TAN ex animal		pct. loss of N ex animal	
Tethered	urine and solid manure	10	-	5	-
	slurry manure	-	6	-	-
Loose-housing with beds	slatted floor	-	16	-	-
	slatted floor and scrape	-	12	-	-
	solid floor	-	20	-	-
	drained floor	-	8	-	-
	solid floor with tilt and scrape	-	8	-	-
	solid floor with tilt	-	12	-	-
Deep litter	All	-	-	-	6
	solid floor	-	-	-	6
	slatted floor	-	16	-	6
	slatted floor and scrape	-	12	-	6
	solid floor and scrape	-	20	-	6
Boxes	sloping bedded floor	-	16	-	-
	slatted floor	-	16	-	-

Denitrification of the N in animal manure, where the NH_4-N undergoes nitrification to N_2, N_2O and NO_X, can occur to a large degree with the use of deep straw bedding. This loss is subtracted from storage. The loss of N_2O is included in the calculation of greenhouse gases.

Storage

The emission factors used for storage are listed in Table 5.4 and are based on normative figures (Poulsen et al., 2001 and Poulsen, 2010).

The figures for slurry take into account that not all slurry tanks are fully covered.

Table 5.4 NH_3 emission factors for storage units.

			Urine	Slurry[1]	Solid manure	Deep litter	Pct. of solid manure stored in heap on field
Cattle		Total N	2	2.1	4	1	35
		TAN	2.2	3.5	-	-	-
Pigs	Sows	Total N	2	2.4	19	6.5	50
		TAN	2.2	2.9	-	-	-
	Weaners	Total N	2	2.4	19	9.8	-
		TAN	2.2	2.9	-	-	-
	Fattening pigs	Total N	2	2.4	19	9,8	75
		TAN	2.2	2.9	-	-	-
Poultry	Hens and pullets	Total N	-	2	7.5	4.8	95
	Broilers	Total N	-	-	11.5	6.8	85
	Turkeys, ducks, and geese	Total N	-	-	-	6.8, 8(Turkeys)	-
Fur animals		Total N	0	3.1	11.5	-	-
		TAN	0	3.1	-	-	-
Sheep and goats		Total N	-	-	-	4	-
Horses		Total N	-	-	-	4	-

[1] It is assumed that 5 % of slurry tanks in pig production and 2 % in cattle production are not fully covered or have an inadequate floating cover. The emission factors were higher in the previous years (see appendix G).

Liquid manure

The emission from urine is, according to the normative figures, an estimated 2 % of total-N ex housing unit and 2.2 % of TAN ex housing unit from a closed urine tank.

As not all slurry tanks have a fixed cover or a full floating cover, this is taken into account in the inventory (COWI, 1999 and 2000). It is assumed that the covered capacity has increased in recent years as a result of the stricter regulations on the management of slurry tanks. For 2009 it is assumed that floating/fixed covers are absent on 5 % of slurry tanks in pig production and on 2 % in cattle production.

The correction for the lack of floating/fixed covers for total-N ex housing unit is based on normative figures (Poulsen et al., 2001), while the correction for TAN is based on Hansen et al. (2008). The emission factor for pig slurry with and without a floating/fixed cover is 2 % and 9 % of total-N ex housing unit and 2.5 and 11.4 % of TAN, respectively. For cattle slurry the factor is approximately 2 % with floating/fixed cover and 6 % of total-N ex housing and 3.4 and 10.3 % of TAN, respectively. Calculation examples of NH_3-N emission factor based on TAN for pig slurry and cattle slurry are shown in Equation 5.3. The unit is kg NH_3-N pr kg TAN.

$$\text{a) Emission}_{\text{pig slury}} = (0.95 \cdot 2.5\%) + (0.05 \cdot 11.4\%) = 2.9\% \quad \text{(Eq. 5.3a)}$$

$$\text{b) Emission}_{\text{cattle slurry}} = (0.98 \cdot 3.4\%) + (0.05 \cdot 10.3\%) = 3.5\% \quad \text{(Eq. 5.3b)}$$

The emission factors for 2009 for pigs (corrected), cattle (corrected) and fur animals are 2.9 %, 3.5 % and 3.1 %, respectively. Emission factors for all years are shown in appendix G.

Solid manure

The volatilization from solid manure is based on normative figures (Poulsen et al., 2001). From august 2006 the law stipulates that manure heaps should be covered, but also here a correction of the emission factor is made for the ones not covered. A calculation example of the correction for pig manure is shown in Equation 5.4. The unit is kg NH_3-N pr kg TAN.

$$\text{Emission}_{\text{pig manure}} = (0.5 \cdot 0{,}25\%) + (0.5 \cdot 0{,}13\%) = 19\% \quad \text{(Eq. 5.4)}$$

Emission factors for cattle, pigs, poultry and fur animals are 4 %, 19 %, 7.5 % (broilers 11.5 %) and 11.5 %, respectively. See emission factors and factors for correction in appendix H.

The emission from deep litter bedding is based on normative figures (Poulsen et al., 2001). The calculation of the emission from cattle, sows, fattening pigs, hens and broilers takes into account that a proportion of the manure is applied directly to the field and, therefore, not stored in the field manure heap. The report containing normative figures estimates percentage of manure stored in the field manure heap (Poulsen, 2010), see Table 5.4.

Denitrification

Table 5.5 lists the emission factors for denitrification of solid manure and deep litter based on normative figures (Poulsen et al., 2001 and Poulsen, 2010). The emission factors are estimated on the basis of measurements in Danish cattle and pig housing units. The factors for the remaining livestock categories are not measured directly; however, they are estimated relative to the denitrification from cattle and pig units. The fact that a certain proportion of the manure is stored in the field manure heap is taken into account (Poulsen et al., 2001).

Table 5.5 Denitrification associated with storage of solid manure and deep litter in the field manure heap.

	Denitrification in percent of total N ex housing unit	
	Solid manure	Deep litter
Cattle	10	5
Pigs	15	15
Poultry	10	10
Horses, sheep and goats	-	10

Field application of manure

A change in practice of manure application has taken place as a result of change in crop pattern and increasing environmental demands. A rise in growing of winter cereals from 1985 to 2009 has lead to a shift from manure application in autumn to early application in spring and changes in application technology. The requirement for an improved N utilisation in manure has also led to a greater proportion of slurry being injected or incorporated directly into the soil. Two further NH_3 reducing measures also require a mention. Following the legislation (BEK, 2002) a ban on traditional broad spreading of liquid manure was introduced, and manure applied to areas without vegetation had to be incorporated into the soil within six hours of application, both effective from 1 August 2003.

To calculate the emission from application of manure to agricultural land three different weighted emission factors are used. These distinguish between solid manure, liquid manure from pigs and liquid manure from cattle and other livestock.

Changes in application practices and technological improvements driven by environmental legislation have led to a decrease in the weighted emission factors – see Table 5.6. The emission factor from liquid cattle manure have decreased from 33.0 % in 1985 to 14.6 % in 2009, corresponding to a 56 % reduction due to approximately two thirds of the slurry now being injected/incorporated directly into the soil. A smaller reduction has taken place for liquid pig manure and solid manure.

Table 5.6 Percentage loss of NH_3 from application of liquid manure (NH_3-N of TAN ex storage) and solid manure (NH_3-N of N ex storage).

Weighted emission factor		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Liquid manure	Cattle[1]	33.0	33.0	32.9	32.9	32.8	34.3	33.5	32.9	32.0	31.3	30.4	29.9	29.6
	Pigs	17.3	17.2	17.2	17.2	17.2	17.9	17.5	17.0	16.3	16.2	15.4	15.2	14.9
Solid manure		9.6	9.2	8.8	8.4	8.0	7.9	7.8	7.7	7.7	7.6	7.5	7.4	7.3
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Liquid manure	Cattle[1]	28.9	28.3	27.5	24.9	22.7	19.4	14.1	14.3	14.7	14.9	14.6	14.6	
	Pigs	14.7	14.4	14.0	12.4	11.4	11.4	11.4	11.3	11.3	11.4	11.2	11.2	
Solid manure		7.2	7.1	6.8	6.9	7.1	6.9	6.9	6.7	6.5	6.4	6.4	6.4	

[1] Value for cattle is also used for all other animal types, except for pigs.

Calculation of the weighted emission factor

The weighted emission factor (EF_w) for each year is calculated as the sum of the proportion of manure applied under a given application practice (i) multiplied by the associated emission factor for this application practice.

$$EF_W = \sum MA_i \cdot EF_i \qquad \text{(Eq. 5.5)}$$

where: EF_w = weighted emission factor, kg NH_3-N pr kg N^{-1} yr^{-1}

MA_i = nitrogen in manure applied under a given application practice I, kg N yr^{-1}

EF_i = emission factor for the application practice I, kg NH_3-N pr kg N^{-1} yr^{-1}

A given application practice is determined by different combinations of variables such as application time, application methods, length of time between application and incorporation of manure, and stage of crop growth.

<u>Application time</u>

a. spring-winter (bare soil, crops, grass)
b. spring-summer (grass)
c. late summer-autumn (rape, seed grass)

<u>Application method</u>

a. injection/direct incorporation
b. trailing hoses
c. broad spreading (prohibited from 2003)

<u>Length of time between application to land and incorporation of manure</u>

a. 6 or 4 hours
b. less than 12 hours
c. more than 12 hours
d. more than a week

<u>Stage of crop growth</u>

a. bare soil
b. growth

There is no annual statistical information on how the farmer handles the manure application in practice. The calculations are based on a study of a limited number of farms, sales figures for manure application machinery as well as development trends in LOOP areas (national monitoring programme for the aquatic environment) (Andersen et al., 2001).

The estimate for application practice in 2001 and 2002 is, in addition to data from LOOP (Grant et al., 2002; Grant et al., 2003), based on information from the organisation for agricultural contractors (Danske Maskinstationer) (Kjeldal, 2002) and a questionnaire survey of application practice implemented by Danish Agriculture (2002) involving 1.600 farmers. From 2003 onwards the estimate of application practice is based on expert judgment (Birkmose, 2009).

An overview of the assumed application practice for 2009 is shown in Table 5.7. A more detailed distribution for 2009, which also includes the crop stage, is given in appendix I. The partitioning into different combinations of practice types is given in percentages. The assumed application practice for the previous years 1985 – 2009 is shown in appendix I.

Table 5.7 Estimate for the distribution of manure in proportion to application method, application time and length of time between application and incorporation of manure, 2009.

Liquid manure				Length of time before incorporation into soil, hours							
Application methods	Application time	Percentage distribution of manure		0		4, and then harrowed		4, and then Ploughed		Not incorporated	
		Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs
Incorporated	winter-spring	49	24	49	24	-	-	-	-	-	-
Incorporated	summer-autumn	14	4	14	4	-	-	-	-	-	-
Trailing horses	winter-spring	26	64	-	-	2	3	2	2	22	59
Trailing horses	spring-summer	2	2	-	-	-	-	-	-	2	2
Trailing horses	late summer-autumn	9	6	-	-	3	2	2	1	4	3
Total		100	100	63	28	5	5	4	3	28	64
Solid manure				Length of time before incorporation into soil, hours							
Application methods	Application time	Percentage distribution of manure		0		4		6		Not incorporated	
		Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs
Broad spreading	winter-spring	81	81	-	-	60	60	12	12	9	9
Broad spreading	spring-summer	0	0	-	-	-	-	-	-	-	-
Broad spreading	late summer-autumn	19	19	-	-	8	8	9	9	2	2
Total		100	100	-	-	68	68	21	21	11	11

Emission factor

The emission factor used for each combination of application practice (equation 5.5) is based on information from Hansen et al. (2008), see Table 5.8.

The resultant emission can vary significantly. The emission will be relatively high in the beginning of the growing season, when the plants, by virtue of their small size, do not contribute significant shade or shelter. With applications later in the season the emission will be significantly lower, despite the higher air temperatures, as a result of the larger leaf area available. In addition to the shade and shelter effect provided by the leaves, which lowers the emission, a proportion of the NH_3 in gaseous form will be absorbed by the leaves themselves.

In accordance to Danish livestock regulations, the maximum time between application and incorporation of manure has been reduced from 12 to 6 hours from BEK (2002). It is assumed that the decrease in the emission factor resulting from this reduction will be 33 % (Sommer, 2002).

Table 5.8 Emission factors for application of animal manure.

		Emission factor under application			
		Liquid manure			
Crop stage	Application time	Injected/incorporated direct		Trailing hoses	
- indicate bare soil + indicate growth		A) hours	NH_3-N in pct. of TAN in manure	A) hours	NH_3-N in pct. of TAN in manure
-	March	0	1.6	4	10.7
-	April	0	1.9	4	11.6
+	March	> 1 week	24.5	> 1 week	26.9
+	April	> 1 week	26.7	> 1 week	28.6
+	May	0	-	> 1 week	28.6
+	Summer	0	32	> 1 week	43.2
-	Summer	0	2.1	4	13.8
+	Autumn	0	28.6	> 1 week	38.6
-	Autumn	0	1.9	4	12.4
		Liquid manure		**Solid manure**	
		Broad spreading		Traditional	
		A) hours	NH_3-N in pct. of TAN in manure	A) hours	NH_3-N in pct. of total in manure
-	Winter-spring	< 12	18.5	4	5.0
-	Winter-spring	> 12	20.1	6	10.0
-	Winter-spring	> 1 week	48.6	> 1 week	16.0
+	Spring-summer	> 1 week	73.5	> 1 week	20.0
+	Late summer-autumn	> 1 week	72.0	> 1 week	14.0
-	Late summer-autumn	< 12	23.0	4	3.0
-	Late summer-autumn	> 12	23.0	6	8.0
-	Late summer-autumn	> 1 week	23.0	> 1 week	11.0

A) Length of time before incorporation into soil.

Grazing

Part of the manure from dairy cattle, heifers, suckling cows, sheep, goats, horses and deer is deposited on the field under grazing (See chapter 4.3).

An emission factor of 7 % of the total nitrogen content is assumed for volatile NH_3-N, which is based on studies of grazing cattle in the Netherlands and the United Kingdom (Jarvis et al., 1989a; Jarvis et al., 1989b; Bussink, 1994). The emission factor is used for all animal categories.

5.2 Synthetic fertilisers

Data on the use of synthetic fertiliser is based on the sale estimations collected by the Danish Plant Directorate (2010). Emission factors are based on the values given in EMEP/EEA (2009).

The emission from synthetic fertilisers depends on type as well as amount used. Data for consumption (Table 5.9), fertiliser type and nitrogen content (Table 5.10) are obtained from the Danish Plant Directorate (2010), which is based on the total sale from all fertiliser suppliers.

The Plant Directorate estimates that 1–2 % of synthetic fertilisers is used in parks, golf courses and sports grounds, etc. (Knudsen, 2010)

– i.e. areas that are not directly associated with agricultural activities. However, the 1–2 % of the emission from these sources is included in the emission from agriculture.

Table 5.9 Synthetic fertiliser consumption 1985 – 2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Consumption						Gg N							
Used in agriculture	398	382	381	367	377	400	395	370	333	326	316	291	288
Other	6	6	6	6	6	6	6	6	6	6	6	6	6
Total	398	382	381	367	377	400	395	370	333	326	316		291
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Consumption						Gg N							
Used in agriculture	283	263	251	234	211	201	207	206	192	195	220	200	283
Other	6	6	6	5	5	2	2	2	2	2	2	2	6
Total	289	269	257	239	215	203	209	208	194	197	223	202	289

The emission factors for the various fertiliser types are listed in Table 5.10 and are based on the EMEP/EEA Guidebook (EMEP/EEA, 2009). The same emission factors are applied for all years.

Table 5.10 Consumption and emission factors used for synthetic fertiliser, 2009.

	Emission factor, Pct. of N in fertiliser	Consumption, Gg N
Fertiliser type:		
Calcium nitrate + boron	1.4	0.2
Ammonium sulphate	2.0	3.8
Calcium ammonium nitrate and other nitrate types	1.4	121.5
Ammonium nitrate	0.7	9.7
Liquid ammonia	2.0	8.0
Urea	12.8	1.1
Other single fertilisers	6.3	18.8
Magnesium fertiliser	1.4	0.0
NPK fertiliser	1.4	30.0
Diammonium phosphate (18-20-0)	1.4	0.5
Other NP fertilisers	0.9	3.8
NK fertilisers	1.4	2.8
Total consumption of fertiliser		200[1]
Emission factor - weighted average	1.9	

[1] Including consumption relating to parks, sports grounds. etc. – representing approximately 1 %.

Since 1985 there has been a significant decrease in the use of synthetic fertiliser (Table 5.9). This is due to requirements to improve the utilisation of nitrogen in manure and restrictions of application rates as outlined, for example, in the Action Plans on the Aquatic Environment. Further, the use of the different fertiliser types has changed. At present, urea constitutes less than 1 % of the total nitrogen used as fertiliser. It is estimated that 1.9 % of the total nitrogen used in synthetic fertiliser is emitted as NH_3 in 2009.

Table 5.11 NH_3-N emission from synthetic fertilisers 1985 – 2009.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Emission						tonnes NH_3-N							
Agriculture	6 982	6 625	6 445	6 445	6 424	7 149	6 857	6 426	6 045	6 287	5 990	5 073	4 607
Other	83	83	83	83	83	83	83	83	83	83	83	83	83
Total	6 900	6 542	6 362	6 363	6 341	7 066	6 774	6 343	5 962	6 205	5 907	4 990	4 524
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Emission						tonnes NH_3-N							
Agriculture	4 637	4 302	4 173	3 838	3 416	3 345	3 549	3 512	3 562	3 686	3 997	3 889	
Other	83	83	83	72	64	29	30	29	27	28	32	29	
Total	4 554	4 219	4 090	3 767	3 352	3 317	3 520	3 483	3 535	3 658	3 966	3 860	

Source: Danish Plant Directorate.

5.3 Crops

Plants exchange NH_3 with the atmosphere both by absorbing and expelling NH_3. The amount can vary significantly depending on the plant's stage of development, conditions surrounding the application of the fertiliser and climatic conditions at the particular location.

Previously, the emission from crops was estimated from studies, which indicate an emission of up to 5 kg NH_3-N per hectare - (Schjoerring & Mattsson, 2001). However, an ongoing literature review indicates that the calculated emission is overestimated and the emission factor has therefore been adjusted to 2 kg N per ha for crops in rotation and 0.5 kg per ha for grass and clover (Gyldenkærne & Albrektsen).

The size of the cultivated area is based on information from Statistics Denmark.

Table 5.12 Emission factor used for crops, kg N per ha.

All crops (excl. grass)	2
Grass/clover in a rotation	0.5
Permanent/long-term grass	0.5

From 1985 to 2009 the NH_3 emission from growing crops has decreased from approximately 4 900 to 4 500 tonnes of NH_3-N corresponding to a small reduction of 9 %, which is due to a reduction in the farmland.

5.4 Sewage sludge

Sludge from wastewater treatment and the manufacturing industry is applied as fertiliser to agricultural soil. Information concerning the amount of sewage sludge applied is obtained from reports prepared by the Danish Environmental Protection Agency. Unfortunately, their most recent figures are from 2005 (DEPA, 2009). From 2005 the amount of N applied from wastewater treatment is based on the fertilizer accounts controlled by The Danish Plant Directorate. Farmers with more than 10 animal units[1] have to be registered and have to

[1] A Danish animal unit is defined as 100 kg Nex Storage from a average housing system. This corresponds to e.g. one jersey dairy cattle or 35 fattening pigs.

keep accounts of the N content in manure, received manure or other organic fertilizer.

The N content varies from year to year and is usually 4–5 % of the total amount of sludge. An emission factor of 3 % of the N content in sludge is used, based on information from the Danish Environmental Protection Agency (Bielecki, 2002). For sludge incorporated into soil within six hours of application the emission factor is expected to be halved, i.e. 1.5 %. Concerning the application to fields it is assumed that 25 % of the sludge is not incorporated, while the remaining 75 % is incorporated within six hours. This gives a weighted emission factor of approximately 1.9 %, same for all years.

$EF_{\text{sewage sludge}} = 0.25 \cdot 0.03 + 0.75 \cdot 0.015 = 0.01875$ NH_3-N of N applied

Table 5.13 shows an increasing amount of sewage sludge being applied to agricultural soil from 1985 to the mid 1990s. From 2003 there is a fall due to the rising interest in using the product in industrial processes, e.g. in cement production and the production of sandblasting materials.

Table 5.13 Emission from sewage sludge applied to agricultural land 1985-2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
						Gg dry matter							
Sewage sludge applied to agricultural soil	50	50	52	58	70	78	80	96	123	111	112	104	91
						pct.							
N-content	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.4	4.4
						tonnes NH3-N							
N applied to agricultural soil[a]	2 000	2 000	2 100	2 300	2 800	3 100	3 200	3 800	4 900	4 400	4 600	4 500	4 000
						tonnes NH3-N							
NH_3-N emission	38	38	39	44	52	58	60	72	93	83	87	85	74
Year *continued*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
						Gg dry matter							
Sewage sludge applied to agricultural soil	87	86	84	81	82	70	58	46	45	46	50	50	
						pct.							
N-content	4.3	4.3	4.3	4.4	4.4	4.5	4.6	4.8	4.8	4.8	4.8	4.8	
						tonnes NH3-N							
N applied to agricultural soil[a]	3 800	3 700	3 600	3 500	3 600	3 200	2 700	2 200	2 200	2 200	2 400	2 400	
						tonnes NH3-N							
NH_3-N emission	70	69	68	66	67	59	50	41	40	41	45	45	

[a] rounded values.

The NH_3 emission from industrial sludge is assumed to be negligible because most of it is immobilised in organic matter (Andersen et al., 1999), which is why there is no estimate for this source.

5.5 NH_3 treated straw

NH_3 treated straw was until 2006 used as cattle feed. By law in 2006 the NH_3 treatment of straw was banned and therefore no emission from 2006 onwards is estimated. The addition of NH_3 promotes the breakdown of the straw, which aids the digestion processes. It is assumed that the sale of NH_3 in the second half of the year is used for the treatment of straw with NH_3. Information on NH_3 sales is obtained from the suppliers. Emissions from NH_3 treated straw are not included when in comes to the NEC directive under the EU.

Studies show that 80 - 90 % of the NH_3-N in the straw can be volatile (Andersen et al., 1999). However, through measuring the concentration of NH_3 in relation to the dry matter content of the straw, the emission can be reduced significantly. The emission is estimated to constitute 65 % of the amount of nitrogen added.

Table 5.14 shows that since 1985 there have been a considerable decrease in the emission from NH_3 treated straw until 2005. After 2005 the process has been banned and no emissions therefore occur.

Table 5.14 Emission from NH_3 treated straw, 1985-2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
						tonnes NH_3-N					
Consumption of NH_3-N	8 285	10 186	11 305	9 181	11 399	12 912	10 951	9 722	9 600	10 264	8 406
Emission of NH_3-N	5 400	6 600	7 300	6 000	7 400	8 400	7 100	6 300	6 200	6 700	5 500
Year *continued*	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006-2009
						tonnes NH_3-N					
Consumption of NH_3-N	6 412	5 672	4 685	2 630	3 125	2 050	1 191	1 017	666	329	NO
Emission of NH_3-N	4 200	3 700	3 000	1 700	2 000	1 300	800	700	400	200	NO

NO – Not occurring.

6 PM emission

Studies have shown that farmers, as well as livestock, are subject to an increased risk of developing lung and respiratory diseases due to particulate emissions (Hartung & Seedorf, 1999). This is because the particles are able to carry bacteria, viruses and other organic compounds.

