# DANISH EMISSION INVENTORIES FOR AGRICULTURE

Inventories 1985 - 2015

Scientific Report from DCE – Danish Centre for Environment and Energy No. 250 2017

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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# Data sheet

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Abstract: Regulations in international conventions obligate Denmark to prepare annual emission inventories and document the methodologies used to calculate emissions. The responsibility for preparing the emission inventories for agriculture is undertaken by the Danish Centre for Environment and Energy (DCE), Aarhus University, Denmark. This report contains a description of the emissions from the agricultural sector from 1985 to 2015 and includes a detailed description of methods and data used to calculate the emissions, which is based on international guidelines as well as national methodologies. The emissions are calculated by using an Integrated Database model for Agricultural emissions (IDA). IDA covers all aspects of the agricultural inputs and estimates both greenhouse gases and air pollutants, methane ($CH_4$), nitrous oxide ($N_2O$), ammonia ($NH_3$), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and other pollutants, which mainly are related to the field burning of agricultural residue such as $NO_x$, $CO_2$, CO, $SO_2$, heavy metals, dioxins, PAHs, HCB and PCBs. The largest contribution to agricultural emissions originates from livestock production, which is dominated by production of cattle and swine. The agricultural $NH_3$ emission from 1985 to 2015 has decreased from 128 800 tonnes $NH_3$ to 69 000 tonnes $NH_3$, corresponding to a reduction of approximately 46 %. The emission of greenhouse gases in 2015 is estimated at 10.4 million tonnes $CO_2$ equivalents and reduced from 13.2 million tonnes $CO_2$ equivalents in 1985. Since 1990, which is the base year of the Kyoto protocol a reduction of 18 % is obtained. Improvements in feed efficiency, the utilisation of nitrogen in livestock manure and a significant decrease in the consumption of inorganic N-fertiliser are the most important explanations for the reduction of $NH_3$. This has furthermore resulted in a significant reduction of $N_2O$ emission, which is the main reason for a considerable decline in the total greenhouse gas.

Keywords: Agriculture, $NH_3$, $CH_4$, $N_2O$, emission, ammonia, methane, nitrous oxide, particulate matter, greenhouse gas, inventory, inventories, Denmark.

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# Contents

# Preface

On behalf of the Ministry of Environment and Food of Denmark and the Ministry of Energy, Utilities and Climate, the Danish Centre for Environment and Energy (DCE) at Aarhus University (AU) is responsible for the calculation and reporting of the Danish national emission inventories. The inventories are compiled to fulfil the Danish obligations under EU directives, the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Economic Commission for Europe's 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 Peter Lund, Department of Animal Science, Aarhus University.

# Summary

International conventions obligate Denmark to prepare annual emission inventories and document the methodologies used to calculate emissions. The responsibility for preparing the emission inventories for agriculture in Denmark is undertaken by DCE - the Danish Centre for Environment and Energy, Aarhus University (AU). This report is an updated version of DCE Technical Report No. 108 published in 2013. 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 ($CH_4$), nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$), as well as the air pollutants: ammonia ($NH_3$), particulate matter (PM), non-methane volatile organic compounds (NMVOC), nitrogen oxides ($NO_x$) and other pollutants specifically related to the field burning of agricultural residues, such as carbon monoxide (CO), sulphur dioxide ($SO_2$), heavy metals, dioxins, polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene (HCB) and polychlorinated biphenyls (PCBs).

The agricultural emissions are calculated by using the data based model *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 DCA - Danish Centre for Food and Agriculture, Aarhus University and DAA - the Danish Agricultural Agency under the Ministry for Environment and Food. These data include the extent of the livestock production, land use, use of inorganic fertilisers and Danish standards for feed consumption and excretion. The emission inventories 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.

The agricultural sector is the main contributor of the $NH_3$ emission and accounts for approximately 95 % of the total $NH_3$ emission in 2015. Most of the ammonia emission is related to the livestock production (animal manure) and mainly from the production of swine and cattle. The agricultural $NH_3$ emission account for 129 kt (kilo tonnes) $NH_3$ in 1985 decreasing to 69 kt $NH_3$ in 2015, corresponding to a reduction of approximately 46 %. Improvements in feed efficiency, improvement of the utilisation of nitrogen in livestock manure combined with a significant decrease in the consumption of inorganic N-fertiliser, are the most important explanations for the reduction of the $NH_3$ emission.

Regarding the emission of $NH_3$, Denmark has applied for and been granted adjustments under the UNECE (United Nations Economic Commission for Europe) Convention on Long-Range Transboundary Air Pollution (CLRTAP).

The adjustments are related to the emission factors for inorganic N-fertiliser that have been changed in the EMEP/EEA Guidebook since the establishment of the reduction commitments. Another adjustment is related to the $NH_3$ emissions from growing crops, which is a source not covered by the EMEP/EEA Guidebook and not considered when establishing the emission ceiling for Denmark. Furthermore, Denmark has also an adjustment for NMVOC emission from manure management, which is a source introduced in the EMEP/EEA Guidebook in 2013.

Under the National Emissions Ceilings Directive (NECD), Denmark has applied for the same adjustments as under CLRTAP. The European Commission will review the application during 2017.

The agricultural emission of greenhouse gases (GHG) contributes with approximately 21 % of the total GHG from Denmark in 2015. The emission is closely related to the livestock production. Especially the $CH_4$ emission from the enteric fermentation process, which accounts for 36 % of the total agricultural GHG emission in 2015, is related to the cattle production.

The GHG emission from the agricultural sector is estimated to 13.3 million tonnes $CO_2$ equivalents in 1985 decreasing to 10.4 million tonnes $CO_2$ equivalents in 2015. Since 1990, which is the base year of the United Nations Framework Convention on Climate Change, the emission has decreased from 12.7 million tonnes $CO_2$ equivalents and a reduction of 18 % has been obtained. The main reason for the reduced emission is a decrease in number of cattle, and thus a decrease in $CH_4$ emission from enteric fermentation. Another important decreasing driver is the use of inorganic N fertilisers, which is a consequence of improved utilisation of nitrogen in animal manure, forced by environmental regulation.

# Sammenfatning

Danmark har via konventioner forpligtet sig til årligt at opgøre udledninger af drivhusgasser og luftforurenende stoffer. Udarbejdelsen af de årlige danske emissionsopgørelser og dokumentationen for hvorledes emissionerne opgøres, varetages af DCE - Nationalt Center for Miljø og Energi ved Aarhus Universitet (AU). Metodebeskrivelsen opdateres jævnligt, og denne rapport er en opdatering af DCE videnskabelig rapport nr. 108 publiceret i 2013.

Rapporten omfatter en opgørelse af landbrugets emissioner i perioden 1985 – 2015 af drivhusgasserne: metan ($CH_4$), lattergas ($N_2O$) og kuldioxid ($CO_2$) og luftforureningskomponenterne: ammoniak ($NH_3$), partikler (PM), flygtige organiske forbindelser (NMVOC), kvælstofilter ($NO_x$), og andre stoffer, der er relateret til markafbrænding af afgrøderester fra landbruget som kulilte (CO), svovldioxid ($SO_2$), tungmetaller, dioxiner, polycykliske aromatiske kulbrinter (PAH'er), hexaklorbenzen (HCB) og polyklorerede bifenyler (PCB'er). Derudover omfatter rapporten en beskrivelse af metoden for, hvordan emissionerne beregnes.

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, DCA - Nationalt Center for Fødevarer og Landbrug ved Aarhus Universitet og Landbrugsstyrelsen under Miljø- og Fødevareministeriet. Disse data omfatter bl.a. omfanget af husdyrproduktionen, arealanvendelse, handelsgødningsforbruget, normdata for foderindtag og dyrenes nitrogenudskillelse via gødningen, som er nogle af de vigtigste parametre for emissionsberegningen. Emissionsopgørelsen tager således højde for de faktiske forhold, der gør sig gældende for den danske landbrugsproduktion. For de forhold, hvor der ikke forefindes nationale data, anvendes standardværdier fra IPCC - The Intergovernmental Panel on Climate Change og EMEP - The European Monitoring and Evaluation Programme.

Langt størstedelen af den samlede $NH_3$-emission, svarende til ca. 95 %, kan henføres til landbrugsproduktionen. Ammoniakemissionen sker i forbindelse med omsætningen af kvælstof og størstedelen af emissionen kommer fra husdyrgødning, hvor produktionen af svin og kvæg er de største bidragydere. Ammoniakemissionen fra landbrugssektoren er fra perioden 1985 til 2015 faldet fra 129 kilo tons (kt) $NH_3$ til 69 kt $NH_3$, svarende til en reduktion på 46 %. De væsentligste årsager til reduktionen er en forbedring i fodereffektivitet, en bedre udnyttelse af kvælstofindholdet i husdyrgødningen og på baggrund heraf, et markant fald i anvendelsen af kvælstof i handelsgødning.

For emissioner af $NH_3$ og NMVOC har Danmark ansøgt under justeringsproceduren og fået godkendt justringerne under UNECE's konvention om langtransporteret grænseoverskridende luftforurening (CLRTAP). Det betyder, at den totale emission må korrigeres for visse emissionskilder, når emissionen skal sammenholdes med de fastsatte emissionslofter. For $NH_3$ er korrektionerne relateret til emissionsfaktorerne for handelsgødning, fordi disse er ændret væsentligt i EMEP/EEA Guidebook siden emissionslofterne blev vedtaget. En anden korrektion omfatter $NH_3$-emissionen fra voksende afgrøder, som ikke er inkluderet som emissionskilde i EMEP/EEA Guidebook, og som derfor ikke var inkluderet i forbindelse med den oprindelige forhandling af emissionsloftet for Danmark. For NMVOC-emissionen er korrektionen relateret til emissionen fra husdyr og gødningshåndtering, som er en kilde, der først blev inkluderet i EMEP/EEA Guidebook i 2013.

Under EU direktivet om nationale emissionslofter (NECD) har Danmark ansøgt om de samme justeringer som under konventionen. Ansøgningen vil blive behandlet af EU Kommissionen i løbet af 2017.

Landbrugets emissioner af drivhusgasser (GHG) bidrager med 21 % af den totale GHG-emission fra Danmark i 2015. Størstedelen af emissionen er knyttet til husdyrproduktionen og særligt fra kvægs fordøjelsesprocesser, som bidrager med 36 % af den samlede GHG-emission fra landbruget i 2015.

I 1985 er GHG-emissionen fra landbrugssektoren opgjort til 13,3 millioner tons $CO_2$-ækvivalenter og er frem til 2015 faldet til 10,4 millioner. Siden 1990, som er klimakonventionens basisår, er emissionen faldet fra 12,7 millioner tons $CO_2$-ækvivalenter, hvilket svarer til en reduktion på 18 %. Den mest betydende årsag til reduktion af emissionen er faldet i antallet af kvæg, som har betydet et væsentligt fald i $CH_4$-emissionen fra fordøjelse. En anden forklaring er reduktion i $N_2O$-emissionen, som skyldes et betydeligt fald i anvendelsen af handelsgødning som følge af miljøreguleringen, der stiller krav til øget anvendelse af kvælstofindholdet i husdyrgødningen og krav til at undgå tab af kvælstof til omgivelserne (luft, jord og vand).

# 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 ($CH_4$), nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$), and other pollutants such as non-methane volatile organic compounds (NMVOC), particulate matter (PM), nitrous oxide ($NO_x$) and a series of other pollutants related to the burning of crop residues on fields such as carbon monoxide (CO), sulphur dioxide ($SO_2$), heavy metals, dioxins, polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene (HCB) and polychlorinated biphenyls (PCBs). DCE – the Danish Centre for Environment and Energy under Aarhus University is responsible for calculating emissions and reporting the annual emission inventories. The primary data is collected from Statistics Denmark, DCA - Danish Centre for Food and Agriculture at Aarhus University and DAA - the Danish Agricultural Agency under the Ministry for Environment and Food. In addition to the reporting of emission data, Denmark is obligated by the conventions to document the calculation methodology. This report, therefore, includes both a review of the emissions for the period 1985–2015 and a description of the methodology on which calculation of emissions is based. The report is an updated version of Scientific Report from DCE – Danish Centre for Environment and Energy No. 108 (Mikkelsen et al., 2013).

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 (2016/2284/EU) commit Denmark to reduce $NH_3$ emissions from all sectors by 24 % in 2020 compared to the emission level in 2005.

In 2015, 95 % 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 CLRTAP includes an adjustment for the $NH_3$ emission from growing crops and use of inorganic N-fertiliser. The same adjustments have been applied for under the NECD and the European Commission will review the application during 2017.

In 2015, the agricultural sector contributed 21 % to the total emission of greenhouse gases in Denmark, measured in $CO_2$ equivalents ($CO_2$-eqv.). The relatively large contribution is due to the emission of $CH_4$ and $N_2O$. 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, 25 and 298 times stronger than that of $CO_2$ (IPCC, 2006).

The IPCC has developed guidance documents on how greenhouse gas emissions should be calculated. The relevant documents for agriculture currently used under the UNFCCC is the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). 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.

Agricultural emissions are calculated in an integrated national model complex IDA - Integrated Database model of Agricultural emissions. This means that the calculation of emissions of $NH_3$, greenhouse gases and other pollutants is based on the same activity data, i.e. the number of livestock, the distribution of types of livestock housing, fertiliser type, land use, etc.

The emission inventories is continuously being improved with the availability of new knowledge. 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. It is prioritised to use national data if these are available to reflect the Danish agricultural and climate conditions. This causes high requirements for documentation of data, especially in areas where the methodology and the national data differ significantly from the IPCC's recommended standard methods or data values.

The current report includes an introductory overview of emission from year 1985 and forward to the recent reported emission year 2015, and describing the changes in agricultural activities that have influenced the emissions. This is followed by a description of the IDA model used to calculate the emissions, and a detailed description is provided on how the emissions for the individual pollutants are calculated.

# 2 Trends in agricultural emissions 1985-2015

This chapter describes the development in the agricultural emissions of air pollutions and greenhouse gases from 1985 to 2015. 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, PAHs, dioxins, PCBs and HCB), 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 ($CH_4$), nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$). Pollutants that have an indirect effect on greenhouse gas emissions, i.e. NMVOC and $NO_x$ from animal manure and 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 reporting 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. Including 8 protocols. | Data: NFR (Nomenclature For Reporting) Report: IIR (Informative Inventory Report) | Main pollutants; $NH_3$, $NO_x$ NMVOC, $SO_2$ Particulate matter; TSP, $PM_{10}$, $PM_{2.5}$, BC Other pollutants; CO Priority metals; Pb, Cd, Hg Other metals; As, Cr, Cu, Ni, Se, Zn PAHs (benzo(a)pyrene, benzo(b)fluoranthene, benzo-(k)fluoranthene, Indeno(1,2,3-cd)pyrene) Dioxins and furans (PCDD/-F) Polychlorinated biphenyls (PCBs) Hexachlorobenzene (HCB) |
| EU's Directive on national emission ceilings (NECD) (2016/2284/EU) | Same as UNECE Convention | Same as UNECE Convention |
| Emission ceilings 2020 and 2030 | | $NH_3$, NMVOC, $NO_x$, $SO_2$, $PM_{2.5}$ |

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

It must be noted that $CO_2$ removals / emissions from agricultural soils are not included in the emission inventories 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). Emissions related to agricultural machinery (tractors, harvesters and other non-road machinery) are reported in the energy sector.

## 2.1 Air pollutants

Table 2.2 shows the agricultural contribution of emissions to the national total in 2015. The main part of the $NH_3$ emission (95 %) and TSP emission (70 %) is related to the agricultural sector.

Table 2.2 Emissions of ammonia ($NH_3$), particulate matter (TSP, $PM_{10}$, $PM_{2.5}$), non-methane volatile organic compounds (NMVOC), sulphur oxides ($SO_x$) and nitrogen oxides ($NO_x$) in 2015, reported to UNECE, January 2017.

| | $NH_3$ | TSP | $PM_{10}$ | $PM_{2.5}$ | NMVOC | $SO_X$ | $NO_X$ |
|---|---|---|---|---|---|---|---|
| National total, kt | 73 | 89 | 30 | 20 | 109 | 11 | 114 |
| Agricultural total, kt | 69 | 62 | 8 | 1 | 38 | <1 | 17 |
| Agricultural part of national total, % | 95 | 70 | 27 | 6 | 35 | <1 | 15 |

### 2.1.1 $NH_3$

Approximately 95 % originates from the agricultural sector and the remainder from the energy sector, industrial processes and waste. Approximately 85 % of the $NH_3$ emissions from agricultural activities relates to livestock production, the remaining 15 % from the use of inorganic N-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 divided into the different sources. The emission of ammonia from the agricultural sector decreased from 106 kt $NH_3$-N in 1985 to 57 kt $NH_3$-N in 2015, which corresponds to a 46 % reduction. 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.

The significant decrease in $NH_3$ emissions is strongly correlated to a decrease in the emission from livestock production and is a consequence of an active national environmental policy over the last 30 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), the Ammonia Action Plan (2001), environmental Approval Act for Livestock Holdings (2007/2011) and agreement on the Green Growth (2009/2010). These actions plans and initiated measures have brought about a decrease in animal nitrogen excretion, improvement in use of nitrogen in manure and a fall in the use of inorganic N-fertiliser, all of which have helped reduce the overall $NH_3$ emission significantly.

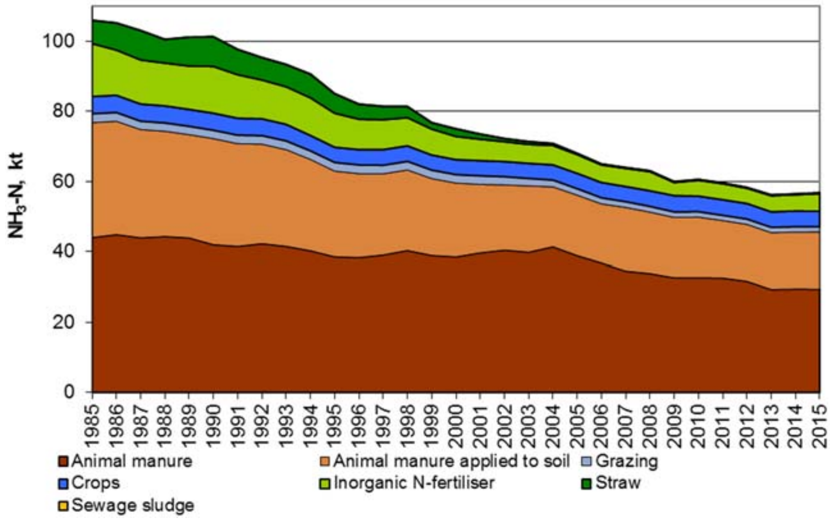



Figure 2.1 $NH_3$-N emissions in the agricultural sector, 1985 to 2015. Straw includes $NH_3$ treated straw and field burning of agricultural residues.

In Appendix A, the trend for $NH_3$ emission from 1985 to 2015 from different sources is expressed in both $NH_3$-N and $NH_3$.

### $NH_3$ emission from animal manure

In 2015, animal manure contributed approximately 52 % to the total $NH_3$ emission from agriculture. From 1985 to 2015, the emission from animal manure has decreased by 33 %.

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 swine and cattle. In 1985, approximately 59 % of the emission was related to the swine production, while 26 % was related to the cattle production. In 2015, the contribution from cattle production had increased to 30 % and the swine production accounted for 44 %

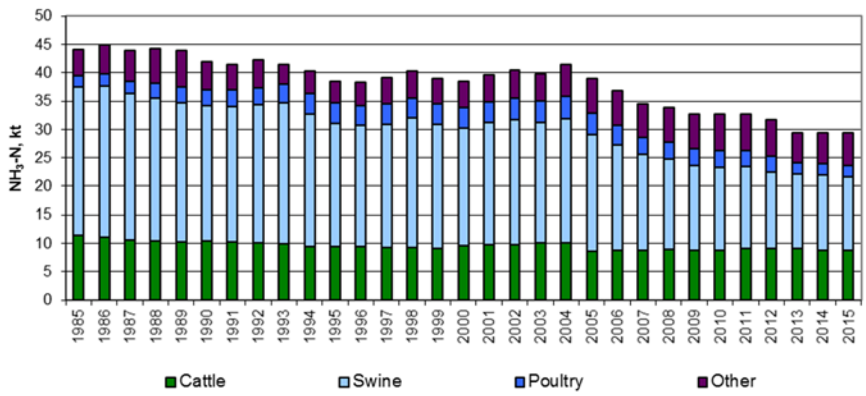



Figure 2.2 $NH_3$-N emissions from animal manure contributed by the different livestock categories. ‘Other’ includes fur bearing animals, horses, sheep, goats and deer.

The emission from manure management decreases from 1985-2015 for both cattle, swine and poultry. For cattle the emissions decreases 23 % mainly due to decrease in number of cattle. The emissions from swine has decreased by 50 % despite an increase in the production of fattening pigs from 14.8 million produced in 1985 to 19.9 million in 2015. One of the most important reasons for this is the improvement in feed efficiency. In 1985, the nitrogen excretion in manure for one produced fattening pig was estimated to 5.09 kg N (Poulsen & Kristensen, 1997). In 2015, that figure was considerably lower at 2.90 kg N per fattening pig produced (Poulsen, 2016). Due to the large contribution from the pig production, the lower level of N-excretion has a significant influence on total agricultural emissions.

Figure 2.3 shows the different emission sources, i.e. from manure handling in animal housing, manure storage, application to fields and from grazing animals. The overall decrease is 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 lead farmers to consider the manure as a nitrogen resource instead of a waste product. Especially the emission from application and storage of manure has decreased significantly.

Regarding the field application of animal manure, considerable changes have taken place. From the beginning of the 1990s, slurry has increasingly been spread using trailing hoses. Furthermore, since the late 1990s, the practice of slurry injection or mechanical incorporation into the soil has increased. For 2015, it is estimated that 77 % for cattle slurry and 37 % for swine slurry is applied using injection/incorporation techniques (Birkmose, 2016, Pers. Comm.). This development is in addition to general environmental requirements also a consequence of a ban on broad spreading from 2003. From 2011, slurry applied on fields with grass for feeding or fields without crop cover, has to be injected directly into the soil (BEK, 2013). However, the injection requirements are not required if the slurry has been acid treated before application to soil.

From 2005 a considerable decrease in the emission from storage is seen, which is due to the requirement to cover manure heaps.

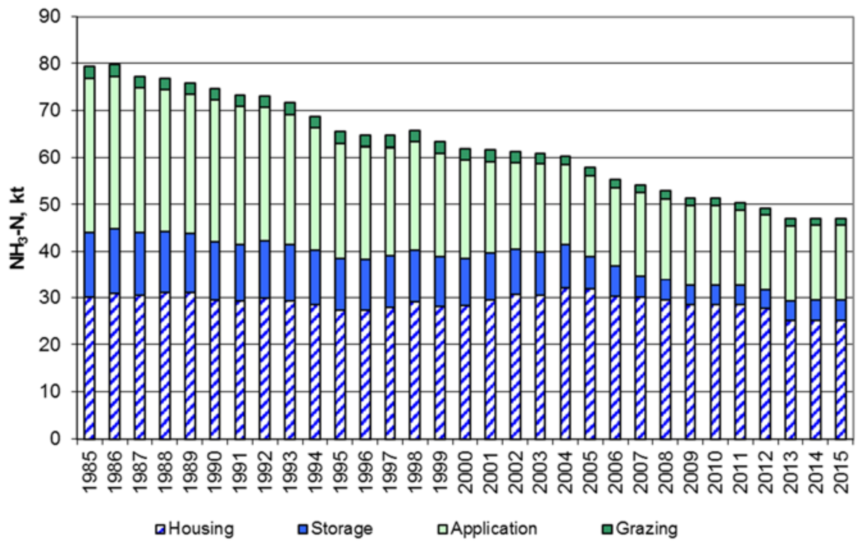



Figure 2.3 $NH_3$-N emissions from animal manure, 1985 to 2015.

#### $NH_3$ emissions from agricultural soils

In 2015, $NH_3$ emission related to the agricultural soils contributed 48 % to total agricultural emissions, and this mainly stems from manure applied to soil, the use of inorganic N-fertiliser and from growing crops as shown in Figure 2.4.

The Danish inventories includes the emission from growing crops. No methodological guidance is provided in the EMEP/EEA Guidebook. Studies have demonstrated that growing crops can emit $NH_3$ (Schjoerring & Mattsson, 2001). Despite the uncertainties related to this emission source due to effect from different geographic and climatic conditions, Denmark has chosen to include the emission and thus avoid an underestimation of $NH_3$ emission.

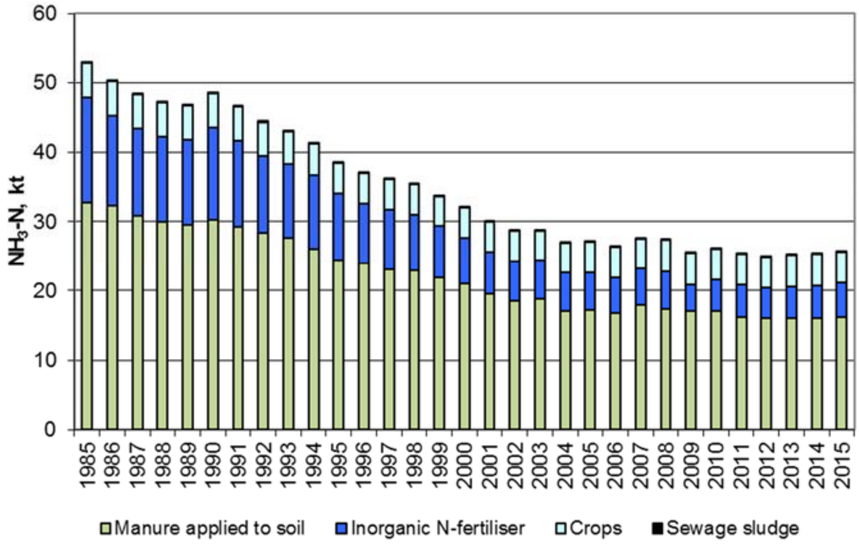



Figure 2.4 $NH_3$-N emission from manure applied to soil, inorganic N-fertiliser, crops and sewage sludge, 1985-2015.

Due to the requirement to improve the utilisation of nitrogen in animal manure, the use of inorganic N-fertilisers has decreased dramatically. The amount of nitrogen applied to soils from inorganic N-fertilisers in 2015 is almost halved compared with the amount used in 1985.

### 2.1.2 PM

Emission of particulate matter (PM) originates from livestock housing, field operations such as soil cultivation and harvesting, and the field burning of agricultural residues.

The PM emissions from the agricultural sector mainly consist of larger particles. In the reporting under CLRTAP, PM is reported as the total suspended particles (TSP), $PM_{10}$ and $PM_{2.5}$ (Particulate matter with diameter of less than 10 µm and less than 2.5 µm). TSP emission from the agricultural sector contributes 70 % to the national TSP emission in 2015 and the emission shares for $PM_{10}$ and $PM_{2.5}$ are 27 % and 6 % respectively. For TSP 89 % of the emission is related to field operations in 2015. The emission from livestock contributes with 11 % and the field burning of agricultural residues, contributes less than

1 % to the agricultural emission. For $PM_{10}$ field operations contribute with 68 %, livestock with 29 % and field burning of agricultural residues with 3 %. For emission of $PM_{2.5}$ the sources contributes, with 37 % from field operations, 43 % from livestock and 20 % from field burning.

Figure 2.5 shows PM emission from the agricultural sector from 1985 to 2015 given in TSP, $PM_{10}$ and $PM_{2.5}$.

Emission from field operations originates from crop harvesting, cultivation of soil, and the cleaning and drying of crops (EMEP, 2016). Harvesting and soil cultivation is the predominant source of PM. The decrease in emission from field operations from 2001 to 2002 is due to reduction in the number of operations in soil cultivation caused by change in cultivation practice.

Since 1985, the overall emission from livestock is almost unaltered. The changes in the total emission for each livestock category mainly reflect the changes in the number of animals, but they are also effected by the distribution of animals in subcategories and changes in housing type.

The emission from field burning of agricultural residues decreases significantly from 1989 to 1990 due to a ban on burning of these residues. From 1990, burning of residues may only take place in connection with production of grass seeds on fields with repeated production and in cases of wet or broken bales of straw.