PM emissions originate from the housing of livestock, from field operations (harvesting and cultivation of soil), the handling of crop products (storage and transport) and from field burning of agricultural residues. In the Danish inventory only PM from livestock and from field burning is included. PM from field operations will be implemented when resources are available. A methodology is provided, but resources are needed to investigate if default values in the EMEP/EEA Guidebook (EMEP/EEA, 2009) can be used to reflect the Danish agricultural conditions. At present, no methodology for calculating the emission from handling crop products has been provided.

The PM emissions from the agricultural sector mainly consist of larger particles. In the reporting under CLRTAP particulate matter is reported as TSP, PM_{10} and $PM_{2.5}$. Tiny airborne particles or aerosols that are smaller than 100 µm are collectively referred to as total suspended particles (TSP). PM_{10} is the fraction of suspended particulate matter with an aerodynamic diameter of 10 µm or smaller and $PM_{2.5}$ represents particles smaller than 2.5 µm.

Agriculture accounts for 29 % of the total TSP emission, the emission shares for PM_{10} and $PM_{2.5}$ are only 18 % and 5 % respectively. Most agricultural emissions originate from livestock and a description of the calculation methodology is set out below. Emissions from the field burning of agricultural residues contribute less than 1 % to the agricultural emissions. The calculation from field burning is described in chapter 10.

6.1 Livestock production

The emission of PM is estimated for the years 1985-2009, but only reported in the Danish inventory for the years 2000 to 2009 in line with the reporting guidelines (UNECE, 2009).

The emissions from animal production include dust from housing systems for cattle, pigs, poultry, horses, sheep and goats. In 2009 these emissions, expressed as TSP, were an estimated 11 255 Mg. Of this, 78 % relates to pig production. The emission from cattle and poultry contributed 12 % and 10 %, respectively.

6.1.1 Calculation method

The estimation of the PM emission is based on the EMEP/EEA Guidebook (EMEP/EEA, 2009) part B, chapter 4B, where the scientific data are based mainly on an investigation of PM emissions from North European housings (Takai et al., 1998). The PM emission is calculated using equation 6.1. The emission calculation distinguishes between liquid and solid manure.

Equation 6.1:

$$PM_{10} = no \cdot \left(1 - \frac{D_G}{365}\right) \cdot \left(EF_{PM_{10}} \cdot B + EF_{PM_{10}} \cdot B\right) \qquad \text{(Eq. 6.1)}$$

where: PM_{10} = emission of PM_{10}
no = number of average annual population (AAP – see definition I section 4.1)
D_G = actual days on grass
$EF_{PM10,\,S\ or\ L}$ = emission factor for solid or liquid manure
$B_{S\ or\ L}$ = percent of solid or liquid manure

As shown in Equation 6.1, the main types of housing are included and divided into subcategories with a distinction for each category between solid and slurry-based housing systems. The PM emission is furthermore related to the number of days the animal is housed. The PM emission from grazing animals is considered negligible. See Table 4.13 for a list of number of grazing days for 2009 and see appendix J for PM emission all years.

6.1.2 Emission factors

The emission factors for PM_{10} and $PM_{2.5}$ are those recommended in the EMEP/EEA Guidebook, (EMEP/EEA, 2009). However, calves and weaners are not included and therefore the 2004 edition of the Guidebook (EMEP/EEA, 2004) is used for these. Emission factors for sheep and goats are based on Fontelle et al. (2009). The same emissions factors are used for all years.

In Takai et al. (1998), dust emission from housings is categorised as ”inhalable dust”. This is defined as particles that can be transported into the body via the respiratory system. “Inhalable dust” equates approximately to TSP (Hinz, 2002). Estimation of TSP is based on the conversion factors for inhalable dust into PM_{10} given in the Guidebook (EMEP/EAA, 2009). The conversion factor for cattle, horses, sheep and goats is 0.46, for pigs 0.45 and poultry 1.00.

Table 6.1 shows the emission factors for livestock. The emission factors are given for the various housing systems and separated into solid or slurry-based systems.

Table 6.1 PM emission factors from animal housing systems, kg pr. AAP (defined in section 4.1).

		Emission factor		
Livestock category	Manure type	TSP	PM_{10}	$PM_{2.5}$
Cattle:				
Dairy cattle	Solid	0.78	0.36	0.23
	Slurry	1.52	0.70	0.45
Calves < ½ yr	Solid	0.35	0.16	0.1
	Slurry	0.33	0.15	0.1
Beef cattle	Solid	0.52	0.24	0.16
	Slurry	0.70	0.32	0.21
Heifer[1]	Solid	0.57	0.26	0.17
	Slurry	0.93	0.43	0.28
Suckling cattle[2]	Solid	0.52	0.24	0.16
	Slurry	0.70	0.32	0.21
Pigs:				
Sows	Solid	1.29	0.58	0.094
	Slurry	1.00	0.45	0.073
Weaners	Solid[3]	0.40	0.18	0.029
	Slurry	0.40	0.18	0.029
Fattening pigs	Solid	1.11	0.50	0.081
	Slurry	0.93	0.42	0.069
Poultry:				
Laying hens	Solid	0.017	0.017	0.002
	Slurry	0.270	0.270	0.052
Broilers	Solid	0.350	0.350	0.045
Turkeys	Solid	0.032	0.032	0.004
Other poultry	Solid	0.032	0.032	0.004
Other:				
Horses	Solid	0.39	0.18	0.12
Sheep	Solid	0.133	0.061	0.018
Goats	Solid	0.133	0.061	0.018

[1] Average of “calves” and “dairy cattle”.

[2] Assumed the same value as “Beef cattle”.

[3] Same as slurry-based systems.

6.2 Field operations

In the EMEP/EEA Guidebook a methodology is provided to account for PM emissions from field operations, which includes emissions from crop harvesting, cultivation of soil, and the cleaning and drying of crops. Harvesting is the predominant source of PM and the emission depends on crop and soil type, cultivation method and the weather before and during work.

6.2.1 Calculation method

The methodology provided in the 2009 edition of the EMEP/EEA Guidebook on emission calculations from field operations and the cleaning and drying of agricultural products is shown below:

$$E_{PM} = EF_{PM} \cdot AR \cdot no \qquad \text{(Eq. 6.2)}$$

where: E_{PM} = emission of PM_{10}, $PM_{2.5}$ or TSP, kg a^{-1}

EF_{PM} = emission factor for crop and operation type, kg ha^{-1}

AR = area of crops, ha

no = production cycles, the number of times the operations are performed, a^{-1}

Emission calculations should be made for each crop and operation type. Data needed to complete the emission calculations are crop production, operation types and operation procedures.

6.2.2 Emission factors

Emission factors for crops and operation type are given in Table 6.2 (EMEP/EEA, 2009). Emission factors for wet climate conditions are the most comparable for Danish conditions. Emission factors for TSP are not available.

Table 6.2 Emission factor for PM_{10} and $PM_{2.5}$ for agricultural crop operations, kg per ha.

Crop	Soil cultivation	Harvesting	Cleaning	Drying
PM_{10}				
Wheat	0.25	0.49	0.19	0.56
Rye	0.25	0.37	0.16	0.37
Barley	0.25	0.41	0.16	0.43
Oat	0.25	0.62	0.25	0.66
Other arable	0.25	NAV[2]	NAV[2]	NAV[2]
Grass[1]	0.25	0.25	NO	NO
$PM_{2.5}$				
Wheat	0.015	0.02	0.009	0.168
Rye	0.015	0.015	0.008	0.111
Barley	0.015	0.016	0.008	0.129
Oat	0.015	0.025	0.0125	0.198
Other arable	0.015	NA	NA	NA
Grass[1]	0.015	0.01	NO	NO

[1]Grass includes hay making only.

[2]NAV = not available.

As mentioned above, resources are needed before PM emissions from field operations can be implemented in the Danish inventory. Information on how the field operations typically are performed for each crop type in Denmark is needed. This includes e.g. estimates on the average number of field operations and type of machinery used during production of the different crop types. Furthermore, it has to be considered if the default values provided in the EMEP/EEA Guidebook reasonably reflect Danish agricultural conditions or if national values are available.

7 NMVOC emission

Around 2 % of the total NMVOC emission originates from the agricultural sector. Three emission sources are known: agricultural soils (crops), manure management and field burning of agricultural residues. For the emission from field burning see chapter 10. In 2009, the emission from agricultural soils contributed 86 % and field burning 14 % to the agricultural emission.

7.1 Agricultural soils

The emission of NMVOC from agricultural soils is included in the Danish inventory and cover emissions from arable crops and grassland. NMVOC emissions can be influenced by a series of factors, such as temperature and light intensity, plant growth stage, water stress, air pollution and senescence (EMEP/EEA, 2009). Because of sparse information on emissions, the EMEP/EEA Guidebook only provides a Tier 1 methodology.

$$E_{pollutant} = AR_{area} \cdot EF_{pollutant} \quad \text{(Eq. 7.1)}$$

where: $E_{pollutant}$ = amount of pollutant emitted, kg a^{-1}
AR_{area} = area covered by crop, ha
$EF_{pollutant}$ = EF of pollutant, kg ha^{-1} a^{-1}

Activity data per hectare with arable crops or grassland are obtained from DSt. In the Danish inventory a national emission factor for NMVOC is used. Emission factors for crops and grass are based on assessments carried out in the beginning of the 1990s (Fenhann & Kilde 1994 and Priemé & Christensen, 1991). The estimated emission factor for arable crops is 393 g NMVOC per ha and 2 120 g NMVOC per ha for grassland.

The total emission of NMVOC from agricultural soils 1985-2009 is listed in Table 7.1. The emission is closely linked to the area under grass, which has decreased by 6 % from 1985 to 2009. A similar decrease is seen for the emission.

Table 7.1 NMVOC emission from agricultural soils 1985 – 2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Arable crops, 1000 ha	2 336	2 341	2 340	2 314	2 303	2 322	2 307	2 293	2 254	2 044	2 064	2 075	2 138
Grassland, 1000 ha	498	478	458	473	472	466	462	463	484	647	446	450	403
NMVOC emission, Gg	1.97	1.93	1.89	1.91	1.90	1.90	1.89	1.88	1.91	2.18	1.76	1.77	1.69
Year *continued*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Arable crops, 1000 ha	2 125	2 064	2 043	2 060	2 065	2 062	2 079	2 086	2 083	2 050	2 107	2 103	
Grassland, 1000 ha	405	398	413	414	396	390	369	446	460	459	490	497	
NMVOC emission, Gg	1.69	1.65	1.68	1.69	1.65	1.64	1.60	1.77	1.79	1.78	1.87	1.88	

There is a need for a review of the emission factors used. When a new methodology and/or data become available, this will be evaluated and implemented in the Danish inventory.

7.2 Manure management

Emission of NMVOC from manure management originates from undigested protein that decomposes in manure, and anything that affects the rate of protein degradation, such as the amount of straw added to the manure and the duration of storage, will affect the NMVOC emission. Studies indicate that emission rates are also affected by climate and management factors. There is a considerable uncertainty attached to these emissions and no methodology is provided in the EMEP/EEA Guidebook (EMEP/EEA, 2009).

Because of the lack of methodology for NMVOC emissions from manure management, this is not implemented in the Danish inventory.

8 CH_4 emission

The digestive processes in ruminants, predominantly cattle, are at approximately 70 % by far the largest source of agricultural CH_4 emissions. The remainder comes from the bacterial breakdown of animal manure under anaerobic conditions (primarily in slurry).

The field burning of agricultural residues is also included as a source of emissions, but contributes less than 1 % to total agriculture emissions of CH_4.

The emission from manure management includes a reduction of emissions due to biogas-treatment of slurry, which is described in section 8.3.

The methodology used to calculate the CH_4 emission is based on guidance given in the 1996 IPCC Guidelines (IPCC, 1997) and the IPCC Good Practice Guidance (IPCC, 2000).

8.1 Enteric fermentation

The CH_4 emission from enteric fermentation can be regarded as an energy loss under the digestion process. It is mainly ruminants that produce CH_4, whereas monogastric animals – i.e. pigs, horses, poultry and fur animals – produce CH_4 to a much smaller degree.

The emission is primarily from cattle, which, in 2009, contributed 86 % of the emission from enteric fermentation. The emission from pig production is the second largest source at 9 %, followed by horses (3 %) and sheep, goats, poultry and deer (2 %). The relative contribution from pig production has increased over the years as a result of a production expansion as well as a reduction in the number of cattle.

The calculation of CH_4 production from the digestive system is based on the animal's total gross energy intake (GE) and the CH_4 conversion factor, which is the fraction of gross energy in feed converted to CH_4 – see Equation 8.1.

Equation 8.1:

$$EF_{CH4} = \frac{GE \cdot Y_m \cdot 365}{55.65} \qquad \text{(Eq. 8.1)}$$

where:

EF_{CH4} = emission factor of CH_4, kg head^{-1} yr^{-1}

GE = gross energy intake, MJ head^{-1} day^{-1} (national data)

Y_m = methane conversion factor, percent of gross energy in feed converted to methane (IPCC, 1997)

55.65 = conversion factor – from MJ to kg CH_4 (IPCC, 1997)

For the conversion of MJ to kg CH_4 the value recommended by the IPCC is used. The CH_4 conversion rate Y_m is the extent to which feed energy is converted to CH_4 and varies depending on the breed of animal and the respective feed strategy (IPCC, 1997). Values of Y_m recommended by the IPCC are used for all livestock categories except for dairy cattle and heifers.

In the Danish emission inventory the difference between summer and winter feed intake is taken into account. Summer feed plans is based on energy content in grass where as winter feed plans is based on energy content in roughage and concentrates.

CH_4enteric, total $$CH4_{enteric,total} = CH4_{enteric,winter} + CH4_{enteric,summer} \quad \text{(Eq. 8.2)}$$

8.1.1 Gross energy intake (GE)

The actual feeding plans provide data for feed units (FU)[2] for each livestock category. To calculate the total gross energy intake, the gross energy per feed unit – defined as GE_{FU} – needs to be estimated.

Feeding with sugar beets is taken into account because sugar beet feeding gives a higher methane production rate compared to grass and maize due to the high content of easily convertible sugar.

$$GE_{total} = FU \cdot GE_{FU} \quad \text{(Eq. 8.3)}$$

The estimate for GE_{FU} is unaltered for all years from 1985 to 2009, while feed units vary from year to year. The CH_4 emission from enteric fermentation for each livestock category is calculated as shown in the following equations:

a) EF_{winter}:

$$EF_{winter} = FU \cdot \left(\frac{GE_{FU\,winter}}{55.65} \cdot Y_{m,\ excl.\ SB} \cdot \left(1 - \frac{D_G}{365} - \frac{D_{SB}}{365}\right) + \left(\frac{GE_{FU\,winter}}{55.65} \cdot Y_{m,\ incl.\ SB} \cdot \frac{D_{SB}}{365}\right)\right) \quad \text{(Eq. 8.4a)}$$

b) EF_{sommer}:

$$EF_{summer} = FU \cdot \frac{GE_{FU\,summer}}{55.65} \cdot Y_{m,\,grazing} \cdot \frac{D_G}{365} \quad \text{(Eq. 8.4b)}$$

Where:

	FU	= feeding units
	GE_{FU}	= gross energy pr feeding unit, MJ pr FU
	D_G	= grazing days
	D_{SB}	= days with sugar beet

Sugar beets are only included in feeding plans for dairy cattle and heifers. The parts of the equation concerning sugar beets are left out

[2] A feed unit in Denmark is defined as the feed value in 1.00 kg barley with a dry matter content of 85 % (Statistics Denmark, yearbook 2010). For other cereals e.g. wheat and rye one feed unit is 0.97 kg and 1.05 kg, respectively.

for the other livestock categories. The calculation of GE_{FU} is based on the composition of feed intake and the energy content in proteins, fats and carbohydrates.

For free-range pigs, hens, etc., it is assumed that grazing does not contribute to feed intake; therefore, the GE_{FU} of the feed is based entirely on the stable feed.

For dairy cows, the energy intake comes out at 18.3 MJ pr. FU_{cattle} in a standard winter feed (Hvelplund, 2004 and Olesen et al., 2001), regardless of whether the animal grazes or not. For bull calves (< ½ year), as well as bulls older than ½ year, the same energy content value is used as for dairy cows.

For horses, heifers, suckling cattle, sheep and goats an average winter feed plan is provided (Refsgaard Andersen, 2003; Clausen, 2004; Bligaard, 2004; Holmenlund, 2004), on which the calculation of the gross energy content is based - see appendix K. Gross energy for deer is based on feed plans for goats, as their feeding conditions resemble those of deer the most. For poultry, fur animals, ostrich and pheasants, data on gross energy are not available in the IPCC Guidelines nor are national data available, therefore the emission is not estimated. When data becomes available the emission from these livestock categories will be estimated and reported. Although emissions occur from these animal categories, it is considered to be of minor importance.

The GE_{FU} content in feeds is measured as the energy content per FU, which is assumed not to have changed since 1985. Therefore, changes in feed efficiency are reflected in changes in feed consumption.

8.1.2 CH_4 conversion rate (Y_m)

New studies from DJF have shown a change in feeding practice with maize (whole crop) replacing sugar beet. Higher CH_4 production from sugar beets compared to grass and maize, result in change of the average Y_m for dairy cattle and heifers from 6.39 in 1990 to 5.94 in 2009.

The estimation of the national values of Y_m uses the model "Karoline" developed by DJF with its database of average feeding plans for 20 % of all dairy cows in Denmark obtained from the DAAS (Olesen et al., 2005). DJF has estimated the Y_m for a winter feeding plan for two years, 1991 (Y_m=6.7) and 2002 (Y_m=6.0). Y_m for the years between 1991 and 2002 is estimated by interpolation and for 1990 and 2003 to 2009 by extrapolation where the actual sugar beet area is taken into account. Data for the actual sugar beet and maize area and Y_m for dairy cattle and heifers for 1990-2009 are given in appendix L. Sugar beets are only included in the winter feeding plan and the Y_m is therefore also adjusted for days on the winter and summer feeding plans. It is assumed that the winter feeding plan covers 200 days (Olesen et al., 2005). The values of the estimated Y_m for 1991 and 2002 are, when adjusted for sugar beets, 6.35 and 5.96, respectively.

8.1.3 CH_4 emission from enteric fermentation

Table 8.1 Feed consumption for 2009 and conversion factors to determine the CH_4 emission from livestock enteric fermentation.

Livestock category	Feed intake	Gross energy (BE)		Feed on grass	CH_4 formation	Emission 2009	
	2009 [a]	Winter feed	Summer feed	Proportion	Y_m	Per unit	Total
	FU pr AAP^{-1} or pr produced animal	MJ FU^{-1}		Pct.	Pct.	kg CH_4 pr AAP^{-1} or pr produced animal[a]	Gg CH_4
Cattle (large breed):							
Dairy cattle	6 984	18.30	18.30	5	5.94	136.46	75.32
Heifer calves, < ½ year	1 047	18.30	18.83	-	5.92	20.38	2.99
Breeding calves, ½ yr to calving	2 094	25.75	18.83	30	5.94	52.00	26.72
Bulls calves, < ½ year	619	18.30	18.83	-	4	8.14	1.90
Bulls, ½ year to slaughter (440 kg)	1 280	18.30	18.83	-	4	16.84	4.43
Suckling cows > 600 kg	2 502	34.02	18.83	61	5.92	65.74	6.08
Pigs:							
Sows inc. piglets < 7.2 kg	1 500	17.49	17.49	-	0.6	1.62	1.76
Weaners, 7.2-30 kg	49	16.46	16.46	-	0.6	0.09	2.41
Fattening pigs, > 30 kg	214	17.25	17.25	-	0.6	0.40	8.29
Other:							
Horses (600 kg)	2 555	29.83	18.83	50	2.5	27.93	3.87
Sheep (incl. lambs)	728	18.99	-	73	6	17.17	1.98
Dairy goats (incl. kids)	667	29.95	18.83	73	5	13.11	0.20
Deer	668	30	18.83	100	5	11.30	0.11
	kg feed hd^{-1}	MJ kg^{-1} feed					
Battery hens	41	17,46	17,46	-	-	0,01	0,05
Broilers 40 days	4	18,99	18,99	-	-	<0,005	<0,005
Other poultry[b]	-	-	-	0/100	-	0,01	<0,005
Mink incl. young:	229	11,47	11,47	-	-	<0,005	<0,005
CH_4 from enteric fermentation in total							**136.14**

[a] For bull calves, bulls, weaners, fattening pigs and broilers the values provided in the table covers data for each produced animal. For all other livestock categories the values are per AAP (annual average population – see definition in Section 4.1). The total emission covers emission from the total livestock production 2009.

[b] Includes ostrich, turkeys, pheasants, geese, ducks.

8.2 Manure management

CH_4 gas production from animal manure is calculated on the basis of the energy in animal manure, taking into account storage conditions. In the emission inventory the added energy resulting spreading straw and spilling feed in the different types of housing system is included based on information from Poulsen et al. (2001).

Storage conditions for livestock manure have an effect on CH_4 production. Anaerobic conditions, as found in slurry, promote CH_4 formation, while CH_4 production is low in solid manure. Developments in recent years, where more livestock are housed in open housing units and in slurry-based housing systems, have led to a relatively high CH_4 production.

CH_4 formation from manure management is calculated on the basis of the IPCC guidelines, where the proportion of volatile solids (VS) of the organic matter is determined and, on the basis of this, the CH_4 emission is calculated. The determination of VS is country-specific, given that it is based on the amount of manure excreted (Equation 8.5 and 8.6).

$$VS_{housing} = \frac{m}{365} \cdot DM_M \cdot VS_{DM} \cdot (365 - g_1) + s \cdot DM_S \cdot (1 - \frac{\% \text{ ash}}{100}) \cdot (365 - g_2) \quad \text{(Eq. 8.5)}$$

$$VS_{grass} = \frac{m}{365} \cdot DM_M \cdot VS_{DM} \cdot g_1 \quad \text{(Eq. 8.6)}$$

where:
- VS = volatile solids, kg animal^{-1} yr^{-1}
- m = amount of manure excreted, kg animal^{-1} yr^{-1}
- DM = dry matter of M manure or S straw, pct
- VS_{DM} = volatile solids of dry matter, pct
- g_1 = feeding days on grass, days yr^{-1}
- g_2 = actual days on grass, days yr^{-1}
- s = amount of straw, kg animal^{-1} yr^{-1}
- % ash = ash content in straw

The ash content in straw is set to 4.5 % (DAAS, 2005). The VS of dry matter is 78 % for cattle, horses, sheep, goats and deer. For pigs, poultry and fur animals the VS of dry matter is 75 % (Møller, 2003). The number of days on grass is shown in Table 8.3. The amount of manure excreted and straw used depends on housing type and is given in the normative figures table (Poulsen, 2010). See appendix C.

The amount of CH_4 produced is determined from Equation 8.7, where VS is multiplied with the maximum CH_4 formation capacity B_0, which is distinct for each livestock type, and the maximum CH_4 conversion factor MCF, which is dependent on the actual temperature and storage conditions. Denmark has a cold climate and, therefore a relatively low MCF.

$$CH_4 = (VS_{housing} \cdot \frac{MCF_{i,j}}{100} \cdot Bo_i) + (VS_{grass} \cdot \frac{MCF_{i,j}}{100} \cdot Bo_i) \quad \text{(Eq. 8.7)}$$

where:
- CH_4 = CH_4 emission for the given livestock category, kg CH_4 animal^{-1} yr^{-1}
- $VS_{housing}$ = volatile solids from housings, kg dry matter animal^{-1} yr^{-1}
- VS_{grass} = volatile solids from grazing, kg dry matter animal^{-1} yr^{-1}
- B_0 = maximum CH_4 producing capacity for manure produced by livestock category (i) (IPCC, 1997)
- MCF = CH_4 conversion factor for a given livestock category (i) and a given manure type (j) (IPCC, 1997)

Table 8.3 provides the B_0 values used in the inventory, based on IPCC standard values. Here it is demonstrated that the maximum CH_4 formation is significantly higher in pig manure than in cattle manure.