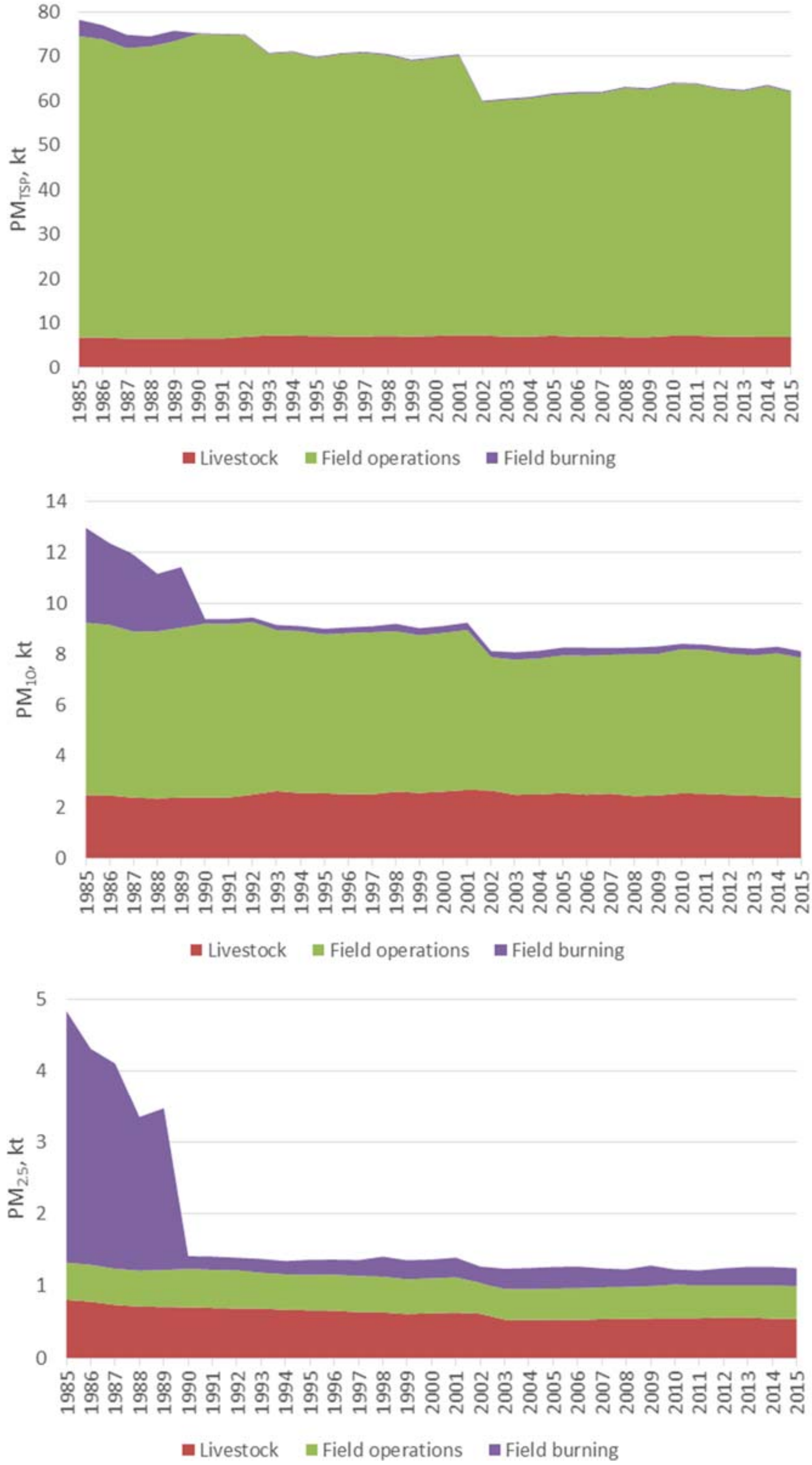


Figure 2.5 Emission of PM, given in TSP, $PM_{10}$ and $PM_{2.5}$ from the agricultural sector, 1985 to 2015.

### 2.1.3 NMVOC

The NMVOC emission includes emission from animal manure, field burning of agricultural residues and from growing crops and grass. Agriculture contributed with 38 kt NMVOC in 2015, corresponding to 35 % of the national NMVOC emission. Of this, emission from animal manure contribute with 94 %, crops with 6 % and field burning less than 1 % in 2015.

The emission has decreased from 1990 to 2015, mainly due to decrease in number of cattle. As mentioned, field burning of agricultural residues was banned in 1990 and therefor a decrease in the emission is seen from 1989 to 1990.

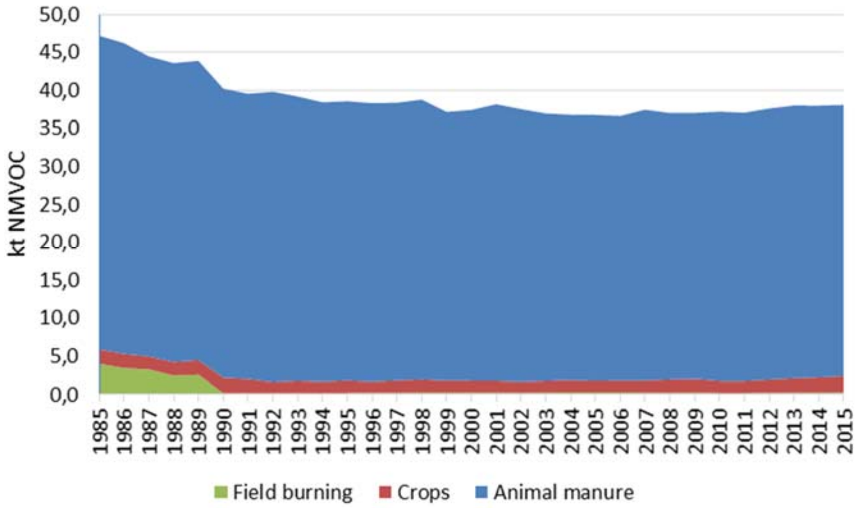



Figure 2.6 Emission of NMVOC from the agricultural sector, 1985-2015.

### 2.1.4 $NO_x$

Emission of $NO_x$ is estimated for animal manure in housing and storage, inorganic N-fertiliser, manure applied to soil, sewage sludge used as fertiliser and from field burning of agricultural residues. Agriculture contributed with 17 kt $NO_x$ in 2015, corresponding to 15 % of the national $NO_x$ emission. From 1985, the emission has decreased mainly due to decrease in use of inorganic N-fertiliser.

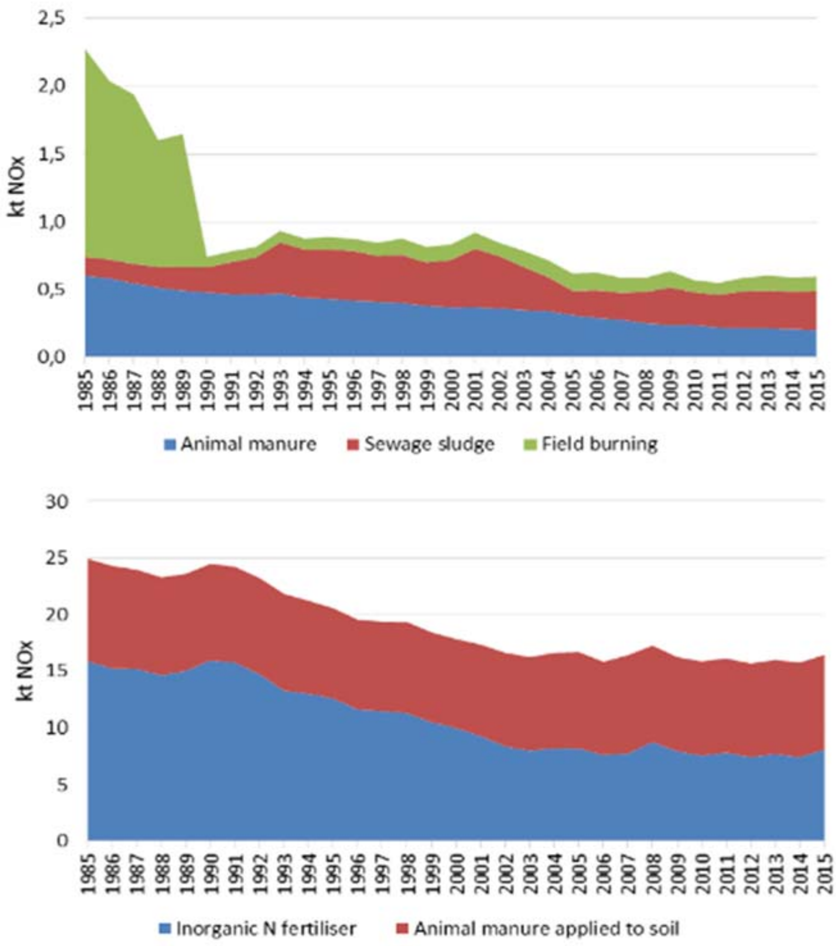



Figure 2.7 $NO_x$ emission for the agricultural sector, 1985-2015.

### 2.1.5 Other air pollutants

Other air pollutants include BC, CO, $SO_2$, heavy metals, dioxins, PAHs, PCBs and HCB. These are estimated from the field burning of agricultural residues; HCB also emits from use of pesticides. In 2015, BC, CO, $SO_2$, heavy metals and dioxin from field burning contributed less than 1 % to the total national emission, while PAHs contributed with around 5 %. From 1989 to 1990, all emissions decreased significantly due to the banning of field burning.

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

## 2.2 Greenhouse gases

Table 2.3 shows the agricultural contribution of emissions to the national total in 2015. The agricultural emission contribution of $N_2O$, $CH_4$ and $CO_2$ is 89 %, 81 % and 1 %, respectively.

Table 2.3 Emission nitrous oxide ($N_2O$), methane ($CH_4$) and carbon dioxide ($CO_2$) 2015, reported to UNFCCC, January 2017.

| | $N_2O$ | $CH_4$ | $CO_2$ |
|---|---|---|---|
| National total, kt | 17 | 274 | 35 147 |
| Agricultural total, kt | 15 | 221 | 177 |
| Agricultural part of national total, % | 89 | 81 | 1 |

Table 2.4 shows the development in greenhouse gas emissions calculated in $CO_2$-eqv.. The overall emission in 1985 is estimated to 13 333 kt, decreasing to 10 411 kt in 2015, corresponding to a 22 % reduction. Since 1990, the base year of the United Nations Framework Convention on Climate Change (UNFCCC) for $CO_2$, $CH_4$ and $N_2O$, the emission has been reduced by 18 %, mainly caused by a decrease in the $N_2O$ emission.

Table 2.4 Development in the emission of greenhouse gases, 1985-2015, measured in kt $CO_2$ equivalents. For all years and distributed on main sources see Appendix B and C.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 5 997 | 5 585 | 5 831 | 5 719 | 5 682 | 5 633 | 5 579 | 5 588 | 5 556 | 5 590 | 5 524 |
| $N_2O$ | 6 605 | 6 508 | 5 795 | 5 318 | 4 961 | 4 636 | 4 690 | 4 606 | 4 594 | 4 649 | 4 709 |
| $CO_2$ | 732 | 619 | 537 | 268 | 222 | 156 | 165 | 192 | 246 | 240 | 177 |
| Total | 13 333 | 12 712 | 12 163 | 11 305 | 10 865 | 10 425 | 10 434 | 10 386 | 10 397 | 10 479 | 10 411 |

### 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 2015, is presented in Figure 2.8 and shows a reduction from 244 kt $CH_4$ in 1985 to 221 kt $CH_4$ in 2015, corresponding to 8 %. From 1985 to 2015, 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.

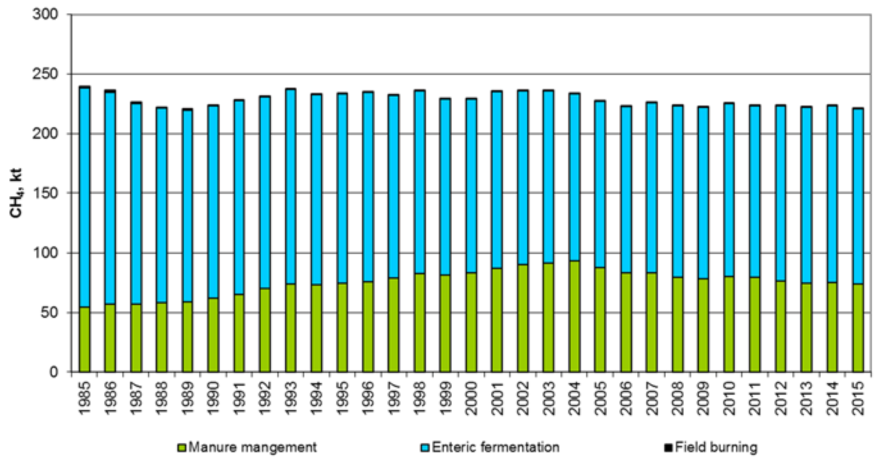



Figure 2.8 $CH_4$ emission 1985-2015, kt $CH_4$ per year.

In 2015, approximately 10 % of slurry was treated in biogas plants. Investigations indicate a lower emission of $CH_4$ from biogas treated slurry (Mikkelsen et al., 2016) and this effect is included in the emission inventories.

### 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 2.9 presents the trend in the emissions of $N_2O$ in the period 1985 to 2015 and reveals that the emission has decreased from 22.2 kt $N_2O$ to 15.8 kt $N_2O$, which corresponds to a 29 % reduction.

$N_2O$ is produced from a range of different sources, which are presented in figure 2.9. The largest sources are animal manure and inorganic N-fertilisers applied to soil. The reduction in total $N_2O$ emissions is strongly related to a significant decrease in emissions from the use of inorganic N-fertiliser and in nitrogen leaching and runoff. This development is primarily a consequence of an improved utilisation of nitrogen in animal manure.

Despite the increasing production of swine and poultry, the total amount of excreted nitrogen in manure has decreased from 1985 to 2015, 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 the reduction is the change from previous, more traditional, tethering systems with solid manure to slurry-based systems, because the $N_2O$ emission is lower for liquid manure than for solid manure.

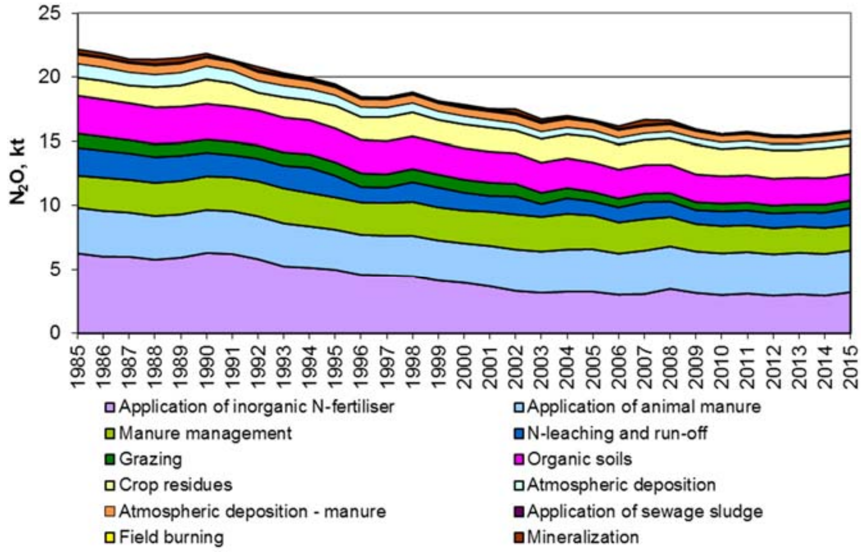



Figure 2.9 Emission of $N_2O$ according to source, 1985-2015.

### 2.2.3 $CO_2$

Emission of $CO_2$ from agriculture originates from liming, urea application and use of other carbon-containing fertilisers. The largest source is liming which contribute with 94 % of the emission in 2015. The emission has decreased from 1985 to 2015 from 732 kt $CO_2$ to 177 kt $CO_2$, which corresponds to a reduction of 76 %, mainly due to decrease in the use of lime.

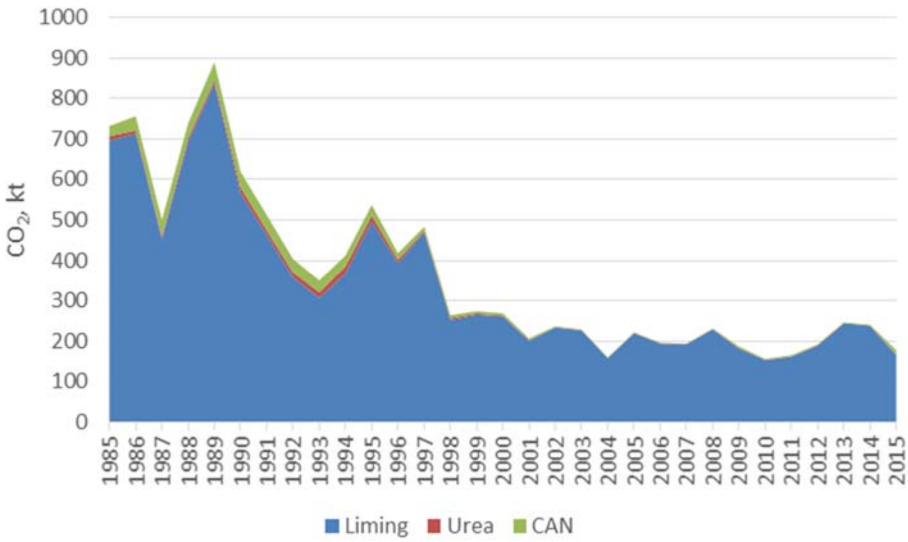



Figure 2.10 Emission of CO2 from liming, urea and carbon-containing fertilisers, 1985-2015.

# 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 all pollutants and all agricultural sectors.

## 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 (*i*). The overall emission is calculated as the sum of the emissions from all activities (see Equation 3.1).

$$\mathrm{E}_{Total} = \sum \mathrm{a}_i \cdot \mathrm{EF}_i \qquad \text{(Eq. 3.1)}$$

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 are 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 in accordance with international guidelines. The emission calculations for the greenhouses gases are in accordance with the methods in the IPCC Guidelines (IPCC, 2006). The calculation of air pollutant emissions are in accordance with the methodologies described in the EMEP/EEA Guidebook (EMEP, 2013). National values and methodological approaches are used where these reflect the Danish agricultural conditions in a better way.

## 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, Danish Centre for Food and Agriculture at Aarhus University, SEGES (agricultural advisory service), the Danish Environmental Protection Agency and the Danish Agricultural Agency.

Table 3.1 provides an overview of the various institutions and organisations who contribute with national data for the preparation of the agricultural emission inventories.

Table 3.1 Organisations contributing with input data to the preparation of the emission inventories for agriculture.

| References | Link | Abbreviation | Data / information |
|---|---|---|---|
| Danish Centre for Environment and Energy, Aarhus University | http://dce.au.dk | DCE | - data collecting<br>- emission calculations<br>- responsible for QA/QC<br>- reporting |
| Statistics Denmark – Agricultural Statistics | www.dst.dk | DSt | - livestock production<br>- milk yield<br>- slaughtering data<br>- export of live animal - poultry<br>- land use<br>- crop production<br>- crop yield |
| Danish Centre for Food and Agriculture, Aarhus University | http://dca.au.dk/ | DCA | - N excretion<br>- feeding situation<br>- animal growth<br>- N content in crops<br>- modelling of data regarding N-leaching/runoff<br>- $NH_3$ emission factor |
| SEGES – The Danish agricultural advisory service | www.seges.dk | SEGES | - housing type (until 2004)<br>- grazing situation<br>- manure application, time and methods<br>- estimation of extent of field burning of agricultural residue<br>- acidification of slurry (housing, storage and application) |
| Danish Environmental Protection Agency | www.mst.dk | EPA | - sewage sludge used as fertiliser (until 2004)<br>- industrial waste used as fertiliser<br>- $NH_3$ emission factor for use of acidification technology (List of Environmental Technologies)<br>- use of pesticides |
| The Danish Agriculture Agency | www.lbst.dk/ | DAA | - inorganic N-fertiliser (consumption and type)<br>- housing type (from 2005)<br>- sewage sludge used as fertiliser (from 2005 based on the register for fertilisation)<br>- number of animals from the Central Husbandry Register |
| 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 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 39 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 269 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 | 35 |
| Non-dairy cattle[1] | Calves (<½ yr), heifers, bulls, suckling cattle | 129 |
| Sheep | Including lambs | 2 |
| Goats | Including kids (meet, dairy and mohair) | 3 |
| Horses | <300 kg, 300-500 kg, 500-700 kg, >700 kg | 4 |
| Swine | Sows, weaners, fattening pigs | 37 |
| Poultry | Hens, pullets, broilers, turkeys, geese, ducks, ostriches, pheasants | 50 |
| Other | Mink, fitchew, foxes, fin raccoon, deer | 9 |

[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 inorganic N-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.

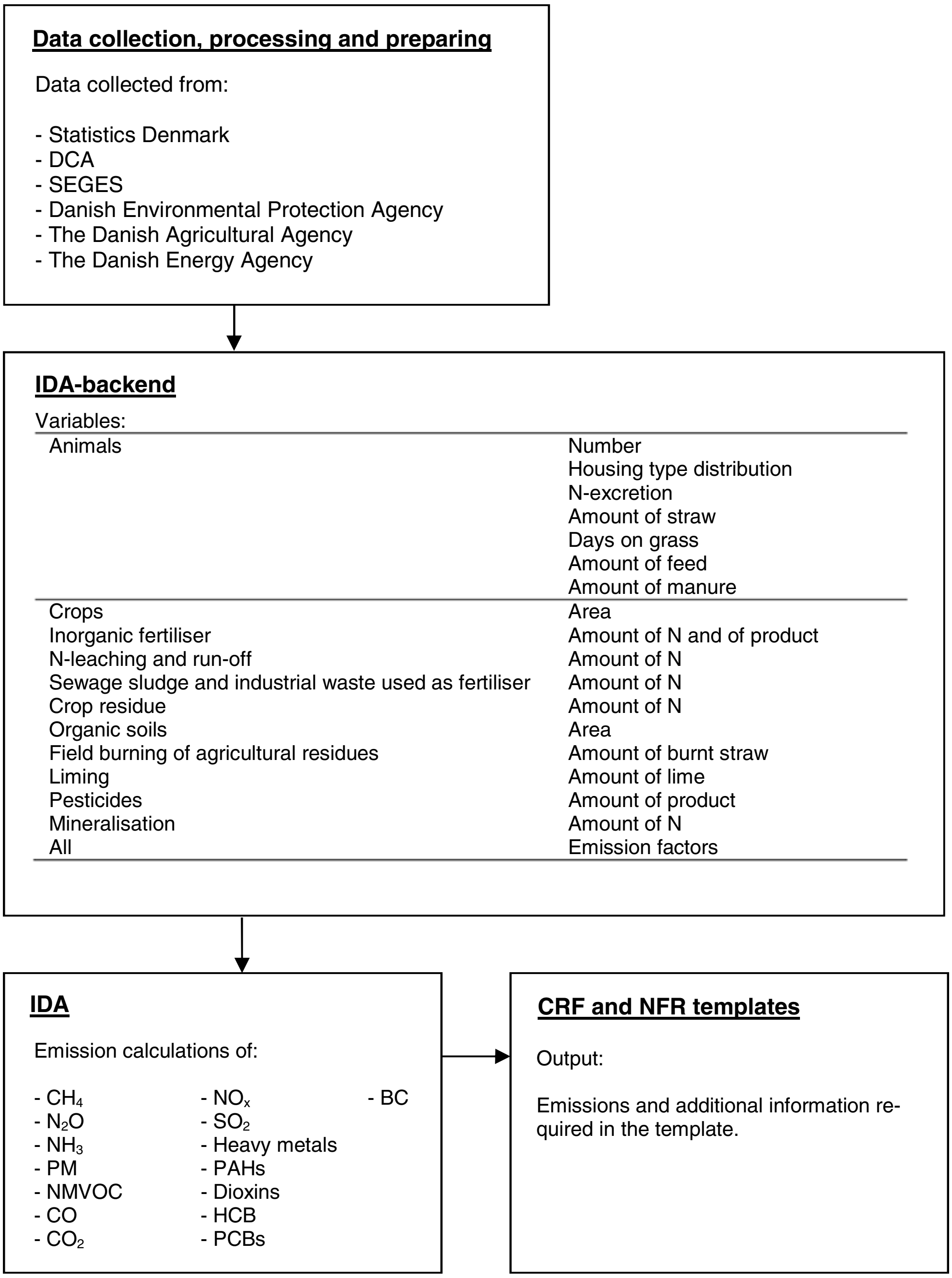



Figure 3.1 Overview of the data process for calculation of agricultural emissions.

# 4 Livestock population data

The livestock production is the main source of the agricultural emissions of the $NH_3$ emission and $CH_4$ 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 animals |
| NMVOC, $NO_x$, PM | - Housing type/manure type |
| | - Days in housing and on pasture |
| $NH_3$, $N_2O$ | - N-excretion (depends on feed intake) |
| $NH_3$, $N_2O$ | - 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 D for numbers of livestock 1985-2015 given in annual average population (AAP), definition in the EMEP/EEA Guidebook (EMEP, 2013).

Only farms larger than five hectares are included in the annual census from Statistics Denmark. Especially horses, goats and sheep are placed on small farms, which mean that the number of animals given in the Agricultural Statistics is not representative. Therefore, the number of horses is based on estimations made by SEGES and the number of sheep and goats is based on the Central Husbandry Register (CHR), which is the central register of farms and animals managed by the Ministry of Environment and Food of Denmark. From 2010, the annual census includes farms with more than 20 goats and sheep, but the CHR is considered as more reliable because the register include all animals regardless of farm size.

The inventories furthermore includes emissions from deer, ostrich and pheasants, but these animal categories 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 expert judgement by the pheasant breeding association (Stenkjær, 2009, Pers. Comm.).

The normative figures for feed intake and N-excretion are for some livestock categories, e.g. dairy cattle, heifers (2003-2015) 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, 2013). For other livestock categories such as heifers (1985-2002), bull calves, bulls, weaners, fattening pigs and pullets, the normative figures are given per animal produced.

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

### 4.1.1 Cattle

Cattle are divided into six main categories dairy cattle**,** bull calves, heifer calves, bulls more than six months destined for slaughter, heifers more than six months to be used for breeding purposes, and suckling cattle. For all categories except for suckling cattle, a distinction is made between large breeds and Jersey cattle (Table 4.2). Suckling cattle are divided in tree groups, based on weight. 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 SEGES, and are based on registrations from annual yield controls covering approximately 90 % of dairy cattle.

Table 4.2 Proportion of Jersey cattle (%)[1].

| Main categories of cattle | 2001 | 2005 | 2010 | 2015 |
|---|---|---|---|---|
| Dairy cattle | 12.2 | 12.5 | 13.1 | 14.4 |
| Heifer calves, 0 - 6 months | 9.4 | 9.4 | 10.1 | 10.6 |
| Heifers, 6 months to calving | 8.5 | 8.6 | 9.3 | 9.4 |
| Bull calves, 0-6 months | 4.2 | 4.0 | 2.7 | 2.2 |
| Bulls, 6 months to slaughter age | 6.6 | 6.2 | 3.8 | 3.6 |
| Suckling cattle | Weight; <400 kg, 400-600 kg and >600 kg | | | |

[1] Source: Flagstad, 2016, Pers. Comm..

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.

From 2003, the number of heifers per year is calculated as:

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

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

Example for 2015 heifer calves (< ½ year):

$no_L = 158\,774 \cdot (1 - 0.106) = 141\,944$

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 DCA represent feed intake and N-excretion per animal produced, therefore the emission calculation has been based on the number of animals produced.

The production of both bulls and bull calves is based on data on slaughter provided by DSt. Animals discarded during the slaughtering process is taken into account.

Number of total bulls and bull calves produced

For the calculation of bulls > 6 months is the number of slaughtered young bulls, bulls, steers and discard cattle given by DSt.

Number of bulls produced per year:

$$no_{bulls} = no_{y\,b} + no_b + no_s + no_{dis} \quad \text{(Eq. 4.2)}$$

where:

| | |
|---|---|
| $no_{bulls}$ | = number of bulls |
| $no_{y\,b}$ | = number of slaughtered young bulls |
| $no_b$ | = number of slaughtered bulls |
| $no_s$ | = number of slaughtered steers |
| $no_{dis}$ | = number of discarded cattle |

Number of bull calves < 6 months is calculated based on the number of bulls and number of veal calves given by DSt:

$$no_{bull\ calves} = no_{bulls} + no_{v\,c} \quad \text{(Eq. 4.3)}$$

where:

| | |
|---|---|
| $no_{bull\ calves}$ | = number of bull calves |
| $no_{bulls}$ | = number of bulls |
| $no_{v\,c}$ | = number of veal calves |

Example from 2015:

$$no_{bulls} = 56\,600 + 158\,600 + 7\,400 + 2\,020 = 224\,620$$

$$no_{bull\ calves} = 224\,620 + 5\,900 = 230\,520$$

### 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. The fraction of suckling cattle is 14.0 % in 2015.

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 4.4:

$$\mathrm{Frac} = \mathrm{no}_{\mathrm{S,\,DSt}} / (\mathrm{no}_{\mathrm{D,\,DSt}} + \mathrm{no}_{\mathrm{S,\,DSt}}) \qquad \text{(Eq. 4.4)}$$

where:
Frac = fraction of suckling cattle
$\mathrm{no}_{\mathrm{S,\,DSt}}$ = number of suckling cattle given by DSt
$\mathrm{no}_{\mathrm{D,\,DSt}}$ = number of dairy cattle given by DSt

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

Equation 4.5 a) and b):

a) $$\mathrm{no}_{\mathrm{B,\,L}} = (\mathrm{no}_{\mathrm{B}} - \mathrm{no}_{\mathrm{B}} \cdot \mathrm{Frac}) \cdot (1 - \mathrm{J}) + (\mathrm{no}_{\mathrm{B}} \cdot \mathrm{Frac}) \qquad \text{(Eq. 4.5a)}$$

b) $$\mathrm{no}_{\mathrm{B,\,J}} = (\mathrm{no}_{\mathrm{B}} - \mathrm{no}_{\mathrm{B}} \cdot \mathrm{Frac}) \cdot \mathrm{J} \qquad \text{(Eq. 4.5b)}$$

where:
$\mathrm{no}_{\mathrm{B,\,L}}$ = number of bulls produced, large breed
$\mathrm{no}_{\mathrm{B}}$ = number of bulls produced
$\mathrm{no}_{\mathrm{B,\,J}}$ = number of breed bulls produced, Jersey
Frac = fraction of suckling cattle
J = % of Jersey bulls

Calculation example for 2015:

Table 4.3 Number of bulls, 2015.

| | No. of animals, DSt | No. of animals produced | Fraction of suckling cattle | No. of bulls produced | |
|---|---|---|---|---|---|
| | | | | Large breed | Jersey |
| Bull calves < ½ year | 122 311 | 230 520 | 0,140 | 226 157 | 4 363 |
| Bulls > ½ year | 126 653 | 224 620 | 0,140 | 217 664 | 6 956 |

#### Suckling cattle

The number for suckling cattle is provided by DSt.

### 4.1.2 Swine

There are three different main swine categories: sows (including piglets up to 7 kg), weaners (7 to 31 kg) and fattening pigs (31 to 110 kg).

#### Sows

The number of 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. Discarded animals during the slaughtering process and export of live animals are taken into account. The calculated emission from weaners and fattening pigs also include the emission related to breeding of boars and slaughtered and discarded sows.

The number of fattening pigs is based on the total meat production divided with an average slaughter weight based on the normative figures, which in 2015 was reported as 84 kg (Poulsen, 2016).

Number of fattening pigs produced:

$$no = \left(\frac{AM}{AS}\right) + Ex \qquad \text{(Eq. 4.6)}$$

where:

no = number of fattening pigs
AM = amount of meat produced, kg
AS = average slaughter weight, kg
Ex = export of live fattening pigs and animals for breeding, number

Example from 2015:

$$no_{fattening} = \left(\frac{1\ 627\ M\ kg}{84\ kg}\right) + 489\ 000 = 19\ 861\ 000 \cong 19.9\ million$$

The number of weaners is calculated as the number of fattening pigs plus the number of exported live weaners, which has increased significantly in the last ten years from 1.1 million in 2001 to 11.6 million in 2015.

Number of weaners produced:

$$no = no_{fattening} + no_{exported} \quad \text{(Eq. 4.7)}$$

where:

$no$ = number of weaners, weight 7-31 kg
$no_{fattening}$ = total number of produced fattening pigs
$no_{exported}$ = number of exported living weaners

Example for 2015:

$$no_{weaners} = 19.8\,million + 11.6\,million = 31.5\,million$$

The normative feed intake and excretion values for fattening pigs are in 2015 based on a 110 kg live weight, equivalent to 84 kg slaughter weight (Poulsen, 2016). Slaughtering data are as mentioned based on Statistics Denmark. Information on discarded animals is based on data from SEGES, which is a cooperative owned by 16 members and these members represent most of the Danish meat industry. In 2015, the total meat production is estimated at 1 627 million kg meat and the number of living animals exported are 12.1 million (Table 4.4).

Table 4.4 Background data for estimating number of produced fattening pigs and weaners, 2015.

| | |
|---|---|
| **Fattening pigs to slaughter (million kg meat)** | |
| Delivered to slaughterhouse | 1 565 |
| Slaughtered for the producer at slaughterhouse | 0 |
| Slaughtered at home | 2 |
| Discarded at slaughterhouse | 3 |
| **Sow unit (million kg meat)** | |
| Gilt to slaughter | 0 |
| Boars | 2 |
| Sows | 45 |
| Discarded sows at slaughterhouse | 10 |
| Total meat production from pigs, million kg meat | 1 627 |
| **Export of living animals (1 000 s)** | |
| Fattening pigs and animals for breeding | 489 |
| Weaners | 11 644 |
| **No of produced animal (1 000 s)** | |
| No. of produced fattening pigs | 19 861 |
| No. of produced weaners | 31 505 |

Table 4.5 shows the number of swine other than sows reported by DSt, compared to the calculated number of weaners and fattening pigs produced per year. The number of animals given by DSt represents the number given in AAP, while the emission calculations are based on number of produced swine.

Table 4.5 Number of weaners and fattening pigs, 2015.

| | No. of animal, DSt, 1 000 unit | No. of produced swine, 1 000 unit |
|---|---|---|
| Swine (other than sows) | 11 506 | |
| Fattening pigs (31-110 kg) | | 19 861 |
| Weaners (7-31 kg) | | 31 505 |

### 4.1.3 Poultry

For poultry, there are four main categories: laying hens, broilers, turkeys and other poultry (geese, ducks, pheasants and ostrich). In the following, an estimation of the numbers of animals is described.

#### 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). The category distinguishes between six main production forms for hens: free-range, organic, barn, battery, aviary as well as production of hens for brooding. The distribution between the different production forms is based on data from DSt, see Table 4.6.

#### Hens

The number of laying hens is based on the egg production. The production of eggs divided on production forms are given by DSt and the production of eggs per hen is given in the normative figures (Poulsen, 2016). The number of hens within each category is calculated as follows:

$$no_i = \frac{(a_i + a_h \cdot P_i/100) \cdot 1000\,000}{Y_i} \qquad \text{(Eq. 4.8)}$$

where:

$no_i$ = number of hens within the production form *i*

$a_i$ = amount of eggs produced for sale in the production form *i*, in million kg (DSt)

$a_h$ = amount of eggs produced for home sale, in million kg (DSt)

P = % share of the production form *i* (DSt)

$Y_i$ = production of eggs per hen per year within the production form *i*, in kg (Poulsen, 2016)

Below is an example of calculation of the number of free-range hens in 2015 (100 unit):

$$no_{free-range} = \frac{(4 + 8 \cdot 6.35/100) \cdot 1000\,000}{19} / 100 = 2\,373$$

Calculations of number of hens for brooding do not include eggs produced for home sale.

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 2015, 100 unit.

| | No of hens, 100 unit | %. distribution on production forms | Number of hens, 100 unit |
|---|---|---|---|
| Hens - total | 45 947 | | |
| - of which egg layers for brooding | 10 000 | | 10 000 |
| - of which egg layers | 35 947 | | |
| Free-range | | 7 | 2 373 |
| Organic | | 24 | 8 805 |
| Barn | | 21 | 7 475 |
| Battery, manure house | | 41 | 14 874 |
| Battery, manure tank | | 3 | 1 159 |
| Battery, manure cellar | | 4 | 1 263 |

**Pullets**

The normative figure for pullets is based on the production of 100 pullets. The production time for pullets is 118 days or 119 days (Poulsen, 2016), which corresponds to approximately three production cycles during the year (365 / 118 = 3.1). Annual production is determined using the population figure provided by DSt (chicken for breeding) multiplied by the number of production cycles.

The total number of pullets produced per 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 from 1985 to 2004 based on information from the Danish Agriculture & Food Council (Jensen, 2008, Pers. Comm.) and from 2005 based on information from DAA – see Table 4.7.

**Calculation of the total number of pullets produced per year:**

$$no_{pu} = no_{DSt} \cdot \frac{365}{T} \cdot \left(\frac{P}{100}\right) \qquad \text{(Eq. 4.9)}$$

where:

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

$no_{DSt}$ = number of pullets given by DSt

T = production time, days

P = % distribution of the production form

Below is, as an example, the calculation of the number of pullets produced for consumption, net production (100 unit), for 2015:

$$no_{pu} = 10\ 232 \cdot \frac{365}{118} \cdot \left(\frac{18.3}{100}\right) = 5\ 792$$

Table 4.7 Calculation of the number of pullets produced in 2015,100 unit.

| | No. of pullets given in DSt 100 unit | Distribution on production forms | Production time | Production runs per year | No. of pullets produced per year 100 unit |
|---|---|---|---|---|---|
| | | % | days | | |
| Pullets - total (population DSt) | 10 232 | 100 | | | |
| Consumption, floor | | 43 | 118 | 3.093 | 13 482 |
| Consumption, net | | 18 | 118 | 3.093 | 5 792 |
| Egg brooding, floor | | 39 | 119 | 3.067 | 12 271 |
| Number of pullets produced | | | | | 31 544 |

**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 and farmers' private consumption of animals are also taken into account and data is obtained from DSt.

Calculation method to estimate poultry production:

$$no_{po} = no_{DS} + no_{PC} + no_E \qquad \text{(Eq. 4.10)}$$

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 2015 (in 1 000 unit):

$$no_{po} = 95\ 681 + 500 + 18\ 556 = 114\ 738$$

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, 2015.

| | No. of animal, DSt, 1 000 unit | No. of produced animals 1 000 unit |
|---|---|---|
| Broilers | 11122 | 114 738 |
| Turkeys | 251 | 5 985 |
| Ducks | 248 | 415 |
| Geese | 7 | 19 |

**Pheasants and ostriches**

DSt has no data on the number of pheasants and ostriches produced. The number of pheasants is based on expert judgement by the pheasant breeding association (Stenkjær, 2009, Pers. Comm.) and is estimated at 1 062 500 in each of the years 1985-2015. Pheasants bred for hunting are estimated as unaltered in the period. The number of ostriches is based on information obtained from the Central Husbandry Register (CHR), which is the central register for farm data of the Ministry of Environment and Food of Denmark, see Table 4.9. The production of ostrich in Denmark started in 1993 and no production of ostrich has taken place before 1993.

Table 4.9 Number of ostrich 1985 to 2015.

| | 1985 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ostrich | 0 | 3 333 | 8 889 | 3 661 | 358 | 191 | 176 | 151 | 96 | 91 |

### 4.1.4 Horses

The number of horses are split into four different weight classes: small ponies up to 300 kg, lighter breeds – 300-500 kg, medium-weight breeds – 500-700 kg and large breeds – more than 700 kg. SEGES 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 inventories is based on the horse breeding register managed by SEGES.

In 2015, 57 720 horses were listed by DSt, as opposed to 155 000 according to SEGES figures. SEGES has estimated the number of horses in 2000 to 150 000 and in 2008 to 190 000. The numbers in between are interpolated. Number of horses in 2009 to 2015 is based on a new judgement from SEGES, which shows a decrease in number of horses. Table 4.10 shows the number of horses registered by, respectively, DSt and SEGES.

Table 4.10 Number of horses 1985 to 2015 (1 000 unit).

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DSt[1] | 32 | 38 | 18 | 40 | 54 | 60 | 61 | 68 | 57 | 49 | 58 |
| SEGES[2] | 140 | 135 | 143 | 150 | 175 | 165 | 155 | 155 | 150 | 150 | 155 |

[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 goats are based on average annual breeding goats including kids, because this corresponds to the unit in the normative data. For sheep normative figures are provided for both sheep and lambs. It is expected that a number of sheep and goats are to be found on farms below five ha and thus the actual number is higher than reported by DSt. Therefore, data on the number of sheep and goats are based on the Central Husbandry Register (CHR).

The number of sheep has been divided in number of mother sheep and lamps. Number of mother sheep is based on numbers from CHR, while the number of lamps is the number of mother sheep multiplied by 1.5, because sheep on average give birth to 1.5 lambs per year.

Table 4.11 Number of mothersheep 1985-2015 (1 000 unit).

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mother sheep | | | | | | | | | | | |
| DSt[1] | 33 | 77 | 67 | 68 | 79 | 72 | 67 | 70 | 72 | 69 | 65 |
| CHR[2] | 40 | 92 | 81 | 112 | 126 | 111 | 94 | 90 | 88 | 88 | 84 |

[1] Agricultural units > 5 ha.

[2] 1985-1996 numbers from DSt multiplied by 1.2.

The production of deer is included in the Danish inventories and covers animals bred for meat on farms (in enclosures) and not deer in the wild. No data on the number of deer are 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, fit chew, foxes and finn racoon 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 determining 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 from 1985 to 2004 is based on expert judgement. For cattle and swine, the distribution is based on information from Rasmussen (2003, Pers. Comm.) and Lundgaard (2003, Pers. Comm.). The distribution of housing systems for fur animals is obtained from Risager (2003, Pers. Comm.). The housing distribution for poultry is determined on the basis of efficiency controls by the Danish Agriculture & Food Council (Jensen, 2008, Pers. Comm.). From 2005 onwards, the distribution of the different housing types is based on information from the Danish Agricultural Agency (DAA) on farm nitrogen budgets, which farmers, by law have to submit annually.

Appendix E presents the distribution of the different housing types for all livestock categories. Table 4.12 and Table 4.13 show the estimated distribution of housing types from 1985 to 2015 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 for dairy cattle, 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 2015 this has reduced to 7 %. 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 4.12 Dairy cattle distributed on main housing types, %.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tethered housing | 85 | 79 | 73 | 46 | 20 | 12 | 10 | 9 | 8 | 7 | 7 |
| Loose-housing with beds | 14 | 18 | 21 | 43 | 70 | 82 | 85 | 86 | 86 | 87 | 87 |
| Deep litter | 1 | 3 | 6 | 11 | 10 | 6 | 5 | 5 | 6 | 6 | 6 |

Table 4.13 Fattening pigs distributed on main housing types, %.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fully slatted floor | 29 | 50 | 58 | 54 | 53 | 54 | 53 | 52 | 46 | 44 | 40 |
| Partly slatted floor | 30 | 24 | 26 | 35 | 38 | 42 | 43 | 46 | 51 | 54 | 58 |
| Solid floor | 40 | 22 | 11 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 1 |
| Deep litter | 1 | 4 | 5 | 6 | 6 | 3 | 2 | 2 | 2 | 2 | 2 |

## 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 cattle is excreted directly onto the field during grazing in 2015, which translates to 18 days on pasture per year (Aaes, 2013, Pers. Comm.). The 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 4.14.

The number of grazing days for dairy cattle decreased in the period 2002-2007 and grazing days for heifers decreased from 1990-2007 due to the structural development towards larger farms (See Appendix F). A production with a large numbers of cattle makes it difficult to drive the animals to pasture because it is time consuming. From 2007 and forward the estimate for grazing days, for both the dairy cattle and heifers, are kept at the same level.

Table 4.14 Number of grazing days corresponding to the proportion of N in manure deposited on the field during grazing, 2015.

| | Grazing days |
|---|---|
| Cattle: | |
| Dairy Cattle | 18 |
| Calves and bulls | 0 |
| Heifers | 132 |
| Suckling Cattle | 224 |
| Swine: | |
| Sows, weaners and fattening pigs | 0 |
| Sows, outdoor | 365 |
| Poultry: | |
| Hens, pullets, broilers, turkeys, ducks and ostrich | 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 2015. The emission from manure management contributes 52 % and manure applied to soils 28 % of the total $NH_3$ emission. The emissions from cultivated crops and inorganic N-fertilisers contribute 8 % and 9 %, 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. Description of trend 1985 – 2015 see also Chapter 2.1.1. Appendix A shows the $NH_3$ emissions from all sources for the period 1985 – 2015.

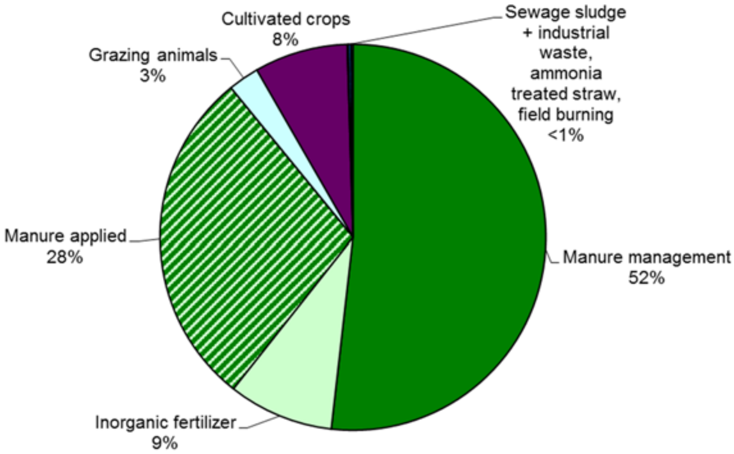



Figure 5.1 $NH_3$ emissions distributed on sources, 2015.

## 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, are found in the urine. Previously, the emission calculation was 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 measures such as improvements in feed intake and composition in the emission inventories, it is necessary to calculate the emission based on the Total Ammonia 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. While for solid manure and deep litter, the emission factors given in the normative figures are based on total N, and therefore the $NH_3$ emission from solid manure and deep litter is based on total N.

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

Acidification of the manure reduces the $NH_3$ emission. Reduction of $NH_3$ emission due to acidification of manure in the housings has been included in the inventories for dairy cattle and fattening pigs for the years 2012-2015.

### 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:

$$AM_t = AM_h + AM_s + AM_{ap} + A_g \qquad \text{(Eq. 5.1)}$$

where:

| | |
|---|---|
| $AM_t$ | = total ammonia emission, kg |
| $AM_h$ | = emission from manure in livestock housing, kg |
| $AM_s$ | = emission from manure storage, kg |
| $AM_{ap}$ | = emission from manure application to fields, kg |
| $AM_g$ | = emission from manure deposited by animals on grass, kg |

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

$$\text{a) } AM_h = \left(no \cdot Nex_a \cdot \left(1 - \frac{D_g}{365}\right) \cdot EF_h\right) - reduc. \qquad \text{(Eq. 5.2a)}$$

$$\text{b) } AM_s = \left(no \cdot Nex_h \cdot \left(1 - \frac{D_g}{365}\right) + reduc.\right) \cdot EF_s \qquad \text{(Eq. 5.2b)}$$

$$\text{c) } AM_{ap} = \left(no \cdot Nex_s \cdot \left(1 - \frac{D_g}{365}\right) + reduc.\right) \cdot EF_{ap} \qquad \text{(Eq. 5.2c)}$$

$$\text{d) } AM_g = no \cdot Nex_a \cdot \left(\frac{D_g}{365}\right) \cdot EF_g \qquad \text{(Eq. 5.2d)}$$

where:

| | |
|---|---|
| no | = number of animals |
| $Nex_a$ | = N excretion from animals, kg per head per year |
| $Nex_h$ | = N excretion in housing unit, kg per head per year |
| $Nex_s$ | = N excretion in storage unit, kg per head per year |
| $D_g$ | = days on grass during the year (see Table 4.14) |
| EF | = emission factor for the given unit (housing, storage, application or grass), % $NH_3$-N of N excreted |
| Reduc. | = amount of $NH_3$-N emission reduced due to acidification, kg $NH_3$-N |

The amount of N reduced in the emission from housings is added to the amount of N excretion used to calculated emission from storage and application because when the N is not evaporated as $NH_3$ in the housing it will stay in the manure.

The amount $NH_3$-N reduced is calculated as:

$$\text{Reduc.} = M \cdot RF \cdot N \qquad \text{(Eq. 5.3)}$$

Where:

| | |
|---|---|
| Reduc. | = amount of $NH_3$-N emission reduced due to acidification, kg $NH_3$-N |
| M | = amount of manure acidified (SEGES, 2015, Pers. Comm.), kg |
| RF | = reduction factor, % (MST, 2016) |
| N | = amount of kg $NH_3$-N per kg manure |

Table 5.1 Amount of manure acidified and reduction factor, 2012-2015

| | RE, % | Amount of manure, kt | | | |
|---|---|---|---|---|---|
| | | 2012 | 2013 | 2014 | 2015 |
| Cattle | 50 | 437 | 550 | 600 | 600 |
| Swine | 65 | 437 | 550 | 600 | 600 |

[1] Same for all years

The emission calculation for fattening pigs in 2015 housed on fully slatted flooring is shown below as an example, based on normative figures and emission factors given in Table 5.2. In 2015, 19.9 million fattening pigs were produced (Table 4.5). Of these, 40 % are housed for 365 days a year in housing systems with fully slatted floor.

Table 5.2 Normative figures and emission factors for one produced fattening pigs in 2015 (DCA).

| Normative figures, kg N per produced animal | | | Emission factors, EF, %. $NH_3$-N of TAN | | |
|---|---|---|---|---|---|
| TAN ex animal | TAN ex housing | TAN ex storage | Housing unit | Storage | Application |
| 1.90 | 1.44 | 1.80 | 24 | 2.9 | 10.77 (slurry) |

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

$$AM_h = (19\,861\,372 \cdot 0.398) \cdot \frac{1.90}{1000} \cdot \left(1 - \frac{0}{365}\right) \cdot \frac{24}{100} - 363 = 3\,242\ tonnes\ NH_3 - N$$

$$AM_s = \left((19\,861\,372 \cdot 0.368) \cdot \frac{1.44}{1000} \cdot \left(1 - \frac{0}{365}\right) + 363\right) \cdot \frac{2.9}{100} = 341\ tonnes\ NH_3 - N$$

$$AM_{ap} = \left((19\,861\,372 \cdot 0.398) \cdot \frac{1.80}{1000} \cdot \left(1 - \frac{0}{365}\right) + 363\right) \cdot \frac{10.77}{100} = 1\,572\ tonnes\ NH_3 - N$$

$$AM_{total} = 3\,242 + 341 + 1\,572 = 5\,154\ tonnes\ NH_3 - N = 6\,258\ tonnes\ NH_3$$

N-excretion and emissions given in $NH_3$-N for all main livestock categories are shown in Appendix G.

### 5.1.3 Normative figures for nitrogen in animal manure

The normative values for nitrogen excretion are estimated by DCA based on research results (Laursen, 1994; Poulsen & Kristensen, 1997; Poulsen et al., 2001; Poulsen, 2016). The normative figures are, since 2002, adjusted annually to take into account the changes in feed composition and feed use efficiency. Values for N ex animal are provided in Appendix H for the most important livestock categories and in Appendix I based on TAN for 2007 to 2015.

For heifers, a change in methodology has taken place. From 1985 to 2002 the normative figures for N ex were provided for each produced animal. This has changed from 2003, where the N ex covers N ex per AAP (annual average population – see definition in section 4.1). For animal categories for which N ex is based on produced animal, this is noticed as a footnote in Appendix H and I.

Appendix G shows the total N excretion for the different main livestock categories from 1985 to 2015 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, Kai et al. 2016). In Appendix J is listed emission factor for housing for all other livestock categories.

Table 5.3 $NH_3$ emission factors for housing units for cattle.

| Cattle | | Urine | Slurry | Solid manure | Deep litter manure |
|---|---|---|---|---|---|
| | | TAN | TAN | Total N | Total N |
| Housing type | | %. loss of TAN ex animal | | %. 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 | - | - |

#### 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, 2016).

Table 5.4 $NH_3$ emission factors for storage units.

| | | | Urine | Slurry[1] | Solid manure | Deep litter | %. of solid manure stored in heap on field |
|---|---|---|---|---|---|---|---|
| Cattle | | Total N | 2 | 2.1 | 4 | 1 | 35 |
| | | TAN | 2.2 | 3.5 | - | - | - |
| Swine | 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 | Total N | - | - | - | 8 | - |
| | Ducks and geese | Total N | - | - | - | 6.8 | - |
| Fur animals | | Total N | 0 | 3.1 | 11.5 | - | - |
| | | TAN | 0 | 3.1 | - | - | - |
| Horses, sheep and goats | | Total N | - | - | - | 4 | - |

[1] It is assumed that 5 % of slurry tanks in swine 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 K).

### 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.

Due to legislation from 2003, all slurry tanks must be fully covered or established with a floating layer as cover. As not all slurry tanks have a fixed cover or a full floating cover, this is taken into account in the inventories (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. However, as it is difficult to achieve a full floating cover every day of the year, some emission can take place during filling and mixing of manure in the tank. Therefore, it is assumed that floating / fixed covers are missing on 5 % of slurry tanks in swine 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 swine 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 swine, cattle and fur slurry are shown in Equation 5.4.

$$\text{a) Emission}_{\text{swine slury}} = (0.95 \cdot 2.5\%) + (0.05 \cdot 11.4\%) = 2.9\% \qquad \text{(Eq. 5.4a)}$$

$$\text{b) Emission}_{\text{cattle slurry}} = (0.98 \cdot 3.4\%) + (0.02 \cdot 10.3\%) = 3.5\% \qquad \text{(Eq. 5.4b)}$$

$$\text{c) Emission}_{\text{fur slurry}} = (0.98 \cdot 2.9\%) + (0.02 \cdot 12.9\%) = 3.1\% \qquad \text{(Eq. 5.4c)}$$

The emission factors for 2015 for swine (corrected), cattle (corrected) and fur animals are 2.9 %, 3.5 % and 3.1 %, respectively. Emission factors for storage of manure for all years are shown in Appendix K.

### Solid manure

The emission 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. In the inventories, it is assumed that 50 % of the manure heaps are covered. A calculation example of the correction for swine manure is shown in Equation 5.5, where emission factors with and without cover is 13 % and 25 % of total-N ex housing unit (Poulsen et al, 2008). The same correction is made for all animal categories.

$$\text{Emission}_{\text{swine solid manure}} = (0.5 \cdot 25\%) + (0.5 \cdot 13\%) = 19\% \qquad \text{(Eq. 5.5)}$$

Emission factors for cattle, swine, 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 L.

The emission from deep litter bedding is based on normative figures (Poulsen et al., 2008). 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, 2008), 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, 2016). The emission factors are estimated based on measurements in Danish cattle and swine housing units. The factors for the remaining livestock categories are not measured directly; however, they are estimated relative to the denitrification from cattle and swine 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 % of total N ex housing unit | |
|---|---|---|
| | Solid manure | Deep litter |
| Cattle | 10 | 5 |
| Swine | 15 | 15 |
| Poultry | 10 | 10 |
| Horses, sheep and goats | - | 10 |

## Field application of manure

Over time, a change in practice of manure application has taken place, which is a result of changes in crop pattern and increasing environmental demands. A rise in growing of winter cereals has led 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 should also be mentioned. 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. From 2011, slurry applied on fields with grass for feeding or fields without crop cover must be injected directly into the soil (BEK, 2013). However, the injection can be substituted by acidification of the slurry. Acidification reduces the pH value and thus reduces ammonia emission, because a larger part of the nitrogen is converted to ammonium, which does not evaporate as easily as ammonia. To calculate the emission from application of manure to agricultural land, four different weighted emission factors are used; liquid and solid manure from swine and cattle, respectively. For all other livestock categories is used same weighted emission factor as for cattle manure.

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 for both cattle- and swine slurry has decreased. For cattle slurry, the emission factor is lowered from 33.0 % in 1985 to 12.7 % in 2015, corresponding to a 62 % reduction due to approximately two thirds of the slurry now being injected / incorporated directly into the soil and the use of acidification of the manure. The weighted emission factor for solid manure has also decreased because the manure applied on bar soil have to be plough down into the soil, which lower the $NH_3$ emission.

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 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liquid manure | Cattle[1] | 33.0 | 34.3 | 30.3 | 27.2 | 14.1 | 14.3 | 13.1 | 13.2 | 12.9 | 12.7 | 12.7 |
| | Swine | 17.3 | 17.9 | 15.3 | 13.8 | 11.1 | 11.0 | 10.8 | 10.8 | 10.8 | 10.8 | 10.8 |
| Solid manure | Cattle[1] | 9.6 | 7.9 | 7.5 | 6.8 | 6.7 | 6.4 | 6.7 | 6.7 | 6.7 | 6.7 | 6.7 |
| | Swine | 9.6 | 7.9 | 7.5 | 6.8 | 6.7 | 6.4 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |

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

### Calculation of the weighted emission factor

The weighted emission factor is calculated for each year and in two stages. $EF_w$ is calculated first 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.

$$EF_w = \sum MA_i \cdot EF_i \quad \text{(Eq. 5.6)}$$

where:

$EF_w$ = weighted emission factor, kg $NH_3$-N per kg N per year

$MA_i$ = nitrogen in manure applied under a given application practice $i$, kg N per year

$EF_i$ = emission factor for the application practice $i$, kg $NH_3$-N per kg N per year

Secondly $EF_{wt}$ is calculated which includes emission reducing technology, such as acidification of manure in connection with application.

$$EF_{wt} = p_t \cdot (EF_w - EF_t) \qquad \text{(Eq. 5.7)}$$

Where:

$EF_{wt}$ = weighted emission factor including technology, kg $NH_3$-N per kg N per year

$p_t$ = % of the manure treated by the technology *t*

$EF_w$ = weighted emission factor by application practice, kg $NH_3$-N per kg N per year

$EF_t$ = emission factor for manure treated by the technology *t*, kg $NH_3$-N per kg N per year

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.

### Application time

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

### Application method

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

### Length of time between application to land and incorporation of manure

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

### Stage of crop growth

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 (catchments included in the national monitoring program for the aquatic environment) (Andersen et al., 2001).

The estimate for application practice in 2001 and 2002 is, in addition to data from LOOP areas (Grant et al., 2002; Grant et al., 2003), based on information from the organisation for agricultural contractors (Kjeldal, 2002, Pers. Comm.) 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 judgement (Birkmose, 2016, Pers. Comm.).

The assumed application practice for the years 1985 – 2015 is shown in Appendix M.

### Emission factor

The emission factor used for each combination of application practice (Equation 5.6) is based on information from Hansen et al. (2008), see Table 5.7.

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 to 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, the leaves themselves will absorb a proportion of the $NH_3$ in gaseous form.

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, Pers. Comm.).

Table 5.7 Emission factors for application of cattle manure.

| | | Emission factor under application | | | |
|---|---|---|---|---|---|
| | | **Liquid manure** | | | |
| Crop stage[a] | Application time | Injected/incorporated direct | | Trailing hoses | |
| | | Hours[b] | $NH_3$-N in %. of TAN in manure | Hours[b] | $NH_3$-N in %. of TAN in manure |
| - | March | 0 | 1.6 | 4 | 10.7 |
| - | April | 0 | 1.8 | 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 | 26.0 |
| + | 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 | |
| | | Hours[b] | $NH_3$-N in %. of TAN in manure | Hours[b] | $NH_3$-N in %. 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] -: indicate bare soil, +: indicate growth.

[b] 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 during grazing (See chapter 4.3 and Appendix F).

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 Inorganic N-fertilisers

Data on the use of inorganic N fertiliser is based on the sale estimations collected by DAA (2016). Emission factors are based on the values given in EMEP / EEA Guidebook (EMEP, 2016).

The emission from inorganic N-fertilisers depends on type as well as amount used. Data for consumption 1985-2015 (Table 5.8) and fertiliser type and nitrogen content for 2015 (Table 5.9) is obtained from the DAA (2016), which is based on the total sale from all fertiliser suppliers.