Table 8.2 lists the MCF factors used. Default values for MCF provided in the IPCC guidelines for the CH_4 production are used. For liquid systems, the MCF of 10 % in the Reference Manual (IPCC, 1997) is used.

The revised 1996 IPCC Guidelines contains a default MCF of 10 % for liquid manure/slurry, which is based on the research of Hashimoto & Steed (1993) and Woodbury & Hashimoto (1993). This MCF value was changed to 39 % in the IPCC Good Practice Guidance (2000), without any scientific argumentation, documentation or specific references. The IPCC 2006 Guidelines (IPCC, 2006) has reverted to an MCF value of 10 % with reference to judgement of the IPCC Expert Group in combination with Mangino et al. (2001) and Sommer et al. (2000).

The CH_4 emission from liquid systems is very sensitive to temperature effects. Basically most of the manure in Denmark is stored under cold conditions (5-10°). The CH_4 formation practically stops at 5° C (Mangino et al., 2001) and therefore there are no plausible arguments for why 39 % of the total CH_4 capacity should be released under Danish conditions. Danish studies confirm this assumption (Husted, 1994; Sommer et al., 2000). Furthermore, scientific articles based on measurements in Canada, where conditions are similar to those in Denmark, support the 10 % value (Massé et al., 2003, Massé et al., 2008). A Swedish review taking into account both the cold climate and the fact that the slurry containers usually have a surface cover, also supports a MCF for liquid manure of 10 % (Dustan, 2002).

Considering the agricultural conditions in Denmark and the present scientific knowledge as described above, an MCF of 10 % for urine/slurry is more appropriate under Danish conditions than the MCF of 39 % recommended by the IPCC GPG (IPCC, 2000). The Danish decision to use an MCF of 10 % is, as demonstrated above, backed by several scientific papers as well as both the 1996 IPCC Guidelines (IPCC, 1997) and the 2006 IPCC Guidelines (IPCC, 2006). Therefore Denmark intends to continue to use an MCF value of 10 %.

Several countries with comparable climatic conditions use an MCF for urine/slurry at the same level as the recommended in the revised IPCC 1996 Guidelines. Sweden and Finland use the same value as Denmark (10 %), Belgium uses 19 %, Germany 13-16 % and Norway and the Netherlands use an MCF below 10 %.

Table 8.2 Values used for CH_4 conversion factor (MCF).

	MCF
Solid manure	1%
Solid manure, poultry	1.5%
Deep litter[a]	10%
Urine and slurry	10%
Manure excreted outside	10%

[a] For farmyard manure < 1 month the MCF is listet as zero (IPCC, 2000 – Table 4.13). Farmyard manure is a system where the manure is accumulated on floor and mixed with straw bedding, which in Denmark is use e.g. in housing of cattle calves.

Animal manure applied to farmland should, according to the IPCC, have the same MCF as solid manure in storage.

Table 8.3 gives an overview of the data used to calculate the CH_4 emission from animal manure from the different categories of livestock. No emission from calves is reistrered because the MCF factor is zero

Table 8.3 Conversion factors to determine the CH_4 emission from animal manure handling.

Livestock category	Days on grass	CH_4 formation capacity	Emission 2009	
	g (act grazing days)	B_0 m^3 CH_4 pr kg VS	Per unit[a] kg CH_4 pr AAP^{-1} or pr produced animal[a]	Total Gg CH_4
Cattle (large breed):				
Dairy cattle	18	0.24	33.94	18.95
Heifer calves, < ½ year	0	0.17	0.00	0.00
Heifer, ½ year to calving	132 (111)	0.17	9.67	4.70
Bull calves, < ½ year	0	0.17	0.00	0.00
Bull, ½ year to slaughter (440 kg)	0	0.17	16.21	4.40
Suckling cows	224	0.17	11.69	1.12
Pigs:				
Sows inc. piglets < 7.2 kg	0	0.45	3.96	4.37
Weaners, 7.2-32 kg	0	0.45	0.16	4.54
Fattening pigs, > 32 kg	0	0.45	0.81	17.52
Poultry:				
Hens (battery)	0	0.32	0.03	0.20
Broilers (40 days)	0	0.32	0.00	0.25
Ostrich	365	0.32	Not estimated	
Pheasant	365	0.32	Not estimated	
Geese, ducks, turkey	365	0.32	0.00	0.04
Other:				
Horses	182.5	0.33	2.95	0.52
Sheep (incl. lambs)	265	0.19	2.82	0.33
Goats (incl. kids)	265	0.17	2.45	0.04
Deer	365	0.17	0.30	0.00
Fur animals	0	0.48	0.97	2.60
CH_4 from manure management				**58.59**

NE – Not estimated.

[a] For bull calves, bulls, weaners, fattening pigs and broilers the values provided in the table covers data for each produced animal. For all other livestock categories the values are per AAP (annual average population – see definition in Section 4.1). The total emission covers emission from the total livestock production 2009.

8.3 Biogas treatment of slurry

In Denmark the first biogas plant was established in 1984 and there are currently around 20 communal plants and around 60 plants operating on farms. In 2009, 2.4 million tonnes of animal manure were treated, equivalent to approximately 8 % of all animal manure (Tafdrup, 2009).

Treating slurry in biogas plants has a lower emission of both CH_4 and N_2O. No description on how to include biogas treated slurry in the inventories is provided in the IPCC guidelines. Therefore, the Danish inventory uses data based on a Danish study (Sommer et al., 2001; Nielsen et al., 2002).

The lower CH_4 emission in biogas treated slurry is based on the amount of organic matter VS. The amount of VS in treated slurry is calculated as the VS percentage of dry matter (DM) which 80 % for both cattle and pig slurry. It is assumed that slurry from cattle stems from dairy cattle and that slurry from pigs stems from fattening pigs. The Danish Energy Agency estimates that cattle slurry makes up 45

% and pig slurry 55 % of the total amount of biogas-treated slurry (Tafdrup, 2003).

$$CH4_{\text{lower}} = VS_{\textit{treated slurry}} \cdot B_0 \cdot MCF \cdot 0.67 \cdot E_{CH4,lower} \qquad \text{(Eq. 8.8)}$$

where:

$CH_{4,R}$	= The amount of lower CH_4 emission from a given livestock type (cattle or pigs)
$VS_{\text{treated slurry}}$	= amount of volatile solids from treated slurry
B_0	= maximum CH_4-forming capacity
MCF	= CH_4 conversion factor
$E_{CH4,\text{ lower}}$	= a lower emission from biogas treated slurry. It is assumed that treated cattle slurry is 0.77 compared with untreated slurry and 0.60 for pig slurry
0.67	= conversion from m^3 to kg

Table 8.4 provides the background data used in the calculation of the CH_4 reduction resulting from biogas production.

Table 8.4 Data used in the calculation of VS in biogas-treated slurry and the reduction in the CH_4 emission in 2009.

2009	Slurry biogas treated	DM[a]	VS in treated slurry	MCF	B_0	$E_{CH4,\text{ lower}}$	CH_4 emission in untreated slurry	CH_4 emission inbiogas treated slurry	Lower the total CH_4 emission with
	1000 Gg	Pct.	10^6 kg VS	Pct.	m^3 CH_4 pr kg VS		Gg CH_4	Gg CH_4	Gg CH_4
Cattle slurry	1.08	10.3	88.62	10	0.24	0.77	1.43	1.09	0.33
Pig slurry	1.31	6.1	64.15	10	0.45	0.60	1.93	1.16	0.78
Lower emission									1.11

[a] Poulsen et al. (2001 and 2010).

In 2009, the total effect of biogas plants result in a lower CH_4 emission by 1.11 Gg CH_4, which corresponds to 0.6 % of the total CH_4 emission from the agricultural sector. The reduction is expected to rise in the coming years due to increased focus on biogas production as a means of reducing greenhouse gas emissions from agricultural activities.

The effect of the biogas treatment of slurry is subtracted from the emission from dairy cows and fattening pigs in the emission inventory.

9 N_2O emission

The emission of nitrous oxide (N_2O) occurs in the chemical transformation of nitrogen and, therefore, is closely linked with the animal manure management. The emission of N_2O comes from a range of different sources as showed in figure 9.1. The major sources originate from application of animal manure and synthetic fertilisers on soil, and nitrogen leaching and run-off. The emissions from synthetic fertiliser and animal manure applied to soil contribute 22 % and 21 %, respectively, to the total N_2O agricultural emission in 2009. The emission from nitrogen leaching represents the largest single emission source at around 25 %.

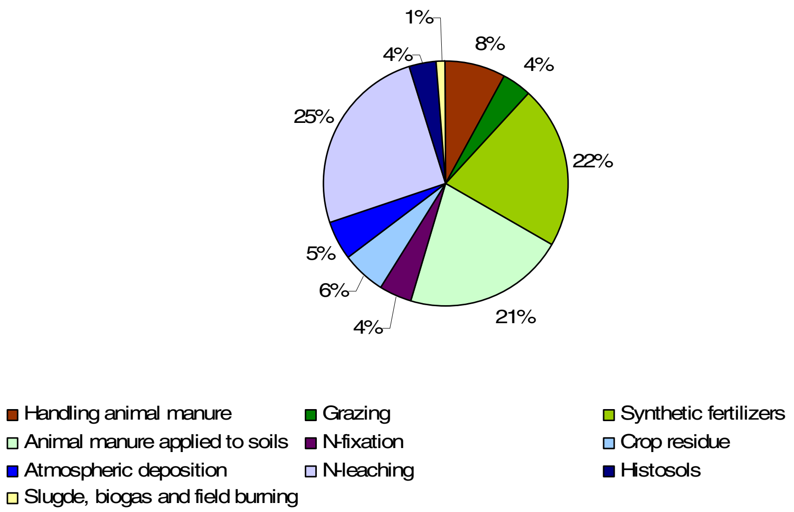

Figure 9.1 Distribution of the N_2O emission in 2009 on sources.

The N_2O emission, given in CO_2 equivalents, contributes 58 % to the total greenhouse gas emission from the agricultural sector in 2009. The following chapters give a survey of the emission factors used and a more detailed description of each emission source. The emission from manure management includes a reduction of emissions due to biogas-treated slurry, which is described in section 9.9.

The calculation of N_2O emission from field burning of agricultural crop residues, which contributes less than 1 % to total agricultural N_2O emissions, is described in chapter 10.

The methodology used to calculate the N_2O emission is based on guidance given in the 1996 IPCC Guidelines (IPCC, 1997) and the IPCC Good Practice Guidance (IPCC, 2000). Please note that convert from N_2O-N to N_2O, the emission is multiplied by 44/28.

9.1 Emission factors

The emission of N_2O is determined as a fraction of the amount of nitrogen. These fractions vary between sources and are often highly uncertain because the emission to a great extent depends on the local biological and climatic conditions.

The N_2O emission is calculated according to equation 9.1.

$$N_2O = N_i \cdot EF_i \cdot \frac{44}{28} \qquad \text{(Eq. 9.1)}$$

where: N_i = N content in the source, i
EF_i = emission factor applicable for source, i

The conversion from N_2O-N to N_2O is carried out by multiplying the respective molecular weights.

Table 9.1 shows the sources from which the N_2O emission is calculated. The calculations are based on standard values for emission factors recommended in the IPCC Reference Manual (IPCC, 1997), except for cultivation of histosols, which is based on a national factor.

Table 9.1 Emission factors used to determine the N_2O emission.

Source		Emission factor	
		Unit	IPCC – default values
Handling of manure:			
Solid manure, poultry	EF_{1a}	kg N_2O-N pr kg N	0.005
Solid manure, other	EF_{1b}	kg N_2O-N pr kg N	0.02
Slurry and urine	EF_2	kg N_2O-N pr kg N	0.001
Deep litter	EF_{3a}	kg N_2O-N pr kg N	0.02
Deep litter, farmyard manure < 1 month[1]	EF_{3b}	kg N_2O-N pr kg N	0.005
Manure deposited under grazing	EF_4	kg N_2O-N pr kg N	0.02
Nitrogen applied to agricultural soils:			
Synthetic fertiliser applied to agricultural soils[2]	EF_5	kg N_2O-N pr kg N	0.0125
Animal manure applied to agricultural soils[3]	EF_6	kg N_2O-N pr kg N	0.0125
Sewage sludge applied to agricultural soils	EF_7	kg N_2O-N pr kg N	0.01
Other:			
N-fixing crops	EF_8	kg N_2O-N pr kg N	0.0125
Crop residues returns to soils	EF_9	kg N_2O-N pr kg N	0.0125
Atmospheric deposition (NH_3 volatilization)	EF_{10}	kg N_2O-N pr kg N	0.01
Nitrogen leaching, groundwater	EF_{11a}	kg N_2O-N pr kg N	0.015
Nitrogen leaching, rivers	EF_{11b}	kg N_2O-N pr kg N	0.0075
Nitrogen leaching, estuaries	EF_{11c}	kg N_2O-N pr kg N	0.0025
Cultivation of histosols	EF_{12}	kg N_2O-N pr ha	8

[1] Farmyard manure, which is feaces and urine mixed with large amounts of bedding (usually straw) on the floors of cattle or pig housing.

[2] Calculated as the amount of N sold in synthetic fertilisers minus NH_3 emission.

[3] Calculated as N ex storage minus NH_3 emission from application of manure on soils.

The estimated emissions from the different sources are described in the following text.

9.2 Manure management and grazing

The amount of nitrogen in animal manure is based on the normative figures (Poulsen et al., 2001; Poulsen, 2010). Besides animal type, the emission depends on housing type which decides the manure type. Under the anaerobic conditions in slurry and urine the emission of N_2O is considered to be relatively low, while the emission from deep litter systems and solid manure in the housing units is higher. The emission from animal manure management is calculated as shown in equation 9.2.

$$N_2O_{MM} = \sum Nex_{j,i} \cdot EF_i \cdot \frac{44}{28} \qquad \text{(Eq. 9.2)}$$

where: N_2O_{MM} = emission of N_2O from manure management and grazing animals

Nex = N excretion from the given animal category (j) and manure type (i)

EF = emission factor for a given manure type, i

As recommended in the IPCC guidelines, an emission factor of 0.005 (EF_{1a}) is used for solid poultry manure and 0.02 (EF_{1a}) for solid manure from other livestock categories. For urine and slurry is used 0.001 (EF_2) and for deep litter is used 0.02 (EF_{3a}). However, for deep litter system with farmyard manure placed less than one month a lower emission factor of 0.005 is used (EF_{3b}). Farmyard manure is a system where the manure is accumulated on floor and mixed with straw bedding, which in Denmark is use e.g. in housing of cattle calves. For animal manure applied to grass an emission factor of 0.02 (EF_4) is used. The distribution of nitrogen excretion into housing and grass for each animal category is shown in chapter 4.3.

Due to a lower emission factor for liquid manure, the development from 1985 to 2009 towards slurry-based housing systems led to a reduction in the emission of N_2O.

The total amount of nitrogen in animal manure (N ex animal) is shown for 1985 to 2009 in figure 9.2 and illustrates a fall from 312 Gg N in 1985 to 263 Gg N in 2009, which equates to a reduction of 16 %. This reduction should be seen in the light of a significant increase in the pig and poultry production since 1985 and can be explained by the improvements in feed efficiency, which has resulted in a lower N excretion, especially for fattening pigs.

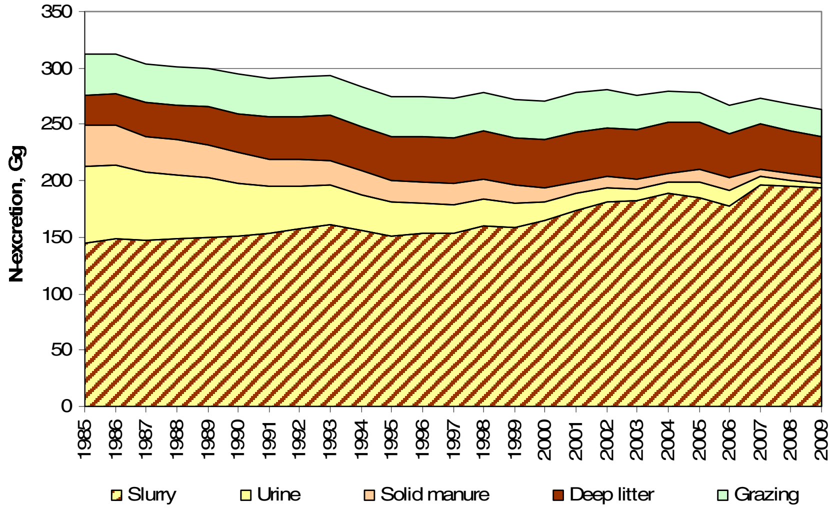

Figure 9.2 Total amount of nitrogen in animal manure (N ex animal).

9.3 Nitrogen applied to agricultural soils

The calculation of N_2O from the application of nitrogen is the sum of N in synthetic fertilisers, N in animal manure and N in the different types of sludge.

$$N_2O_{AS} = ((N_{SF} - NH_{3,\ SF}) \cdot EF_5 + (N_{AM} - NH_{3,\ A}) \cdot EF_6 + (N_{SS} - NH_{3,\ SS}) \cdot EF_7) \cdot \frac{44}{28} \qquad \text{(Eq. 9.3)}$$

where:

N_2O_{AS}	= N_2O emission from nitrogen sources applied to agricultural soils
N_{SF}	= consumption of N in synthetic fertiliser
$NH_{3,\ SF}$	= NH_3 emission from synthetic fertiliser
N_{AM}	= amount of nitrogen in animal manure ex storage
$NH_{3,\ A}$	= NH_3 loss from application of animal manure
N_{SS}	= amount of nitrogen in sewage or industrial sludge applied to agricultural soils
$NH_{3,\ SS}$	= NH_3 emission from application of sewage sludge
EF_x	= emission coefficient (see Table 9.1)

All calculations concerning the content of nitrogen in manure ex storage, synthetic fertiliser and sewage sludge are incorporated in the NH_3 emission and therefore described in chapter 5, likewise the estimates of NH_3 emission.

Table 9.2 shows the total amount of nitrogen from animal manure, synthetic fertilisers and sewage sludge applied to agricultural soils, as well as the emission of N_2O given as both total N_2O and CO_2 equivalents from 1985 to 2009.

The N_2O emission from applications to soils fell from 7.3 Gg N_2O-N in 1985 to 5.0 Gg N_2O-N in 2009 – i.e. 31 % over the period. The reduction is primarily due to the reduction in the use of synthetic fertilisers as a consequence of improvements in the utilisation of nitrogen in animal manure.

Table 9.2 The calculation of N_2O emission from sources of nitrogen applied to agricultural soils.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
N applied to soils						Gg N							
N in synthetic fertilisers	398	382	381	367	377	400	395	370	333	326	316	291	288
NH_3-N, synthetic fertiliser	7	7	6	6	6	7	7	6	6	6	6	5	5
N in animal manure (ex storage)	229	229	221	219	217	215	213	214	216	208	201	201	199
NH_3-N, animal manure	39	39	37	36	35	35	34	32	31	29	27	25	25
N in sewage sludge	4	4	4	4	4	5	6	7	9	9	9	9	8
NH_3-N, sewage sludge	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N-total applied to soils	584	569	563	547	557	578	574	551	521	508	493	471	465
Emission													
Gg N_2O-N	7.30	7.11	7.03	6.84	6.96	7.22	7.17	6.89	6.51	6.34	6.16	5.88	5.82
Gg N_2O	11.47	11.17	11.05	10.75	10.94	11.35	11.27	10.82	10.23	9.97	9.69	9.24	9.14
Gg CO_2 equivalents	3 555	3 463	3 426	3 331	3 390	3 519	3 493	3 355	3 171	3 091	3 003	2 865	2 833

Year *continued*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N applied to soils					Gg N							
N in synthetic fertilisers	283	263	251	234	211	201	207	206	192	195	220	200
NH_3-N, synthetic fertiliser	5	4	4	4	3	3	4	4	4	4	4	4
N in animal manure (ex storage)	203	201	198	204	207	207	210	212	204	211	210	208
NH_3-N, animal manure	25	25	25	25	23	19	17	17	17	18	17	17
N in sewage sludge	9	8	9	11	12	11	13	12	13	13	13	13
NH_3-N, sewage sludge	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
N-total applied to soils	465	443	429	420	403	396	409	409	389	397	422	401
Emission												
Gg N_2O-N	5.81	5.53	5.37	5.25	5.03	4.96	5.11	5.12	4.86	4.97	5.28	5.01
Gg N_2O	9.14	8.70	8.43	8.25	7.91	7.79	8.03	8.04	7.64	7.80	8.29	7.87
Gg CO_2 equivalents	2 832	2 696	2 615	2 558	2 452	2 414	2 489	2 493	2 367	2 419	2 571	2 440

9.4 Nitrogen-fixing plants

According to the IPCC guidelines, the total amount of nitrogen from nitrogen-fixing plants should be included as an N_2O emission source.

The estimates regarding the amount of nitrogen fixed in crops are made by mainly DJF (Kristensen & Kristensen, 2002, Kyllingsbæk, 2000, Høgh- Jensen et al., 1998). The calculation of the emission from nitrogen-fixing plants is based on the nitrogen content and the fraction of dry matter for each crop type harvested. The calculation of N-fixation from legumes, peas/barley (whole-crop), peas for conservation, lucerne, grass-clover and catch crop is based on the harvest yield. The calculation for seeds of legume grass crops is based on the cultivated area. Values of yield and area are based on data from DSt. Information on dry matter content and N-content are from the feedstuffs table (DAAS, 2000). The N-content in roots and stubble is taken into consideration in the calculation as well as the proportion of plant N that can be attributed to nitrogen fixation. The emission is calculated according to equation 9.4.

$$N_2O_{\text{N-fix}} = \left(\sum\left((DM_{\text{i, yield}} \cdot N_{\text{i, pct}}) \cdot (1 + N_{\text{i, pct in root and stub}})\right) \cdot Pct_{\text{fix}} \cdot EF_8\right) \cdot \frac{44}{28} \quad \text{(Eq. 9.4)}$$

where

$N_2O_{N\text{-fix}}$ = N_2O emission from N-fixing crops

$DM_{i,\ yield}$ = dry matter, yield, kg per ha for crop i
$N_{i,\ pct}$ = nitrogen percentage in dry matter
$N_{i,pct\ root\ +\ stub}$ = nitrogen percentage in root and stubble
Pct_{fix} = percentage of nitrogen that is fixed

The Danish inventory includes emissions from grass-clover, despite the fact that this source is not mentioned in the IPCC reference manual (IPCC, 1997) or Good Practice Guidance (IPCC, 2000). The area with grass and clover made up approximately 20 % of the total agricultural area in 2009, and is for this reason an important source to the national emission from N-fixing crops.

Table 9.3 provides background data for the calculation of the amount of nitrogen from nitrogen-fixing crops.

Table 9.3 Background data for calculation of N content in nitrogen fixing crops.

Crop	DM content[1]	N-content in DM[1]	Straw yield of grain yield[2]	Share, root+ stubble[3]	N in crop (fixed)[3]	N-fixed
	pct.	pct.	pct.	pct.	pct.	kg N pr tonnes harvested
Based on yield						
Field peas, grain	85	3.97	-	25	75	-
Field peas, straw	87	1.15	60	-	-	-
Legumes grown to maturity, in total	-	-	-	-	-	37.3
Peas/barley- whole-crop for silage	23	2.64	-	25	80	6.1
Legumes, marrow-stem kale and green fodder	23	2.64	-	25	80	6.1
Lucerne	21	3.04	-	60	75	7.7
Grass, clover fields and fields with an undersown crop	13	4.00	-	75	90	8.2
Peas for conservation[4]	23	2.64	-	25	80	6.1
Fields with catch crop	13	4.00	-	75	90	8.2
Based on area	kg N pr ha					
Seeds:						
Red clover	200					
White clover	180					
Black medic	180					

[1] Feedstuff table (DAAS, 2000).
[2] Kyllingsbæk (2000).
[3] Kristensen (2002) and Kyllingsbæk (2000).
[4] Assumed that nitrogen fixing from peas for conservation is 80 % compared to field peas.

Changes in the percentages of nitrogen-fixing plants during the years are taken into account (Table 9.4). Since 1985, there has been a growing production of peas and grass-clover as a result of stricter regulations on the use of nitrogen. The information on nitrogen-fixing crops is provided by DJF (Kyllingsbæk, 2000).

Table 9.4 Estimated share of nitrogen-fixing plants in crops.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999-2009
								pct.							
Crops for silage															
Share of peas (whole-crop)[a]	15	20	20	25	25	30	30	35	35	40	40	45	45	50	50
Share of peas[b]	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Legumes, marrow-stem kale and other green fodder															
Share with legumes:	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
-of which share with peas	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Peas for conservation	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Grass in rotation															
Share of grass-clover fields	64	66	68	70	72	74	76	78	80	82	84	85	86	87	88
Clover pct. in grass-clover fields	20	20	20	20	20	20	20	20	20	20	22	24	26	28	30
Grass not in a rotation															
Clover percentage	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Fields with catch crop															
Share with grass-clover	64	66	68	70	72	74	76	78	80	82	84	85	86	87	88
Clover pct.	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

Source: Kyllingsbæk, 2000.

[a]share of peas (whole crop) in proportion to total area of crops for silage.

[b]share of peas in proportion to peas (whole crop).

The nitrogen fixation for each crop type is estimated presented in Table 9.5. The N-fixation per hectare varies significantly from year to year as a consequence of changes in yield level due to the climatic conditions.

Table 9.5 Variations in N-fixation 1985 – 2009.

	N-fixation pr hectare		N- fixation 2009	
	1985-2009	2009	N- fixation	Distribution
	kg N pr ha	kg N pr ha	tonnes N fix	pct.
Legumes to maturity	95-179	132	835	2
Crops for silage	1-38	22	1 215	3
Legumes/marrow-stem kale	0-1	0	0	0
Lucerne	302-517	403	2 162	5
Grass and clover in rotation	40-107	107	32 656	80
Grass not in rotation	6-11	8	1 508	4
Fields with catch crop	6-16	9	1 075	3
Peas for conservation	76-144	105	394	1
Seeds of leguminous grass crops	181-186	182	825	2
Total N-fix			**40 670**	**100**

NO = Not occurring.

As illustrated in figure 9.3 and Table 9.6, the level of nitrogen fixation has changed between 30-40 Gg N in 1985 to 2009, which is due to changes in crop types. It is seen a change in increase of the area with grass-clover and a reduction in the area with legumes to maturity (see appendix M). In 2009 grass-clover fields were responsible for approximately 80 % of the total N-fixation.

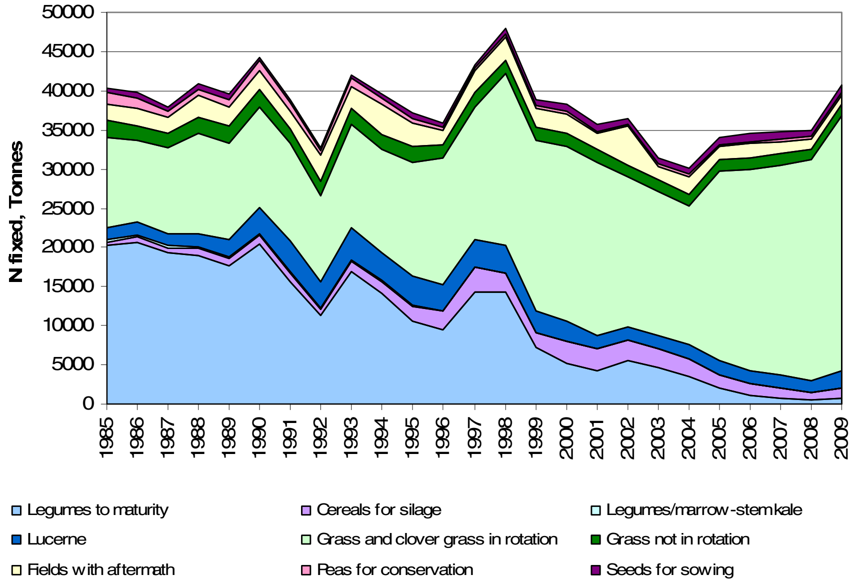

Figure 9.3 Total nitrogen fixation distributed on different crop types 1985-2009.

Table 9.6 Emission of N_2O from N-fixing crops, 1985-2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
N, Gg	40.3	39.8	38.0	40.9	39.6	44.3	38.8	32.7	42.1	39.6	37.2	35.8	43.4
N_2O, Gg	0.79	0.78	0.75	0.80	0.78	0.87	0.76	0.64	0.83	0.78	0.73	0.70	0.85
CO_2 eqv., 1000 Gg	0.25	0.24	0.23	0.25	0.24	0.27	0.24	0.20	0.26	0.24	0.23	0.22	0.26
Year *continued*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
N, Gg	48.0	38.9	38.3	35.6	36.5	31.5	30.1	34.1	34.6	34.8	34.9	40.7	
N_2O, Gg	0.94	0.76	0.75	0.70	0.72	0.62	0.59	0.67	0.68	0.68	0.69	0.80	
CO_2 eqv., 1000 Gg	0.29	0.24	0.23	0.22	0.22	0.19	0.18	0.21	0.21	0.21	0.21	0.25	

9.5 Crop residues

According to the IPCC guidelines, the nitrogen from crop residues left on the field after harvest should be included as an N_2O emission source. Emissions from crop residues are calculated as the N content in the total above-ground biomass of crop residues returned to the soil in the form of stubble, husks, tops and leaves. Furthermore, the amount of straw left in the field after harvest is taken into account.

The emission from agricultural crop residues is calculated according to Equation 9.5.

$$N_2O_{CR} = (\sum AR \cdot ((\frac{N_{ST}}{no_{PF}}) + N_{HU} + N_{PT} + N_{LR}) \cdot EF_9) \cdot \frac{44}{28} \qquad \text{(Eq. 9.5)}$$

where:

	N_2O_{CR}	= emission of N_2O from crop residue
	ha	= area on which a given crop is grown
	N_{ST}	= nitrogen derived from stubble, kg ha^{-1}
	N_{HU}	= nitrogen derived from husks, kg ha^{-1}
	N_{PT}	= nitrogen derived from plant tops, kg ha^{-1}
	N_{LR}	= nitrogen derived from leaf litter kg ha^{-1}
	no_{PF}	= number of years between ploughing

Data concerning the cultivated area, unharvested plant tops from beets and potatoes and the amount of unharvested straw are based on information from DSt (2010).

9.5.1 N-content in crops

National values for nitrogen content are provided by DJF (Djurhuus & Hansen, 2003). Calculations are based on relatively few observations, but are at present the best available data. Same values are used for all years.

Table 9.7 shows the estimated N-content in crop residues, ploughing frequency and total N-content in all crop residues from 2009. It is assumed that grass fields on average are ploughed in every other year, lucerne every three years and set-aside fields every 10 years.

Table 9.7 Overview of the N-content in residues from agricultural crops under conditions of normal fertilisation.

	Stubble	Husks	Tops	Leaf litter	Ploughing frequency	N-content in crop residues	
Crop	kg N pr ha	kg N pr ha	kg N pr ha	kg N pr ha	yrs between ploughing	kg N pr ha pr yr	Gg N pr yr
Winter wheat	6.3	10.7	-	-	1	17.0	12.28
Spring wheat	6.3	7.4	-	-	1	13.7	0.13
Winter rye	6.3	10.7	-	-	1	17.0	0.72
Triticale	6.3	10.7	-	-	1	17.0	0.81
Winter barley	6.3	5.9	-	-	1	12.2	1.72
Spring barley	6.3	4.1	-	-	1	10.4	4.61
Oats	6.3	4.1	-	-	1	10.4	0.56
Winter rape	4.4	-	-	-	1	4.4	0.71
Spring rape	4.4	-	-	-	1	4.4	0.00
Potato (tops)	-	-	48.7	-	1	48.7	1.85
Lucerne	32.3	-	-	-	3	10.8	0.06
Maize for silage	6.3	-	-	-	1	6.3	1.06
Grain for silage	6.3	-	-	-	1	6.3	0.35
Catch crop	6.3	-	-	-	1	6.3	0.72
Peas for conservation	11.3	-	-	-	1	11.3	0.04
Vegetables	11.3	-	-	-	1	11.3	0.09
Grass field legumes	11.3	-	-	-	2	5.7	0.03
Legume seed	11.3	-	-	-	1	11.3	0.07
Grass seed	6.3	10.7	-	-	2	13.9	1.11
Other plants for seed	6.3	10.7	-	-	2	13.9	0.03
Grass and clover + rotation	32.3	-	-	10.0	2	26.2	7.99
Grass and clover - rotation	38.8	-	-	20.0	-	20.0	3.83
Set-aside	38.8	-	-	15.0	10	18.9	0.11
Total							**38.77**

9.5.2 N-content in straw and plant tops from fodder beets

The amount of nitrogen in straw and tops from fodder beets, which are left in the field after harvest, is based on yield levels from DSt, and DM and raw protein contents from the feedstuff table published by DAAS (2000).

Wheat is the largest source of unharvested straw. The amount of N is calculated as the total amount of unharvested straw, multiplied by the DM percentage (85 %) and the raw protein content of the DM (3.3 %). Converting raw protein to N-content uses a conversion factor of 6.25 (Jones, 1941).

For beet tops, it is assumed that factory and fodder beets have the same top yield. The nitrogen content is calculated in the same way as straw. The DM content is 12 % and the raw protein content of the DM is 16.4 %.

The basic data used for calculating the N-content in straw and fodder beet tops are shown in Table 9.8 for year 2009.

Table 9.8 Data used for calculation of N-content in straw and fodder beet tops, 2009.

2009	Yield	DM	Raw protein of DM	Conversion factor to N	Crop residue
	Gg	Pct.	Pct.		Gg N pr year
Straw – not harvested	2 230	85	3.3	6.25	10.01
Fodder beet (tops) – not harvested	773	12	16.4	6.25	2.43
Total					12.44

9.5.3 Emission

Figure 9.4 shows the distribution of nitrogen in crop residues between stubble, husks, plant tops and leaf litter. The total-N content in crop residues from 1985 to 2009 is nearly unaltered, which is also reflected in the N_2O emission (see Table 9.9). However, there has been a little variation for some of the years, particularly for straw.

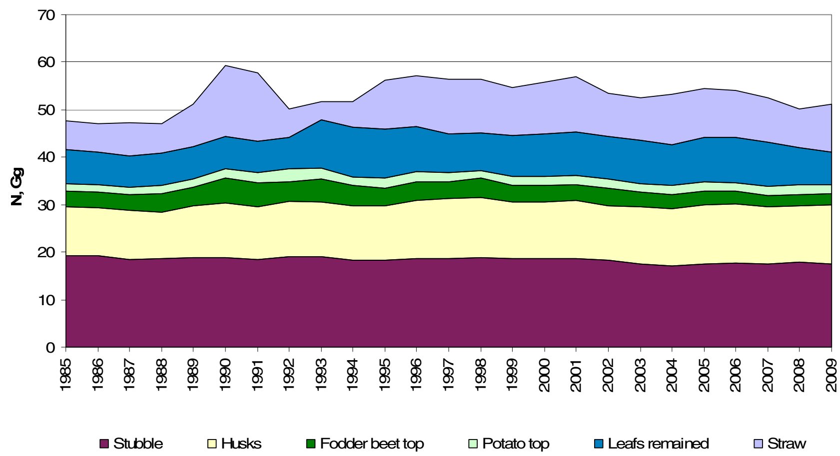

Figure 9.4 N content in crop residues, 1985 – 2009.

Table 9.9 Emission of N_2O from crop residues, 1985-2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
N, Gg	47.7	47.1	47.3	47.1	51.2	59.3	57.7	50.3	51.7	51.7	56.2	57.2	56.5
N_2O, Gg	0.94	0.93	0.93	0.93	1.01	1.17	1.13	0.99	1.01	1.02	1.10	1.12	1.11
CO_2-eqv.,1000 Gg	0.29	0.29	0.29	0.29	0.31	0.36	0.35	0.31	0.31	0.31	0.34	0.35	0.34
Year *continued*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
N, Gg	56.5	54.7	55.7	57.0	53.4	52.5	53.3	54.4	54.1	52.6	50.1	51.21	
N_2O, Gg	1.11	1.07	1.09	1.12	1.05	1.03	1.05	1.07	1.06	1.03	0.98	1.01	
CO_2-eqv.,1000 Gg	0.34	0.33	0.34	0.35	0.33	0.32	0.32	0.33	0.33	0.32	0.31	0.31	

9.6 Atmospheric deposition

The emissions of NH_3 and NO_X contribute to the emission of N_2O.

Around 97 % of the total NH_3 emission stems from agriculture (Nielsen et al., 2010a). In addition to the formation of N_2O, a release of N_2 and NO_X also occurs. Neither the IPCC Reference manual (IPCC, 1997) nor the IPCC Good Practice Guidance (IPCC, 2000) has a methodology for their quantification and neither are there currently any Danish data.

The emission is calculated as illustrated in Equation 9.6 - i.e. as the total NH_3 emission multiplied by the IPCC standard value for the emission factor of 0.01 (EF_{10}).

$$N_2O_{dep} = ((NH_{3MM} + NH_{3SF} + NH_{3SS} + NH_{3C} + NH_{3A\text{-straw}}) \cdot EF_{10}) \cdot \frac{44}{28} \quad \text{(Eq. 9.6)}$$

Where:
- N_2O_{dep} = N_2O emission from atmospheric deposition
- $NH_{3,MM}$ = NH_3 emission from manure management
- $NH_{3,SF}$ = NH_3 emission from synthetic fertiliser
- $NH_{3,SS}$ = NH_3 emission from sewage sludge
- $NH_{3,C}$ = NH_3 emission from crops
- $NH_{3,A\text{-straw}}$ = NH_3 emission from NH_3 treated straw

The total NH_3 emission from all emission sources is shown in Table 9.10 together with the calculated N_2O emission. From 1985 to 2009 the N_2O emission has decreased from 1.5 Gg N_2O to 1.0 Gg N_2O, which equates to a fall of 38 %. As mentioned in chapter 5 regarding the NH_3 emission, this emission reduction is a consequence of an active environmental policy to reduce the loss of nitrogen to the aquatic recipients.

Table 9.10 Total NH_3 emission and the N_2O emission, 1985 – 2009.

Emission pr year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NH_3 emission, Gg NH_3-N	98.25	99.21	97.32	95.15	95.70	95.51	92.19	90.87	89.14	86.70	81.71	78.93	77.73
N_2O emission, Gg N_2O	1.54	1.56	1.53	1.50	1.50	1.50	1.45	1.43	1.40	1.36	1.28	1.24	1.22
CO_2 emission, 1000 Gg CO_2-eqv.	0.48	0.48	0.47	0.46	0.47	0.47	0.45	0.44	0.43	0.42	0.40	0.38	0.38
Year *continued*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
NH_3 emission, Gg NH_3-N	78.30	74.23	73.23	72.15	70.45	69.63	69.31	66.01	63.50	62.90	61.71	60.80	
N_2O emission, Gg N_2O	1.23	1.17	1.15	1.13	1.11	1.09	1.09	1.04	1.00	0.99	0.97	0.96	
CO_2 emission, 1000 Gg CO_2-eqv.	0.38	0.36	0.36	0.35	0.34	0.34	0.34	0.32	0.31	0.31	0.30	0.30	

9.7 Leaching and run-off

Nitrogen, which is transported through the soil can be transformed to N_2O. The IPCC recommends an N_2O emission factor of 0.025 used, of which 0.015 is for leaching to groundwater, 0.0075 for transport to watercourses (in IPCC definition called rivers) and 0.0025 for transport out to sea (in IPCC definition called estuaries). The N_2O emission from nitrogen leaching is a sum of the emission for all three parts calculated as given in equation 9.7:

$$N_2O_{leaching} = (N_{leach\text{-}ground} \cdot EF_{11a} + N_{leach\text{-}rivers} \cdot EF_{11b} + N_{leach\text{-}estuatires} \cdot EF_{11c}) \cdot \frac{44}{28}$$

In connection with the Action Plans for the Aquatic Environment, nitrogen leaching to groundwater, to the watercourses and to the sea has been estimated. The calculation of N to the groundwater is based on two different models– SKEP/Daisy and N-LES (Børgesen & Grant, 2003) carried out by DJF and NERI (see overview of model in appendix N). SKEP/DAISY is a dynamical crop growth model taking into account the growth factors, whereas N-LES is an empirical leaching model based on more than 1500 leaching studies performed in Denmark during the last 15 years. The models produce rather similar results for nitrogen leaching on a national basis (Waagepetersen et al., 2008). The SKEP/Daisy model has estimated the total N leached from 2003-2007 to be 172-159 thousand tonnes N, where as N-LES model has estimated the total N leached to be 163-154 thousand tonnes in the same period. An average of the results from the two models is used in the emission inventory.

Data conrning the N-leaching to watercourses and to the sea is based on data from NOVANA (National Monitoring program of the Water Environment and Nature) recived from NERI the department of Freshwater Ecology. NOVANA data is available from 1990 and the emission from 1985 to 1989 is the same as for 1990 until background data is estimated.

Since 1985, the amount of nitrogen leached has almost halved as a result of the significant decrease in consumption of synthetic fertilisers and the improved utilisation of the nitrogen content in animal manure (Table 9.11). The same trend is reflected in the N_2O emission by a decrease from 7.9 Gg N_2O in 1985 (1990) to 4.6 Gg N_2O in 2009, or 1416 Gg CO_2 equivalents.

Table 9.11 Leaching of nitrogen and associated emissions, 1985 - 2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
N-leaching$_{groundwater}$, Gg N	304	296	289	281	274	267	261	254	248	241	235	219	213
N-leaching$_{rivers}$, Gg N						104	91	102	108	139	107	46	51
N-leaching$_{estuaries}$, Gg N						100	86	95	97	127	91	44	46
N_2O, Gg	7.92	7.92	7.92	7.92	7.92	7.92	7.56	7.57	7.49	7.83	7.16	5.89	5.79
CO_2-eqv.,1000 Gg	2.46	2.46	2.46	2.46	2.46	2.46	2.34	2.35	2.32	2.43	2.22	1.82	1.80
Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
N-leaching$_{groundwater}$, Gg N	207	192	179	174	168	161	162	160	156	157	163	155	
N-leaching$_{rivers}$, Gg N	102	112	97	79	103	53	81	67	78	98	80	61	
N-leaching$_{estuaries}$, Gg N	85	95	82	65	88	43	67	55	64	79	64	49	
N_2O, Gg	6.41	6.22	5.69	5.28	5.52	4.59	5.03	4.77	4.84	5.16	5.04	4.57	
CO_2-eqv.,1000 Gg	1.99	1.93	1.76	1.64	1.71	1.42	1.56	1.48	1.50	1.60	1.56	1.42	

Figure 9.5 illustrates the total amount of nitrogen applied as fertiliser on agricultural land in the form of animal manure, synthetic fertiliser and sewage sludge compared with the amount of N leached to the groundwater. It can be seen that the percentage of N of that applied fell from 43 % in 1985 to 33 % in 2009.

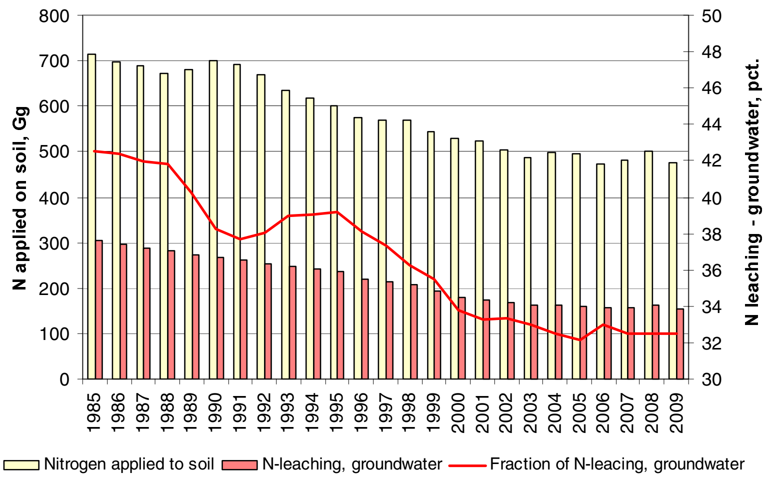

Figure 9.5 Leaching of nitrogen from 1985 to 2009.

9.8 Cultivation of histosols

The cultivation of histosols (humus-rich soils) breaks down organic matter and, thereby, releases both CO_2 and N_2O. The size of the emission depends on the circumstances surrounding cultivation (crop type, rotation, soil management, saturation, pH, etc.). The cultivated area of organics soils is estimated to approximately 50 000 ha.

The calculation of the N_2O emission is based on IPCC guidelines, which recommend an emission of 8 kg N_2O-N per hectare of cultivated organic soils.

Table 9.12 Area, N_2O emission and implied emission factor for histosols, 1985-2009.

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Cultivated area, ha	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000
N_2O, Gg	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
IEF, N_2O-N kg pr ha	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Year *continued*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Cultivated area, ha	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	
N_2O, Gg	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	
IEF, N_2O-N kg pr ha	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	

9.9 Biogas treatment of slurry

The lower emissions achieved from biogas treated slurry is included in the N_2O emission from manure management (housing and storage). The digestive process of the biogas treatment reduces the dry matter content of the slurry and this leads to a reduced N_2O emission under and after the spreading of the biogas treated slurry.

There is no methodology available in the IPCC Reference Manual (IPCC, 1997) or the IPCC GPG (IPCC, 2000) on how to calculate this reduction. Therefore is the estimation based on Danish studies (Nielsen et al., 2002, Sommer et al., 2001). The lower N_2O emission is calculated according to equation 9.8:

$$N_2O_{lower} = (S_{treated\ slurry} \cdot N_C \cdot E_{N_2O,lower} \cdot EF_{N_2O}) \cdot \frac{44}{28} \quad \text{(Eq. 9.8)}$$

where: N_2O_{lower} = the amount of lower N_2O emission from a given livestock type (cattle or pigs)

$S_{treated\ slurry}$ = amount of treated slurry, tonnes

N_C = content of N in the treated slurry, pct

$R_{N2O,\ lower}$ = a lower emission from biogas treated slurry. It is assumed that treated cattle slurry is 64 % compared with untreated slurry and 60% for pig slurry

EF_{N2O} = emission factor for N_2O

The background data for the calculation of the reduction in N_2O emission is shown in Table 9.13.