Table 5.8 Inorganic N-fertiliser consumption 1985 – 2015, kt N.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Used in agriculture | 392 | 395 | 310 | 246 | 204 | 188 | 195 | 185 | 192 | 185 | 201 |

Emission factors for the various fertiliser types are based on the recommendations in the EMEP / EEA Guidebook (EMEP, 2016), see Table 5.9. The same emission factors are applied for all years.

Table 5.9 Consumption and emission factors used for inorganic N-fertiliser, 2015.

| | Emission factor, % of N in fertiliser | Consumption, kt N |
|---|---|---|
| Fertiliser type: | | |
| Calcium nitrate + boron | 5.0 | 0.2 |
| Ammonium sulphate | 9.0 | 7.0 |
| Calcium ammonium nitrate and other nitrate types | 0.8 | 98.7 |
| Ammonium nitrate | 1.5 | 3.7 |
| Liquid ammonia | 1.9 | 5.9 |
| Urea | 15.5 | 0.9 |
| Other single fertilisers | 1.0 | 24.4 |
| Magnesium fertiliser | 5.0 | 0.0 |
| NPK fertiliser | 5.0 | 54.4 |
| Diammonium phosphate (18-20-0) | 5.0 | 0.3 |
| Other NP fertilisers | 5.0 | 5.4 |
| NK fertilisers | 1.5 | 2.5 |
| Total consumption of fertiliser | | 203[1] |
| Emission factor - weighted average | 2.5 | |

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

Since 1985, there has been a significant decrease in the use of inorganic N-fertiliser (Table 5.8). This is mainly due to stricter requirements to the utilisation of nitrogen in manure and requirements to handling of manure applied to the soil. Also, changes in the distribution of the different types of fertiliser decreases the emission. Use of urea, which has a high emission factor, has decreased and contributes today less than 1 % of the total nitrogen used as fertiliser. In average 2.5 % of the total nitrogen used in inorganic N fertiliser is emitted as $NH_3$ in 2015.

Table 5.10 $NH_3$-N emission from inorganic N fertilisers and IEF (implied emission factor), 1985 – 2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| tonnes $NH_3$-N | 15 085 | 13 351 | 9 712 | 6 634 | 5 367 | 4 539 | 4 583 | 4 347 | 4 600 | 4 644 | 5 021 |
| IEF, % | 3.8 | 3.3 | 3.1 | 2.6 | 2.6 | 2.4 | 2.3 | 2.3 | 2.4 | 2.5 | 2.5 |

## 5.3 Crops

Plants exchange $NH_3$ with the atmosphere 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. A study from Schjoerring and Mattsson (2001) indicate an emission of up to 5 kg $NH_3$-N per hectare. Based on a literature view the emission from growing crops is estimated to 2 kg N per ha for crops in rotation and 0.5 kg per ha for grass and clover. Despite uncertainties related to the use of these emission factors, the emission from growing crops is included in the Danish emission inventories, because otherwise the total $NH_3$ emission considered to be underestimated. The size of the cultivated area is based on information from Statistics Denmark.

Table 5.11 Emission factor used for crops, kg N per ha.

| | |
|---|---|
| All crops ex grass | 2 |
| Grass/clover in a rotation | 0.5 |
| Permanent/long-term grass | 0.5 |

From 1985 to 2015 the $NH_3$ emission from growing crops has decreased from approximately 4 900 to 4 400 tonnes of $NH_3$-N corresponding to a reduction of 10 %, which is due to a decrease in the area with crops.

## 5.4 Sewage sludge

Some of the sludge from wastewater treatment and the manufacturing industry is applied as fertiliser to agricultural soil. Information on the amount of sewage sludge applied is obtained from reports prepared by the Danish Environmental Protection Agency, where the latest one is DEPA (2009). From 2005 and onwards the amount of N applied from wastewater treatment is based on the fertiliser accounts controlled by DAA. Farmers with more than 10 animal units[1] have to be registered and have to keep accounts of the N content in manure, received manure or other organic fertiliser.

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. 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,

[1] A Danish animal unit is defined as 100 kg Nex Storage from an average housing system. This corresponds to e.g. 0.75 large breed dairy cattle or 36 fattening pigs.

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.

$$EF_{sewage\ sludge} = 0.25 \cdot 0.03 + 0.75 \cdot 0.015 = 0.019\ NH_3 - N\ applied$$

Table 5.12 shows an increasing amount of sewage sludge being applied to agricultural soil from 1985 to the mid-1990s, which is replaced by a decrease until 2008 due to use of the product in industrial processes, e.g. in cement production and the production of sandblasting materials. From 2008 and forward, the amount of applied sewage sludge on agricultural soils is stabilised at the same level.

Table 5.12 Emission from sewage sludge applied to agricultural land 1985-2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sewage sludge applied to agricultural soil, kt dry matter | 50 | 78 | 112 | 84 | 46 | 57 | 55 | 52 | 52 | 54 | 58 |
| N content, %. | 4.0 | 4.0 | 4.1 | 4.3 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 |
| N applied to agricultural soil, tonnes $NH_3$-N | 2 000 | 3 115 | 4 635 | 3 625 | 2 173 | 2 692 | 2 592 | 2 470 | 2 457 | 2 554 | 2 768 |
| $NH_3$-N emission, tonnes $NH_3$-N | 38 | 58 | 87 | 68 | 41 | 50 | 49 | 46 | 46 | 48 | 52 |

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

The addition of $NH_3$ promotes the breakdown of straw, which increase the digestion processes. $NH_3$ treated straw is used as cattle feed. It is assumed that the sale of $NH_3$ in the second half of the year is used for the treatment of straw with $NH_3$ and the $NH_3$ sales are obtained from the suppliers. By law, the $NH_3$ treatment of straw was banned in 2006. However, due to wet weather conditions, a dispensation to the law can be given in affected areas and dispensations are given in different areas every year from 2006 and forward. No statistics is provided for the dispensations and therefore the amount of $NH_3$ used for treatment of straw is assumed to be 200 tonnes $NH_3$ per year, which account for 10% of the average consumption in year 2000 – 2004.

The emission from ammonia treatment of straw is estimated to 65% kg $NH_3$-N per kg N added to straw. This estimate is based on few studies and depends on the dry matter content in straw and the storage conditions (Andersen et al., 1999). There is no statistics regarding how the farmers handle the ammonia treated straw in practice, so the emission factor is highly uncertain.

Table 5.13 shows that since 1985 there have been a considerable decrease in the emission from $NH_3$ treated straw until the ban in 2006.

Table 5.13 Emission from $NH_3$ treated straw, 1985-2015, tonnes $NH_3$-N.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumption of $NH_3$-N | 8 300 | 12 936 | 8 421 | 3 131 | 329 | 200 | 200 | 200 | 200 | 200 | 200 |
| Emission of $NH_3$-N | 5 395 | 8 408 | 5 474 | 2 035 | 214 | 130 | 130 | 130 | 130 | 130 | 130 |

# 6 PM emission

PM emissions originate from the livestock housing, from field operations and from field burning of agricultural residues. In the Danish inventories, PM from handling of crop products is not included as there is no default methodology provided in the EMEP/EEA Guidebook and no national activity data or emission factors are available.

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 70 % of the total TSP emission in 2015 and the emission shares for $PM_{10}$ and $PM_{2.5}$ are 27 % and 6% respectively. Most agricultural emissions originate from field operations, contributing with 89 % of the agricultural emission. Emissions from livestock production contribute with 11 % and the field burning of agricultural residues contribute less than 1 % to the agricultural emissions. A description of the calculation methodology is set out below. The calculation from field burning is described in Chapter 7.

## 6.1 Livestock production

The PM emissions from animal production include dust from housing systems. In 2015, these emissions, expressed as TSP, were estimated to 6.92 kt. Of this, 56 % relates to swine production. The emission from cattle and poultry contributed 20 % and 23 %, respectively.

Table 6.1 shows emission of PM from livestock production 1985 – 2015. See Appendix N for PM emission for all years distributed on the different animal categories. The emission of TSP and $PM_{10}$ increases from 1985 to 2005 and decreases from 2005 to 2015 mainly due to change in number of animals. The $PM_{2.5}$ emission decreases from 1985 to 2005 and from 2005 to 2015 is almost unaltered.

Table 6.1 PM emission from livestock 1985-2015, kt.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TSP | 6.83 | 6.65 | 7.14 | 7.17 | 7.23 | 7.22 | 7.21 | 7.04 | 7.00 | 6.97 | 6.92 |
| $PM_{10}$ | 2.48 | 2.38 | 2.54 | 2.61 | 2.56 | 2.55 | 2.52 | 2.48 | 2.45 | 2.42 | 2.37 |
| $PM_{2.5}$ | 0.81 | 0.71 | 0.66 | 0.63 | 0.53 | 0.56 | 0.55 | 0.57 | 0.56 | 0.55 | 0.54 |

### 6.1.1 Calculation method

The estimation of the PM emission is based on the EMEP/EEA Guidebook (EMEP, 2016). The PM emission is calculated using equation 6.1 and thus distinguishes between emission from liquid and solid manure.

$$PM_{10} = no \cdot (1 - \frac{D_G}{365}) \cdot (EF_{PM10_S} \cdot B_S + EF_{PM10_L} \cdot B_L) \qquad \text{(Eq. 6.1)}$$

where:

$PM_{10}$ = emission of $PM_{10}$, kg per year

no = number of average annual population (AAP – see definition in section 4.1)

$D_G$ = actual days on grass

$EF_{PM10,\ S\ or\ L}$ = emission factor for solid or liquid manure, kg per head per year

$B_{S\ or\ L}$ = % of solid or liquid manure

The main types of housing are 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 as negligible. Number of grazing days for 2015 is listed in Table 4.

### 6.1.2 Activity data

Calculation of PM from livestock is based on data for the number of animals, type housings and manure and days on grass.

### 6.1.3 Emission factors

The emission factors for $PM_{10}$ and $PM_{2.5}$ are those recommended in the EMEP/EEA Guidebook, (EMEP, 2016). The same emissions factors are used for all years.

Table 6.2 shows the emission factors for livestock. The emission factors are given for a range of livestock categories and separated into solid or slurry based systems.

Table 6.2 PM emission factors from animal housing systems, kg per AAP (defined in section 4.1).

| Livestock category | Manure type | Emission factor TSP | Emission factor $PM_{10}$ | Emission factor $PM_{2.5}$ |
|---|---|---|---|---|
| Cattle: | | | | |
| Dairy cattle | Slurry | 1.81 | 0.83 | 0.54 |
| | Solid | 0.94 | 0.43 | 0.28 |
| Calves < ½ year | Slurry | 0.34 | 0.15 | 0.10 |
| | Solid | 0.35 | 0.16 | 0.10 |
| Beef cattle | Slurry | 0.69 | 0.32 | 0.21 |
| | Solid | 0.52 | 0.24 | 0.16 |
| Heifers[1] | Slurry | 1.07 | 0.49 | 0.32 |
| | Solid | 0.64 | 0.30 | 0.19 |
| Suckling cattle[2] | Slurry | 0.69 | 0.32 | 0.21 |
| | Solid | 0.52 | 0.24 | 0.16 |
| Swine: | | | | |
| Sows | Slurry | 0.62 | 0.17 | 0.01 |
| | Solid | 0.62 | 0.17 | 0.01 |
| Weaners | Slurry | 0.27 | 0.05 | 0.002 |
| | Solid[3] | 0.27 | 0.05 | 0.002 |
| Fattening pigs | Slurry | 1.05 | 0.14 | 0.01 |
| | Solid | 1.05 | 0.14 | 0.01 |
| Poultry: | | | | |
| Laying hens | Solid | 0.19 | 0.04 | 0.003 |
| Broilers | Solid | 0.04 | 0.02 | 0.002 |
| Turkeys | Solid | 0.11 | 0.11 | 0.02 |
| Ducks | Solid | 0.14 | 0.14 | 0.02 |
| Geese | Solid | 0.24 | 0.24 | 0.03 |
| Other: | | | | |
| Horses | Solid | 0.48 | 0.22 | 0.14 |
| Sheep | Solid | 0.14 | 0.06 | 0.02 |
| Goats | Solid | 0.14 | 0.06 | 0.02 |
| Fur | Slurry | 0.02 | 0.008 | 0.004 |

[1] Average of "calves" and "dairy cattle".

[2] Assumed the same value as for "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 (EMEP, 2016). Harvesting and soil cultivation is the predominant source of PM and the emission depends on crop type, soil type, cultivation method and the weather before and during work.

The emission of TSP, $PM_{10}$ and $PM_{2.5}$ are shown in Table 6.3. The emission of TSP has decreased 19 % from 1985 to 2015 due to decrease in the area of cultivated crops and number of treatments of the fields.

Table 6.3 Emissions of $PM_{10}$, $PM_{2.5}$ and TSP from field operations, tonnes.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TSP | 67 720 | 68 392 | 62 496 | 62 382 | 54 146 | 56 655 | 56 541 | 55 587 | 55 218 | 56 365 | 55 040 |
| $PM_{10}$ | 6 772 | 6 839 | 6 250 | 6 238 | 5 415 | 5 665 | 5 654 | 5 559 | 5 522 | 5 637 | 5 504 |
| $PM_{2.5}$ | 510 | 527 | 485 | 479 | 436 | 468 | 457 | 445 | 448 | 466 | 458 |

### 6.2.1 Calculation method

The methodology provided in the EMEP / EEA Guidebook on emission calculations from field operations is shown below:

$$E_{PM} = EF_{PM} \cdot AR \cdot no_o \quad \text{(Eq. 6.2)}$$

where: $E_{PM}$ = emission of $PM_{10}$, $PM_{2.5}$ or TSP, kg
$EF_{PM}$ = emission factor for crop and operation type, kg per ha
AR = area of crops, ha
$no_o$ = production cycles, the number of times the operations are performed

### 6.2.2 Activity data

For activity data are used area of cultivated crops and number of operations for each crop. The area of crops is estimated by Statistic Denmark (DSt, 2016) and number of operations are based on budget estimates made by SEGES. See Appendix O for area of cultivated crops and Appendix P for number of operations divided in soil cultivation, harvesting, cleaning and drying.

The number of operations changes over time for some crop types, especially change in number of soil cultivations. Number of soil cultivations decreases from 2001-2002 for cereals, rape and grass and increases from 2001-2010 for potatoes which affects the emission of PM.

### 6.2.3 Emission factors

Emission factors for crops and operation type are given in Table 6.4 (EMEP, 2016). Emission factors for wet climate conditions are the most suitable for Danish conditions.

Table 6.4 Emission factor for field operations, kg per ha.

| Crop | Soil cultivation | Harvesting | Cleaning | Drying |
|---|---|---|---|---|
| **$PM_{10}$** | | | | |
| Wheat | 0.25[a] | 0.27[b] | 0.19[a] | 0.56[a] |
| Rye | 0.25[a] | 0.2[b] | 0.16[a] | 0.37[a] |
| Barley | 0.25[a] | 0.23[b] | 0.16[a] | 0.43[a] |
| Oat | 0.25[a] | 0.34[b] | 0.25[a] | 0.66[a] |
| Other arable | 0.25[a] | 0.26[c] | 0.19[c] | 0.51[c] |
| Grass | 0.25[a] | 0.25[a] | 0[a] | 0[a] |
| **$PM_{2.5}$** | | | | |
| Wheat | 0.015[a] | 0.011[b] | 0.009[a] | 0.168[a] |
| Rye | 0.015[a] | 0.008[b] | 0.008[a] | 0.111[a] |
| Barley | 0.015[a] | 0.009[b] | 0.008[a] | 0.129[a] |
| Oat | 0.015[a] | 0.014[b] | 0.0125[a] | 0.198[a] |
| Other arable | 0.015[a] | 0.010[c] | 0.009[c] | 0.152[c] |
| Grass | 0.015[a] | 0.01[a] | 0[a] | 0[a] |
| **TSP** | | | | |
| Wheat | 2.5 | 2.7 | 1.9 | 5.6 |
| Rye | 2.5 | 2 | 1.6 | 3.7 |
| Barley | 2.5 | 2.3 | 1.6 | 4.3 |
| Oat | 2.5 | 3.4 | 2.5 | 6.6 |
| Other arable | 2.5 | 2.6 | 1.9 | 5.1 |
| Grass | 2.5 | 2.5 | 0 | 0 |

[a] EMEP (2016).

[b] van der Hoek & Hinz (2007).

[c] average of wheat, rye, barley and oat.

[d] $PM_{10}$ multiplied by 10 (van der Hoek & Hinz, 2007).

# 7 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 provided by the Danish Agricultural Advisory Service (Feidenhans'l, 2009, Pers. Comm.). 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, dioxins, PAHs, HCB and PCBs. Default values given by the EMEP/EEA Guidebook (EMEP, 2016) are used for $NH_3$, $NO_x$, CO, $SO_2$, NMVOC, PM, BC, heavy metals (except for Cu) and dioxins. For Cu and for PAHs, 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). Emission factors for HCB are based on Hübner (2001) and for PCBs on Black et al. (2012).

Figure 7.1 shows the trend of the emission of $NH_3$, $PM_{10}$, $PM_{2.5}$, $CH_4$ and NMVOC from field burning for 1985-2015. 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 Q.

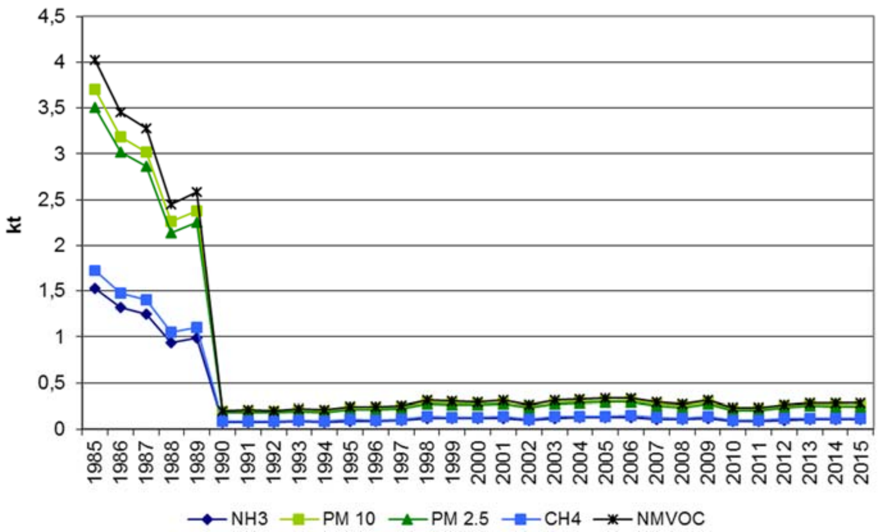



Figure 7.1 Trend of the emission of selected pollutants from field burning of agricultural residues.

### 7.1.1 Calculation method

The equation for calculating the emission is shown below. The parameters used for the calculation of emissions are given in Table 7.1, Table 7.2 and the EFs are provided in Table 7.3. EFs are the same for all years.

$$Emi = BB \cdot \frac{EF}{1\,000} \cdot FO \qquad \text{(Eq. 7.1)}$$

$$BB = \frac{CP \cdot FB \cdot FR_{DM}}{1\,000}$$

Where:
Emi = emission of pollutants, kt
BB = total burned biomass, kt dry matter (DM)
CP = crop production, t
FB = fraction burned in fields
$FR_{DM}$ = dry matter fraction of residue
EF = emission factor, g per kg DM
FO = fraction oxidised

Table 7.1 Parameters for estimating emissions from field burning, 2015.

| | Crop production | Fraction burned in fields | Dry matter fraction of residue[a] | Total biomass burned | Fraction oxidised[b] |
|---|---|---|---|---|---|
| | tonnes | | | kt DM | |
| Mixed cereals | 5 772 900 | 0.001 | 0.85 | 4.91 | 0.90 |
| Straw from seeds of grass | 347 500 | 0.15 | 0.85 | 44.31 | 0.90 |

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

### 7.1.2 Activity data

The amount of burnt straw from the grass seed production is estimated as 15-20 % of the total amount produced. The amount of burnt bales of wet straw is estimated as 0.1 % of total amount of straw. Both estimates are based on expert judgement by SEGES. The total amounts of burned biomass are based on data for crop production from Statistics Denmark and dry matter fraction of the crops (SEGES, 2005).

### 7.1.3 Emission factor

Table 7.3 shows the emission factor used of all pollutants from field burning of agricultural residues and the emission for the year 2015.

Table 7.3 Emission factors and emissions for the different pollutants from field burning of agricultural residues, 2015.

| Pollutant | EF | Unit for EF | Emission 2015 | Unit for emission |
|---|---|---|---|---|
| $NH_3$ | 2.4 | g per kg DM | 0.11 | kt |
| $CH_4$ | 2.7 | g per kg DM | 0.12 | kt |
| $N_2O$ | 0.07 | g per kg DM | 0.003 | kt |
| $NO_x$ | 2.4 | g per kg DM | 0.11 | kt |
| CO | 58.9 | g per kg DM | 2.61 | kt |
| $CO_2$ | 1.515 | kg per kg DM | 67.10 | kt |
| $SO_2$ | 0.3 | g per kg DM | 0.01 | kt |
| NMVOC | 6.3 | g per kg DM | 0.28 | kt |
| PM | | | | |
| TSP | 5.8 | g per kg DM | 0.26 | kt |
| $PM_{10}$ | 5.8 | g per kg DM | 0.26 | kt |
| $PM_{2.5}$ | 5.5 | g per kg DM | 0.24 | kt |
| BC | 0.5 | g per kg DM | 0.02 | kt |
| Metals | | | | |
| Pb | 0.865 | mg per kg DM | 0.04 | t |
| Cd | 0.049 | mg per kg DM | 0.002 | t |
| Hg | 0.008 | mg per kg DM | 0.0004 | t |
| As | 0.058 | mg per kg DM | 0.003 | t |
| Cr | 0.22 | mg per kg DM | 0.01 | t |
| Ni | 0.177 | mg per kg DM | 0.01 | t |
| Se | 0.036 | mg per kg DM | 0.002 | t |
| Zn | 0.028 | mg per kg DM | 0.001 | t |
| Cu | 0.0003 | mg per kg DM | 0.00001 | t |
| Dioxins | 500 | ng TEQ per t | 0.03 | g/TEQ |
| PAHs | | | | |
| Benzo(a)pyrene | 2 787 | µg per kg DM | 0.12 | t |
| benzo(b)fluoranthene | 2 735 | µg per kg DM | 0.12 | t |
| benzo(k)fluoranthene | 1 073 | µg per kg DM | 0.05 | t |
| Indeno(1,2,3-cd)pyrene | 1 017 | µg per kg DM | 0.05 | t |
| HCB - mixed cereals[1] | 0.003 | g per t | | |
| HCB - grass seed[1] | 0.002 | g per t | | |
| HCB | | | 0.11 | Kg |
| PCBs - mixed cereals | 3 | µg TEQ per t | | |
| PCBs - grass seed | 0.05 | µg TEQ per t | | |
| PCBs | | | 0.00002 | Kg |

[1] See Chapter 7.1.1 for conversion of EF from the unit ha to g per t.

References: EMEP, 2016, Jenkins, 1996, Andreae & Merlet, 2001, Hübner, 2001

### 7.1.4 Conversion of EF for HCB

The emission factor for HCB from field burning of agricultural residue is given by Hübner (2001) as 10 000 µg per ha. This factor has been converted to the unit g per tonnes by following equation:

$$\mathrm{EF}_{Used} = (\ \mathrm{EF}_{Hubner}/Y)/1\ 000\ 000 \qquad \text{(Eq. 7.1)}$$

Where:

$EF_{Used}$ = emission factor, g per tonnes
$EF_{Hubner}$ = emission factor given by Hübner (2001), 10 000 µg per ha
Y = yield, tonnes per ha

Table 7.2 Emission factor for HCB from field burning of agricultural waste.

| | Yield, tonnes per ha | EF, g per tonnes |
|---|---|---|
| Straw from cereals | 3.4 | 0.003 |
| Straw from seed production | 5 | 0.002 |

# 8 HCB emission from use of pesticides

Hexachlorobenzene (HCB) is a poisonous substance, which is dangerous to human and animal health. HCB is used as agent in pesticides and some of the pesticides used in Denmark contain HCB, but pure HCB used as pesticide is banned.

There are two sources for HCB emission in the agricultural sector; field burning of agricultural residue and the use of pesticides. Emissions of HCB from field burning of agricultural residues are described in Chapter 7.

Table 8.1 shows the emission of HCB from use of pesticides for the years 1990-2015. The emission has decreased significantly from 1990 to 2015 due to decrease in use of pesticides containing HCB.

Table 8.1 Emission of HBC, 1990-2015, kg.

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pesticides | 18.28 | 0.50 | 0.33 | 0.01 | 0.02 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 |

## 8.1 Calculation method

The emission is calculated using following equation:

$$\mathrm{E}_{pes} = \sum a_i/1000 \cdot \mathrm{EF}_i/1000 \qquad \text{(Eq. 8.1)}$$

Where:

$\mathrm{E}_{pes}$ = emission of HCB from pesticides, kg
$a_i$ = amount of effectual substance in the pesticide *i*, kg
$\mathrm{EF}_i$ = emission factor for the pesticide *i*, g per ton

## 8.2 Activity data

A range of pesticides are used in Denmark. In the period 1990 to 2015, six types of pesticides containing HCB have been identified as used in Denmark. These are atrazine, chlorothalonil, clopyralid, lindane, pichloram and simazine. Data on the amounts of active substances used in Denmark are collected from the Environmental Protection Agency (EPA), see Table 8.2. The use of atrazine and lindane stopped in 1994 and the use of chlorothalonil and simazine ceased in 2000 and 2004, respectively.

Table 8.2 Amounts of effectual substance used in Denmark, 1990-2015, kg (EPA, 2015)

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Atrazine | 91 294 | - | - | - | - | - | - | - | - | - |
| Chlorothalonil | 10 512 | 10 980 | 7 340 | - | - | - | - | - | - | - |
| Clopyralid | 16 461 | 22 587 | 7 446 | 5 874 | 9 122 | 11 840 | 8 170 | 14 258 | 13 525 | 13 525 |
| Lindane | 8 356 | - | - | - | - | - | - | - | - | - |
| Pichloram | - | - | - | - | 723 | 1 349 | 206 | 256 | 258 | 258 |
| Simazine | 30 234 | 19 865 | 23 620 | - | - | - | - | - | - | - |

## 8.3 Emission factors

Emission factors given in Yang (2006) are used in the calculation of the emissions, see Table 8.3.

Table 8.3 Emission factors for HCB from pesticides, 1990-2015, g per tonnes.

| | 1990 | 1995 | 2000 | 2005-2015 |
|---|---|---|---|---|
| Atrazine | 100 | 1 | 1 | 1 |
| Chlorothalonil | 500 | 40 | 40 | 10 |
| Clopyralid | 2.5 | 2.5 | 2.5 | 2.5 |
| Lindane | 100 | 50 | 50 | 1 |
| Pichloram | 100 | 50 | 50 | 8 |
| Simazine | 100 | 1 | 1 | 1 |

# 9 NMVOC emission

NMVOC emission originates from animal manure, growing crops and grass and field burning of agricultural residues. Agriculture accounts for 35 % of the national NMVOC emission in 2015 and is mainly related to emission from animal manure, which accounts for 94 % in 2015.

## 9.1 Manure management

NMVOC from manure has been calculated and is related to animal husbandry and mainly to the cattle production.

### 9.1.1 Emission

The trend in NMVOC emission from 1985 to 2015 shows a decrease from 41 kt to 36 kt with the highest fall in the beginning of the period (Figure 9.1). Back in 1985 two thirds of the emission originates from the cattle production, while it is half the emission in 2015. A decrease of emission from cattle is a consequence of less animals due to higher milk yield and production ceiling due to the EU milk quota. An increase of the production of swine and fur bearing animals has resulted in an increase of the emission from these categories in the period 1985 to 2015.

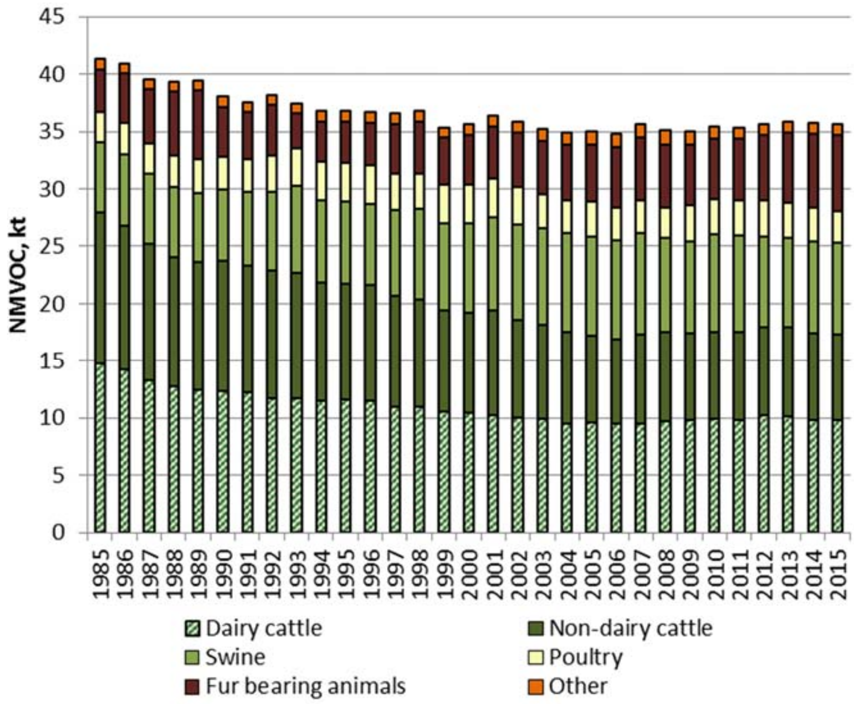



Figure 9.1 Emission of NMVOC from manure management, 1985-2015.

### 9.1.2 Calculation method

The estimation of NMVOC emissions is based on the EMEP / EEA guidebook (2016). NMVOC emissions from animal husbandry comes from feed, degradation of feed in the rumen and from undigested fat, carbohydrate and protein decomposition in the rumen and in the manure**.** Silage is a major source of NMVOC emissions and therefore two sets of emission factors are introduced in the Guidebook; a high emission factor based on feeding with silage and a low emission factor based on feeding without silage.

The calculation of NMVOC emissions is based on the Tier 1 approach and is estimated as the number of animal multiplied with the NMVOC emission factor for each animal category. The number of animals is given as the average annual population (AAP).

$$\mathrm{E}_{NMVOC} = \sum AAP_i \cdot \mathrm{EF}_i \qquad \text{(Eq. 9.1)}$$

Where:

$\mathrm{E}_{NMVOC}$ = emission of NMVOC, kg

$\mathrm{AAP}_i$ = number of animals given in average annual population for the animal category *i*

$\mathrm{EF}_i$ = emission factor for the animal category *i*, kg per AAP

### 9.1.3 Activity data

The activity data for the NMVOC emission from manure management is number of animals, see Chapter 4.

### 9.1.4 Emission factor

NMVOC emission factors recommended in EMEP / EEA Guidebook 2016, Table 3-4 are used (Table 9.1). For days on grass, the emission factor for feeding without silage is used for cattle, sheep, goats and horses. However, all emissions are entered in NFR category 3B, while the notation key IE is used for NFR category 3Da3.

The same emissions factors are used for all years, which means that changes of the emission over time depends on change in animal production or change in grazing days.

Table 9.1 NMVOC emission factors (EMEP/EEA Guidebook 2016, Tier1).

| | EF NMVOC with silage | EF NMVOC without silage[1] |
|---|---|---|
| Dairy Cattle | 17.937 | 8.047 |
| Non-Dairy Cattle | 8.902 | 3.602 |
| Sheep | 0.279 | 0.169 |
| Swine – sows | | 1.704 |
| Swine – other | | 0.551 |
| Goats | 0.624 | 0.542 |
| Horses | 7.781 | 4.275 |
| Laying hens | | 0.165 |
| Broilers | | 0.108 |
| Turkeys | | 0.489 |
| Other poultry | | 0.489 |
| Fur bearing animals | | 1.941 |

[1] Emission factor is also used for time on grass.

## 9.2 Growing crops

Emission of NMVOC from growing crops may arise to attract pollinating insects, eliminate waste product or as a means of losing surplus energy (EMEP/EEA, 2016). The calculation of the NMVOC emission from growing crops is based on emission factors recommended in EMEP/EEA Guidebook 2016.

### 9.2.1 Emission

The NMVOC emission from cultivated crops is estimated to 2.11 kt in 2015 based on an IEF at 0.80 and a cultivated area of 1 437 900 hectares. The IEF varies annually from 0.51 - 0.80 kg NMVOC per hectare (Table 9.2) depending on the allocation of the four mentioned crop types. Higher allocation of rape and rye result in higher IEF due to a higher emission factor for these two crop types.

Table 9.2 Cultivated area, IEF and emission of NMVOC.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total cultivated area, 1000 ha | 2 834 | 2 788 | 2 726 | 2 647 | 2 707 | 2 646 | 2 640 | 2 645 | 2 628 | 2 652 | 2 633 |
| IEF, kg per ha | 0.66 | 0.71 | 0.58 | 0.56 | 0.53 | 0.57 | 0.57 | 0.63 | 0.70 | 0.73 | 0.80 |
| Emission, kt | 1.87 | 1.99 | 1.57 | 1.48 | 1.42 | 1.51 | 1.50 | 1.66 | 1.83 | 1.94 | 2.11 |

### 9.2.2 Calculation method

In Table 3-3 in EMEP/EEA Guidebook 2016 emission factors for cultivation of wheat, rye, rape and grass (15°C) are given. A Tier 2 IEF is estimated corresponding to Danish yield level of dry matter content (DM) for these crop types. The emission from other crop types is not available in the Guidebook. However, the total NMVOC emission is estimated as the Tier 2 IEF multiplied with the total cultivated area. See equation 9.2:

$$E_{NMVOC} = A \cdot IEF \qquad \text{(Eq. 9.2)}$$

Where:
$E_{NMVOC}$ = emission of NMVOC from agricultural soils, kg (1)
A = total cultivated area, ha (2)
IEF = implied emission factor, kg per ha (3) (see Chapter 9.2.4)

### 9.2.3 Activity data

Area of wheat, rye, rape and grass is used for estimating IEF. The total area of cultivated crops is used to estimate the total emission of NMVOC from growing crops. All areas are based on Statistics Denmark (DSt).

### 9.2.4 Emission factors

Here are given the equations for the calculation of the IEF. See Table 9.3 for factors used.

$$IEF=\frac{\sum E_i}{\sum ha_i} \quad \text{(Eq. 9.3)}$$

Where:
IEF = implied emission factor, kg per ha (3)
$E_i$ = emission for the crop $i$, kg (4)
$ha_i$ = area of the crop $i$, ha (5)

$$E_i=EF_i \cdot \text{hours pr day} \cdot \text{days pr year} \cdot Frac_i \cdot DM_i \cdot ha_i \quad \text{(Eq.9.4)}$$

Where:
$E_i$ = emission for the crop $i$, kg per ha per year (4)
$EF_i$ = emission factor for crop $i$, kg per kg DM per hour (6)
hours per day = 24 hour per day
days per year = 365 days per year
$Frac_i$ = fraction of year emitting for crop $i$ (7)
$DM_i$ = mean dry matter for crop $i$, kg DM per ha (8)
$ha_i$ = area for crop $i$, ha (5)

Table 9.3 Estimation of NMVOC emission factor, 2015.

| 2015 | $EF_i$ [6] (EEA/EMEP) | $Frac_i$ [7] | $DM_i$ [8] | Cultivated area[5] | NMVOC emission[4] | IEF[3] – Tier 2 DK |
|---|---|---|---|---|---|---|
| Crop | Kg NMVOC /kg DM/yr | | kg DM/ha | ha | Kg/ha/yr | kg NMVOC/ha |
| Wheat | 2.60E-08 | 0.3 | 6 826 | 608 733 | 283 351 | |
| Rye | 1.41E-07 | 0.3 | 5 389 | 125 540 | 250 422 | |
| Rape | 2.02E-07 | 0.3 | 3 945 | 193 234 | 403 842 | |
| Grass land* | 1.03E-08 | 0.5 | 9 230 | 510 393 | 212 528 | |
| Total | | | | 1 437 900[2] | 1 150 142[1] | 0.80[3] |

*Grass land 15 °C.
[1-8] see Eq. 9.2-9.4.

# 10 $NO_x$

Emission of $NO_x$ includes emission from manure management and agricultural soils. The emission from agricultural soil includes emission from nitrogen applied to soil as animal manure, inorganic N fertiliser and sewage sludge. Agriculture accounts for 15 % of the total $NO_x$ emission in 2015 and the main part occurs from animal manure applied to soil and inorganic N fertiliser.

## 10.1 Manure management

$NO_x$ emission from manure management relates to the emissions from housings and account for around 1 % of the agricultural emission of $NO_x$.

### 10.1.1 Emission

The $NO_x$ emission from 1985 to 2015 decreased significantly from 0.6 kt $NO_x$ to 0.2 kt $NO_x$ corresponding to a 58 % reduction. The emission depends on number of animal and manure type, and the decrease is mainly related to changes from solid based systems to slurry-based systems for both dairy cattle and swine production. Thus, the share of solid manure was 23 % in 1985 and dropped to 10 % in 2015.

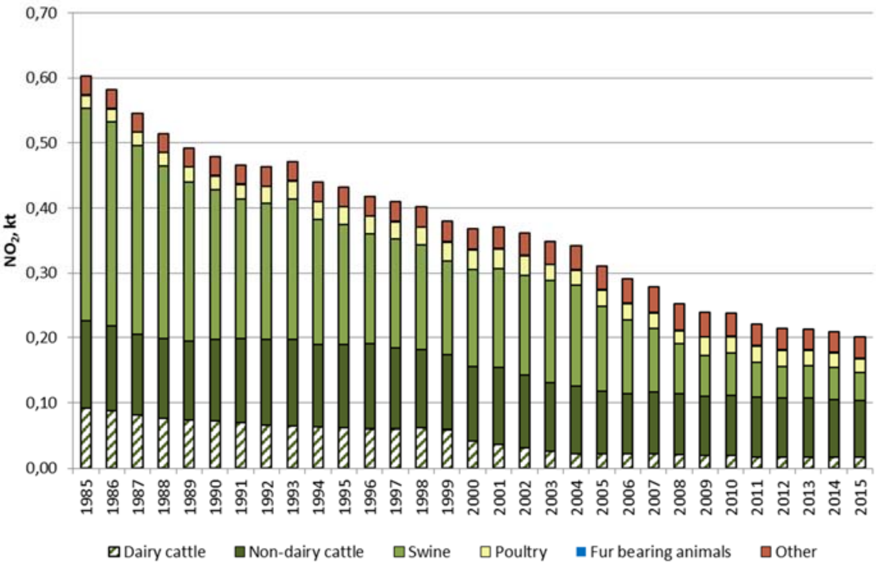



Figure 10.1 $NO_x$ emission from manure management 1985–2015.

### 10.1.2 Calculation method

The estimation of $NO_x$ emission is based on the EMEP / EEA guidebook (2016) and is based on number of animals given as the average annual population (AAP).

$$E_{NO_x} = AAP_i \cdot EF_i \qquad \text{(Eq. 10.1)}$$

Where:
$E_{NOx}$ = emission of $NO_x$, kg
$AAP_i$ = average annual population of animal category *i*
$EF_i$ = emission factor for animal category *i*, kg per AAP

### 10.1.3 Activity data

The emission calculations is based on number of animals and housing / manure type (See Chapter 4).

### 10.1.4 Emission factor

Emission factor for estimation of $NO_x$ emission from manure management is listed in Table 10.1. Some of the manure from the mink production is handled as slurry, but no EF for slurry is mentioned in the Guidebook. Therefore, the same emissions factor is used for both slurry and solid systems.

Table 10.1 $NO_x$ emission factors (EMEP/EEA Guidebook 2016), kg $NO_2$ per AAP.

| NFR code | Livestock | slurry | solid |
|---|---|---|---|
| 3B1a | Dairy cattle | 0.011 | 0.236 |
| 3B1b | Other cattle | 0.003 | 0.144 |
| 3B2 | Sheep | | 0.008 |
| 3B3 | Sows | 0.006 | 0.204 |
| 3B3 | Fattening pigs | 0.002 | 0.069 |
| 3B4d | Goats | | 0.008 |
| 3B4e | Horses | | 0.201 |
| 3B4gi | Laying hens | 0.0002 | 0.005 |
| 3B4gii | Broilers | | 0.002 |
| 3B4giii | Turkeys | | 0.008 |
| 3B4giv | Ducks | | 0.004 |
| 3B4giv | Geese | | 0.002 |
| 3B4h | Fur bearing animals | 0.0003[1] | 0.0003 |

[1] Used the same EF as given for solid manure.

## 10.2 Agricultural soils

Emission of $NO_x$ from manure applied on soils, inorganic N fertiliser and sewage sludge is estimated and accounts for 49 %, 48 % and 2 %, respectively, of the agricultural emission of $NO_x$.

### 10.2.1 Emission

The main part of the $NO_x$ emission from agricultural soils comes from manure applied to soil and use of inorganic N-fertiliser. The emission has decreased from 1985 to 2015 by 33 % mainly due to decrease in use of inorganic N fertiliser.

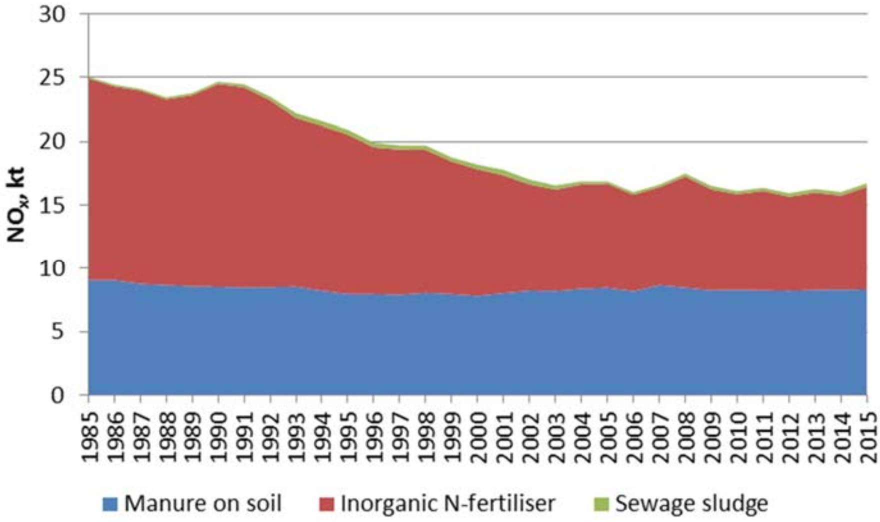



Figure 10.2 $NO_x$ emission from agricultural soils, 1985-2015.

### 10.2.2 Calculation method

The emission of NOx is calculated as emission of $NO_2$ based on following equation:

$$E_{NO_x} = \sum N_i \cdot EF \qquad \text{(Eq. 10.2)}$$

Where:

$E_{NOx}$ = emission of $NO_x$, kg $NO_2$
$N_i$ = amount N applied from *i* fertiliser type, kg
EF = emission factor, 0.04 kg $NO_2$ per kg N applied

### 10.2.3 Emission factor

The emission factor for $NO_x$ is default value from the EMEP/EEA guidebook (2016), which recommend an emission factor of 0.04 kg $NO_2$ per kg N applied. The background reference is based on a literature study, which do not distinguish between different kinds of fertiliser types. The default emission factor is used for both manure applied on soils, inorganic N fertiliser and sewage sludge. This indicate that the same emission factor can be used independently of the crops being fertilised with inorganic N fertiliser or manure.

# 11 $CH_4$ emission

The major part of the agricultural $CH_4$ emission originates from the digestive processes, but also emission from manure management and field burning takes place. The agricultural $CH_4$ emissions accounts for 81 % of the total $CH_4$ emission in 2015. The digestive processes in ruminants, predominantly cattle, are the largest source of agricultural $CH_4$ emissions. The emission from manure is due to the bacterial breakdown 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 agricultural emissions of $CH_4$.

For the $CH_4$ emission from manure management, a lower emission from biogas treatment of slurry is taken into account, which is described in section 11.3.

The methodology used to calculate the $CH_4$ emission is based on guidance given in the 2006 IPCC Guidelines (IPCC, 2006).

## 11.1 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 – e.g. swine, horses, poultry and fur animals – produce $CH_4$ to a much smaller degree.

The emission is primarily from cattle, which, in 2015, contributed 87 % of the emission from enteric fermentation. The emission from swine production is the second largest source at 9 % and the rest of the animals; horses, sheep, goats, poultry and deer make up the remaining 4 %. The relative contribution from swine production has increased over the years as a result of a production expansion as well as a reduction in the number of cattle.

From 1990 to 2015, the emission from enteric fermentation has overall decreased by 9 %, which is primarily related to a decrease in the number of cattle. The number of swine has increased from 9.5 million in 1990 to 12.5 million in 2015, but this increase is only of minor importance for the total $CH_4$ emission from enteric fermentation. The emission was at its lowest in 2005 but has increased slightly until 2015, mainly due to a slight increase in emission from cattle, which is due to increase in feed.

### 11.1.1 Calculation method

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 11.1.

$$EF_{CH4} = \frac{GE \cdot Y_m \cdot 365}{55.65} \qquad \text{(Eq. 11.1)}$$

Where:

$EF_{CH4}$ = emission factor of $CH_4$, kg per head per year

GE = gross energy intake, MJ per head per day (national data)

$Y_m$ = methane conversion rate, % of gross energy in feed converted to methane

55.65 = conversion factor, from MJ to kg $CH_4$ (IPCC, 2006)

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 feeding strategy. $Y_m$ for dairy cattle are based on a national value (Hellwing et al, 2014). For non-dairy cattle and sheep $Y_m$ given in IPCC (2006) are used. For swine, horses and goats the values of $Y_m$ are based on Crutzen et al (1986).

The difference between summer and winter feed intake is taken into account. Feed intake in summer are based on feed plans with mainly grass whereas winter feed plans are based on roughage and concentrates.

$$CH_{4\,enteric,total} = CH_{4\,enteric,winter} + CH_{4\,enteric,summer} \quad \text{(Eq. 11.2)}$$

### 11.1.2 Emission calculation for poultry and fur animals – Tier 1

For fur animals, poultry, ostrich and pheasants, data on gross energy are not available in the IPCC Guidelines. Based on country specific information (Hansen, 2010, Pers. Comm.) $CH_4$ emission from enteric fermentation from fur farming is considered not applicable.

The emission calculation for poultry, ostrich and pheasants is calculated by a Tier 1 methodology:

$$\mathrm{CH}_{4,\,\mathrm{enteric}} = \sum \mathrm{EF}_i \cdot \mathrm{no}_i \quad \text{(Eq. 11.3)}$$

Where:

$CH_{4,\,enteric}$ = emission of $CH_4$

$EF_i$ = emission factor for animal category *i*, $CH_4$ per animal

$no_i$ = number of animals, category *i*

Emission factors used for poultry, ostrich and pheasants are based on the emission factors given by Wang & Huang (2005) (see Table 11.1). EF for broilers with a life cycle of 30-56 days is scaled in proportion to 42 days for broilers given by Wang & Huang (2005). Organic broilers with a life cycle of 81 days are scaled in proportion to the Taiwan country chicken with 91 days of life cycle and pullets with a life cycle of 112-119 days is scaled in proportion to the 140 days given for pullets by Wang & Huang (2005). EF for ducks, geese, turkeys, ostrich chicken and pheasant chicken are scaled by weight in proportion to a broiler with 40 days of life cycle. For laying hens, the EF given by Wang & Huang (2005) is used and for ostrich hens and pheasant hens, the EFs are scaled by weight in proportion to a laying hen.

Table 11.1 Emission factors for poultry in mg $CH_4$ per head per lifecycle.

| | $CH_4$ emission factor |
|---|---|
| Broilers, 42 days | 15.87 |
| Taiwan country chicken, 91 days | 84.82 |
| Pullets, 140 days | 3 561 |
| Laying hens, 365 days | 10 610 |

### 11.1.3 Emission calculation for cattle, swine, sheep, goats and horses by Tier 2

The calculation of $CH_4$ from enteric fermentation for animals other than poultry and fur animals, is calculated using a method based on IPCC 2006 Tier 2.

The Tier 2 / country specific (CS) equation for EF of enteric fermentation is the sum of the feeding situation in winter and summer. EF is based on actual feeding plans, which is provided from data for feed units (FU) in the feed for each livestock category. Except from dairy cattle, where the EF is based on kg dry matter (DM) in the feed. For dairy cattle, feeding with beets is taken into account, because beet feeding gives a higher methane production rate compared to grass and maize due to the high content of easily convertible sugar. Feeding with beets is only relevant for dairy cattle, therefore the equation below concerning beet will be left out for the remaining animal categories.

$$EF = EF_{winter} + EF_{summer} \qquad \text{(Eq. 11.4)}$$

Dairy cattle:

$$EF_{winter,\ dairy\ cattle} = F \cdot \qquad \text{(Eq. 11.5)}$$

$$(\ (GE_{F\ winter}/55.65) \cdot Y_{m\ excl\ beet} \cdot (1 - grazing\ days/365 - days\ with\ beet/365)$$

$$+ (GE_{F\ winter}/55.65) \cdot Y_{m\ incl\ beet} \cdot days\ with\ beet/365\ )$$

$$EF_{summer,\ dairy\ cattle} = F \cdot \left(\frac{GE_{F\ summer}}{55.65}\right) \cdot Y_{m\ grazing} \cdot \frac{grazing\ days}{365} \qquad \text{(Eq. 11.6)}$$

Where:

| | |
|---|---|
| $EF_{winter}$ | = Emission factor for winter feed, kg $CH_4$ per head per year |
| $EF_{summer}$ | = Emission factor for summer feed, kg $CH_4$ per head per year |
| F | = feed, kg DM |
| $GE_{F,winter}$ | = gross energy per kg DM, MJ per kg DM in winter |
| $GE_{F,\ summer}$ | = gross energy per kg DM, MJ per kg DM in summer |
| $Y_m$ | = methane conversion rate, % of gross energy in feed converted to methane |
| 55.56 | = energy content of $CH_4$, MJ per $CH_4$ |

Other animals:

$$EF_{winter} = FU \cdot \left(\left(\frac{GE_{FUwinter}}{55.65}\right) \cdot Y_m \cdot \left(1 - \frac{grazing\ days}{365}\right)\right) \qquad \text{(Eq. 11.7)}$$

$$EF_{summer} = FU \cdot \left(\frac{GE_{FU\ summer}}{55.65}\right) \cdot Y_{m\ grazing} \cdot \frac{grazing\ days}{365} \qquad \text{(Eq. 11.8)}$$

Where:

$EF_{winter}$ = Emission factor for winter feed, kg $CH_4$ per head per year
$EF_{summer}$ = Emission factor for summer feed, kg $CH_4$ per head per year
FU = feeding units
$GE_{FU,winter}$ = gross energy per feeding unit, MJ per FU in winter
$GE_{FU, summer}$ = gross energy per feeding unit, MJ per FU in summer
$Y_m$ = methane conversion rate, % of gross energy in feed converted to methane
55.56 = energy content of $CH_4$, MJ per $CH_4$

Thus, to calculate the total gross energy (GE) intake, the estimation of GE per kg DM or GE per feed unit – defined as $GF_F$ or $GE_{FU}$, respectively is needed. 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.

### 11.1.4 Gross energy intake (GE)

$GE_F$ for dairy cattle are estimated by SEGES (Aaes, 2016, Pers. Comm.). From 2014 feed intake for dairy cattle given in the normative figures are provided in kg DM per year and the energy in the feed is provided in MJ per kg DM. The energy intake is a standard winter feed regardless of whether the animal grazes or not. See Appendix R for time series for GE for dairy cattle

For all other livestock categories than dairy cattle, the estimation of GE ($GE_{FU}$). $GE_{FU}$ is based on the composition of feed intake and the energy content in proteins, fats and carbohydrates based on actual efficacy feeding controls or actual feeding plans at farm level, collected by SEGES or DCA. The data are provided in Danish feed units or kg feedstuff and these values are converted to mega joule (MJ). The calculation is shown in the equations below:

$$GE_{FU} = \frac{MJ/day}{FU/day} \qquad \text{(Eq. 11.9a)}$$

$$FU/day = \frac{kg\ DM}{day} \cdot \frac{FU}{kg\ DM} \qquad \text{(Eq. 11.9b)}$$

$$MJ/day = \frac{kg\ DM}{day} \cdot \frac{MJ}{kg\ DM} \qquad \text{(Eq. 11.9c)}$$

$$MJ/kg\ DM = \%_{crude\ protein} \cdot E_{crude\ protein} + \%_{crude\ fat} \cdot E_{crude\ fat} + \%_{carbohydrates} \cdot E_{carbohydrates} \qquad \text{(Eq. 11.9d)}$$

$$\%_{carbohydrates} = 100 - (\%_{crude\ protein} + \%_{crude\ fat} + \%_{raw\ ashes}) \qquad \text{(Eq. 11.9e)}$$

Where:

$GE_{FU}$ = gross energy per feed unit, MJ per FU
FU = feed unit
MJ = mega joule
DM = dry matter
$\%_{crude\ protein}$ = share of crude protein in the feed, %
$E_{crude\ protein}$ = energy factor for crude protein, 24.24 MJ per kg DM
$\%_{raw\ fat}$ = share of crude fat in the feed, %

$E_{raw\ fat}$ = energy factor for crude fat, 34.12 MJ per kg DM
$\%_{carbohydrates}$ = share of carbohydrates in the feed, %
$E_{carbohydrates}$ = energy factor for carbohydrates, 17.30 MJ per kg DM
$\%_{raw\ ashes}$ = share of raw ashes in the feed, %

For horses, heifers, suckling cattle, sheep and goats an average winter feed plan is provided (Andersen, 2003, Pers. Comm.; Clausen, 2004, Pers. Comm. Bligaard, 2004, Pers. Comm.; Holmenlund, 2004, Pers. Comm.), on which the calculation of GE content is based (See Appendix S). Gross energy for deer is based on feed plans for goats, as their feeding conditions resemble those of deer the most.

### 11.1.5 $CH_4$ conversion rate ($Y_m$)

Investigations from DCA have shown a change in feed practice from use of feeding beet to maize (whole cereal). Feeding with beet gives a higher methane production rate compared to grass and maize due to the high content of easily convertible sugar. The development in feed practice reflects the change in the average $Y_m$ for dairy cattle and heifers from 6.38 in 1990 to 6.00 in 2002 and onwards.

The estimation of the national values of $Y_m$ is based on model "Karoline" developed by DCA based on average feeding plans for 20 % of all dairy cattle in Denmark obtained from SEGES (Olesen et al.; 2005). DCA have estimated the $CH_4$ emission for a winter feeding plan for two years, 1991 ($Y_m$=6.70) and 2002 ($Y_m$=6.00). $Y_m$ for the years between 1991 and 2002 are estimated by interpolation. Feeding beets are only included in the winter feeding plan and the $Y_m$ is therefore also adjusted for days on winter and summer feeding plan. It is assumed that the winter feeding plan covers 200 days.

Further knowledge regarding the $Y_m$ is provided by DCA in 2014 (Hellwing et al., 2014), which covers calculation based on experiments with Holstein cows conducted from May 2010 to May 2014 at Aarhus University including 41 different diets from 10 experiments; in total 185 observations (two observations were omitted). The calculation is based on analysed concentrations of ash, crude protein, fat and carbohydrate in the diet using the same equation as the Norfor feed evaluation system. This study showed an $Y_m$ value between 5.98 and 6.13, which confirms the values from the older study (Olesen et al., 2005) and supports the continued use of an $Y_m$ value at 6.00 from 2002 and forward.

The $Y_m$ for feeding with beet is higher in 1990 compared to year 2000, which is due to the proportion of the beet in the total feeding during the year. In 1990 the total cultivated area with fodder beet account for 102 thousand ha decreasing to 18 thousand ha in year 2000, which result in significantly lower beet proportion in feeding in year 2000.

Table 11.2 $CH_4$ conversion rate ($Y_m$) – national factor used for dairy cattle and 1990 – 2015, % of gross energy.

| Dairy cattle | 1990 | 1991 | 1995 | 2000 | 2002-2015 |
|---|---|---|---|---|---|
| $Y_{m\ incl.\ beet}$ | 6.70 | 6.70 | 6.45 | 6.13 | 6.00 |
| $Y_{m\ excl.\ beet}$ | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| $Y_{m\ grazing}$ | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Average $Y_m$ | 6.38 | 6.38 | 6.24 | 6.07 | 6.00 |

For non-dairy cattle and sheep $Y_m$ given in IPCC (2006) are used. For swine, horses and goats $Y_m$ are based on Crutzen et al. (1986).

### 11.1.6 $CH_4$ emission from enteric fermentation 2015

An overview of the most important variables and the implied emission factor (IEF) for 2015 is shown in Table 11.3a-b. A distinction is made between animals where emissions are calculated based on an annual average population (AAP) (see Table 11.3a) and animals where the emission is based on one produced animal (see Table 11.3b).

Table 11.3a Feed consumption and conversion rates to determine the $CH_4$ emission from livestock enteric fermentation, values per AAP[a], 2015.

| Livestock category | Feed intake | Gross energy (GE) | | Feed on grass | $Y_m$ | IEF[b] |
|---|---|---|---|---|---|---|
| | | Winter | Summer | | | |
| | FU per year | MJ per FU | | %. feeding days per year | % of gross energy | kg $CH_4$ per AAP |
| Cattle (large breed): | | | | | | |
| Dairy cattle | 7 761[c] | 18.90[d] | 18.90 | 5 | 6.0 | 158.15 |
| Heifer calves, < ½ year | 1 047 | 18.30 | 18.83 | - | 6.5 | 22.38 |
| Breeding calves, ½ year to calving | 2 094 | 25.75 | 18.83 | 30 | 6.5 | 56.86 |
| Suckling cows > 600 kg | 2 502 | 34.02 | 18.83 | 61 | 6.5 | 72.18 |
| Swine: | | | | | | |
| Sows incl. piglets < 7.3 kg | 1 510 | 17.49 | 17.49 | - | 0.6 | 2.83 |
| Other: | | | | | | |
| Horses, 600 kg | 2 555 | 29.83 | 18.83 | 50 | 2.5 | 27.93 |
| Sheep incl. lambs | 498 | 29.95 | 18.83 | 73 | 6.5 | 12.72 |
| Lambs | 153 | 29.95 | 18.83 | 73 | 4.5 | 2.71 |
| Goats for meat production incl. kids | 667 | 29.95 | 18.83 | 73 | 5.0 | 13.11 |
| Deer | 668 | 29.95 | 18.83 | 73 | 5.0 | 11.30 |
| | kg feed | MJ per kg feed | | | | |
| Battery hens (100 unit) | 4 070 | 17.46 | 17.46 | - | - | 1.06 |
| Mink incl. young | 258 | 11.47 | 11.47 | - | - | 0 |

[a] AAP - annual average population (See definition in Section 4.1).