Table 9.13 Data used in calculation of the reduction in N_2O emission in 2009.

2009	Slurry treated[a]	Average N-content in slurry[b]	$E_{N2O, lower}$	N_2O emission in untreated slurry	N_2O emission in biogas treated slurry	Lower the total N_2O emission
	1000 Gg slurry	Pct.		Gg N_2O	Gg N_2O	Gg N_2O
Cattle slurry	0.98	0.00538	0.64	0.07	0.04	0.02
Pig slurry	1.20	0.00541	0.59	0.07	0.05	0.03
Total						0.05

[a] Tafdrup, (2010).

[b] Poulsen et al. (2001) and Poulsen, 2010.

For 2009, the N_2O reduction was 0.05 Gg, which corresponds to a 4 % reduction of the N_2O emission from manure management in 2009. The reduction is subtracted from the emissions from dairy cattle and fattening pigs, respectively.

The total reduction from 1990 to 2009, which stems from biogas treatment of manure, is shown in appendix O.

10 Field burning of agricultural residues

The field burning of agricultural residues has been prohibited in Denmark since 1990 (LBK, 1989; BEK, 1991) and may only take place in connection with the production of grass seeds on fields with repeated production (straw from seeds of grass) and in cases of wet or broken bales of straw (mixed cereals). The amount of burnt straw from the grass seed production is estimated at 15 % of the total amount produced. The amount of burnt bales or wet straw is estimated at 0.1 % of the total amount of straw. Both estimates are based on an expert judgement (Feidenhans'l, 2009). The total production is based on data from DSt.

Field burning produces emissions of a series of different pollutants: NH_3, CH_4, N_2O, NO_x, CO, CO_2, SO_2, NMVOC, PM, heavy metals, dioxin and PAH. Default values given by the EMEP/EEA Guidebook (EMEP/EEA, 2009) are used for NH_3, NO_x, CO, SO_2, NMVOC, PM, heavy metals (except for Cu) and dioxin. For Cu and for PAH, emission factors are based on Jenkins (1996) and for N_2O, CH_4 and CO_2 the emission factors are based on Andreae & Merlet (2001).

The equation for calculating the emission is shown below. The parameters used for the calculation of emissions are given in Table 10.1 and the emission factors are provided in Table 10.2.

$$\text{Emi} = \text{BB} \cdot \frac{\text{EF}}{1000} \cdot \text{FO} \qquad \text{(Eq. 10.1)}$$

$$\text{BB} = \frac{\text{CP} \cdot \text{FB} \cdot \text{FR}_{\text{DM}}}{1000}$$

where Emi = emission of pollutants, Gg
BB = total burned biomass, Gg DM
CP = crop production, t
FB = fraction burned in fields
FR_{DM} = dry matter fraction of residue
EF = emission factor, g pr kg DM
FO = fraction oxidized

Table 10.1 Parameters for estimating emissions from field burning, 2009.

	Crop production tonnes	Fraction burned in fields	DM fraction of residue[a]	Total biomass burned Gg DM	Fraction oxidized[b]
Mixed cereals	6 280 000	0.001	0.85	5.34	0.90
Straw from seeds of grass	399 010	0.15	0.85	50.87	0.90

[a] DAAS (2005).
[b] IPCC (1997).

Table 10.2 Emission factors and emissions for the different pollutants from field burning of agricultural residues, 2009.

Pollutant	EF	Unit for EF	Emission 2009	Unit for emission
NH_3	2.4	G pr kg DM	0.12	Gg
CH_4	2.7	G pr kg DM	0.14	Gg
N_2O	0.07	G pr kg DM	0.004	Gg
NO_x	2.4	G pr kg DM	0.12	Gg
CO	58.9	G pr kg DM	2.98	Gg
CO_2	1.515	Kg pr kg DM	76.64	Gg
SO_2	0.3	G pr kg DM	0.02	Gg
NMVOC	6.3	G pr kg DM	0.32	Gg
PM				
TSP	5.8	G pr kg DM	0.29	Gg
PM_{10}	5.8	G pr kg DM	0.29	Gg
$PM_{2.5}$	5.5	G pr kg DM	0.28	Gg
Metals				
Pb	0.865	Mg pr kg DM	0.04	Tonnes
Cd	0.049	Mg pr kg DM	0.002	Tonnes
Hg	0.008	Mg pr kg DM	0.0004	Tonnes
As	0.058	Mg pr kg DM	0.003	Tonnes
Cr	0.22	Mg pr kg DM	0.01	Tonnes
Ni	0.177	Mg pr kg DM	0.009	Tonnes
Se	0.036	Mg pr kg DM	0.002	Tonnes
Zn	0.028	Mg pr kg DM	0.001	Tonnes
Cu	0.0003	Mg pr kg DM	0.00002	Tonnes
Dioxin	500	ng TEQ/t	0.03	g/TEQ
PAH				
Benzo(a)pyrene	2 787	µg pr kg DM	0.14	Tonnes
benzo(b)fluoranthene	2 735	µg pr kg DM	0.14	Tonnes
benzo(k)fluoranthene	1 073	µg pr kg DM	0.05	Tonnes
Indeno(1,2,3-cd)pyrene	1 017	µg pr kg DM	0.05	Tonnes

Figure 10.1 shows the trend of the emission of NH_3, PM_{10}, $PM_{2.5}$, CH_4 and NMVOC from field burning for 1985-2009. The large decrease of the emissions in 1990 is due to the ban on field burning of agricultural residues. The trend of the emission of the remaining pollutants is similar to the ones shown. Emissions for all pollutants and all years are shown in appendix P.

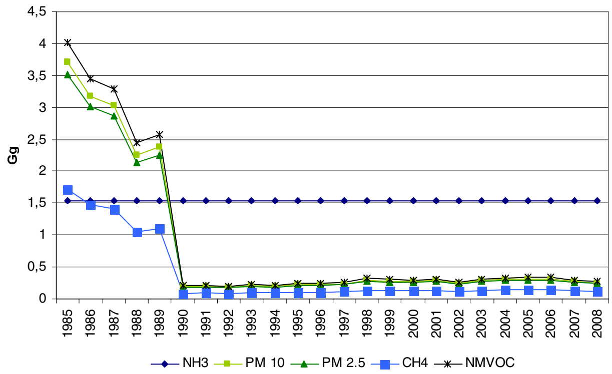

Figure 10.1 Trend of the emission of selected pollutants from field burning of agricultural residues.

11 Quality assurance and quality control

In accordance with the reporting guidelines to the UNFCCC (UNFCCC, 2006) and the IPCC Good Practice Guidance (IPCC, 2000), a Quality Control and Quality Assurance (QA/QC) plan has been elaborated by the National Environmental Research Institute (Sørensen et al., 2005). In general terms, this plan describes the concept of quality management. For more detailed information, please refer to Nielsen et al. (2010b) sections 1.6 and 6.8.

A general QA/QC and verification plan for the agricultural sector is still under development. Some measures have been formulated as general guidelines for the future work. The objectives for the quality planning are to improve the transparency, consistency, comparability, completeness and accuracy of the agricultural inventory.

This report describes in detail the methods and the data foundation used to estimate the agricultural emissions and together with the National Inventory Report (NIR) and the Informative Inventory Report (IIR), a high degree of transparency is ensured.

To ensure consistency, a quality check procedure is provided. All input data from external data sources are checked. Trend analysis are performed of both total emissions and disaggregated emissions for each pollutant, and there is an annual check of all activity data, emission factors, implied emission factors and other important variables such as N-excretion, feed intake, distribution of housing. Considerable annual variations can reveal miscalculations or inconsistencies in methods and are therefore investigated further and explained in the reporting.

The check of comparability with the reporting of other countries is ensured through the international review processes, where a lot of parameters are compared across countries and also compared to the IPCC default. Additionally Denmark has carried out a project of verification, where the emissions from key categories in the Danish inventory were compared against other countries with similar circumstances. (Fauser et al., 2006)

Regarding completeness it is ensured that the Danish inventory to the extent possible includes emissions of all relevant pollutants for all source categories where the IPCC Guidelines (IPCC, 1997), the IPCC GPG (IPCC, 2000) or the EMEP/EEA Guidebook (EMEP, EEA, 2009) contain methodological guidance and default emission factors. The Danish inventory for the agricultural sector is regarded as almost complete. Regarding the greenhouse gas inventory only a few minor sources where no methodology/default values are available in the IPCC Guidelines. For instance this is CH_4 emission from enteric fermentation in poultry. For the emission inventory of air pollutants reported under the UNECE, some recently introduced sources of especially particulate matter are not estimated due to a lack of resources.

One of the key elements to assess the accuracy of the inventory is estimating the uncertainties of the emission estimates. The procedure for estimating the uncertainties is described in chapter 12.

As quality assurance the most importing aspects are external reviews of the inventory by independent experts. For the Danish agricultural inventory the external review consists of two main elements.

The first element is the international reviews carried out under the UNFCCC and UNECE, these reviews consists of review teams of internationally appointed experts, who are assigned to review the reporting of the different countries. These review teams consists of experts within all sectors and therefore cover the entire emission inventory. The recommendations received by the review teams form an important basis for improving both the inventories themselves but also the documentation.

The second element is the external review of the sectoral reports, such as this one. The sectoral reports are externally reviewed by national or international experts in the field.

The first version of this report (Mikkelsen et al., 2006) was reviewed by Statistics Sweden, who is responsible for the Swedish agricultural inventory.

This report was reviewed by Nicholas J. Hutchings from the Faculty of Agricultural Sciences, Aarhus University and by Johnny M. Andersen from the Faculty of Life Sciences, University of Copenhagen. The comments provided were to a large degree incorporated into this version of the report. However, some of the recommendations have not been possible to implement at this stage but they will be addressed in the next sectoral report.

12 Uncertainties

Uncertainty estimates are based on the methodology described in the IPCC Good Practice Guidance (IPCC, 2000) and the EEA/EMEP Guidebook (EEA/EMEP, 2009) The guidebooks use a tiered methodology representing a level of methodological complexity. Tier 1 represents a simple methodology, while the Tier 2 approach represents a more advanced methodology. In case of uncertainties, a Monte Carlo analysis is recommended as a Tier 2 methodology.

The uncertainty calculation for NH_3, PM, NMVOC and the remaining pollutants related to the field burning of agricultural residues is provided on a Tier 1 approach. Emissions concerning the greenhouse gases N_2O and CH_4 are calculated by using both a Tier 1 and a Tier 2 approach. To ensure comparability the same uncertainty values for activity data and emission factors are used for both Tier 1 and Tier 2.

12.1 Uncertainty values

12.1.1 Activity data

Uncertainties regarding animal production are very small. Numbers of animals are based on DSt, which has estimated the uncertainties for year 2009 for the main livestock categories pigs and cattle as 1.5 % and 1.4 %, respectively.

The Danish Normative System for animal excretions is based on data from the Danish Agricultural Advisory Services (DAAS), which is the central office for all Danish agricultural advisory services. DAAS engages in a great deal of research as well as the collection of efficacy reports from Danish farmers for dairy production, meat production, pig production, etc., to optimise productivity in Danish agriculture. Feeding plans from 15-18 % of the Danish dairy production, 25-30 % of pig production, 80-90 % of poultry production and approximately 100 % of fur production are collected annually. These basic feeding plans are used to develop the standard values of the "Danish Normative System".

The normative figures (Poulsen et al., 2001; Poulsen, 2010) are comprised of arithmetic means. Based on feeding plans, the standard deviation in N-excretion rates between farms can be estimated to ±20 % for all animal types (Poulsen, pers. comm.). However, due to the large number of farms included in the norm figures, the arithmetic mean can be assumed as a very good estimate with a low uncertainty.

Data for hectares under cultivation are estimated by DSt and the uncertainties are based on their calculations. For the most common crops the uncertainties are below 5 %.

The uncertainty for activity data for field burning of agricultural residues is a combination of the uncertainty for crop production, which is low, and the uncertainty of the amount of burned straw, which is high.

The combined effect of low uncertainty in actual animal numbers and relatively low uncertainty for feed consumption and excretion rates gives a relatively low uncertainty for the activity data as a whole. The major uncertainties are related to the emission factors.

12.1.2 Emission factors

High uncertainties are connected with the emission factors for N_2O and CH_4 from manure management. Until further investigations provide new data, an uncertainty value of 100 % is used. Uncertainties relating to the N_2O emission factor are based on combination of expert judgement and the IPCC Good Practice Guidance (IPCC, 2000). Uncertainties relating to the CH_4 emission factor are based on expert judgement.

The uncertainties concerning the PM emission factor are at present based on expert judgement. These uncertainties have previously been very high. However, the EMEP/EEA Guidebook (2009) indicates a lower level of uncertainties and the possibilities of implementing these estimates in the future will be studied.

The uncertainties for the emission factors for field burning of agricultural residues are based on the EMEP/EEA Guidebook (EMEP/EEA, 2009). All uncertainties for field burning are relatively high.

12.2 Result of the uncertainty calculation

Table 12.1 shows uncertainty values for activity and emission factors and combined and total uncertainties for the pollutants, apart from N_2O and CH_4.

The total uncertainty for the NH_3 emission inventory is calculated at 18 %. Uncertainty values, of activity data for the main emission sources such as manure management and agricultural soils are relatively low. The relatively high uncertainty values for the field burning of crop residues have only minor effect on the total uncertainty estimate.

A high total uncertainty of 500 % is associated with PM emission. This is due to the high uncertainty of the emission factors. The total uncertainties for the remaining pollutants are all relatively high.

Table 12.1 Estimated uncertainty for agricultural activity data and emission factors.

Pollutant	Sector	Emission	Activity data %	EF %	Combined Uncertainty %	Total Uncertainty %
NO_x, Gg	4.F Field burning	0	25	25	35	35
CO, Gg	4.F Field burning	2.98	25	100	103	103
NMVOC, Gg	4.D Direct soil emission	1.88	2	500	500	428
	4.F Field burning	0.32	25	100	103	0
SO_2, Gg	4.F Field burning	0.02	25	100	103	103
NH_3, Gg	4.B Manure management	61.53	10	20	22	19
	4 D1a Synthetic N-fertilizers	4.72	3	25	25	0
	4 D2c N-excretion on pasture	2.00	5	25	25	0
	4.F Field burning	0.12	25	50	56	0
	4.G Other	5.46	20	50	54	0
TSP, tonnes	4.B Manure management	11 251	2	300	300	300
	4.F Field burning	0.29	25	50	56	0
PM_{10}, tonnes	4.B Manure management	5 678	2	300	300	300
	4.F Field burning	0.29	25	50	0	0
$PM_{2.5}$, tonnes	4.B Manure management	1 218	2	300	300	300
	4.F Field burning	0.28	25	50	56	0
Pb, tonnes	4.F Field burning	0.04	25	50	56	56
Cd, tonnes	4.F Field burning	0.00	25	100	103	103
Hg, tonnes	4.F Field burning	0.00	25	200	202	202
As, tonnes	4.F Field burning	0.00	25	100	103	103
Cr, tonnes	4.F Field burning	0.01	25	200	202	202
Cu, tonnes	4.F Field burning	0.00	25	200	202	202
Ni, tonnes	4.F Field burning	0.01	25	200	202	202
Se, tonnes	4.F Field burning	0.00	25	100	103	103
Zn, tonnes	4.F Field burning	0.00	25	200	202	202
Dioxin, g I-Teq	4.F Field burning	0.03	25	500	501	501
Benzo(a)pyrene, tonnes	4.F Field burning	0.14	25	500	501	501
Benzo(b)fluoranthen, tonnes	4.F Field burning	0.14	25	500	501	501
Benzo(k)fluoranthen, tonnes	4.F Field burning	0.05	25	500	501	501

Uncertainty values for activity and emission factors for N_2O and CH_4 are shown in Table 12.2.

Table 12.2 Uncertainty values for activity data and emission factors for N_2O and CH_4.

CRF category			Uncertainty value, pct. Activity data	Uncertainty value, pct. Emission factor
4.A Enteric Fermentation		CH_4	2	20
4.B Manure Management		CH_4	5	20
		N_2O	22	50
4.D Agricultural Soils				
4.D1 Direct soil emissions	Synthetic Fertiliser	N_2O	25	100
	Animal Waste Applied to Soils	N_2O	30	100
	N-fixing Crops	N_2O	20	100
	Crop Residue	N_2O	20	100
	Cultivation of Histosols	N_2O	20	100
	Sewage sludge/industrial waste applied to agricultural soils	N_2O	20	100
4.D2 Animal Production		N_2O	25	100
4.D3 Indirect soil emissions	Atmospheric Deposition	N_2O	19	100
	N-Leaching and Runoff	N_2O	20	100
4.F Field Burning of Agricultural Residues		CH_4	25	50
		N_2O	25	50

Table 12.3 shows the result of the Tier 1 and Tier 2 uncertainty calculation for 2008. A calculation for year 1990 gives nearly the same uncertainty values for all emission sources. The overall uncertainty calculation for the agricultural sector based on Tier 1 is estimated at ±19 %. The Tier 2 calculation shows an uncertainty interval from -12 % to +16 %, which is a bit lower. For most of the emission sources the uncertainty levels based on Tier 2 are lower, but still nearly at the same level, see figure 12.1. The two calculations can be considered as consistent. The lowest uncertainties are seen for CH_4 emission from enteric fermentation and the highest for emission from manure management and this pattern is reflected in both calculations.

Table 12.3 Comparison between Tier 1 and Tier 2 uncertainty calculation, 2008.

Uncertainty 2008		Tier 1 Emission Gg CO_2-eqv.	Tier 1 Uncertainty Pct.	Tier 2 Median emission Gg CO_2-eqv.	Tier 2 Uncertainty Pct. Lower (-)	Tier 2 Uncertainty Pct. Upper (+)
4 Agriculture total	CH_4 & N_2O	10 043	19	10 275	12	16
4.A Enteric Fermentation	CH_4	2 819	13	2 823	5	4
4.B Manure Management	CH_4	1 050	100	1 082	38	70
	N_2O	523	100	555	33	50
4.D Agricultural soil:						
4.D1 Direct soil emissions	N_2O	3 154	29	3 176	20	33
4.D2 Grazing animals	N_2O	214	32	215	30	27
4.D3 Indirect soil emissions	N_2O	2 279	48	2 287	34	47
4.F Field Burning	CH_4	2	51	2	40	65
	N_2O	1	51	1	43	63

The biggest difference between the Tier 1 and Tier 2 uncertainty calculations is seen for N_2O and CH_4 from manure management (Table 12.3 and figure 12.1). These are also the categories that have the highest uncertainties, which could indicate that the Tier 2 approach is better at coping with high levels of uncertainty.

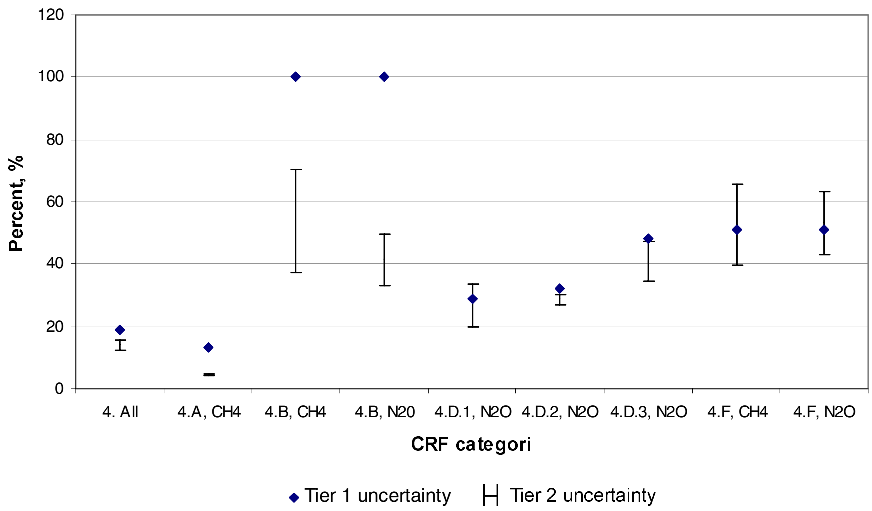

Figure 12.1 Tier 1 and Tier 2 uncertainties for the agricultural sector, 2008.

13 Conclusion

In response to a number of international conventions, Denmark is committed to calculating the Danish emissions to the atmosphere of a range of different pollutants. For the agricultural sector, the emissions to be calculated are ammonia (NH_3), the greenhouse gases methane (CH_4) and nitrous oxide (N_2O), the indirect greenhouse gases non-methane volatile organic compounds (NMVOC), particulate matter (PM) and a series of other pollutants related to the field burning of crop residues (NOx, CO, SO_2, heavy metals, PAH and dioxin).

Denmark's National Environmental Research Institute (NERI) is responsible for preparing and reporting the annual emissions inventories. In addition to the emissions inventories themselves, requirements in the various conventions call for documentation of the calculation methodology. This report should be viewed in the light of the reporting requirements of these conventions. The report includes the emissions from the agricultural sector from 1985 to 2009, a description of the methodology used and a description of background data used in the emission calculations.

13.1 Agricultural emissions from 1985 to 2009

The emission of NH_3 and greenhouse gases from the agricultural sector stems primarily from livestock production, while a smaller part of the emission is from the fertilisation and cultivation of crops.

The NH_3 emission has deceased from 98.1 Gg NH_3-N in 1985 to 60.8 Gg NH_3-N in 2009. By using the conversion factor 17/14, the emission in pure NH_3 corresponds to 119.3 Gg NH_3 in 1985 and 73.8 Gg NH_3 in 2009. In percentage terms the reduction is 38 %. Similarly, for the greenhouse gas emissions there has been a reduction from 10.4 million tonnes to 9.6 million tonnes CO_2 equivalents, which corresponds to a reduction of 22 %.

The significant decrease of emissions of both NH_3 and greenhouse gases is a consequence of an active national environmental policy over the last 20 years. A string of measures have been introduced by action plans to prevent loss of nitrogen from agriculture to the aquatic environment. The focus on improvement of nitrogen utilisation in manure has led to a fall in consumption of fertiliser. The improvement in the utilisation of nitrogen has occurred via improvements in feed efficiency and stricter legal requirements surrounding the handling of animal manure during storage and application. In addition, these environmental measures have a significant effect on the total greenhouse gas emission, which is due to the close correlation between nitrogen turnover and the emission of N_2O, which has a strong global warming potential.

13.2 Methodology and documentation

Preparation of the Danish emission inventories is based on the international guidelines EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2004; EMEP/EEA 2009), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). In Denmark, a relatively large amount of data and information is available on agricultural production, including livestock populations, slaughter data, feed intake, N-excretion, etc. Where data relevant for Danish agricultural production are not available, standard values recommended in the international guidelines are used.

Data used to calculate the agricultural emissions are collected, assessed and discussed in cooperation with a range of different institutions involved in research or administration within the agricultural sector. Especially of relevance are Statistics Denmark, Faculty of Agricultural Sciences at Aarhus University and the Danish Agricultural Advisory Service. Furthermore, the following institutions have been involved: the Danish Environmental Protection Agency, the Danish Plant Directorate and the Danish Energy Authority.

Calculation methodology and background data will be continually evaluated and, where necessary, adjusted as part of developments in research on a national scale, as well as on an international scale via changes in the guidelines.

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Appendix

A) Ammonia emission from Danish agriculture 1985 – 2009.

NH_3-N	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
						Gg NH_3-N							
Agricultural sector - total	**98.25**	**99.21**	**97.32**	**95.15**	**95.70**	**95.51**	**92.19**	**90.87**	**89.14**	**86.70**	**81.71**	**78.93**	**77.73**
Manure management	77.09	77.40	75.13	74.67	73.78	72.57	70.78	70.71	69.44	66.72	63.25	62.64	62.36
Agricultural soils - total	9.56	9.15	8.86	8.84	8.81	9.55	9.32	8.89	8.55	8.74	8.48	7.58	7.06
-Synthetic fertiliser	6.98	6.62	6.45	6.45	6.42	7.15	6.86	6.43	6.05	6.29	5.99	5.07	4.61
-Pasture, range and paddock	2.58	2.52	2.42	2.39	2.38	2.40	2.46	2.46	2.50	2.45	2.49	2.51	2.45
Field burning of agricultural residue	1.26	1.08	1.03	0.77	0.81	0.06	0.07	0.06	0.07	0.07	0.08	0.07	0.08
Agriculture Other - total	10.34	11.58	12.30	10.88	12.30	13.33	12.02	11.21	11.08	11.17	9.90	8.63	8.24
-Sewage sludge used as fertiliser	0.04	0.04	0.04	0.04	0.05	0.06	0.06	0.07	0.09	0.08	0.09	0.09	0.07
-Growing crops	4.92	4.92	4.91	4.86	4.84	4.88	4.85	4.82	4.75	4.41	4.35	4.38	4.48
-NH_3 treated straw	5.39	6.62	7.35	5.97	7.41	8.39	7.12	6.32	6.24	6.67	5.46	4.17	3.69

Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
						Gg NH_3-N						
Agricultural sector - total	**78.30**	**74.23**	**73.23**	**72.15**	**70.45**	**69.63**	**69.31**	**66.01**	**63.50**	**62.90**	**61.71**	**60.80**
Manure management	63.55	61.34	60.16	60.04	59.42	59.03	58.89	55.92	53.67	53.11	51.48	50.67
Agricultural soils - total	7.08	6.69	6.58	6.29	5.78	5.46	5.50	5.34	5.29	5.33	5.64	5.53
-Synthetic fertiliser	4.64	4.30	4.17	3.84	3.42	3.35	3.55	3.51	3.56	3.69	4.00	3.89
-Pasture, range and paddock	2.44	2.39	2.41	2.45	2.36	2.11	1.95	1.82	1.72	1.64	1.64	1.64
Field burning of agricultural residue	0.10	0.09	0.09	0.10	0.08	0.10	0.10	0.10	0.11	0.09	0.08	0.10
Agriculture Other - total	7.57	6.10	6.39	5.72	5.17	5.04	4.83	4.65	4.44	4.37	4.50	4.50
-Sewage sludge used as fertiliser	0.07	0.07	0.07	0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.04
-Growing crops	4.45	4.33	4.29	4.33	4.33	4.32	4.34	4.40	4.40	4.33	4.46	4.45
-NH_3 treated straw	3.05	1.71	2.03	1.33	0.77	0.66	0.43	0.21	0.00	0.00	0.00	0.00

NH_3	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	Gg NH_3												
Agricultural sector - total	**119.31**	**120.47**	**118.17**	**115.54**	**116.20**	**115.98**	**111.95**	**110.34**	**108.24**	**105.27**	**99.22**	**95.84**	**94.39**
Manure management	93.61	93.99	91.22	90.67	89.59	88.12	85.95	85.86	84.32	81.02	76.81	76.06	75.72
Agricultural soils - total	11.61	11.11	10.76	10.73	10.70	11.60	11.32	10.79	10.38	10.61	10.30	9.21	8.57
-Synthetic fertiliser	8.48	8.04	7.83	7.83	7.80	8.68	8.33	7.81	7.34	7.64	7.27	6.16	5.59
-Pasture, range and paddock	3.13	3.06	2.94	2.90	2.90	2.92	2.99	2.99	3.04	2.97	3.03	3.05	2.98
Field burning of agricultural residue	1.53	1.32	1.25	0.93	0.98	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.10
Agriculture Other - total	12.56	14.06	14.93	13.21	14.94	16.18	14.60	13.61	13.46	13.56	12.02	10.48	10.00
-Sewage sludge used as fertiliser	0.05	0.05	0.05	0.05	0.06	0.07	0.07	0.09	0.11	0.10	0.11	0.10	0.09
-Growing crops	5.97	5.97	5.96	5.91	5.88	5.92	5.88	5.85	5.77	5.36	5.28	5.31	5.44
-NH_3 treated straw	6.54	8.04	8.92	7.25	9.00	10.19	8.64	7.67	7.58	8.10	6.63	5.06	4.48
Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
	Gg NH_3												
Agricultural sector - total	**95.07**	**90.14**	**88.92**	**87.61**	**85.54**	**84.55**	**84.16**	**80.15**	**77.10**	**76.38**	**74.94**	**73.83**	
Manure management	77.17	74.48	73.06	72.90	72.15	71.68	71.50	67.90	65.17	64.49	62.51	61.53	
Agricultural soils - total	8.59	8.13	7.99	7.64	7.01	6.63	6.68	6.48	6.42	6.47	6.85	6.72	
-Synthetic fertiliser	5.63	5.23	5.07	4.66	4.15	4.06	4.31	4.27	4.33	4.48	4.86	4.72	
-Pasture, range and paddock	2.96	2.90	2.92	2.97	2.86	2.57	2.36	2.21	2.09	1.99	1.99	2.00	
Field burning of agricultural residue	0.12	0.12	0.11	0.12	0.10	0.12	0.13	0.13	0.13	0.11	0.10	0.12	
Agriculture Other - total	9.19	7.41	7.76	6.95	6.28	6.12	5.86	5.65	5.39	5.31	5.47	5.46	
-Sewage sludge used as fertiliser	0.09	0.08	0.08	0.08	0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05	
-Growing crops	5.41	5.25	5.21	5.25	5.26	5.24	5.27	5.34	5.34	5.26	5.41	5.41	
-NH_3 treated straw	3.70	2.08	2.47	1.62	0.94	0.80	0.53	0.26	0.00	0.00	0.00	0.00	

B) Number of livestock given in AAP (average annual production), thousands.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Dairy Cattle	896	864	811	774	759	753	742	712	714	700	702	701	670
Non-Dairy Cattle[1]	1 721	1 631	1 540	1 488	1 462	1 486	1 480	1 478	1 481	1 405	1 388	1 393	1 334
Pigs[2]	9 089	9 321	9 266	9 217	9 190	9 497	9 783	10 455	11 568	10 923	11 084	10 842	11 383
Poultry[3]	16 282	16 282	16 603	16 586	18 257	17 311	16 995	20 103	20 962	20 916	20 685	20 955	20 062
Horses	140	139	138	137	136	135	137	138	140	141	143	144	146
Sheep	40	52	59	73	83	92	107	102	88	80	81	94	96
Goats	8	8	8	8	8	7	7	7	7	7	7	7	7
Fur farming	1 906	2 194	2 402	2 877	3 055	2 264	2 112	2 283	1 537	1 828	1 850	1 918	2 212
Deer	9	10	10	10	10	10	10	10	10	10	10	10	10

Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy Cattle	669	640	636	623	610	596	563	564	550	545	558	563
Non-Dairy Cattle[1]	1 308	1 247	1 232	1 284	1 187	1 128	1 082	1 006	984	1 021	1 006	977
Pigs[2]	12 095	11 626	11 922	12 608	12 732	12 949	13 233	13 534	13 361	13 723	12 738	12 369
Poultry[3]	19 743	22 080	22 902	22 308	21 649	18 911	17 716	18 699	18 491	17 805	16 469	20 738
Horses	147	149	150	155	160	165	170	175	180	185	190	178
Sheep	101	106	112	119	117	121	124	126	128	124	117	116
Goats	8	8	8	9	9	10	11	11	12	13	14	16
Fur farming	2 345	2 089	2 199	2 304	2 422	2 361	2 471	2 552	2 708	2 837	2 747	2 677
Deer	10	10	10	11	10	10	10	10	10	10	10	9

[1]Non-Dairy Cattle includes: Calves, bulls, heifers and suckling cattle.

[2]Pigs includes: Sows, weaners and fattening pigs.

[3]Poultry includes: Hens, pullets, broilers, turkeys, ducks, geese, pheasants and ostrich.

C) Stable type distribution in percent, 1985-2009.

Cattle:

Dairy cattle:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Dairy cattle	Tethered with urine and solid manure	40	39	38	37	36	35	35	34	33	32	31	30	30
	Tethered with slurry	45	45	44	44	44	44	43	43	43	43	42	42	36
	Loose-holding with beds, slatted floor	9	10	11	11	12	13	14	15	15	16	17	18	21
	Loose-holding with beds, slatted floor, scrape	1	1	1	1	1	1	1	1	1	1	1	1	2
	Loose-holding with beds, solid floor	4	4	4	4	4	3	3	3	3	3	3	3	3
	Deep litter (all)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deep litter, slatted floor	1	1	1	2	2	3	3	3	4	4	5	5	6
	Deep litter, slatted floor, scrape	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deep litter, solid floor, scrape	0	0	1	1	1	1	1	1	1	1	1	1	2
	Loose-holding with beds, drained floor	0	0	0	0	0	0	0	0	0	0	0	0	0
	Loose-holding with beds, solid floor with tilt	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy cattle	Tethered with urine and solid manure	30	30	18	15	12	8	6	12	12	7	6	5
	Tethered with slurry	30	30	28	25	23	18	16	14	14	10	9	7
	Loose-holding with beds, slatted floor	24	24	34	36	39	42	44	44	44	42	44	45
	Loose-holding with beds, slatted floor, scrape	3	3	3	4	4	5	6	11	11	20	20	21
	Loose-holding with beds, solid floor	3	3	6	9	11	16	17	11	11	13	14	14
	Deep litter (all)	0	0	0	0	0	0	0	2	2	2	2	2
	Deep litter, slatted floor	8	8	7	7	7	7	7	4	4	2	2	2
	Deep litter, slatted floor, scrape	1	1	1	1	1	1	1	2	2	2	1	1
	Deep litter, solid floor, scrape	1	1	3	3	3	3	3	0	0	0	0	0
	Loose-holding with beds, drained floor	0	0	0	0	0	0	0	0	0	0(0.1)	0(0.4)	0(0.3)
	Loose-holding with beds, solid floor with tilt	0	0	0	0	0	0	0	0	0	1	1	2
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	1	1	1

Heifers:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Heifer calves, 0-6 mth.	Deep litter (boxes)	100	100	100	100	100	100	100	100	100	100	100	100	100
	Deep litter, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0
Heifer, 6 mth.-calving	Tethered with urine and solid manure	25	24	23	22	20	19	18	17	16	14	13	12	11
	Tethered with slurry	25	24	23	22	20	19	18	17	16	14	13	12	11
	Slatted floor-boxes	45	44	43	42	41	40	39	38	37	36	35	34	33
	Loose-housing with beds, slatted floor	0	1	2	2	3	4	4	5	6	6	7	8	10
	Deep litter (all)	5	4	4	4	4	3	3	2	2	2	1	1	0
	Deep litter, solid floor	0	2	4	5	7	9	12	13	14	16	18	22	24
	Deep litter, slatted floor	0	1	1	2	3	4	4	5	6	7	7	7	7
	Deep litter, slatted floor, scrape	0	0	0	0	1	1	1	1	1	1	1	1	1
	Deep litter, solid floor, scrape	0	0	0	1	1	1	1	2	2	2	3	3	3
	Loose-housing with beds, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0
	Loose-housing with beds, slatted floor, scrape	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0
	Boxes with sloping bedded floor	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued

Livestock categories	Stable type	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Heifer calves, 0-6 mth.	Deep litter (boxes)	100	100	100	89	84	83	80	93	93	96	96	96
	Deep litter, solid floor	0	0	0	11	16	17	20	7	7	4	4	4
Heifer, 6 mth.-calving	Tethered with urine and solid manure	10	10	9	8	7	7	5	14	14	7	6	6
	Tethered with slurry	10	10	9	8	7	7	5	5	5	2	2	2
	Slatted floor-boxes	33	32	32	31	30	30	29	23	23	38	37	35
	Loose-housing with beds, slatted floor	12	13	14	17	20	21	23	19	19	12	14	16
	Deep litter (all)	0	0	0	0	0	0	0	30	30	24	22	22
	Deep litter, solid floor	24	24	25	26	26	26	28	3	3	1	1	1
	Deep litter, slatted floor	6	6	6	5	5	5	5	3	3	2	2	2
	Deep litter, slatted floor, scrape	2	2	2	2	2	1	2	2	2	2	2	2
	Deep litter, solid floor, scrape	3	3	3	3	3	3	3	1	1	0	0	0
	Loose-housing with beds, solid floor	0	0	0	0	0	0	0	0	0	5	6	6
	Loose-housing with beds, slatted floor, scrape	0	0	0	0	0	0	0	0	0	5	6	6
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	2	2	2
	Boxes with sloping bedded floor	0	0	0	0	0	0	0	0	0	0 (0.1)	0 (0.1)	0 (0.1)

Bulls:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Bull calves, 0-6 mth.	Deep litter (boxes)	100	100	100	100	100	100	100	100	100	100	100	100	100
	Deep litter, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0
Bull, 6 mth -440 kg	Tethered with urine and solid manure	25	24	23	22	21	20	19	17	16	15	14	13	12
	Tethered with slurry	25	24	23	22	21	20	19	17	16	15	14	13	12
	Slatted floor-boxes	45	44	43	43	42	41	40	40	39	38	37	37	36
	Deep litter (all)	5	5	4	4	3	3	2	2	2	2	1	1	0
	Deep litter, solid floor	0	2	4	6	8	10	12	15	17	19	21	22	25
	Deep litter, slatted floor	0	1	2	2	3	4	5	6	7	8	8	9	10
	Deep litter, slatted floor, scrape	0	0	0	0	1	1	1	1	1	1	2	2	2
	Deep litter, solid floor, scrape	0	0	1	1	1	1	2	2	2	2	3	3	3
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0
	Boxes with sloping bedded floor	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bull calves, 0-6 mth.	Deep litter (boxes)	100	100	100	91	86	82	77	95	95	97	97	97
	Deep litter, solid floor	0	0	0	9	14	18	23	5	5	3	3	3
Bull, 6 mth -440 kg	Tethered with urine and solid manure	11	11	10	9	8	8	7	9	9	4	4	3
	Tethered with slurry	11	11	10	9	8	8	7	2	2	1	1	1
	Slatted floor-boxes	35	34	33	32	31	30	28	31	31	30	30	27
	Deep litter (all)	0	0	0	0	0	0	0	47	47	57	58	60
	Deep litter, solid floor	27	29	33	37	41	45	48	8	8	5	4	4
	Deep litter, slatted floor	11	10	9	8	7	5	6	1	1	1	1	2
	Deep litter, slatted floor, scrape	2	2	2	2	2	1	1	0	0	1	1	2
	Deep litter, solid floor, scrape	3	3	3	3	3	3	3	2	2	0	0	0
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	1	1	1
	Boxes with sloping bedded floor	0	0	0	0	0	0	0	0	0	0 (0.1)	0 (0.1)	0 (0.1)

Suckling cattle:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Suckling cattle	Tethered with urine and solid manure	10	10	10	10	10	10	10	10	10	10	10	10	10
	Deep litter (all)	90	87	83	80	76	73	69	66	62	59	55	52	48
	Deep litter, solid floor	0	3	7	10	14	17	21	24	28	31	35	38	42
	Tethered with slurry	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deep litter, slatted floor	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deep litter, slatted floor, scrape	0	0	0	0	0	0	0	0	0	0	0	0	0
	Boxes with sloping bedded floor	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Suckling cattle	Tethered with urine and solid manure	10	10	9	8	7	4	5	30	30	18	16	15
	Deep litter (all)	45	45	45	44	43	44	43	35	35	66	68	68
	Deep litter, solid floor	45	45	46	48	50	52	52	35	35	2	2	3
	Tethered with slurry	0	0	0	0	0	0	0	0	0	9	9	9
	Deep litter, long eating space, solid floor	0	0	0	0	0	0	0	0	0	1	1	1
	Deep litter, slatted floor	0	0	0	0	0	0	0	0	0	1	1	1
	Deep litter, slatted floor, scrape	0	0	0	0	0	0	0	0	0	2	2	2
	Boxes with sloping bedded floor	0	0	0	0	0	0	0	0	0	1	1	1

Pigs:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Sows	Full slatted floor	3	4	5	6	7	9	10	10	11	12	12	13	14
	Partly slatted floor	50	51	52	54	55	56	57	57	57	57	57	57	57
	Solid floor	44	41	39	36	33	30	28	25	23	20	18	15	13
	Deep litter	3	4	4	4	5	5	5	5	6	6	7	7	8
	Deep litter + slatted floor	0	0	0	0	0	0	0	1	1	2	2	3	3
	Deep litter + solid floor	0	0	0	0	0	0	0	1	1	2	2	3	3
	Outdoor sows	0	0	0	0	0	0	0	1	1	1	2	2	2
Weaners	Fully slatted floor	40	43	46	49	51	54	57	60	56	54	51	49	46
	Partly slatted floor	20	20	20	20	20	20	20	20	24	27	31	34	37
	Solid floor	35	32	29	26	24	21	18	15	14	13	11	9	8
	Deep litter (to-climate housings)	5	5	5	5	5	5	5	5	5	5	5	5	5
	Deep litter + slatted floor	0	0	0	0	0	0	0	0	1	1	2	3	4
	Partly slatted and drained floor	0	0	0	0	0	0	0	0	0	0	0	0	0
Fattening pigs	Fully slatted floor	29	33	38	42	47	51	56	60	60	60	60	60	60
	Partly slatted floor	30	29	27	26	24	23	21	20	21	23	24	25	26
	Solid floor	40	36	33	29	26	22	19	15	14	12	11	9	8
	Deep litter	1	2	2	3	3	4	4	5	4	4	3	3	2
	Partly slatted floor and partly deep litter	0	0	0	0	0	0	0	0	1	1	2	3	4
	Partly slatted and drained floor	3	4	5	6	7	9	10	10	11	12	12	13	0

Continued													
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sows	Full slatted floor	14	14	13	13	13	12	12	13	13	14	14	15
	Partly slatted floor	57	57	56	55	54	53	51	70	70	74	75	75
	Solid floor	10	9	7	6	6	6	5	4	4	1	1	1
	Deep litter	8	9	10	10	10	10	11	2	2	2	1	1
	Deep litter + slatted floor	4	4	6	7	8	9	10	8	8	6	6	5
	Deep litter + solid floor	4	4	5	6	7	8	9	1	1	1	1	1
	Outdoor sows	3	3	3	3	2	2	2	2	2	2	2	2
Weaners	Fully slatted floor	43	40	38	36	35	33	31	23	23	26	23	22
	Partly slatted floor	41	45	47	49	50	52	54	66	66	63	67	68
	Solid floor	7	5	5	5	5	5	5	3	3	1	1	<1
	Deep litter (to-climate housings)	5	5	5	5	5	5	5	4	4	3	2	2
	Deep litter + slatted floor	4	5	5	5	5	5	5	4	4	0	0	0
	Partly slatted and drained floor	0	0	0	0	0	0	0	0	0	7	7	8
Fattening pigs	Fully slatted floor	60	60	58	57	56	55	53	49	49	53	53	54
	Partly slatted floor	28	29	31	33	34	35	38	38	38	34	35	35
	Solid floor	6	5	5	4	4	4	3	7	7	4	3	2
	Deep litter	2	1	1	1	1	1	1	5	5	4	3	2
	Partly slatted floor and partly deep litter	4	5	5	5	5	5	5	1	1	<1	<1	<1
	Partly slatted and drained floor	0	0	0	0	0	0	0	0	0	5	6	7

Poultry:

Livestock categories	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Free-range hens	0	0	0	0	0	0	1	2	4	5	6	7	8
Organic hens	0	0	0	0	0	0	1	2	4	5	6	7	10
Barn hens	7	8	9	9	10	11	11	12	12	12	13	14	15
Battery hens, manure shed	60	59	58	57	55	54	52	49	46	44	42	39	36
Battery hens, manure tank	14	14	13	13	13	12	12	11	10	9	8	7	6
Battery hens, manure cellar	19	19	20	21	22	23	23	24	24	25	25	26	25
Hens for production of brood egg	100	100	100	100	100	100	100	100	100	100	100	100	100
Pullet, consumption, net	22	21	20	19	18	17	16	15	14	13	12	11	10
Pullet, consumption, floor	52	53	54	55	56	57	58	59	60	61	62	63	64
Pullet, brood egg, floor	26	26	26	26	26	26	26	26	26	26	26	26	26
Broilers, (conv. 30 days)	0	0	0	0	0	0	0	0	0	0	0	0	0
Broilers, (conv. 32 days)	0	0	0	0	0	0	0	0	0	0	0	0	0
Broilers, (conv. 35 days)	0	0	0	0	0	0	0	0	0	0	0	0	0
Broilers, (conv. 40 days)	100	100	100	100	100	100	100	100	100	100	100	100	100
Broilers, (conv. 45 days)	0	0	0	0	0	0	0	0	0	0	0	0	0
Broilers, barn (56 days)	0	0	0	0	0	0	0	0	0	0	0	0	0
Organic broilers (81 days)	0	0	0	0	0	0	0	0	0	0	0	0	0
Turkey, male	50	50	50	50	50	50	50	50	50	50	50	50	50
Turkey, female	50	50	50	50	50	50	50	50	50	50	50	50	50
Ducks	100	100	100	100	100	100	100	100	100	100	100	100	100
Geese	100	100	100	100	100	100	100	100	100	100	100	100	100
Pheasant	100	100	100	100	100	100	100	100	100	100	100	100	100

Continued												
Livestock categories	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Free-range hens	9	9	9	9	7	8	7	7	7	8	9	10
organic hens	12	15	15	15	15	16	16	16	16	19	17	17
Barn hens	17	18	18	18	19	18	20	20	20	19	20	20
Battery hens, manure shed	32	29	26	26	23	23	20	20	20	36	39	39
Battery hens, manure tank	5	5	5	5	4	5	4	4	4	7	7	6
Battery hens, manure cellar	25	24	27	27	32	30	33	33	33	11	8	8
Hens for production of brood egg	100	100	100	100	100	100	100	100	100	100	100	100
Pullet, consumption, net	8	7	8	7	6	7	5	5	5	7	7	7
Pullet, consumption, floor	66	67	69	68	69	68	69	69	69	73	84	78
Pullet, brood egg, floor	26	26	23	25	25	25	26	26	26	20	9	15
Broilers, (conv. 30 days)	0	0	0	0	0	0	0	0	0	0	0	0
Broilers, (conv. 32 days)	0	0	0	0	0	0	0	0	0	1	4	7
Broilers, (conv. 35 days)	0	0	0	0	0	0	0	0	0	77	80	84
Broilers, (conv. 40 days)	100	100	100	100	100	100	100	99	99	22	16	9
Broilers, (conv. 45 days)	0	0	0	0	0	0	0	0	0	0	0	<1
Broilers, barn (56 days)	0	0	0	0	0	0	0	1	1	0	0	0
Organic broilers (81 days)	0	0	0	0	0	0	0	0	0	0	0	0
Turkey, male	50	50	50	50	50	50	50	50	50	50	50	50
Turkey, female	50	50	50	50	50	50	50	50	50	50	50	50
Ducks	100	100	100	100	100	100	100	100	100	100	100	100
Geese	100	100	100	100	100	100	100	100	100	100	100	100
Pheasant	100	100	100	100	100	100	100	100	100	100	100	100