[b] IEF – implied emission factor.

[c] kg dry matter.

[d] See Appendix R for the time series.

Table 11.3b Feed consumption and conversion factors to determine the $CH_4$ emission from livestock enteric fermentation, values per produced animal, 2015.

| Livestock category | Feed intake | Gross energy (BE) | | Feed on grass | $Y_m$ | IEF |
|---|---|---|---|---|---|---|
| | | Winter | Summer | | | |
| | FU | MJ per FU | | % | % of gross energy | kg $CH_4$ per prod. animal |
| Cattle (large breed): | | | | | | |
| Bulls calves, < ½ year | 665 | 18.30 | 18.83 | - | 3.0 | 6.56 |
| Bulls, ½ year to slaughter, 440 kg | 1 234 | 18.30 | 18.83 | - | 3.0 | 12.17 |
| Swine: | | | | | | |
| Weaners, 7.3-31 kg | 46 | 16.46 | 16.46 | - | 0.6 | 0.08 |
| Fattening pigs, > 31 kg | 226 | 17.25 | 17.25 | - | 0.6 | 0.42 |
| | kg feed | MJ per kg feed | | | | |
| Broilers, 35 days (1 000) | 3 390 | 18.99 | 18.99 | - | - | 0.01 |
| Ostrich | - | - | - | - | - | 0.66 |
| Pheasant (100 unit) | - | - | - | 100 | - | 0.47 |
| Geese (100 unit) | 2 800 | 18.19 | 18.19 | 100 | - | 0.005 |
| Turkeys, cock/hen (100) | 5 070/2 430 | 18.55 | 18.55 | - | - | 0.01 |
| Ducks (100) | 975 | 18.19 | 18.19 | - | - | 0.003 |

The total $CH_4$ emission from enteric fermentation 2015 is estimated to 147 kt $CH_4$ and the major part is related to the production of dairy cattle (See Table 11.4).

Table 11.4 $CH_4$ emission from enteric fermentation.

| | Emission 2015 | Share of total |
|---|---|---|
| | kt $CH_4$ | % |
| Cattle: | | |
| Dairy cattle | 86.59 | 59.0 |
| Heifer calves, < ½ year | 3.46 | 2.4 |
| Heifer, ½ year to calving | 27.32 | 18.6 |
| Bull, calves < ½ year | 1.50 | 1.0 |
| Bulls, ½ year to slaughter | 2.72 | 1.9 |
| Suckling cows | 6.21 | 4.2 |
| Swine: | | |
| Sows incl. piglets < 7 kg | 2.92 | 2.0 |
| Weaners, 7-31 kg | 2.59 | 1.8 |
| Fattening pigs, > 31 kg | 8.29 | 5.7 |
| Poultry: | | |
| Hens | 0.06 | <0.1 |
| Broilers | 0.0015 | <0.1 |
| Other poultry | 0.0004 | <0.1 |
| Other: | | |
| Horses | 3.38 | 2.3 |
| Sheep | 1.07 | 0.7 |
| Lamps | 0.34 | 0.2 |
| Goats (incl. kids) | 0.15 | 0.1 |
| Deer | 0.09 | 0.1 |
| Mink incl. young | 0 | 0 |
| Total | 146.69 | |

## 11.2 Manure management

$CH_4$ emission from animal manure is calculated based on the energy in animal manure, taking into account housing conditions as manure type and use of straw for bedding based on information from Poulsen et al. (2001) and Poulsen (2008 and 2016).

The housing type determines the manure type and the $CH_4$ production varies depending on the manure type. 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 slurry based housing systems, have led to an increase of the $CH_4$ emission.

The overall $CH_4$ emission from manure management increased by 36% from 1985 to 2015 and this is from both the cattle and swine production. The emission from swine increased from 1985 to 2004 and decreased subsequently until 2015. The emission is mainly determined by the production of fattening pigs and the emission development follows the same trend as the number of produced fattening pigs. Change in housing types however also influence the emission. The emission increases due to change to more slurry based housing systems but decreases again due to change to housing systems with a shorter storage time and HRT (Hydraulic Retention Time) for the manure in the barns.

The emission from dairy cattle also increased from 1985 to 2015, despite a decrease in number of dairy cattle. This is related to higher milk yield and thus higher feed intake and higher manure excretion.

### 11.2.1 Calculation method

$CH_4$ formation from manure management is calculated based on IPCC Guidelines 2006, where the proportion of excreted volatile solids (VS) is determined. The determination of VS is country specific and based on the amount of manure excreted (Equation 11.10 and 11.11).

$$\mathrm{VS_{housing}} = \mathrm{VS_{manure}} + \mathrm{VS_{straw}} \qquad \text{(Eq. 11.10a)}$$

$$\mathrm{VS_{manure}} = \frac{\mathrm{m}}{365} \cdot \mathrm{DM_M} \cdot \mathrm{VS_{DM}} \cdot (365 - \mathrm{g_1}) \qquad \text{(Eq. 11.10b)}$$

$$\mathrm{VS_{straw}} = \mathrm{s} \cdot \mathrm{DM_S} \cdot \left(1 - \frac{\mathrm{ash}}{100}\right) \cdot (365 - \mathrm{g_2}) \qquad \text{(Eq. 11.10c)}$$

$$\mathrm{VS_{grass}} = \frac{\mathrm{m}}{365} \cdot \mathrm{DM_M} \cdot \mathrm{VS_{DM}} \cdot \mathrm{g_1} \qquad \text{(Eq. 11.11)}$$

Where:

| | |
|---|---|
| VS | = volatile solids excreted, kg per animal per year |
| m | = amount of manure excreted, kg per animal per year |
| DM | = dry matter of (M) manure or (S) straw, % |
| $VS_{DM}$ | = share of volatile solids of dry matter, 80 % |

$g_1$ = feeding days on grass, days per year [2]
$g_2$ = actual days on grass, days per year
s = amount of straw, kg per animal per year
ash = ash content in straw, %

The ash content in straw is set to 4.5 % (SEGES, 2005). Dry matter content in manure is based on the normative data (Poulsen, 2016). VS of dry matter ($VS_{DM}$) is 80 % for all animal categories. The number of days on grass is shown in Table 4.14. The amount of manure excreted and straw used depend on housing type and are given in Poulsen (2016).

The amount of $CH_4$ produced is determined from Equation 11.12, where VS is multiplied with the maximum $CH_4$ formation capacity $B_0$, which varies for each livestock type. The $CH_4$ conversion factor, MCF depends on the actual temperature and storage conditions. Denmark has a cold climate and, therefore a relatively low MCF.

$$CH_4 = \left(VS_{\text{housing}} \cdot \frac{MCF_{i,j}}{100} \cdot 0.67 \cdot B_{0,i}\right) + \left(VS_{\text{grass}} \cdot \frac{MCF_{i,j}}{100} \cdot 0.67 \cdot B_{0,i}\right) \qquad \text{(Eq. 11.12)}$$

Where:

$CH_4$ = $CH_4$ emission for the given livestock category, kg $CH_4$ per animal per year
$VS_{housing}$ = volatile solids from housings, kg dry matter per animal per year
$VS_{grass}$ = volatile solids from grazing, kg dry matter per animal per year
0.67 = conversion factor, $m^3$ $CH_4$ to kg $CH_4$
$B_0$ = maximum $CH_4$ producing capacity for manure produced by livestock category (*i*), $m^3$ $CH_4$ per kg VS (IPCC, 2006)
MCF = $CH_4$ conversion factor for a given livestock category (*i*) and a given manure type (*j*) (Country specific for cattle and swine, others IPCC, 2006)

### 11.2.2 MCF - Methane conversion factor

During the last years, several studies have been carried out to support the calculation of an MCF value for slurry treated in anaerobic digestion systems. This work has led to the development of a national MCF for liquid cattle and swine manure, for slurry treated in a biogas plant and untreated raw slurry (Mikkelsen et al, 2016). For all other animal categories and manure types, default MCF values provided in the IPCC guidelines are used (IPCC, 2006). For liquid systems for fur bearing animals the MCF is a weighted value depending on the situation for covered and uncovered slurry tanks. Also for swine on deep bedding housing systems, a weighted value is used due to the residence time of manure in the barn

[2] Actual days on grass is the number of days the heifer is out of the housing. Feeding days on grass is higher than actual days on grass due to a higher feed intake during grazing compared to the period in housing. Feeding days on grass is a conversion of this higher feed intake to days on grass.

For a more detailed description and documentation of the national MCF refer to Chapter 11.3.

Table 11.5 Methane conversion factor (MCF) for 2015, %.

| Livestock category | Manure type | MCF |
|---|---|---|
| Cattle | Slurry | 4.82 |
| | Slurry - biogas treated | 2.62 |
| | Deep litter > 1 month | 17.00 |
| | Deep litter < 1 month | 3.00 |
| | Solid | 2.00 |
| | Pasture/Range/Paddock | 1.00 |
| Swine | Slurry | 13.92 |
| | Slurry - biogas treated | 10.25 |
| | Deep bedding weaners | 7.20 |
| | Deep bedding fattening | 11.40 |
| | Deep bedding sows | 14.67 |
| | Solid | 3.00 |
| Fur bearing animals | Slurry | 10.14 |
| | Deep litter | 3.00 |
| | Solid | 2.00 |
| Poultry | All types | 1.50 |
| | Pasture/Range/Paddock | 1.00 |
| Horses, sheep and goats | Deep litter | 1.00 |
| | Pasture/Range/Paddock | 1.00 |
| Ostich | Solid | 2.00 |
| | Pasture/Range/Paddock | 1.00 |
| Pheasant and deer | Pasture/Range/Paddock | 1.00 |

### Slurry

National MCFs for both untreated and biogas treated liquid manure from cattle and swine have been estimated, see Chapter 11.3. MCF for liquid cattle manure is lower compared to the MCF given in IPCC 2006, while the MCF for liquid swine manure is higher. See Appendix T for time series for the national MCF.

Due to legislation from 2003, all slurry tanks have to be fully covered or have established a floating cover. However, it is difficult to achieve full floating cover all days of the year and some emission can take place during filling and mixing of manure in the tank. Therefore, it is assumed that floating / fixed covers are absent on 2 % in fur production. MCF for fur slurry is estimated as 98 % with an MCF of 10 % (covered) and 2 % with an MCF of 17 % (uncovered). This results in a MCF of 10.14 for fur slurry.

### Deep bedding

The MCF for swine deep bedding depends on how long time the manure is stored in the barn and the emission is particularly high for bedding stored more than one month. The bedding situation is based on information from

SEGES and is different for the three swine subcategories. The lowest MCF at 7.2 % is seen for weaners because 70% of the bedding material is removed during the first month. The situation is opposite for sows where only 20 % of the bedding is removed during the first month, which lead to a higher MCF at 14.7 %.

Table 11.6 Methane conversion factor (MCF) for swine, deep bedding.

| | | DK condition, % of yr | | IPCC, 2006 | |
|---|---|---|---|---|---|
| MCF, swine deep bedding | MCF, DK | > 1 month | < 1 month | > 1 month | < 1 month |
| Deep bedding weaners | 7.2 % | 30 | 70 | 17 % | 3 % |
| Deep bedding fattening | 11.4 % | 60 | 40 | 17 % | 3 % |
| Deep bedding sows | 14.7 % | 80 | 20 | 17 % | 3 % |

### 11.2.3 $CH_4$ emission from manure management 2015

Table 11.7 gives an overview of data used to calculate the $CH_4$ emission and the implied emission factor (IEF) from animal manure covering different categories of livestock.

The $B_0$ values used in the inventories are based on IPCC default values. Here it is demonstrated that the maximum $CH_4$ formation is significantly higher in swine manure than in cattle manure.

Table 11.7a Conversion factors to determine the $CH_4$ emission from animal manure handling, values per AAP[a], 2015.

| Livestock category | Days on grass | Max.$CH_4$ producing capacity | IEF[b] |
|---|---|---|---|
| | $g_1$ ($g_2$)[a] days per year | $B_0$ $m^3$ $CH_4$ per kg VS | kg $CH_4$ per AAP[c] |
| Cattle (large breed): | | | |
| Dairy cattle | 18 | 0.24 | 23.14 |
| Heifer calves, < ½ year | 0 | 0.18 | 2.45 |
| Heifer, ½ year to calving | 132 (111) | 0.18 | 11.33 |
| Suckling cows, > 600 kg | 224 | 0.18 | 21.75 |
| Swine: | | | |
| Sows incl. piglets < 7.1 kg | 0 | 0.45 | 12.06 |
| Poultry: | | | |
| Hens, battery (100 units) | 0 | 0.39 | 4.44 |
| Other: | | | |
| Horses, 600 kg | 182.5 | 0.3 | 3.25 |
| Sheep | 265 | 0.19 | 0.38 |
| Lamps | 265 | 0.19 | 0.07 |
| Goats incl. kids | 265 | 0.18 | 0.45 |
| Deer | 365 | 0.18 | 0.33 |
| Fur animals | 0 | 0.25 | 0.51 |

Table 11.7b Conversion factors to determine the $CH_4$ emission from animal manure handling, values per produced animal, 2015.

| Livestock category | Days on grass | Max.$CH_4$ producing capacity | IEF[b] |
|---|---|---|---|
| | $g_1$ ($g_2$)[a] days per year | $B_0$ $m^3$ $CH_4$ per kg VS | kg $CH_4$ per prod. animal |
| Cattle (large breed): | | | |
| Bull calves, < ½ year | 0 | 0.18 | 2.08 |
| Bull, ½ year to slaughter, 440 kg | 0 | 0.18 | 19.21 |
| Swine: | | | |
| Weaners, 7.1-31 kg | 0 | 0.45 | 0.22 |
| Fattening pigs, > 31 kg | 0 | 0.45 | 1.30 |
| Poultry: | | | |
| Broilers (1 000 units) | 0 | 0.36 | 2.53 |
| Ostrich | 0 | 0.25 | 3.97 |
| Pheasant (100 units) | 365 | 0.36 | 1.48 |
| Geese (100 units) | 365 | 0.36 | 2.11 |
| Turkeys (100 units) | 0 | 0.36 | 2.94 |
| Ducks (100 units) | 0 | 0.36 | 1.45 |

[a] $g_1$ feeding days on grass, $g_2$ actual days on grass.

[b] IEF – implied emission factor.

[c] AAP - annual average population (See definition in Section 4.1).

The total $CH_4$ emission from manure management 2015 is estimated to 74 kt $CH_4$ and the main emission originates from the production of swine, which has a high proportion of slurry based housing system (See Table 11.8).

Table 11.8 $CH_4$ emission from animal manure.

| Livestock Category | Emission 2015 | Share of total |
|---|---|---|
| | kt $CH_4$ | % |
| Cattle | | |
| Dairy cattle | 13.44 | 18.1 |
| Heifer calves, < ½ year | 0.38 | 0.5 |
| Heifer, ½ year to calving | 5.61 | 7.6 |
| Bull, calves < ½ year | 0.48 | 0.6 |
| Bulls, ½ year to slaughter | 4.30 | 5.8 |
| Suckling cows | 1.94 | 2.6 |
| Swine: | | |
| Sows incl. piglets < 7.1 kg | 12.44 | 16.8 |
| Weaners, 7.1-31 kg | 7.01 | 9.5 |
| Fattening pigs, > 31 kg | 25.83 | 34.8 |
| Poultry: | | |
| Hens | 0.22 | 0.3 |
| Broilers | 0.29 | 0.4 |
| Other poultry | 0.03 | <0.1 |
| Other: | | |
| Horses | 0.42 | 0.6 |
| Sheep | 0.03 | <0.1 |
| Lambs | 0.01 | <0.1 |
| Goats (incl. kids) | 0.01 | <0.1 |
| Deer | 0.002 | <0.1 |
| Mink incl. Young | 1.73 | 2.3 |
| Total | 74.16 | |

## 11.3 Biogas treatment of slurry

### 11.3.1 Introduction

A significant and growing part of the Danish animal slurry is being used for production of biogas (10 % in 2015). The production uses anaerobic digestion of animal manure in combination with other biodegradable products, e.g. agricultural waste and slaughterhouse waste. Biogas treatment is important to be included in the inventories, because the anaerobic digested slurry produces lower $CH_4$ emission from storage and from applied slurry on cultivated soils.

As mentioned in Chapter 11.2.1 the $CH_4$ emission from manure management depends, among other variables, on the $CH_4$ conversion factor (MCF), which depends on the actual temperature and storage conditions. The 2006 IPCC Guidelines Tier 2 approach recommends an MCF at 10 % for covered and an MCF at 17% for uncovered manure (cool climate) for swine and cattle. Based on study activities in 2015-2016, a national MCF has been estimated for raw untreated slurry and for anaerobic digested slurry, from cattle and swine slurry respectively. Focus has been on cattle and swine slurry, which cover >96 % of the total $CH_4$ emission from manure management in the 2015 submission.

First, the result of the national MCF estimated will be presented. Following is an overview of the biogas production in Denmark and the estimation of the amount of treated slurry. Finally, a description and documentation of the estimation of the national MCF are provided.

### 11.3.2 National estimated MCF for cattle- and swine slurry

In 2015-2016 national studies were conducted covering e.g. manure storage time in Danish barns (Kai et al, 2015) and the emissions from anaerobically digested material (Petersen et al, 2016).

During the work with estimating the $CH_4$ emission from anaerobic digested cattle and swine slurry, it became apparent that the currently used MCF for cattle and swine slurry (the default values from the 2006 IPCC Guidelines) were not properly reflecting the Danish conditions. The analyses based on new measurements showed that the emission from untreated swine slurry was underestimated. It was therefore decided also to estimate a country specific MCF for untreated cattle and swine slurry.

The national estimates of MCF are based on temperature dependent degradation functions, which take into account the different temperature conditions inside the barns and during outdoor storage. The storage time and the related $CH_4$ emission inside the barns, outdoor storage and storage of anaerobic digested biomass are also taken into account. The approach uses temperature dependent functions adapted to Danish conditions. The emissions are estimated separately from the barns and pre-tanks at the farm. After the manure has left the barn, it is split in two fractions. The major fraction of 90 % is left on the farms as untreated raw liquid manure and currently 10 % is brought to anaerobic digestion either on the farms or at large-scale biogas plants. The digested material is returned for storage on the farms until field application.

In Table 11.9, the MCF values used in previous emission inventories are compared to the new national estimated values.

Table 11.9 Methane conversion factor (MCF) values previously used and from the current study (Nielsen et al, 2017).

| MCF in 2015, % | Previously used[a] | New – liquid system | New - anaerobic digesters |
|---|---|---|---|
| Untreated cattle slurry | 10.14 | 4.82 | |
| Untreated swine slurry | 10.35 | 13.92 | |
| Biogas treated cattle slurry | 10.14 | | 2.62 |
| Biogas treated swine slurry | 10.35 | | 10.25 |

[a] weighted average for covered (MCF 10 %) and uncovered (MCF 17 %) slurry.

The national MCF for cattle slurry is lower than the 2006 IPCC Guidelines default and also lower than the MCF, which has been found in Swedish studies (Rodhe et al. 2009, 2012 and 2015). The lower MCF for Danish conditions is furthermore supported by studies by Møller (2013), who investigated the $CH_4$ emission from cattle and swine manure under different temperatures. This study indicates low $CH_4$ emissions from dairy cattle slurry stored below 15 °C. This is probably due to the fact, that the methanogens in the slurry are not very active at these relatively low temperatures. When the temperatures were higher than 20 °C, the $CH_4$ emission from cattle slurry increases, although not comparable to the emissions from swine slurry.

The national estimated MCF for untreated swine slurry is higher than the 2006 IPCC Guidelines default. The national study shows a very fast turnover of VS in the swine slurry, and especially inside the barns caused by the relatively high temperatures (Møller, 2013), which leading to a high emission of methane per kg of VS.

Table 11.10 shows the trend 1990 – 2015 for the national estimated MCF for cattle and swine slurry both digested and undigested. The national estimated MCF for not digested slurry for cattle is changing slightly over time, from 4.85 in 1990 and 4.82 in 2015. The MCF not digested slurry for swine, is reduced from 15.19 in 1990 to 13.92 in 2015 due to changes in housing system. The MCF depends on storage time in housing, which differ from system to system. The development from housing systems with fully slatted floor towards systems with partly slatted floor, shorter than storage time for slurry and thus reduces the MCF.

The MCF for undigested cattle slurry 2015 is estimated to 4.82 % and the MCF for digested cattle slurry is 2.62 %, which corresponds to a 46 % reduction of $CH_4$ emission. The MCF for undigested swine slurry in 2015 is estimated to 13.92 % and the MCF for digested swine slurry to 10.25 %, which corresponds to a 26 % reduction. The changes over time is mainly due to changes in housing types.

Table 11.10 Estimated methane conversion factor (MCF) for digested and undigested cattle and swine slurry from 1990 to 2015, %.

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | | | | | | | | | | |
| MCF for digested cattle slurry | 2.68 | 2.61 | 2.88 | 2.77 | 2.75 | 2.77 | 2.85 | 2.93 | 2.78 | 2.62 |
| MCF for undigested cattle slurry | 4.85 | 4.76 | 5.03 | 4.92 | 4.88 | 4.90 | 4.91 | 5.00 | 4.88 | 4.82 |
| | | | | | | | | | | |
| Swine | | | | | | | | | | |
| MCF for digested swine slurry | 11.94 | 11.79 | 11.55 | 10.70 | 10.66 | 10.59 | 10.52 | 10.46 | 10.39 | 10.25 |
| MCF for undigested swine slurry | 15.19 | 15.12 | 14.94 | 14.18 | 14.14 | 14.07 | 14.00 | 13.95 | 13.93 | 13.92 |

### 11.3.3 Estimation of slurry treated in biogas plants in Denmark

In Denmark, the biogas plants are divided into five facility types; wastewater, industrial, landfills, large-scale plants (centralised multi farms) and farm-level plants. Large-scale biogas plants are larger facilities, where slurry is received from several farms and farm-level plants are characterised by receiving manure from one or a few farms. In 2015, the total biogas production is estimated by the Danish Energy Agency to 6 348 PJ (DEA, 2016a) and the manure based biogas plants account for approximately 82 % of the total biogas production produced at 26 large-scale plants and 51 farm-level plants.

The livestock production mainly takes place in the western parts of Denmark in Jutland and consequently the majority of manure based biogas plants are located here.

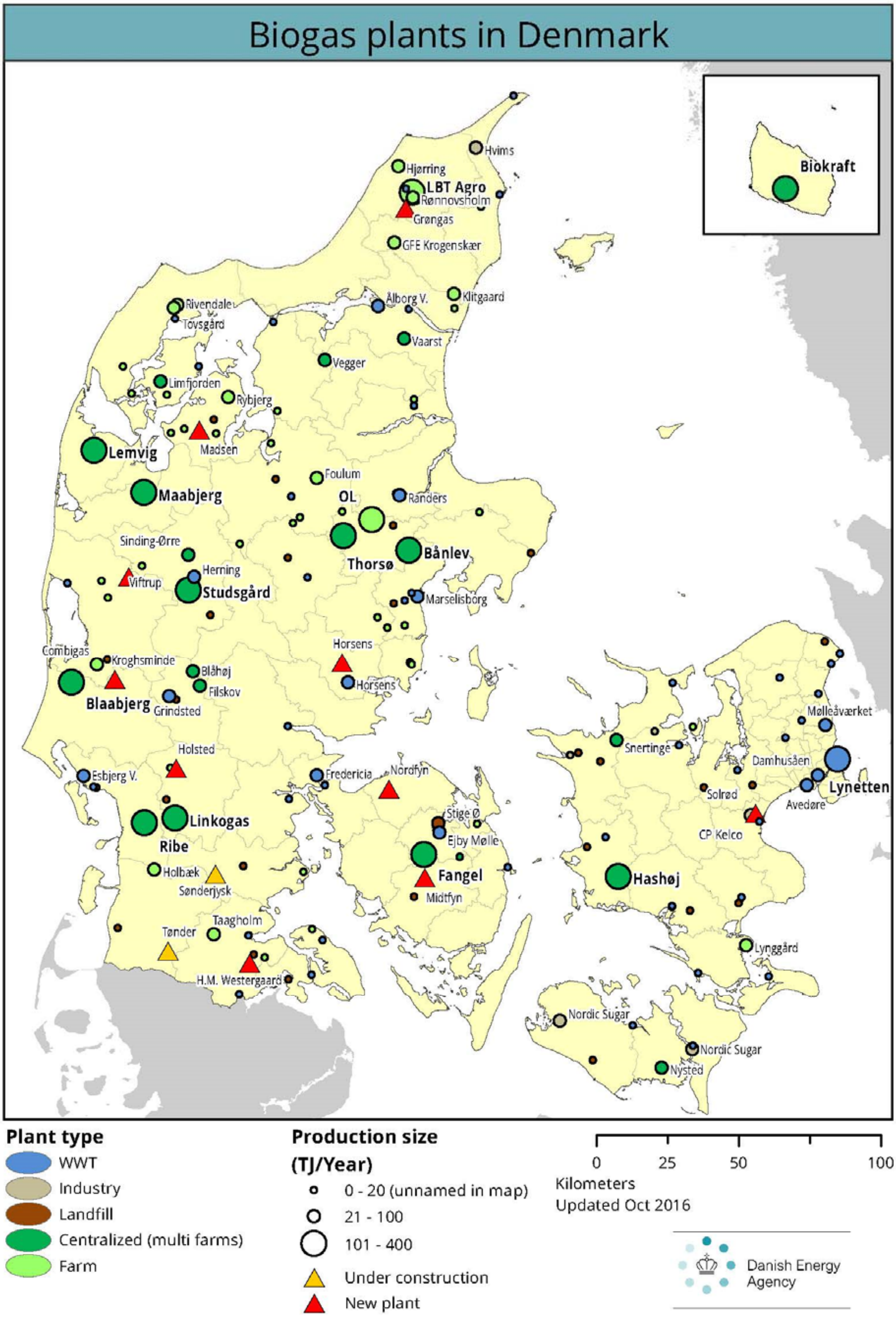



Figure 11.1 Biogas producers in Denmark, 2016 (DEA, 2016c). WWT – waste water treatment.

Data collected by the Danish Energy Agency (DEA) is based on reporting from each biogas plant. The data gives, for the first time, an overview of the actual amount and different types of biomass used in biogas production. In the following, the data are referenced as register of Biomass Input to Biogas production (BIB). The BIB register reflects the situation in 2015 (DEA, 2016b). The data given in the BIB register is used to find the relation between the biogas production and the amount of slurry delivered to biogas plants. This relation has been used to estimate the amount of biomass input for previous years 1990 – 2014.

The anaerobic digestion process is complicated and sensitive to several factors, such as different biomass types and different combination of biomass input, nutrients concentration, species and concentration of bacteria, operational conditions for each biogas plants, etc. Uses of current data from the BIB register will to some extend take these variations from biogas plant to biogas plant into account, because the data is based on existing production.

**BIB register**

The BIB register does not fully cover all biogas plants. It includes however, the most important biogas producers, and thus it covers 93 % of the total biogas production. Animal manure for biogas production mainly takes place at the large-scale- or the farm-scale biogas plants and only 1 % is delivered to industrial biogas plants.

Data covering the large-scale plants and farm-level biogas plants show that manure accounts for 79 % of the total biomass input. The remaining biomass input is from sewage sludge, residues from the meat production and biomass from crops. The BIB register shows that the majority of manure sent to anaerobic digestion is slurry (96 %). Deep litter to biogas treatment accounts for 2% of the total amount of manure.

The emission inventories only includes biogas treated slurry from cattle and swine, which account for 88 % of the total amount of slurry delivered to biogas plants. The BIB register allows to include biogas treated slurry from mink- and poultry production, deep litter and other manure types, which is planned to be implemented in later emission inventories.

In 2015, large-scale and farm-level biogas plants produced 4 161 TJ, which correspond to 70 % of the total biogas production. The total biomass input to all facilities is estimated to 8 535 kt and the amount used in large-scale and farm-level biogas plants accounts for 4 143 kt (49 %).

Table 11.11 Biomass input and biogas production, 2015.

| Facility type | Biomass input, kt | % | Biogas production, TJ* | % |
|---|---|---|---|---|
| Wastewater treatment | 2 522 | 30 | 776 | 13 |
| Industrial | 1 871 | 22 | 927 | 16 |
| Landfill | - | - | 70 | 1 |
| Large-scale | 3 289 | 39 | 3 085 | 52 |
| Farm-scale | 854 | 10 | 1 086 | 18 |
| Total | 8 535 | 100 | 5 944 | 100 |

*Used a conversion factor of 35.8 MJ/m3 and $CH_4$ content of 65 %.

### Biogas treated slurry 1990 – 2015

The biogas production 1990-2015 is specified in the Danish Energy Statistics (DEA, 2016d). Assuming that the relation between biogas production and input of slurry given in BIB register for 2015 is roughly similar in recent years 1990-2015, the biogas treated slurry can be estimated based on the energy production.

In 1990, the biogas production at the large-scale, farm-level and industrial biogas plants was 752 TJ which correspond to a slurry input of 194 kt, increasing to 5 259 TJ and 3 832 kt slurry in 2015.

In 2015, around 10 % of total amount of slurry is delivered to biogas production, 14 % of the total amount of cattle slurry and 8 % for swine slurry.

Table 11.12 Biogas production, 1990-2015 (DEA, 2016b and DEA, 2016d).