Fur farming:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Mink	Slurry system	10	12	13	15	17	18	20	20	22	23	25	26	27
	Solid manure and urine	90	88	87	85	83	82	80	80	78	77	75	74	73
Foxes	Slurry system	0	0	0	0	0	0	0	0	0	0	0	0	0
	Solid manure and urine	100	100	100	100	100	100	100	100	100	100	100	100	100
Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Mink	Slurry system	29	30	42	50	55	60	65	70	70	91	95	98	
	Solid manure and urine	71	70	58	50	45	40	35	30	30	9	5	2	
Foxes	Slurry system	0	0	2	5	10	15	30	0	0	0	0	0	
	Solid manure and urine	100	100	98	95	90	85	70	100	100	100	100	100	

Horses, sheep, goats, deer and ostrich:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Horses, sheep, goats, ostrich	Deep litter	100	100	100	100	100	100	100	100	100	100	100	100	100
Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Horses, sheep, goats, ostrich	Deep litter	100	100	100	100	100	100	100	100	100	100	100	100	

Deer:

Livestock categories	Stable type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Deer	Pasture	100	100	100	100	100	100	100	100	100	100	100	100	100
Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Deer	Pasture	100	100	100	100	100	100	100	100	100	100	100	100	

D) Number of grazing days corresponding to the proportion of N in manure deposited on the field during grazing. Days per year.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Cattle:													
Dairy Cattle	55	55	55	55	55	55	55	55	55	55	55	55	55
Calves and bulls	0	0	0	0	0	0	0	0	0	0	0	0	0
Heifers	165	165	165	165	165	165	171	177	184	190	196	196	196
Suckling Cattle	184	184	184	184	184	184	192	200	208	216	224	224	224
Pigs:													
Sows, weaners and fattening pigs	0	0	0	0	0	0	0	0	0	0	0	0	0
Sows, outdoor	365	365	365	365	365	365	365	365	365	365	365	365	365
Poultry:													
Hens, pullets, Broilers, Turkeys and Ducks	0	0	0	0	0	0	0	0	0	0	0	0	0
Geese, Pheasant and Ostrich	365	365	365	365	365	365	365	365	365	365	365	365	365
Other:													
Horses	183	183	183	183	183	183	183	183	183	183	183	183	183
Sheep and Goats	265	265	265	265	265	265	265	265	265	265	265	265	265
Deer	365	365	365	365	365	365	365	365	365	365	365	365	365
Fur animals	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle:												
Dairy Cattle	55	55	55	55	55	46	39	32	25	18	18	18
Calves and bulls	0	0	0	0	0	0	0	0	0	0	0	0
Heifers	196	196	196	196	196	180	168	156	144	132	132	132
Suckling Cattle	224	224	224	224	224	224	224	224	224	224	224	224
Pigs:												
Sows, weaners and fattening pigs	0	0	0	0	0	0	0	0	0	0	0	0
Sows, outdoor	365	365	365	365	365	365	365	365	365	365	365	365
Poultry:												
Hens, pullets, Broilers, Turkeys and Ducks	0	0	0	0	0	0	0	0	0	0	0	0
Geese, Pheasant and Ostrich	365	365	365	365	365	365	365	365	365	365	365	365
Other:												
Horses	183	183	183	183	183	183	183	183	183	183	183	183
Sheep and Goats	265	265	265	265	265	265	265	265	265	265	265	265
Deer	365	365	365	365	365	365	365	365	365	365	365	365
Fur animals	0	0	0	0	0	0	0	0	0	0	0	0

E) Nitrogen excretion and ammonia emission according to livestock category 1985 – 2009.

1) Nitrogen excretion distributed on livestock groups.

N-excretion	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
						tonnes N							
Cattle	170 399	165 183	157 332	152 902	152 083	151 850	149 663	145 336	145 297	139 674	138 708	138 633	132 754
Pigs	117 025	120 633	117 960	116 771	113 660	112 529	112 672	116 840	121 078	114 526	107 793	107 627	110 276
Poultry	7 472	7 820	8 092	9 111	10 211	10 329	10 335	10 949	11 718	13 043	12 271	12 034	11 958
Horses	6 309	6 264	6 219	6 174	6 129	5 960	5 901	5 839	5 775	5 707	5 637	5 696	5 756
Sheep	835	1 100	1 248	1 533	1 749	1 947	2 272	2 199	1 907	1 740	1 767	1 891	1 758
Goats	168	166	164	162	160	159	158	157	156	154	153	139	124
Fur animals	10 071	11 397	12 268	14 481	15 066	11 089	10 189	10 952	7 295	8 588	8 608	8 935	10 294
Deer	144	152	160	160	160	160	160	160	160	160	160	160	160
N-excretion total	**312 423**	**312 715**	**303 443**	**301 294**	**299 219**	**294 023**	**291 349**	**292 432**	**293 385**	**283 593**	**275 098**	**275 115**	**273 079**
Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
						tonnes N							
Cattle	131 609	125 894	125 419	126 434	122 058	119 613	115 673	116 242	116 482	120 864	122 173	124 510	
Pigs	116 595	116 118	114 739	120 456	126 707	123 617	128 928	124 836	114 417	117 512	110 530	103 875	
Poultry	11 798	12 232	12 171	12 346	12 308	12 506	13 266	13 954	12 253	10 671	10 907	10 467	
Horses	5 815	5 874	5 934	6 131	6 329	6 527	6 725	6 923	7 121	7 319	7 516	7 022	
Sheep	1 668	1 559	1 892	2 010	1 991	2 051	2 105	2 140	2 165	2 098	1 991	1 958	
Goats	128	119	143	160	151	164	176	187	199	198	231	257	
Fur animals	10 893	9 676	10 169	10 639	11 172	10 886	12 585	13 718	14 023	14 698	14 546	14 773	
Deer	160	160	160	170	158	155	155	154	154	155	153	152	
N-excretion total	**278 666**	**271 633**	**270 627**	**278 347**	**280 874**	**275 519**	**279 613**	**278 154**	**266 814**	**273 515**	**268 049**	**263 014**	

2) Ammonia emission from animal manure (incl. pasture) distributed on livestock groups.

Ammonia emission	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
							tonnes NH_3-N						
Cattle	35 653	34 405	32 605	31 484	31 163	31 718	30 704	29 334	28 795	27 320	26 647	26 373	25 134
Pigs	36 137	36 992	35 930	35 327	34 131	33 995	33 568	34 340	34 969	32 776	30 166	29 789	30 116
Poultry	2 510	2 594	2 718	3 034	3 395	3 411	3 462	3 702	3 936	4 334	4 187	4 087	4 105
Horses	1 099	1 081	1 063	1 046	1 028	998	988	976	964	952	939	947	954
Sheep	106	138	156	190	215	239	278	269	233	212	215	230	214
Goats	21	21	20	20	20	19	19	19	19	19	19	17	15
Fur animals	4 132	4 681	5 041	5 952	6 199	4 578	4 212	4 519	3 013	3 551	3 559	3 696	4 260
Deer	10	11	11	11	11	11	11	11	11	11	11	11	11
Emission total	**79 668**	**79 924**	**77 545**	**77 064**	**76 161**	**74 970**	**73 243**	**73 171**	**71 940**	**69 174**	**65 744**	**65 151**	**64 809**

Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
							tonnes NH_3-N					
Cattle	24 731	23 511	23 568	22 984	21 519	21 024	18 587	17 196	17 524	18 133	18 637	18 850
Pigs	31 509	30 796	29 284	29 472	29 990	29 751	31 123	28 641	26 396	25 827	24 098	22 521
Poultry	4 050	4 212	4 217	4 279	4 271	4 351	4 546	4 790	4 176	3 310	3 380	3 234
Horses	962	989	982	1 016	1 054	1 083	1 113	1 140	1 169	1 126	1 156	1 080
Sheep	204	192	229	244	242	249	255	258	261	241	229	225
Goats	16	15	17	19	18	20	21	23	24	23	27	30
Fur animals	4 507	4 004	4 260	4 458	4 671	4 657	5 175	5 682	5 829	6 078	5 586	6 364
Deer	11	11	11	12	11	11	11	11	11	11	11	11
Emission total	**65 990**	**63 730**	**62 570**	**62 485**	**61 775**	**61 145**	**60 832**	**57 741**	**55 390**	**54 749**	**53 124**	**52 315**

3) Ammonia emission from manure (incl. pasture) distributed on the different parts of the production.

Ammonia emission	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
							tonnes NH_3-N						
Stable	30 119	30 981	30 668	31 279	31 198	29 605	29 190	29 976	29 294	28 654	27 394	27 353	27 964
Storage	13 958	13 944	13 419	13 187	12 900	12 519	12 254	12 272	12 333	11 779	11 229	11 072	11 046
Spreading	33 011	32 478	31 039	30 208	29 679	30 444	29 340	28 462	27 811	26 291	24 629	24 216	23 347
Pasture	2 579	2 521	2 419	2 390	2 384	2 403	2 459	2 461	2 503	2 450	2 492	2 510	2 452
Emission total	**79 668**	**79 924**	**77 545**	**77 064**	**76 161**	**74 970**	**73 243**	**73 171**	**71 940**	**69 174**	**65 744**	**65 151**	**64 809**
Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
							tonnes NH_3-N						
Stable	29 040	28 225	28 523	29 689	30 745	30 603	31 997	30 943	29 553	30 922	30 228	29 223	
Storage	11 276	10 855	10 194	10 301	9 770	9 296	9 380	7 497	7 164	4 383	4 204	4 124	
Spreading	23 234	22 259	21 445	20 046	18 904	19 134	17 508	17 478	16 949	17 806	17 049	17 324	
Pasture	2 439	2 391	2 407	2 448	2 357	2 112	1 946	1 822	1 724	1 638	1 642	1 645	
Emission total	**65 990**	**63 730**	**62 570**	**62 485**	**61 775**	**61 145**	**60 832**	**57 741**	**55 390**	**54 749**	**53 124**	**52 315**	

F) Ammonia emission factors for housing units.

Pigs			Urine TAN	Slurry TAN	Solid manure Total N	Deep litter Total N
	Stable type	Floor or manure type	Pct. loss of TAN ex animal		pct. loss of N ex animal	
Sows	Individual, mating and gestation	Partly slatted floor	-	13	-	-
		Full slatted floor	-	19	-	-
		Solid floor	21	-	16	-
	Group, mating and gestation	Deep litter	-	-	-	15
		Deep litter + slatted floor	-	16	-	15
		Deep litter + solid floor	-	19	-	15
		Partly slatted floor	-	16	-	-
	Farrowing crate	Full slatted floor	-	13	-	-
		Partly slatted floor	-	26	-	-
	Farrowing pen	Solid floor	20	-	15	-
		Partly slatted floor	-	22	15	-
Weaners		Full slatted floor	-	24	-	-
		Drained + Partly slatted floor	-	21	-	-
		Deep litter (to-clima stables)	-	10	-	15
		Solid floor	37	-	25	-
		Deep litter	-	-	-	15
Fattening pigs		Partly slatted floor (50-75 % solid)	-	13	-	-
		Partly slatted floor (25-49% solid)	-	17	-	-
		Drained + Partly slatted floor	-	21	-	-
		Full slatted floor	-	24	-	-
		Solid floor	27	-	18	-
		Deep litter, divided	-	18	-	15
		Deep litter	-	-	-	15

Poultry			Solid manure Total N	Deep litter Total N
	Stable type	Floor or manure type	pct. loss of N ex animal	
Hens and pullets	Free-range, organic and barn	Deep pit	40	25
		Deep litter	-	28
		Manure belt	10	25
	Battery	Deep pit	12	-
		Manure belt	10	-
Broilers	Conventional	Deep litter	-	20
	Organic and barn	Deep litter	-	25
Turkeys, ducks and geese		Deep litter	-	20

Other	Urine TAN	Slurry TAN	Solid manure Total N	Deep litter Total N
	Pct. loss of TAN ex animal		pct. loss of N ex animal	
Fur animals	35	47	35	-
Horses, sheep and goats	-	-	-	15

G) Correction for lack of floating/fixed cover on slurry tanks.

	Emission factor[1] NH_3-N in % of N ex housing-total	Emissions faktor[5] NH3-N in % of TAN ex housing-total	1985-1999[2]	2000-2001[3]	2002[4]	2003-2006[4]	2007-2009[4] TAN
Pigs							
No cover	9%	11.4%	40%	20%	10%	5%	5%
Full cover	2%	2.5%	60%	80%	90%	95%	95%
Emission under storage			**4.8%**	**3.4%**	**2.7%**	**2.4%**	**2.9%**
Cattle							
No cover	6%	10.3%	20%	5%	5%	2%	2%
Full cover	2%	3.4%	80%	95%	95%	98%	98%
Emission under storage			**2.8%**	**2.2%**	**2.2%**	**2.1%**	**3.5%**
Fur animals							
No cover		12.9%	20%	5%	5%	2%	2%
Full cover		2.9%	80%	95%	95%	98%	98%
Emission under storage			**4.9%**	**3.4%**	**3.4%**	**3.1%**	**3.1%**

[1] Poulsen et al., 2001.

[2] COWI 1999.

[3] COWI 2000.

[4] Estimate – DMU.

[5] Hansen et al., 2008.

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H) Correction for lack of floating/fixed cover on manure heaps.

	Emission factor NH_3-N in % of N ex housing-total	Solid manure 2007-2009
Cattle		
No cover	5%	50 %
Full cover	3%	50 %
Emission under storage		**4%**
Pigs		
No cover	25%	50 %
Full cover	13%	50 %
Emission under storage		**19%**
Poultry		
No cover	10%	50 %
Full cover	5%	50 %
Emission under storage		**7.5%**
Fur animals		
No cover	15%	50 %
Full cover	8%	50 %
Emission under storage		**11.5%**

I) Estimate of how liquid and solid manure has been handled in practice, 1985-2009.

Cattle and other livestock except from pigs:

Crop stage	Application time	Lying time	Percent of N ex storage per manure type																							
			1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		Hours	pct. distribution																								
	Liquid manure																										
	Injection																										
-	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5	8	11	21	20	20	20	21	21
-	April	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	3	5	8	12	21	21	20	20	21	21
+	March	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	3	3
+	April	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	4	4	4
+	Summer, grass injection	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	3	4	4	5	5	6	6	7	7
-	Summer, before winter rape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	6	7	7	7	7
+	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hose application																										
-	March	4	0	0	0	0	0	0	1	2	3	4	6	7	8	9	10	9	10	10	14	8	8	6	5	3	3
-	April	4	0	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5	5	5	4	2	2	1	1	1	1
+	March	< week	0	0	0	0	0	0	1	1	2	3	3	4	5	5	6	6	7	7	7	5	5	5	4	4	4
+	April	< week	0	0	0	0	0	0	2	3	3	5	6	8	9	11	12	13	18	17	15	10	9	9	9	9	9
+	May	< week	0	0	0	0	0	0	1	3	3	5	7	8	10	11	12	13	18	17	15	10	9	9	9	9	9
+	Summer	< week	0	0	0	0	0	0	1	2	3	3	4	5	5	4	4	4	4	3	3	3	3	3	3	2	2
-	Summer	4	0	0	0	0	0	0	1	1	2	2	3	3	3	2	2	2	3	3	5	5	5	5	5	5	5
+	Autumn	< week	0	0	0	0	0	0	0	1	2	3	3	4	4	4	4	4	5	5	5	4	4	4	4	4	4
-	Autumn	4	0	0	0	0	0	0	0	1	1	1	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0
	Broad spreading																										
-	Winter-spring	< 12	26	27	28	29	30	26	25	24	23	22	21	20	18	17	15	14	6	5	2	0	0	0	0	0	0
-	Winter-spring	> 12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	1	0	0	0	0	0	0	0
-	Winter-spring	< week	15	15	15	15	15	20	20	20	20	20	20	20	18	17	15	14	6	4	2	0	0	0	0	0	0
+	Spring-summer	< week	8	8	8	8	8	8	7	6	5	4	3	2	2	2	2	2	1	1	0	0	0	0	0	0	0
+	Late summer-autumn	< week	7	7	7	7	7	7	6	5	5	4	3	2	2	1	1	1	0,5	0	0	0	0	0	0	0	0
-	Late summer-autumn	< 12	2	3	3	4	4	4	4	4	4	3	3	3	3	2	2	2	1	2	0	0	0	0	0	0	0
-	Late summer-autumn	> 12	8	7	7	6	6	6	5	4	4	3	3	2	2	1	1	1	0,5	0	0	0	0	0	0	0	0
-	Late summer-autumn	< week	29	28	27	26	25	24	20	16	12	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Continued

Crop stage	Application time	Lying time	Percent of N ex storage per manure type																							
			1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Solid manure																										
	Broad spreading																										
-	Winter-spring	4	13	16	19	22	25	26	26	27	28	29	29	30	32	33	35	38	49	54	54	56	57	59	60	60	60
-	Winter-spring	6	18	16	14	12	10	11	11	12	13	14	14	15	15	15	15	14	14	15	15	14	14	13	12	12	12
-	Winter-spring	< week	19	18	17	16	15	14	14	13	12	11	11	10	10	10	10	9	10	11	11	11	10	9	9	9	9
+	Spring-summer	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	4	13	16	19	22	25	25	25	25	25	25	25	25	25	25	25	26	18	13	15	15	16	16	17	17	17
-	Late summer-autumn	6	13	11	9	7	5	5	5	5	5	5	5	5	5	5	5	5	3	2	1	0	0	0	0	0	0
-	Late summer-autumn	< week	24	23	22	21	20	19	19	18	17	16	16	15	13	12	10	9	6	5	4	4	3	3	2	2	2
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Pigs:

Crop status	Application time	Lying time	Percent of N ex storage per manure type																							
			1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		Hours	pct. distribution																								
	Liquid manure																										
	Injection																										
-	March	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	5	8	6	6	7	7	8	10	10
-	April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	6	8	7	7	7	8	8	9	9
+	March	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2
+	April	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	3
+	Summer, grass injection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	1	1	1	2	2
-	Summer, before winter rape	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	1	1	2	2	2	2	2
+	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hose application																										
-	March	4	0	0	0	0	0	0	1	1	2	3	4	5	6	6	10	7	7	7	9	8	7	6	4	2	2
-	April	4	0	0	0	0	0	0	1	2	3	3	5	5	6	7	5	7	8	8	9	8	7	6	4	3	3
+	March	< week	0	0	0	0	0	0	1	1	2	3	4	4	5	5	6	6	11	11	13	14	14	14	14	14	14
+	April	< week	0	0	0	0	0	0	1	3	3	6	6	9	10	12	13	14	16	15	20	23	28	30	32	32	32
+	May	< week	0	0	0	0	0	0	1	4	4	6	6	9	10	12	13	14	16	15	21	23	18	14	13	13	13

Continued

Crop status	Application time	Lying time	Percent of N ex storage per manure type																							
			1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	<u>Hose application</u>																										
+	Summer	< week	0	0	0	0	0	0	1	1	2	3	3	4	4	4	4	4	5	5	3	3	3	3	3	2	2
-	Summer	4	0	0	0	0	0	0	1	1	2	2	3	3	3	2	2	2	3	3	3	3	3	3	3	3	3
+	Autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	4	0	0	0	0	0	0	1	2	3	3	5	5	4	3	2	2	3	3	3	3	3	3	3	3	3
	<u>Broad spreading</u>																										
-	Winter-spring	< 12	26	27	28	29	30	26	25	24	23	22	21	20	18	17	15	14	6	5	2	0	0	0	0	0	0
-	Winter-spring	> 12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	1	0	0	0	0	0	0	0
-	Winter-spring	< week	15	15	15	15	15	20	20	20	20	20	20	20	18	17	15	14	6	4	2	0	0	0	0	0	0
+	Spring-summer	< week	8	8	8	8	8	8	7	6	5	4	3	2	2	2	2	2	1	1	0	0	0	0	0	0	0
+	Late summer-autumn	< week	7	7	7	7	7	7	6	5	5	4	3	2	2	1	1	1	0,5	0	0	0	0	0	0	0	0
-	Late summer-autumn	< 12	2	3	3	4	4	4	4	4	4	3	3	3	3	2	2	2	1	2	0	0	0	0	0	0	0
-	Late summer-autumn	> 12	8	7	7	6	6	6	5	4	4	3	3	2	2	1	1	1	0,5	0	0	0	0	0	0	0	0
-	Late summer-autumn	< week	29	28	27	26	25	24	20	16	12	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	<u>Solid manure</u>																										
	<u>Broad spreading</u>																										
-	Winter-spring	4	13	16	19	22	25	26	26	27	28	29	29	30	32	33	35	38	49	54	54	56	57	59	60	60	60
-	Winter-spring	6	18	16	14	12	10	11	11	12	13	14	14	15	15	15	15	14	14	15	15	14	14	13	12	12	12
-	Winter-spring	< week	19	18	17	16	15	14	14	13	12	11	11	10	10	10	10	9	10	11	11	11	10	9	9	9	9
+	Spring-summer	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	4	13	16	19	22	25	25	25	25	25	25	25	25	25	25	25	26	18	13	15	15	16	16	17	17	17
-	Late summer-autumn	6	13	11	9	7	5	5	5	5	5	5	5	5	5	5	5	5	3	2	1	0	0	0	0	0	0
-	Late summer-autumn	< week	24	23	22	21	20	19	19	18	17	16	16	15	13	12	10	9	6	5	4	4	3	3	2	2	2
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

J) Emission of particular matter, 1985-2009.

TSP

	Tonnes TSP	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NFR	Animal Category													
4B 1a	Dairy cattle	1 404	1 351	1 265	1 206	1 180	1 168	1 148	1 100	1 101	1 077	1 079	1 074	1 037
4B 1b	Non-dairy cattle	1 390	1 315	1 235	1 188	1 160	1 169	1 139	1 113	1 089	1 021	990	984	938
4B3	Sheep	1	2	2	3	3	3	4	4	3	3	3	3	3
4B4	Goats	0	0	0	0	0	0	0	0	0	0	0	0	0
4B 6	Horses	27	27	27	27	27	26	27	27	27	28	28	28	28
4B 8	Swine	8 747	8 728	8 465	8 204	7 983	8 034	8 056	8 395	9 307	8 624	8 664	8 388	8 716
4B 9a	Laying hens	301	286	275	306	293	298	277	358	320	402	425	442	417
4B 9b	Broilers	433	429	489	476	553	500	511	643	673	613	641	658	638
4B 9c	Turkeys	10	13	7	7	10	8	11	10	17	15	15	13	18
4B 9d	Other poultry	12	11	10	10	12	10	11	10	10	12	13	9	8
4B 13	Other	0	0	0	0	0	0	0	0	0	0	0	0	0
	TSP total	12 326	12 163	11 776	11 426	11 221	11 217	11 183	11 660	12 548	11 793	11 858	11 599	11 805

Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NFR	Animal Category												
4B 1a	Dairy cattle	1 043	998	945	914	882	870	833	859	856	836	847	850
4B 1b	Non-dairy cattle	921	868	845	860	792	501	491	480	485	502	492	512
4B3	Sheep	4	4	4	4	4	4	5	5	5	4	4	4
4B4	Goats	0	0	0	0	0	0	0	0	0	0	1	1
4B 6	Horses	29	29	29	30	31	32	33	34	35	36	37	35
4B 8	Swine	9 667	9 181	9 440	9 911	10 018	10 184	10 355	10 373	10 203	10 060	9 187	8 757
4B 9a	Laying hens	359	390	392	375	361	404	381	434	305	307	368	307
4B 9b	Broilers	668	760	818	811	787	635	587	619	672	611	505	769
4B 9c	Turkeys	15	14	15	14	14	10	14	17	10	13	14	16
4B 9d	Other poultry	9	10	8	9	10	9	9	8	9	5	5	4
4B 13	Other	0	0	0	0	0	0	0	0	0	0	0	0
	TSP total	12 716	12 254	12 496	12 929	12 900	12 651	12 708	12 829	12 581	12 376	11 462	11 255

PM_{10}

NFR	Tonnes PM_{10} / Animal Category	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
4B 1a	Dairy cattle	646	621	582	555	543	537	528	506	507	495	496	494	477
4B 1b	Non-dairy cattle	639	605	568	547	533	538	524	512	501	469	455	453	432
4B3	Sheep	1	1	1	1	1	2	2	2	1	1	1	2	2
4B4	Goats	0	0	0	0	0	0	0	0	0	0	0	0	0
4B 6	Horses	13	13	12	12	12	12	12	12	13	13	13	13	13
4B 8	Swine	3 936	3 928	3 809	3 692	3 592	3 615	3 625	3 778	4 188	3 881	3 899	3 774	3 922
4B 9a	Laying hens	301	286	275	306	293	298	277	358	320	402	425	442	417
4B 9b	Broilers	433	429	489	476	553	500	511	643	673	613	641	658	638
4B 9c	Turkeys	10	13	7	7	10	8	11	10	17	15	15	13	18
4B 9d	Other poultry	12	11	10	10	12	10	11	10	10	12	13	9	8
4B 13	Other	0	0	0	0	0	0	0	0	0	0	0	0	0
	PM_{10} total	5 991	5 907	5 755	5 605	5 551	5 520	5 501	5 831	6 230	5 901	5 959	5 857	5 927

Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NFR	Animal Category												
4B 1a	Dairy cattle	480	459	435	420	406	400	383	395	394	385	390	391
4B 1b	Non-dairy cattle	424	399	389	395	365	231	226	221	223	231	226	236
4B3	Sheep	2	2	2	2	2	2	2	2	2	2	2	2
4B4	Goats	0	0	0	0	0	0	0	0	0	0	0	0
4B 6	Horses	13	13	14	14	14	15	15	16	16	17	17	16
4B 8	Swine	4 350	4 131	4 248	4 460	4 508	4 583	4 660	4 668	4 592	4 527	4 134	3 941
4B 9a	Laying hens	359	390	392	375	361	404	381	434	305	307	368	307
4B 9b	Broilers	668	760	818	811	787	635	587	619	672	611	505	769
4B 9c	Turkeys	15	14	15	14	14	10	14	17	10	13	14	16
4B 9d	Other poultry	9	10	8	9	10	9	9	8	9	5	5	4
4B 13	Other	0	0	0	0	0	0	0	0	0	0	0	0
	PM_{10} total	6 320	6 179	6 319	6 501	6 467	6 289	6 277	6 379	6 223	6 098	5 663	5 682

$PM_{2,5}$

	Tonnes $PM_{2,5}$	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NFR	Animal Category													
4B 1a	Dairy cattle	415	399	374	356	349	345	339	325	325	318	319	317	306
4B 1b	Non-dairy cattle	410	387	364	350	342	344	335	328	321	300	291	289	276
4B3	Sheep	0	0	0	0	0	0	1	1	0	0	0	0	0
4B4	Goats	0	0	0	0	0	0	0	0	0	0	0	0	0
4B 6	Horses	8	8	8	8	8	8	8	8	8	8	9	9	9
4B 8	Swine	640	639	619	601	584	588	590	615	682	632	635	615	639
4B 9a	Laying hens	56	53	51	57	55	55	52	68	60	76	81	84	80
4B 9b	Broilers	57	56	64	62	72	65	67	84	88	80	84	86	83
4B 9c	Turkeys	1	2	1	1	1	1	1	1	2	2	2	2	2
4B 9d	Other poultry	2	1	1	1	2	1	1	1	1	1	2	1	1
4B 13	Other	0	0	0	0	0	0	0	0	0	0	0	0	0
	$PM_{2,5}$ total	1 588	1 546	1 483	1 437	1 413	1 409	1 394	1 431	1 488	1 418	1 422	1 403	1 396

Continued		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NFR	Animal Category												
4B 1a	Dairy cattle	308	295	279	270	261	257	246	254	253	247	250	251
4B 1b	Non-dairy cattle	271	255	249	253	233	149	146	142	144	149	146	152
4B3	Sheep	0	1	1	1	1	1	1	1	1	1	1	1
4B4	Goats	0	0	0	0	0	0	0	0	0	0	0	0
4B 6	Horses	9	9	9	9	10	10	10	11	11	11	11	11
4B 8	Swine	709	674	693	727	735	747	760	761	748	738	674	643
4B 9a	Laying hens	68	75	75	72	69	77	73	83	58	59	71	59
4B 9b	Broilers	87	99	107	106	103	83	77	81	88	80	66	101
4B 9c	Turkeys	2	2	2	2	2	1	2	2	1	2	2	2
4B 9d	Other poultry	1	1	1	1	1	1	1	1	1	1	1	1
4B 13	Other	0	0	0	0	0	0	0	0	0	0	0	0
	$PM_{2,5}$ total	1 456	1 410	1 415	1 441	1 414	1 326	1 315	1 336	1 305	1 287	1 222	1 219

K) Feeding plans - average feeding level.

Winter feeding plans		Feeding code	Pct. dm	Pct. Crude protein	Pct. Raw fat	Pct. Raw ashes	Pct. Carbon-hydrates	FE pr kg dm	kg feed pr day	MJ pr day	MJ pr FE
		PDIR (2002)									
Heifers:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	33.4	571.8	
	Maize silage	593	31.0	8.7	2.2	4.2	84.9	0.9	57.5	1 009.0	
	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	8.1	161.7	
	Total	-	-	-	-	-	-	-	99.0	1 742.4	**25.8**
Suckling cattle:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	1.6	119.1	
Period 1 (2 mth)	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	3.4	49.6	
	Barley	201	85.0	11.2	2.9	2.2	83.7	1.1	1.8	29.2	
Period 2 (4 mth)	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	3.2	238.2	
	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	3.0	29.1	
	Barley	202	85.0	11.2	2.9	2.2	83.7	1.1	3.2	52.0	
	Total	-	-	-	-	-	-	-	15.2	517.1	**34.0**
Horses:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	4.0	58.2	
	Hay	665	85.0	12.1	2.6	7.7	77.6	0.6	3.0	44.0	
	Oat	202	86.0	12.1	5.7	2.7	79.5	0.9	2.5	40.1	
	Supplemental		86.4	15.4	4.3	6.6	73.7	1.0	1.0	15.5	
	Total	-	-	-	-	-	-	-	-	157.7	**29.8**
Sheep and Goats:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	1.0	14.6	
	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	0.1	1.8	
	Barley	202	85.0	11.2	2.9	2.2	83.7	1.1	0.4	6.2	
	Grass pills (dried)	707	92.0	17.0	3.1	11.0	68.9	0.6	1.0	15.7	
	Total	-	-	-	-	-	-	-	-	38.2	**30.0**
Summer grazing[1]											
Grazing	Clover grass, 2 weeks old	422	18.0	22.0	4.1	9.4	64.5	1.0	1.0	18.8	
	Total	-	-	-	-	-	-	-	1.0	18.8	**18.8**
Pigs:	Full feeding										
	Sows	-	87.1	16.1	5.2	5.5	73.2	1.2	-	64.2	**17.5**
	Weaners	-	87.4	18.8	5.7	5.5	70.0	1.3	-	2.1	**16.5**
	Fattening pigs	-	86.9	17.0	4.7	5.1	73.3	1.2	-	9.6	**17.3**

L)

1) Area grown with sugar beet and maize for feeding.

Area, ha	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sugar beet for feeding	102 347	93 170	80 979	70 993	60 380	52 927	41 347	37 414	32 188	22 917
Maize for feeding	18 735	19 164	20 245	26 187	31 269	36 583	41 652	42 701	46 992	48 452
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sugar beet for feeding	17 577	13 302	9 953	7 991	6 233	4 974	4 035	3 819	5 206	5 257
Maize for feeding	61 493	78 814	95 741	118 267	129 317	131 027	135 245	144 869	159 030	168 917

2) Average CH_4 conversion rate (Y_m) – national factor used for dairy cattle and heifer > ½ year 1990 – 2009, %.

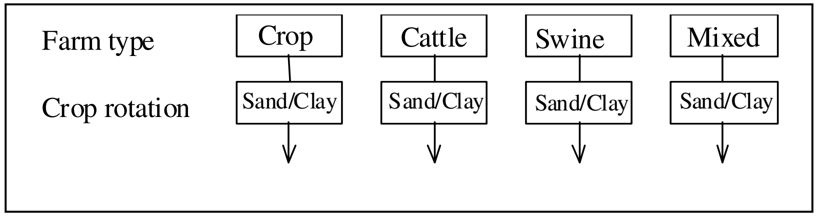
Dairy cattle + Heifer > ½ year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Ym - average	6.39	6.35	6.29	6.24	6.19	6.16	6.11	6.09	6.06	6.02
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ym - average	6.00	5.98	5.96	5.95	5.95	5.94	5.93	5.93	5.94	5.94

M) Area for N-fixing crops.

Area, ha	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Legumes to maturity	126 836	144 595	203 604	146 927	122 572	114 354	98 876	118 123	120 295	100 883	74 178	69 158	952 56
Lucerne	4 189	4 742	4 555	4 608	6 373	8 494	10 810	10 838	11 650	10 629	10 099	11 145	7 342
Crops for silage	50 629	55 220	47 416	52 819	50 104	47 772	53 621	6 3761	68 015	77 696	87 893	58 997	101 124
Legumes/marrow-stem kale	243 473	177 131	181 671	212 662	154 420	186 217	199 957	116 007	94 678	138 940	154 963	54 449	16 602
Peas for conservation	11 194	11 716	7 456	7 949	8 992	8 791	8 716	8 723	8 977	6 103	5 529	3 758	3 124
Seeds of leguminous grass crops	3 138	3 535	3 932	3 835	3 735	2 334	2 017	2 047	2 975	3 555	3 835	2 977	2 848
Grass and clover in rotation	277 857	263 719	247 327	256 032	252 453	248 815	250 129	255 069	287 109	330 370	238 384	257 398	235 285
Grass not in rotation	220 564	214 446	210 480	216 775	219 085	217 235	212 030	207 932	197 229	316 668	207 122	192 851	167 600
Fields with catch crop	NO	NO	NO	NO	NO	232 000	180 000	228 000	231 000	241 000	236 000	258 000	270 000
Continued	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Legumes to maturity	106 051	65 762	35 590	31 964	40 184	313 56	26 593	15 819	11 353	5 639	4 910	6 332	
Lucerne	6 850	5 514	5 245	3 451	3 566	3 946	4 147	4 575	3 982	3 682	3 756	5 366	
Crops for silage	115 657	117 782	118 763	113 504	112 469	110 089	102 041	75 512	63 998	60 348	60 348	55 848	
Legumes/marrow-stem kale	28 019	25 000	23 000	34 000	NO	NO	NO	NO	NO	NO	NO	NO	
Peas for conservation	3 962	4 172	4 149	3 441	2 689	3 386	2 979	2 999	2 841	2 741	3 592	3 737	
Seeds of leguminous grass crops	3 890	4 385	4 603	4 157	3 812	4 271	4 386	5 258	6 274	5 454	4 457	4 542	
Grass and clover in rotation	249 128	238 107	246 656	240 320	218 000	211 950	196 375	253 007	270 840	262 429	300 251	305 476	
Grass not in rotation	156 260	159 530	166 261	173 702	177 546	177 635	172 536	192 968	189 384	196 630	189 962	191 529	
Fields with catch crop	274 000	325 800	309 100	297 200	282 000	190 000	152 700	121 000	115 000	126 000	114 000	115 000	

N) Model calculation of nitrogen leaching nationwide by SKEP/DAISY and N-LES.

Basic DAISY calculations of N-leaching



<u>Each crop rotation calculates for:</u>
6 climate regions
30 fertilizer plan
4 soil type (here 2 w/w.out water)

38.000 combinations

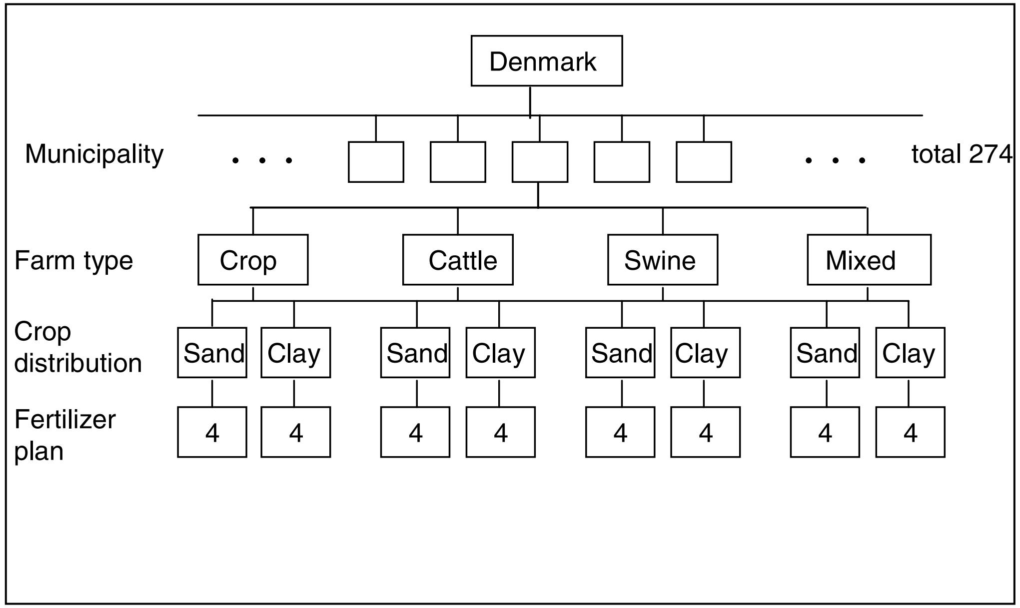
<u>Data base</u>
Calculation for all combinations for each of 4 climate year
Calculation for 12 combinations for each year in a 11 years period (1989-2001).

N-LES calculations

Model calculations for the crop rotations and fertilizer planes in SKEP plus appurtenant percolations from the DAISY calculations. Model calculations for each of the 11 years in the period 1989-2001, mean of the 11 years is up scaled nationwide by SKEP

Upscaling by the SKEP model

In the up scaling of DAISY calculations a climate normalisation and yield correction is made



O) Biogas production.

Production of biogas 1990-2009, and the amount of slurry used.

		Energy production		Estimated M tonnes slurry used in biogas production				Reduction
	Communal plants	Farm plants	Total	Cattle slurry,	Pig slurry,	Gg CH_4	Gg N_2O	CO_2-eq.
	T Joule	T Joule	T Joule	1000 Gg	1000 Gg			1000 Gg CO_2
1990	211	19	230	0.09	0.10	0.088	0.005	0.003
1991	369	19	388	0.14	0.18	0.149	0.008	0.006
1992	449	24	473	0.18	0.21	0.181	0.010	0.007
1993	529	27	556	0.21	0.25	0.214	0.012	0.008
1994	632	26	658	0.24	0.30	0.251	0.014	0.010
1995	745	27	772	0.29	0.35	0.298	0.017	0.011
1996	803	27	830	0.31	0.38	0.321	0.018	0.012
1997	973	32	1005	0.37	0.46	0.386	0.022	0.015
1998	1166	56	1222	0.45	0.56	0.470	0.026	0.018
1999	1183	70	1253	0.47	0.57	0.483	0.027	0.019
2000	1279	129	1408	0.52	0.64	0.539	0.030	0.021
2001	1345	179	1524	0.57	0.69	0.586	0.033	0.023
2002	1403	344	1747	0.65	0.79	0.669	0.038	0.026
2003	1508	625	2133	0.79	0.97	0.818	0.046	0.031
2004	1531	745	2276	0.85	1.03	0.874	0.049	0.034
2005	1593	745	2338	0.87	1.06	0.897	0.051	0.035
2006	1678	907	2585	0.96	1.18	0.995	0.056	0.038
2007	1699	904	2603	0.97	1.18	1.000	0.056	0.038
2008	1739	907	2646	0.99	1.20	1.018	0.057	0.039
2009	1839	1046	2885	1.08	1.31	1.111	0.063	0.043

Source: Pers. comm.. Søren Tafdrup (The Danish Energy Authority) and own calculations.

P) Emission of different pollutants from field burning of agricultural residue.

Pollutants	Unit	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NH_3	Gg	1.53	1.32	1.25	0.93	0.98	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.10
CH_4	Gg	1.72	1.48	1.41	1.05	1.11	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.11
N_2O	Gg	0.045	0.038	0.036	0.027	0.029	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003
NO_x	Gg	1.53	1.32	1.25	0.93	0.98	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.10
CO	Gg	37.58	32.29	30.67	22.93	24.13	1.89	1.97	1.88	2.06	1.98	2.24	2.23	2.37
CO_2	Gg	966.54	830.46	788.90	589.70	620.62	48.73	50.66	48.44	52.89	51.00	57.72	57.40	60.85
SO_2	Gg	0.19	0.16	0.16	0.12	0.12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NMVOC	Gg	4.02	3.45	3.28	2.45	2.58	0.20	0.21	0.20	0.22	0.21	0.24	0.24	0.25
PM														
TSP	Gg	3.70	3.18	3.02	2.26	2.38	0.19	0.19	0.19	0.20	0.20	0.22	0.22	0.23
PM10	Gg	3.70	3.18	3.02	2.26	2.38	0.19	0.19	0.19	0.20	0.20	0.22	0.22	0.23
PM2.5	Gg	3.51	3.01	2.86	2.14	2.25	0.18	0.18	0.18	0.19	0.19	0.21	0.21	0.22
Metals														
Pb	Tonnes	0.55	0.47	0.45	0.34	0.35	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Cd	Tonnes	0.031	0.027	0.026	0.019	0.020	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Hg	Tonnes	0.0051	0.0044	0.0042	0.0031	0.0033	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
As	Tonnes	0.037	0.032	0.030	0.023	0.024	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cr	Tonnes	0.140	0.121	0.115	0.086	0.090	0.007	0.007	0.007	0.008	0.007	0.008	0.008	0.009
Ni	Tonnes	0.113	0.097	0.092	0.069	0.073	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.007
Se	Tonnes	0.023	0.020	0.019	0.014	0.015	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	Tonnes	0.018	0.015	0.015	0.011	0.011	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	Tonnes	0.00019	0.00016	0.00016	0.00012	0.00012	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Dioxin	g I-TEQ	0.38	0.32	0.31	0.23	0.24	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PAH														
Benzo(a)pyrene	Tonnes	1.78	1.53	1.45	1.08	1.14	0.09	0.09	0.09	0.10	0.09	0.11	0.11	0.11
Benzo(b)fluoranthene	Tonnes	1.74	1.50	1.42	1.06	1.12	0.09	0.09	0.09	0.10	0.09	0.10	0.10	0.11
Benzo(k)fluoranthene	Tonnes	0.68	0.59	0.56	0.42	0.44	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.04
Indeno(1,2,3-cd)pyrene	Tonnes	0.65	0.56	0.53	0.40	0.42	0.03	0.03	0.03	0.04	0.03	0.04	0.04	0.04

Continued													
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NH_3	Gg	0.12	0.12	0.11	0.12	0.10	0.12	0.13	0.13	0.13	0.11	0.10	0.12
CH_4	Gg	0.14	0.13	0.13	0.13	0.11	0.13	0.14	0.14	0.14	0.13	0.12	0.14
N_2O	Gg	0.004	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.003	0.003	0.004
NO_x	Gg	0.12	0.12	0.11	0.12	0.10	0.12	0.13	0.13	0.13	0.11	0.10	0.12
CO	Gg	2.98	2.83	2.79	2.93	2.44	2.93	3.07	3.12	3.16	2.73	2.53	2.98
CO_2	Gg	76.60	72.77	71.68	75.33	62.66	75.33	78.98	80.14	81.30	70.35	65.15	76.64
SO_2	Gg	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.02
NMVOC	Gg	0.32	0.30	0.30	0.31	0.26	0.31	0.33	0.33	0.34	0.29	0.27	0.32
PM													
TSP	Gg	0.29	0.28	0.27	0.29	0.24	0.29	0.30	0.31	0.31	0.27	0.25	0.29
PM10	Gg	0.29	0.28	0.27	0.29	0.24	0.29	0.30	0.31	0.31	0.27	0.25	0.29
PM2.5	Gg	0.28	0.26	0.26	0.27	0.23	0.27	0.29	0.29	0.30	0.26	0.24	0.28
Metals													
Pb	Tonnes	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.04	0.04	0.04
Cd	Tonnes	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.002
Hg	Tonnes	0.0004	0.0004	0.0004	0.0004	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0004
As	Tonnes	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.003	0.003	0.002	0.003
Cr	Tonnes	0.011	0.011	0.010	0.011	0.009	0.011	0.011	0.012	0.012	0.010	0.009	0.011
Ni	Tonnes	0.009	0.009	0.008	0.009	0.007	0.009	0.009	0.009	0.009	0.008	0.008	0.009
Se	Tonnes	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Zn	Tonnes	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Cu	Tonnes	0.00002	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002	0.00002	0.00002	0.00001	0.00001	0.00002
Dioxin	g I-TEQ	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
PAH													
Benzo(a)pyrene	Tonnes	0.14	0.13	0.13	0.14	0.12	0.14	0.15	0.15	0.15	0.13	0.12	0.14
Benzo(b)fluoranthene	Tonnes	0.14	0.13	0.13	0.14	0.11	0.14	0.14	0.14	0.15	0.13	0.12	0.14
Benzo(k)fluoranthene	Tonnes	0.05	0.05	0.05	0.05	0.04	0.05	0.06	0.06	0.06	0.05	0.05	0.05
Indeno(1,2,3-cd)pyrene	Tonnes	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05

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DANISH EMISSION INVENTORY FOR AGRICULTURE

Inventories 1985 - 2009

By regulations given in international conventions Denmark is obliged to work out an annual emission inventory and document the methodology. The National Environmental Research Institute (NERI) at Aarhus University (AU) in Denmark is responsible for calculating and reporting the emissions. This report contains a description of the emissions from the agricultural sector from 1985 to 2009. Furthermore, the report includes a detailed description of methods and data used to calculate the emissions, which is based on national methodologies as well as international guidelines. For the Danish emissions calculations and data management an Integrated Database model for Agricultural emissions (IDA) is used. The emission from the agricultural sector includes emission of the greenhouse gases methane (CH_4), nitrous oxide (N_2O), ammonia (NH_3), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and other pollutants related to the field burning of agricultural residue such as NO_x, CO_2, CO, SO_2, heavy metals, dioxin and PAH. The ammonia emission from 1985 to 2009 has decreased from 119 300 tonnes of NH_3 to 73 800 tonnes NH_3, corresponding to a 38 % reduction. The emission of greenhouse gases has decreased by 25 % from 12.9 M tonnes CO_2 equivalents to 9.6 M tonnes CO_2 equivalents from 1985 to 2009. Improvements in feed efficiency and utilisation of nitrogen in livestock manure are the most important reasons for the reduction of both the ammonia and greenhouse gas emissions.

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