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|
| **Biogas production, TJ** | | | | | | |
| Total | 752 | 1758 | 2912 | 3830 | 4337 | 6348 |
| Large-scale, farm-level and industrial biogas plants | 266 | 746 | 1442 | 2375 | 3184 | 5259 |
| **Slurry delivered to biogas plants, kt** | | | | | | |
| Cattle, swine and mixed | 194 | 543 | 1050 | 1731 | 2320 | 3832 |
| % of total produced slurry | <1 | 2 | 4 | 5 | 7 | 10 |

## 11.3.4 Calculation method for the national MCF

MCF is estimated by using the Tier 2 equation for estimating $CH_4$ emission factor from manure management from IPCC 2006:

$$MCF_{not\ digested} = \left(\frac{E_{barns} + E_{storage,not\ digested}}{VS_{barns}}\right) / (0.67 \cdot B_0) \qquad \text{(Eq. 11.13)}$$

Where:

$MCF_{not\ digested}$ = methane conversion factor for not digested slurry, %

$E_{barns}$ = emission of $CH_4$ from barns, kg $CH_4$, see Equation 11.15

$E_{storage,\ not\ digested}$ = emission of $CH_4$ from storage of not digested slurry, kg $CH_4$, see Equation 11.16

$VS_{barns}$ = amount of volatile solids, kg VS, based on VS excreted, see Table 11.14

$B_0$ = maximum methane producing capacity, $m^3$ $CH_4$ per VS

0.67 = conversion factor, $m^3$ $CH_4$ to kg $CH_4$

$$MCF_{digested} = \left(\frac{E_{barns} + E_{storage,digested}}{VS_{barns}}\right) / (0.67 \cdot B_0) \qquad \text{(Eq. 11.14)}$$

Where:

$MCF_{digested}$ = methane conversion factor for digested slurry, %

$E_{barns}$ = emission of $CH_4$ from barns, kg $CH_4$, see Equation 11.15

$E_{storage,\ digested}$ = emission of $CH_4$ from storage of not digested slurry, kg $CH_4$, see Equation 11.16

| | |
|---|---|
| $VS_{barns}$ | = amount of volatile solids, kg VS, based on VS excreted, see Table 11.14 |
| $B_0$ | = maximum methane producing capacity, $m^3$ $CH_4$ per VS |
| 0.67 | = conversion factor, $CH_4$ per $m^3$ $CH_4$ |

### 11.3.5 Estimation of methane emission from raw cattle and swine slurry and anaerobic digested animal manure

The $CH_4$ emission from liquid cattle and swine manure is based on $CH_4$ emission from barns, from outdoor stored raw cattle and swine slurry, from anaerobic digesters and from anaerobically digested biomass / primarily animal manure.

#### Emission of $CH_4$ from barns

$$E_{barns} = VS_{barns} \cdot EF_{barns} \cdot HRT/365 \qquad \text{(Eq. 11.15)}$$

Where:

| | |
|---|---|
| $E_{barns}$ | = emission of $CH_4$ from barns, kg $CH_4$ |
| $VS_{barns}$ | = amount of volatile solids, kg VS, based on VS excreted, see Table 11.14 |
| $EF_{barns}$ | = emission factor for $CH_4$, based on measurements, see Table 11.13 |
| HRT | = Hydraulic Retention Time, days, see Table 11.14 |

#### Emission of $CH_4$ from storage of not digested slurry

$CH_4$ emission from storage of slurry is estimated as VS multiplied by EF where VS is divided in VS degradable (VSd) and VS non-degradable[3] (VSnd).

$$E_{Storage,not\ digested} = VSd_{storage,not\ digested} \cdot EFd_{storage,not\ digested} + VSnd_{storage,not\ digested} \cdot EFnd_{storage,not\ digested} \qquad \text{(Eq. 11.16)}$$

Where:

| | |
|---|---|
| $E_{storage,\ not\ digested}$ | = emission of $CH_4$ from storage of not digested slurry, kg $CH_4$ |
| $VSd_{storage,\ not\ digested}$ | = amount of degradable volatile solids in the slurry not digested, see Table 11.14, kg VSd |
| $EFd_{storage,\ not\ digested}$ | = emission factor for $CH_4$ for degradable VS, see Table 11.13, g $CH_4$ per kg VSd per year |
| $VSnd_{storage,\ not\ digested}$ | = amount of non-degradable volatile solids in the slurry not digested, see Table 11.14, kg VSnd |
| $EFnd_{storage,\ not\ digested}$ | = emission factor for $CH_4$ for degradable VS, see Table 11.13, g $CH_4$ per kg VSnd per year |

#### Emission of $CH_4$ from storage of digested slurry

$$E_{Storage,digested} = VSd_{storage,digested} \cdot EFd_{storage,digested} + VSnd_{storage,digested} \cdot EFnd_{storage,digested} \qquad \text{(Eq. 11.17)}$$

Where:

| | |
|---|---|
| $E_{storage,\ digested}$ | = emission of $CH_4$ from storage of digested slurry, kg $CH_4$ |

[3] Non-degradable could also be refed to as low-degradable because a small decomposition is possible.

| | |
|---|---|
| $VSd_{storage, digested}$ | = amount of degradable volatile solids in the slurry digested, see Table 11.14, kg VSd |
| $EFd_{storage, digested}$ | = emission factor for $CH_4$ for degradable VS, see Table 11.13, g $CH_4$ per kg VSd per year |
| $VSnd_{storage, digested}$ | = amount of non-degradable volatile solids in the slurry digested, see Table 11.14, kg VSnd |
| $EFnd_{storage, digested}$ | = emission factor for $CH_4$ for degradable VS, see Table 11.13, g $CH_4$ per kg VSnd per year |

Table 11.13 Estimated emission factors.

| Cattle | |
|---|---|
| $EF_{barns}$, g $CH_4$ per kg VS per year | 66.92 |
| $EFd_{storage, not digested}$, g $CH_4$ per kg VSd per year | 12.02 |
| $EFnd_{storage, not digested}$, g $CH_4$ per kg VSnd per year | 0.16 |
| $EFd_{storage, digested}$, g $CH_4$ per kg VSd per year | 10.13 |
| $EFnd_{storage, digested}$, g $CH_4$ per kg VSnd per year | 0.19 |
| Swine | |
| $EF_{barns}$, g $CH_4$ per kg VS per year | 569.50 |
| $EFd_{storage, not digested}$, g $CH_4$ per kg VSd per year | 29.64 |
| $EFnd_{storage, not digested}$, g $CH_4$ per kg VSnd per year | 0.63 |
| $EFd_{storage, digested}$, g $CH_4$ per kg VSd per year | 10.13 |
| $EFnd_{storage, digested}$, g $CH_4$ per kg VSnd per year | 0.19 |

Table 11.14a-c shows the estimated $CH_4$ emission from liquid cattle and swine slurry for the years 1990-2015. Table 11.14a-c shows the total amount of liquid VS excreted by cattle and swine, the average HRT, the estimated g $CH_4$ per kg VS and the total emission of $CH_4$ from that category.

For cattle slurry, the total emission in barns in 1990 has been estimated to 3.64 kt $CH_4$ increasing to 4.48 kt $CH_4$ in 2015. The increase in this emission is due to change in housing systems where the slurry is kept in the housings longer and more slurry. In addition to this comes an emission from outdoor storage, estimated to 4.25 kt $CH_4$ in 1990 and remains almost constant to 2015. To this comes a small amount from digested manure.

For swine slurry has the total emission inside the barns in 1990 been estimated to 16.26 kt $CH_4$ in 1990 increasing to 27.44 kt $CH_4$ in 2015, due to a growing swine production until 2011. To this comes an emission from outdoor storage. This has been estimated to 5.75 kt $CH_4$ in 1990 and an increase to 10.65 kt $CH_4$ in 2015. The increase in this emission is due to increase in the share of degradable volatile solids in the slurry. In addition, a small amount is realised from the digested manure.

Table 11.14a Emission estimates for cattle slurry inside the barns and undigested stored liquid manure.

| Cattle | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barns | | | | | | | | | | |
| Slurry, tonnes VS per year | 1 081 908 | 998 008 | 989 831 | 1 149 864 | 1 193 926 | 1 200 212 | 1 274 389 | 1 278 969 | 1 277 397 | 1 275 456 |
| EF, g $CH_4$ per kg VS per year | 66.92 | 66.92 | 66.92 | 66.92 | 66.92 | 66.92 | 66.92 | 66.92 | 66.92 | 66.92 |
| Average HRT, days | 18.33 | 18.12 | 20.81 | 20.14 | 19.64 | 19.77 | 19.94 | 20.58 | 19.63 | 19.15 |
| EF, g $CH_4$ per kg VS per year | 3.36 | 3.32 | 3.82 | 3.69 | 3.60 | 3.62 | 3.66 | 3.77 | 3.60 | 3.51 |
| Emission, kt $CH_4$ per year | 3.64 | 3.31 | 3.78 | 4.25 | 4.30 | 4.35 | 4.66 | 4.83 | 4.60 | 4.48 |
| Storage, not digested | | | | | | | | | | |
| Slurry, not digested, tonnes VSd ab barn | 343 702 | 311 113 | 298 667 | 337 274 | 344 740 | 347 694 | 373 843 | 373 288 | 363 712 | 353 552 |
| Slurry, not digested, tonnes VSnd ab barn | 722 043 | 653 443 | 628 941 | 709 778 | 725 139 | 731 445 | 786 584 | 785 905 | 765 042 | 743 325 |
| EF, g $CH_4$ per kg VSd per year | 12.02 | 12.02 | 12.02 | 12.02 | 12.02 | 12.02 | 12.02 | 12.02 | 12.02 | 12.02 |
| EF, g $CH_4$ per kg VSnd per year | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| Emission, kt $CH_4$ per year | 4.25 | 3.85 | 3.69 | 4.17 | 4.26 | 4.30 | 4.62 | 4.62 | 4.50 | 4.37 |

Table 11.14b Emission estimates for swine slurry inside the barns and undigested stored liquid manure.

| Swine | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barns | | | | | | | | | | |
| Slurry, tonnes VS per year | 481 523 | 678 185 | 800 154 | 931 488 | 947 759 | 963 417 | 914 097 | 900 361 | 930 935 | 929 047 |
| EF, g $CH_4$ per kg VS per year | 569.50 | 569.50 | 569.50 | 569.50 | 569.50 | 569.50 | 569.50 | 569.50 | 569.50 | 569.50 |
| Average HRT, days | 21.64 | 21.49 | 21.10 | 19.47 | 19.39 | 19.23 | 19.10 | 18.98 | 18.94 | 18.93 |
| EF, g $CH_4$ per kg VS per year | 33.77 | 33.53 | 32.93 | 30.38 | 30.26 | 30.01 | 29.80 | 29.62 | 29.55 | 29.54 |
| Emission, kt $CH_4$ per year | 16.26 | 22.74 | 26.35 | 28.29 | 28.68 | 28.91 | 27.24 | 26.67 | 27.51 | 27.44 |
| Storage, not digested | | | | | | | | | | |
| Slurry, not digested, tons VSd ab barn | 189 073 | 264.662 | 310 420 | 365 040 | 367 433 | 375 360 | 354 815 | 348 580 | 356 235 | 350 390 |
| Slurry, not digested, tons VSnd ab barn | 234 480 | 327.562. | 382 251 | 440 107 | 442 561 | 451 201 | 425 762 | 417 669 | 426 599 | 419 553 |
| EF, g $CH_4$ per kg VSd per year | 29.64 | 29.64 | 29.64 | 29.64 | 29.64 | 29.64 | 29.64 | 29.64 | 29.64 | 29.64 |
| EF, g $CH_4$ per kg VSnd per year | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 |
| Emission, kt $CH_4$ per year | 5.75 | 8.05 | 9.44 | 11.10 | 11.17 | 11.41 | 10.78 | 10.59 | 10.83 | 10.65 |

Table 11.14c Emission estimates for digested biomass.

| Digested biomass | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| VSd, tonne | 1 215 | 3 403 | 6 578 | 10 837 | 14 528 | 14 018 | 14 938 | 15 737 | 18 322 | 17 113 |
| VSnd, tonne | 7 529 | 21 079 | 40 745 | 67 129 | 89 990 | 86 834 | 92 531 | 97 479 | 113 493 | 106 004 |
| EF, g $CH_4$ per kg VSd per year | 10.13 | 10.13 | 10.13 | 10.13 | 10.13 | 10.13 | 10.13 | 10.13 | 10.13 | 10.13 |
| EF, g $CH_4$ per kg VSnd per year | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| Emission, kt $CH_4$ per year | 0.01 | 0.04 | 0.07 | 0.12 | 0.16 | 0.16 | 0.17 | 0.18 | 0.21 | 0.19 |

### 11.3.6 Documentation for estimation of the national MCF

$CH_4$ formation in manure is mainly formed by microorganisms that produce methane as a metabolic by-product in anoxic conditions. They are classified as archaea, a domain distinct from bacteria. The metabolism is temperature dependent, and actual temperatures are therefore the main driver for the methanogenesis. The overall methodology for estimating the $CH_4$ emission from liquid animal manure and anaerobically digested biomass is based on the available amount of volatile substance (VS) in the biomass and the temperature dependent $CH_4$ formation functions (Van't-Hoof / Arrhenius equation) (Sommer et al., 2004). The model by Sommer et al. (2004) uses a 2-pooled concept for estimating the $CH_4$ emission from degradable VS (VSd) and from non-degradable[4] VS (VSnd). The emission from VSnd has been set to 1 % of VS (Sommer et al., 2001, 2004). During storage inside the barns, in outdoor storages and in the anaerobic digesters VS is degraded. To take into account a “decreasing” emission due to depletion of the VS in the manure in up to 8-9 months, a degradation model has been developed.

For the purpose of documenting the emission estimate in the inventories, the following tasks have been performed:

- a thorough literature search
- estimation of temperature functions for animal manure stored
    - inside the barns for swine and cattle barns
    - outdoor storage for untreated liquid manure
    - anaerobically digested manure
- estimation of storage time, HRT (Hydraulic Retention Time) in the barns (Kai et al., 2015)
- temperature dependent $CH_4$ formation from 27 samples of different types of liquid swine manure and 12 samples of different type of liquid dairy cattle manure (Petersen et al., 2016)
- developing a model to estimate the storage time in outdoor liquid manure stores
- compilation of data from BIB. The BIB include information on suppliers, amount and types of manure and other biomass used in the Danish anaerobic digesters
- developing an emission model based on time steps of 10 days

#### Dry matter excretion and VS, VSd and VSnd

The amount of excreted dry matter is taken from the Danish Normative System for animal manure (data included in IDA). The share of VS of dry matter is set as a default to 80 % as used in the agricultural inventories.

In the model for estimating the $CH_4$ emission a 2-pooled model is used, dividing the VS in VSd and VSnd (Tong et al., 1990, Sommer et al., 2004). The share of VSd and VSnd has for the purpose of the inventories been estimated by Petersen et al. (2016) for swine (sow, weaners and fattening pigs) and cattle slurry (mainly dairy cattle slurry). The manure samples were taken in barns in full production and can thus be seen as normal farming practise. Petersen et al. (2016) estimated the average age of the swine slurry to 13-15 days and

[4] Non-degradable could also be refed to as low-degradable because a small decomposition is possible.

the cattle slurry to around 20-30 days. The slurry samples can therefore be seen as quite fresh manure with only little degradation.

Petersen et al. (2016) sampled 27 swine slurry samples and 12 dairy cattle slurry samples and estimated the VSd. For swine manure they found an average VSd of 50.87 (95 % Confidence Interval: 44.49 - 57.26) and for slurry for dairy cattle a VSd of 32.63 (95 % Confidence Interval: 28.65 – 36.62).

Møller and Moset (2015) has measured dry matter and VS in digested manure from eight biogas plants. They found an average dry matter in the digested manure of 4.88 % were VS of dry matter in average were 3.32 %. The main part 86.1 % of VS in the digested manure were non-degradable VS (VSnd). Based on the model, which take storage time and temperature into account, the emission factor for $VSnd_{digested}$ and $VSd_{digested}$ were estimated to 0.19 g $CH_4$ per kg VS per year and 10.13 g $CH_4$ per kg VS per year, respectively.

### Parameters for Arrhenius function

Estimation of the parameters for Arrhenius function is based on Petersen et al. (2016) combined on data from Elsgaard et al. (2016).

The determination of methane production rates largely followed the description of Elsgaard et al. (2016). Two temperatures were selected at approximately 10 and 20°C (Petersen et al., 2016). To estimate the parameters, 20 samples from swine slurry and 11 samples from cattle slurry were used. In effect, cattle slurry was always incubated at around 10 °C, and swine slurry around 20 °C.

Methane production rates that have been observed, corrected to the ambient temperature in slurry pits and channels at sampling time, were compared with predictions based on the model presented by Sommer et al. (2001):

$$F(T) = \left(VS_d * b_1 * \exp\left(lnA - E_a * \left(\frac{1}{RT}\right)\right) + VS_{nd} * b_2 * \exp(lnA - E_a * \left(\frac{1}{RT}\right))\right) \cdot 24 \quad \text{(Eq. 11.18)}$$

Where:

| | |
|---|---|
| F(T) | = g $CH_4$ per day |
| VSd | = volatile solids, degradable, kg |
| VSnd | = volatile solids, non-degradable, kg |
| b1 and b2 | = scaling factors, 1 for VSd and 0.01 for VSnd (dimension-less) |
| A | = Arrhenius parameter, g $CH_4$ per kg VS per h |
| Ea | = the apparent activation energy, J per mol |
| R | = the gas constant, 8.314 J per mol per K |
| T | = temperature, K |
| 24 | = conversion from hour to day |

An activation energy, Ea, of 80.9 kJ per mol was recently proposed by Elsgaard et al. (2016) which represented the temperature response of a cattle slurry, a swine slurry, fresh digestate and stored digestate (no significant differences).

In Table 11.15 is shown the parameters used.

Table 11.15 $CH_4$ emission estimate parameters.

| | Ea, J per mol | Ln(A), g $CH_4$ per kg VS per hour | VSd, % | VSnd, % | Source |
|---|---|---|---|---|---|
| Liquid cattle manure | 80.900 | 29.96 | 32.63 | 67.37 | Petersen et al. (2016) |
| Liquid swine manure | 80.900 | 31.30 | 50.87 | 49.13 | Petersen et al. (2016) |
| Digestate | 80.900 | 30.10 | 13.9 | 86.1 | Elsgard et al. (2016) |

### Degradation function

To take into account long time storage of the slurry, the loss of VSd during storage and the actual amount of VSd and VSnd has to be determined.

Based on literature data and unpublished research data, it was estimated that the C loss from manure stores constitutes roughly of 20 % $CH_4$-C and 80 % $CO_2$-C (Dinuccion et al., 2008). In the emission estimate, a conservative figure of 25 % is used. Beside this Patni and Jui (1987) found 10-25 % losses of dry matter during storage of dairy cattle slurry supporting that a high share of loss of VS is taken place as $CO_2$ as this is not lost as $CH_4$. For effluent from digested animal manure, Wang et al. (2016) found very low $CH_4$ / $CO_2$ ratios at around 3-4 % (unpublished data received from Yue Wang). For the digestate, an estimate for $CH_4$-C / $CO_2$-C fraction of 10 % is used (Dong, 2013, Pers. Comm.).

The $CH_4$ / degradation model was built in an excel spreadsheet with a time step of 10 days.

### Danish animal housing systems and Hydraulic Retention Time (HRT)

The most common housing systems for swine in Denmark are partly plug-systems with slatted floors and a depth of the slurry channels of 40-60 cm. The storage capacity inside the barns in these systems is around 40 days. After 40 days the farmers pull the plugs and the slurry under the slats are flushed to the outdoor storage tanks. During the production cycle of weaners and fattening pigs it is normally only needed to flush once during the production, and once after the pigs have been moved and the barn is washed and cleaned. In these systems the average storage time is therefore app. 40 days / 2 = 20 days. The average storage time is called the Hydraulic Retention Time (HRT).

For the purpose of the Danish inventories, Kai et al. (2015) have investigated / measured the storage capacity in swine and cattle barns and estimated the HRT for all barn types mentioned in the Danish Normative System for animal manure.

Animal housing systems change over time. To take into account changes in the HRT inside the barns over time since 1990, the shares of the different barn types have been multiplied with the HRT for each barn type and summed for swine and cattle slurry to get the average HRT for swine and cattle slurry (Table 11.16). The HRT for liquid cattle manure has increased since 1990. This is mainly because in the 1990'ies there was a high share of tied-up dairy cattle with liquid handling and frequent removal of the slurry. These were later replaced by cubicles combined with slats. In recent years, cubicles with scrapers are becoming more common so a decrease in the HRT for cattle is expected in the future. The most common housing system for swine has until recently been fully slatted floors. A ban on fully slatted floors forced the farmers to build partly slatted floors / drained floors. This has reduced the storage capacity below the slats and thus reduced the average HRT for swine slurry.

Table 11.16 Average Hydraulic Retention Time (HRT) in cattle and swine barns from 1990 to 2015, days.

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | 18.33 | 18.12 | 20.81 | 20.14 | 19.64 | 19.77 | 19.94 | 20.58 | 19.63 | 19.15 |
| Swine | 21.64 | 21.49 | 21.10 | 19.47 | 19.39 | 19.23 | 19.10 | 18.98 | 18.94 | 18.93 |

In the emission estimate, it is assumed that all manure regardless of whether it is used for anaerobic digestion or not is having the same HRT. The data collected by Kai et al. (2015) do not prove that farms delivering manure to anaerobic digestion are empting their slurry channels more frequently than farmers who are not.

### Temperatures

Based on average air temperature for the period 2001-2010, measured temperatures and literature data temperature functions have been developed.

### Insulated swine barns

Only few measured slurry temperatures inside the barns can be found in the literature. Some measurements have been made by SEGES (Holm, 2015). Besides this, Petersen et al. (2016) have measured slurry temperatures in 27 different swine barns in November and December 2014 in connection with the $CH_4$ emission parameterisation. Holm (2015, Pers. Comm.) has made 48 measurements in barns with fattening pigs at different times of the year and found an average slurry temperature of 18.6 °C (16.0-21.8 °C) with a standard deviation of 1.29. The highest temperatures were measured in summer. When the average outdoor temperature was 16-17 °C the slurry temperature tended to be around 19 °C. In winter when the average outdoor temperature was around 2-5 °C the slurry temperature was 17-18 °C (Figure 11.4). The dots represent different combinations of slurry height and temperatures. Petersen et al. (2016) found an average temperature of 18.7 °C in their measurements in November and December. In the inventories are used the average data of 18.6 °C from SEGES throughout as the data are not sufficient qualified to distinguish between winter and summer. Figure 11.2 shows the measured data by SEGES.

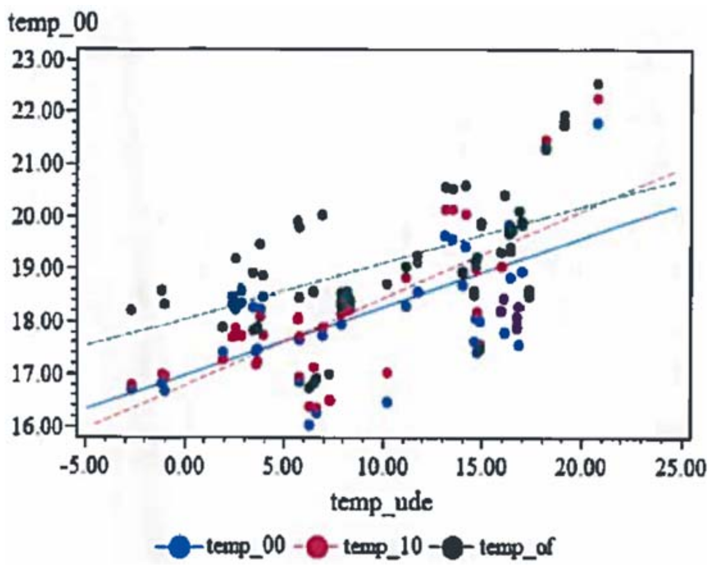


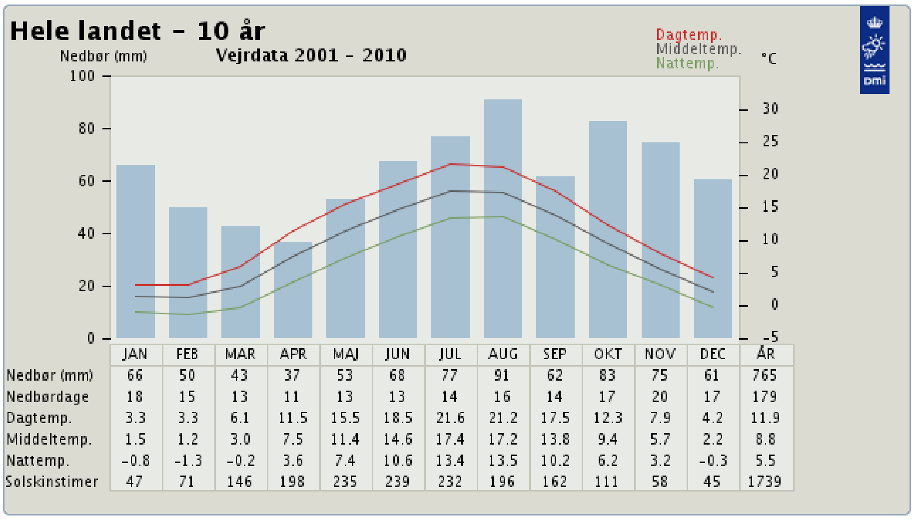

Figure 11.2 Measured slurry temperature in fattening pig slurry channel in different times during the production cycle. The different colours indicate different slurry heights in the slurry channel (Holm, 2015, Pers. Comm.).

## Open cattle barns

Most cattle barns in Denmark are naturally ventilated. Inside the barns the air temperature is generally 5-6 °C higher than the outdoor temperature. Only a few measurements of the slurry temperatures can be found in the literature. Furthermore, Petersen et al. (2016) made 12 measurements in different dairy barns in November and December 2014. They measured an average air temperature of 5.2 °C and an average slurry temperature of 9.8 °C, thus a 4.6 °C higher slurry temperature than the air temperature. Because of the lack of data, the temperature of liquid manure in naturally ventilated barns is conservatively set to outdoor air temperature plus 5 °C. More measurements are needed on this.

## Air temperature

As temperature input annual monthly mean temperatures are used from the Danish Meteorological Institute (DMI) from 2001 to 2010 (Wang, 2012, DMI report 12-24) (Figure 11.3). The monthly average mean has been converted to a Sine-function (y=a+ bsin(2πx / d+c)) to estimate daily average temperatures.




| | JAN | FEB | MAR | APR | MAJ | JUN | JUL | AUG | SEP | OKT | NOV | DEC | ÅR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nedbør (mm) | 66 | 50 | 43 | 37 | 53 | 68 | 77 | 91 | 62 | 83 | 75 | 61 | 765 |
| Nedbørdage | 18 | 15 | 13 | 11 | 13 | 13 | 14 | 16 | 14 | 17 | 20 | 17 | 179 |
| Dagtemp. | 3.3 | 3.3 | 6.1 | 11.5 | 15.5 | 18.5 | 21.6 | 21.2 | 17.5 | 12.3 | 7.9 | 4.2 | 11.9 |
| Middeltemp. | 1.5 | 1.2 | 3.0 | 7.5 | 11.4 | 14.6 | 17.4 | 17.2 | 13.8 | 9.4 | 5.7 | 2.2 | 8.8 |
| Nattemp. | -0.8 | -1.3 | -0.2 | 3.6 | 7.4 | 10.6 | 13.4 | 13.5 | 10.2 | 6.2 | 3.2 | -0.3 | 5.5 |
| Solskinstimer | 47 | 71 | 146 | 198 | 235 | 239 | 232 | 196 | 162 | 111 | 58 | 45 | 1739 |

Figure 11.3 Average daily mean temperature in Denmark 2001-2010 (Wang, 2012).

In Table 11.17 the parameters for the Sine-function, which estimates the daily average air temperatures are provided.

Table 11.17 Parameters for the Sine-function (y=a+ b sin(2πx/d+c)) for air temperature.

$R^2$ = 0.994

| Parameter | Value | Std Error | t-value | 95% confidence limits | |
|---|---|---|---|---|---|
| a | 8.697 | 0.167 | 81.49 | 8.47 | 8.92 |
| b | 8.234 | 0.141 | 58.38 | 7.94 | 8.52 |
| c | 4.253 | 0.028 | 110.00 | 4.17 | 4.25 |
| d | 363.134 | 1.878 | 193.31 | 359.21 | 367.05 |

## Outdoor storage temperatures

The temperature in outdoor slurry tanks is expected to follow the outdoor temperature to a great extent. As with indoor storage, only few data can be found in the literature. The temperature is a function of the loading with slurry, the actual amount stored and the solar radiation. If data from other climatic conditions is used they therefore have to be converted to Danish conditions. E.g. Park et al. (2006) found a linear relation between air temperature and slurry temperature in Canada with the following model parameters: Slurry_temperature = Air_temperature * 0.879 + 4.24 (Figure 11.4). However, the locations used for this study is far more southern than Denmark and are thus not suited for Danish conditions, especially not during summer where a higher solar radiation is occurring. Hansen et al. (2006) measured the slurry temperatures in slurry tanks throughout a year on three farms receiving digestate from anaerobic digesters. They found also a linear relation similar to Park et al. (2006) with the parameters Slurry_temperature = Air_temperature * 0.75 + 6.23 (Figure 11.4). The measurements by Hansen et al. (2006) cannot be seen as representative for raw liquid manure as the digestate as a starting point is having a higher temperature than raw undigested slurry due to the exothermic process in the anaerobic digesters. The model by Hansen et al. (2006) is used for anaerobic digested manure as this is likely a normal temperature profile for digestate returned to the farms for continued storage.

For raw undigested slurry a linear model has been constructed with data from Husted (1994) and Rodhe et al. (2009, 2012, 2015) with the following parameters Slurry_temperature = Air_temperature * 0.5011 + 5.1886 ($r^2 = 0.75$).

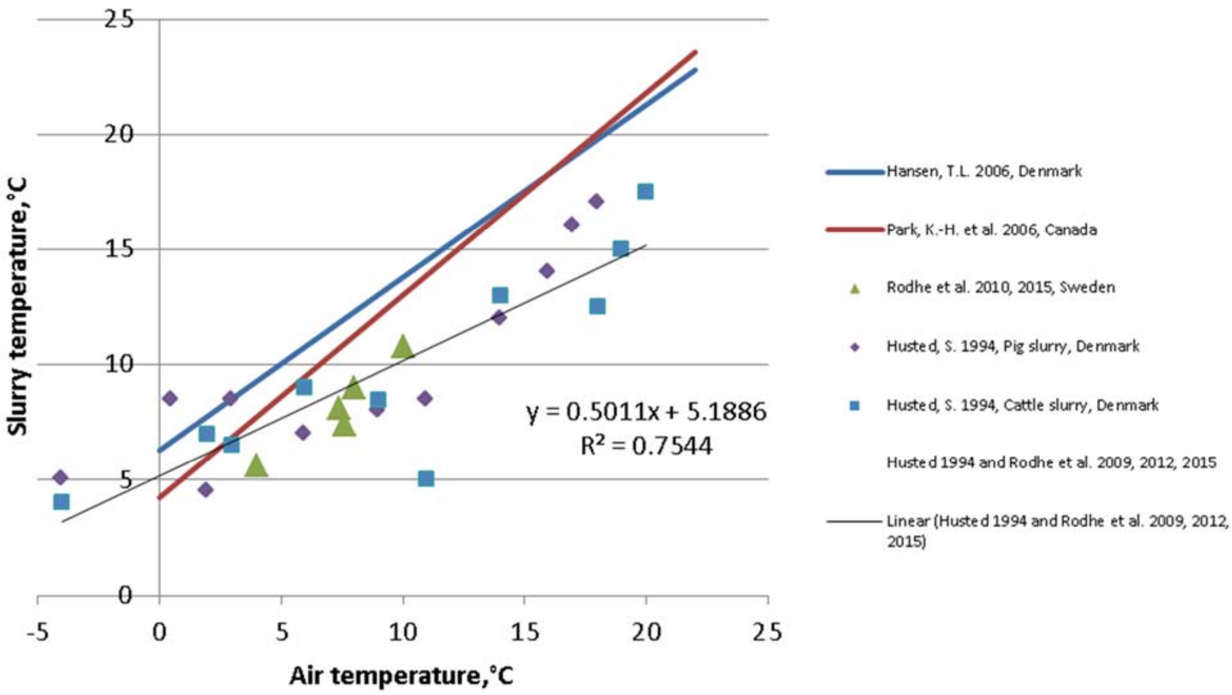


Figure 11.4 Measured and modelled slurry temperatures in outdoor storage tanks.

### Manure storage and application to fields

The Ministry of Environment and Food of Denmark regulate the storage time and the secondary field application of raw undigested and digested biomass. The general rule is that manure is only allowed to be applied to crops, which have a nitrogen norm and is harvested the same calendar year. Only crops with an official nitrogen norm are allowed to be fertilised (BEK, 2015). This means that autumn application is not allowed as these crops are not harvested within the calendar year. The storage manure capacity is therefore 8-10 months including eventually storage capacity inside the barns.

Field application of manure is not allowed before February 1st and not on frozen or snow covered areas. Because of difficulties for driving in the fields the optimum application time is March and April, plus some application to grass cuttings during summer. In cooperation with the Danish Agricultural Advisory Centre (SEGES), a general storage profile for animal manure storages has been developed, Figure 11.5. The figure shows that the maximum storage is in February and the minimum in end April. Slurry is generally stored in four meter deep concrete tanks where two meters are above ground and two meters below ground. As it is not possible to empty the tanks completely (crust cover) it is assumed that 10 % of the annual production is the minimum amount stored by end of April.

No reduction in the $CH_4$ emission due to microbial degradation in the crust cover (IPCC 2006) is implemented in the emission estimate so far.

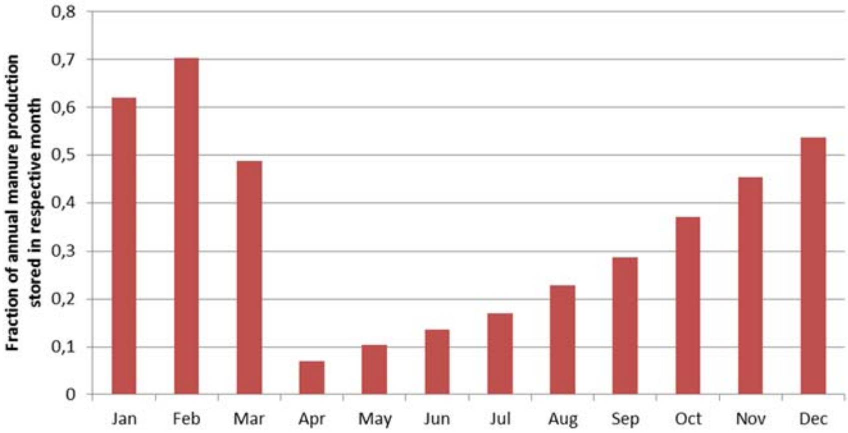



Figure 11.5 The fraction of animal manure stored during different month of the year. The fraction is the share of the total annual manure production corrected for grazing. Small amounts are applied to grass during summer giving a lower increase in the summer months than in the winter period.

### 11.3.7 The model

The model estimates methane emission for slurry from cattle and swine. Estimations of $CH_4$, VSd and VSnd is based on measurements (Petersen et al., 2016). The measurements are not made on the exact time for excretion of the manure and the $CH_4$ emission is therefore calculated as a constant emission per day, even though some degrading of VS in the barn will take place. The $CH_4$ emission in barns for swine at 18.6 °C is estimated to 569.5 g $CH_4$ per kg VS per year, corresponding to 1.56 g $CH_4$ per kg VS per day. VS from barns are not divided in VSd and VSnd because the measured emission relate to the total amount of VS. The total $CH_4$ emission from barns is calculated as excreted VS multiplied by 1.56 g $CH_4$ per kg VS per day and average storage time (HRT) in the barn.

For cattle barns, the temperature varies through the year. The emission factor of 66.92 g $CH_4$ per kg VS per year given in Table 11.13 is an average for a year. For cattle, total $CH_4$ emission from barns is also calculated as VS multiplied with average store time (HRT). It is assumed that excretion of VS in barns is constant. The period in which the cattle is on grass gives less manure in the barns, but this is not taken in to account. It is assumed that the effect of grazing is very small because the majority of dairy cattle in Denmark spend most of the time in the barns.

Methane emission from outdoor storage of undigested slurry is estimated in a matrix, where slurry is supplied and taken away with a time step of 10 days. The matrix sums the total methane emission until the decomposition of VS is almost null (around 2 years). The amount of VS supplied the storage is the total VS excretion from the animals and the straw used for bedding, subtracted VS-loss from barns. Removal of VSd and VSnd from storage is estimated for every time step and a new methane emission is calculated. For cattle slurry the estimation gives an emission of 12.02 g $CH_4$ per kg VSd and 0.16 g $CH_4$ per kg VSnd (Table 11.13). For swine slurry the estimation gives 29.64 g $CH_4$ per kg VSd and 0.63 g $CH_4$ per kg VSnd (Table 3D-22).

For estimation of methane emission from outdoor storage of digested slurry, the amount of digested slurry delivered to the biogas plants based on the BIB register is used. Same model as used for undigested slurry is used for digested slurry, though with a higher temperature in the storage after biogas treatment. The stored digested slurry has a high content of VSnd and the emission of methane is therefore low. Due to the low activity of the decomposition, a lower $CH_4$:$CO_2$-ratio (of 0.1) is assumed for digested slurry compared to undigested slurry (Dong, 2013, Pers. Comm.).

# 12 $N_2O$ emission

The agricultural $N_2O$ emissions accounts for 89 % of the total $N_2O$ emission in 2015. The emission of $N_2O$ comes from a range of different sources as showed in figure 12.1. The major sources originate from application of animal manure and inorganic N fertilisers on soil and from crop residues. 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 7.

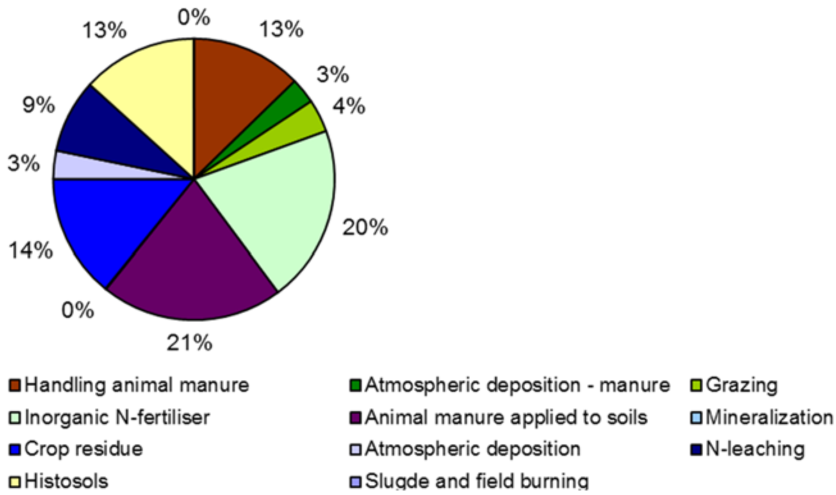



Figure 12.1 Distribution of the $N_2O$ emission in 2015 on sources (Nielsen et al., 2017).

The methodology used to calculate the $N_2O$ emission is based on guidance given in the 2006 IPCC Guidelines (IPCC, 2006). The following chapters provide a more detailed description on the methodologies and emission factors used. The emission sources are divided in to three main categories. The first covers the emission from the management of manure. The second category is direct $N_2O$ emissions from managed soils, which covers emission from the N sources related to cultivation of agricultural soils. The last one covers indirect $N_2O$ emissions from managed soils, which are atmospheric deposition of nitrogen volatilised from agricultural inputs and emission from nitrogen leaching and runoff.

## 12.1 Manure management

Emission of $N_2O$ from manure management comes from a direct emission from the handling of the manure in housing and during storage and an indirect emission (atmospheric deposition) from the emission of $NH_3$ and $NO_x$ from manure management.

The $N_2O$ emission from manure management is estimated to 2.5 kt in 2015 of which only 0.5 is related to the indirect emission. The overall emission has decreased with 0.8 kt $N_2O$ from 1985 – 2015 corresponding to 23 %. This decrease is mainly caused by a decreased emission from swine, which is driven by improvement of feed efficiency. The average N ex per swine has decreased dramatically from 1990 due to the farmer's economic benefit of increased feed efficiency and due to environmental requirements.

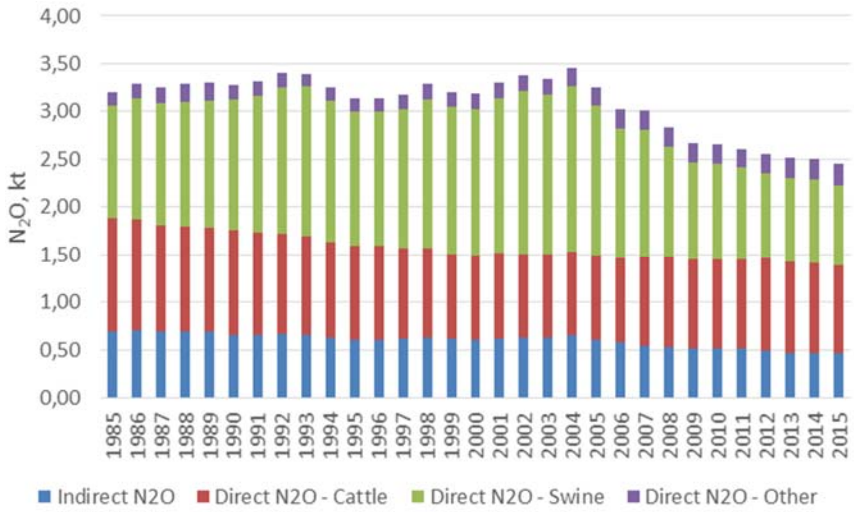



Figure 12.2 $N_2O$ direct and indirect emission from manure management, 1985-2015.

### 12.1.1 Calculation method

The $N_2O$ emission depends on N excretion in manure, and the housing / manure type. The nitrogen content in animal manure is based on the normative figures (Poulsen et al., 2001; Poulsen, 2016). Under the anaerobic conditions in slurry and urine, the emission of $N_2O$ is considered relatively low, while the emission from deep litter systems and solid manure in the housing units is higher. The direct emission from animal manure management is calculated as shown in equation 12.1.

$$N_2O_{\text{MM, direct}} = \sum \text{Nex}_{j,i} \cdot \text{EF}_{j,i} \cdot \frac{44}{28} \qquad \text{(Eq. 12.1)}$$

Where:

$N_2O_{\text{MM, direct}}$ = direct emission of $N_2O$ from manure management, kg

$\text{Nex}_{j,i}$ = N excretion from the given animal category (*j*) and manure type (*i*), kg N

$\text{EF}_{j,i}$ = emission factor for a given manure animal category (*j*) and manure type (*i*), kg $N_2O$-N per kg N

44 / 28 = conversion from $N_2O$-N to $N_2O$

The indirect emission of $N_2O$ from manure management is calculated as shown in equation 12.2.

$$N_2O_{\text{MM, indirect}} = \sum N_{Vol} \cdot \text{EF} \cdot \frac{44}{28} \qquad \text{(Eq. 12.2)}$$

Where:

$N_2O_{\text{MM, indirect}}$ = indirect emission of $N_2O$ from manure management, kg $N_2O$

$N_{Vol}$ = N volatilised as $NH_3$-N and $NO_x$-N from manure management, kg N

EF = emission factor based on IPCC (2006) kg $N_2O$-N per kg N

44 / 28 = conversion from $N_2O$-N to $N_2O$

### 12.1.2 Emission factor

For the direct emission, the IPCC default $N_2O$ emission factors are applied for all livestock categories. Due to transparency of the emission factor used, Table 12.1 show the Danish housing system compared to the housing system given in IPCC 2006 Guidelines Table 10.21 and the respective default emission factors.

Table 12.1 Manure management system (MMS) - emission factors.

| DK MMS | IPCC MMS | Emission factor, kg $N_2O$-N pr kg Nex |
|---|---|---|
| **Cattle** | | |
| Liquid/Slurry | Liquid/slurry, with natural crust cover | 0.005 |
| Solid | Solid storage | 0.005 |
| Deep bedding | Cattle and swine deep bedding, no mixing | 0.01 |
| Biogas treated slurry | Anaerobic digester | 0 |
| **Swine** | | |
| Liquid/Slurry | Liquid/slurry, with natural crust cover | 0.005 |
| Solid | Solid storage | 0.005 |
| Deep bedding | Cattle and swine deep bedding, Active mixing | 0.07 |
| Biogas treated slurry | Anaerobic digester | 0 |
| **Poultry** | | |
| Housing with or without litter | Poultry manure with or without litter | 0.001 |
| **Fur-bearing animals** | | |
| Slurry | Liquid/slurry, with natural crust cover | 0.005 |
| Solid | Cattle and swine deep bedding, no mixing | 0.01 |
| **Sheep and goats** | | |
| Deep bedding | Cattle and swine deep bedding, no mixing | 0.01 |
| **Horses and ostrich** | | |
| Deep bedding | Cattle and swine deep bedding, no mixing | 0.01 |

The $N_2O$ emission factor for indirect emission is based on the IPCC default at 0.01 kg $N_2O$-N per kg $NH_3$-N and $NO_x$-N volatilised.

## 12.2 Agriculture soils – direct emissions

Direct emissions of $N_2O$ from agricultural soils come from a range of sources. The emission from all sources, apart from cultivation of organic soils and mineralisation, is calculated based on the amount of N applied to soils as shown in equation 12.3.

$$N_2O = N_i \cdot EF_i \cdot \frac{44}{28} \qquad \text{(Eq. 12.3)}$$

Where:

$N_2O$ = emission of N2O, kg $N_2O$

$N_i$ = N applied to soil from the source *i* (inorganic or organic N fertiliser, crop residue, urine and dung deposit during grazing), kg N

$EF_i$ = emission factor for the source *i* (see Table 12.2), kg $N_2O$-N per kg N

44/28 = conversion from $N_2O$-N to $N_2O$

The emission factors for $N_2O$ from agricultural soils for all sources are based on the default values given by the IPCC (IPCC, 2006). A $NH_3$ and $N_2O$ emission factor overview is presented in Table 12.2.

Table 12.2 Emission factors – $NH_3$ and $N_2O$ from agricultural soils – direct emissions.

| | $NH_3$ emission factor (national data[1]) Kg $NH_3$-N per kg N | $N_2O$ emission factor (IPCC default value) kg $N_2O$-N per kg N |
|---|---|---|
| Inorganic N fertilisers | 0.02 | 0.01 |
| Animal manure applied to soils | 0.19* | 0.01 |
| Sewage sludge applied to soils | 0.02 | 0.01 |
| Other organic fertilisers applied to soils | | 0.01 |
| Urine and dung deposited by grazing animals | 0.07 | 0.01-0.02 |
| Crop residues | | 0.01 |
| Mineralisation/immobilisation associated with loss/gain of soil organic matter | | 0.01 |
| Cultivation of organic soils | | 8.2-13** |

[1] See Chapter 5.

*Varies from year to year, has decreased from 0.28 in 1990.

**Unit: kg $N_2O$-N pr ha.

### 12.2.1 Inorganic N fertiliser

The amount of nitrogen (N) applied to soil by use of inorganic N fertiliser is estimated from sales estimates from DAA (2016). The consumption of each fertiliser type is shown in Chapter 5, Table 5.9.

As a result of increasing requirements for improved use of nitrogen in livestock manure and reduce the nitrogen loss to the environment, the consumption of nitrogen in inorganic N fertiliser has almost halved from 1985 to 2015 (Table 12.3).

Table 12.3 Nitrogen applied as fertiliser to agricultural soils 1985 – 2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N content in inorganic N fertiliser, kt N | 398 | 400 | 316 | 251 | 206 | 190 | 197 | 187 | 194 | 187 | 203 |
| $N_2O$ emission, kt $N_2O$ | 6.26 | 6.29 | 4.96 | 3.95 | 3.24 | 2.98 | 3.10 | 2.94 | 3.04 | 2.94 | 3.20 |

### 12.2.2 Organic N fertiliser

#### Animal manure applied to soils

The amount of nitrogen applied to soil is estimated as the N-excretion in housings (Poulsen, 2016). The total N excretion in housings from 1985 to 2015 has decreased by 14 %, due to improvement of feed efficiency and change in housing systems.

Table 12.4 Nitrogen applied as manure to agricultural soils 1985 – 2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N-excretion, housing, kt N | 274 | 258 | 239 | 235 | 251 | 239 | 238 | 236 | 234 | 235 | 235 |
| N in manure applied on soil, kt N | 227 | 214 | 200 | 196 | 212 | 208 | 208 | 206 | 208 | 209 | 209 |
| $N_2O$ emission, kt $N_2O$ | 3.57 | 3.37 | 3.14 | 3.08 | 3.34 | 3.27 | 3.26 | 3.24 | 3.26 | 3.28 | 3.28 |

#### Sewage sludge

Information about sewage sludge applied on agricultural soil and the content of nitrogen is obtained from a series of reports published by the Danish Environmental Protection Agency. From 2005, the amount of sewage sludge and N content is based on the information registered in the fertiliser accounts controlled by The Danish Agricultural Agency (See Chapter 5.4).

Table 12.5 Emission from sewage sludge applied on agricultural soils 1985 – 2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen in sewage sludge, t N | 2 000 | 3 115 | 4 635 | 3 625 | 2 173 | 2 692 | 2 592 | 2 470 | 2 457 | 2 554 | 2 768 |
| $N_2O$ emission, kt $N_2O$ | 0.03 | 0.05 | 0.07 | 0.06 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |

**Other**

The category, "Other", includes emission from sludge from industries applied to agricultural soils as fertiliser. Information about industrial waste applied on agricultural soil and the content of nitrogen is obtained from a series of reports published by the Danish Environmental Protection Agency (DEPA, 2009). The recent official figures regarding the amount of sludge from the industrial waste are data covering year 2001 (Petersen & Kielland, 2003). From 2005, the amount of sludge from industries is based on the information registered in the fertiliser accounts controlled by The Danish Agricultural Agency. Amounts in 2002- 2004 are interpolated.

Table 12.6 Emission from sludge from industries applied on agricultural soils 1985 – 2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen in industrial waste, t N | 1 500 | 1 529 | 4 500 | 5 147 | 5 509 | 3 401 | 3 474 | 4 356 | 4 596 | 4 342 | 4 455 |
| $N_2O$ emission, kt $N_2O$ | 0.02 | 0.02 | 0.07 | 0.08 | 0.04 | 0.05 | 0.05 | 0.07 | 0.07 | 0.07 | 0.07 |

### 12.2.3 Grazing

The amount of nitrogen deposited on grass is based on estimations from the $NH_3$ inventory. The number of grazing days is based on expert judgement from SEGES. N excretion on grass has decreased due to a reduction in the number of dairy cattle and days on grass. Emission factors are based on IPCC (2006); 0.02 kg $N_2O$-N per kg N for cattle, poultry and swine and 0.01 kg $N_2O$-N per kg N for sheep and other animals.

The $N_2O$ emission is estimated to 1.09 kt in 1985 decreasing to 0.59 kt in 2015, due to a fall in grazing days for the large dairy cattle farms.

Table 12.7 Nitrogen excreted on grass 1985 – 2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N excretion, grass, kt N | 37 | 34 | 36 | 34 | 26 | 22 | 21 | 22 | 22 | 22 | 21 |
| $N_2O$ emission, kt | 1.09 | 1.00 | 1.05 | 1.01 | 0.73 | 0.61 | 0.60 | 0.61 | 0.62 | 0.62 | 0.59 |

### 12.2.4 Crop residues

The emission from crop residues is based on the 2006 IPCC Guidelines methodology. Default values for all parameters given in IPCCC 2006, Table 11.2 are used except from dry matter fractions and crop yield, which are based on national values. The default $N_2O$ emission factor at 0.01 kg $N_2O$-N per kg N in crop residues is used.

$$N_2O = N_{crop\ reside} \cdot EF \cdot 44/28 \qquad \text{(Eq. 12.4)}$$

Where:

$N_2O$ = emission of $N_2O$ from crop residue, kg $N_2O$-N
$N_{crop\ residue}$ = nitrogen from crop residue, kg N
EF = emission factor (Table 12.2), kg $N_2O$-N per kg N
44/28 = conversion from $N_2O$-N to $N_2O$

$$\mathrm{N}_{crop\ residue} = \mathrm{N}_{Above\ ground} + \mathrm{N}_{Below\ ground} \tag{Eq. 12.5}$$

Where:
$\mathrm{N}_{crop\ residue}$ = nitrogen from crop residue, kg
$\mathrm{N}_{Above\ ground}$ = total N in above ground residue (Eq. 12.6), kg
$\mathrm{N}_{Below\ ground}$ = total N in below ground residue (Eq. 12.7), kg

$$\mathrm{N}_{Above\ ground} = area_i \cdot \left(\left(\left(harvest_i \cdot DRY_i / Frac_{renev,i} / area_i\right) \cdot slope_i + intercept_i\right) \cdot \mathrm{N}_{AG,i}\right) \tag{Eq. 12.6}$$

Where:
$\mathrm{N}_{Above\ ground}$ = total N in above ground residue, kg
$i$ = crop type
Area = area of cultivated crops, ha
Harvest = amount of harvested crop, kg
DRY = dry matter fraction of harvest product, kg DM per kg harvest
$\mathrm{Frac}_{\mathrm{renev}}$ = fraction of total area of crop type *i* that is renewed annually
Slope = constant given by IPCC (2006) (fractionless)
Intercept = constant given by IPCC (2006) (fractionless)
$\mathrm{N}_{\mathrm{AG}}$ = N content of above ground residue, kg N per kg DM

$$\mathrm{N}_{below\ ground} = area_i \cdot \left(\left(harvest_i \cdot DRY_i / Frac_{renev,i} / area_i\right) \cdot \mathrm{R}_{BG-BIO} \cdot \mathrm{N}_{BG}\right) \tag{Eq. 12.7}$$

Where:
$\mathrm{N}_{Below\ ground}$ = total N in below ground residue, kg
$i$ = crop type
Area = area of cultivated crops, ha
Harvest = amount of harvested crop, kg
DRY = dry matter fraction of harvest product, kg DM per kg harvest
$\mathrm{Frac}_{\mathrm{renev}}$ = fraction of total area of crop type *i* that is renewed annually
$\mathrm{R}_{BG\text{-}BIO}$ = Ratio of below-ground residues to above-ground biomas, kg DM per kg DM
$\mathrm{N}_{BG}$ = N content of below-ground residue, kg N per kg DM

The dry matter fraction in crops is based on feedstuff table produced by SEGES, which has information for content of dry matter, fatty acid, protein, starch, sugar and energy for each crop type. The total amount of dry matter in harvest products is based on data from Statistic Denmark and varies from year to year depending on the climatic conditions.

The total amount of nitrogen in crop residues is calculated and then the N content in harvested straw is deducted. The N content in crop residues has increased from 90 million kg N in 1985 to 141 million kg N in 2015, which is mainly a result of a lower amount of harvest straw.

Table 12.8 N content in crop residue, million kg N, 1985-2015.

| | 1986 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total N in crop residue | 120.0 | 145.8 | 132.5 | 134.1 | 140.2 | 149.9 | 154.1 | 157.4 | 151.0 | 161.6 | 155.0 |
| N in harvested straw | 30.0 | 24.2 | 20.1 | 17.4 | 14.6 | 14.8 | 14.7 | 16.5 | 14.2 | 13.5 | 13.6 |
| N in crop residue | 89.9 | 121.6 | 112.4 | 116.7 | 125.6 | 135.1 | 139.4 | 140.9 | 136.8 | 148.5 | 141.4 |

The $N_2O$ emission is depending on the N amount in crop residues. Figure 12.3 shows the total N content in crop residues allocated on the main crop types. As a consequence of increase in areas with maize and grass-clover mixtures in rotation, the total N content in these crop types is also increased. Some annual variations takes place due to changes in climate conditions from year to year - e.g. in 1992 the spring and summer was extremely dry, which lower the yield.

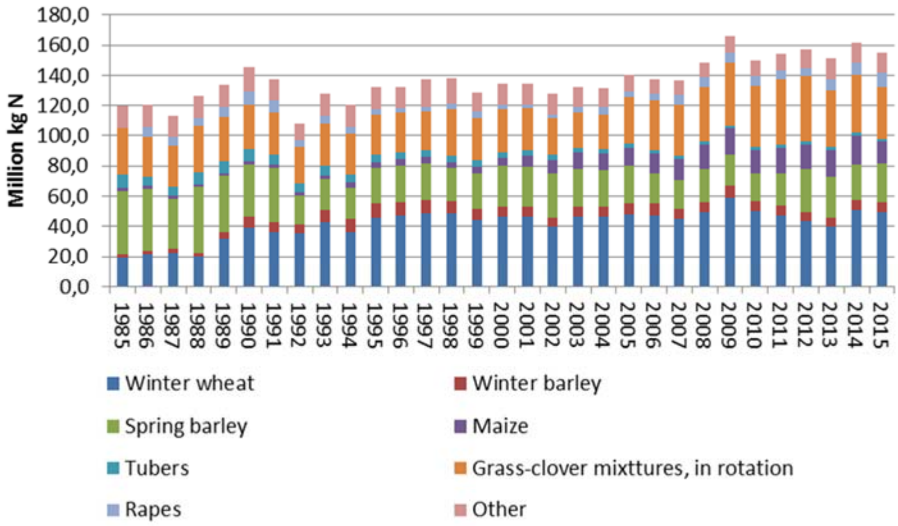



Figure 12.3 Total N in crop residue, 1985 – 2015.

### 12.2.5 Mineralisation/immobilisation associated with loss/gain of soil organic matter

The N mineralisation from mineral soils associated with loss / gain of soil organic matter is estimated with a dynamic modelling tool (C-TOOL) which is used to estimate long-term changes in carbon from mineral soils. C-TOOL is a 3-pooled dynamic model, where the approximate average half-live times for the three different pools, Fresh organic matter (FOM), Humified organic matter (HUM) and ROM (Resilient Organic Matter) are 0.6-0.7 years, 50 years and 600-800 years, respectively. The main part of biomass returned to soil each year is in the first and easiest degradable FOM pool. This pool consists of mainly fresh straw, fresh manure, root residues, fungi and small animals and fluctuates very much between years depending on the harvest yield and climatic conditions. The annual input to the FOM pool is close to the estimated annual amount of crop residues.

The estimated release of $N_2O$ follows eq. equation 11.8, page 11.16 in IPCC 2006 Guidelines. The $N_2O$ formation is estimated from the annual changes in the HUM and ROM pool. Changes in the FOM pool is considered as being the same as crop residues incorporated in the soil and to avoid double-counting changes in the FOM is not included.

The estimation of carbon stock changes in mineral soils with C-TOOL is subdivided into 20 combinations of regions and soil types. Within each subdivision only losses are included in the estimate. If a subdivision one year has an increase in the HUM and ROM pool the release of $N_2O$ by default are zero as only losses are included, cf. eq. 11.8. The C:N ratios are based on measured values in the Danish Agricultural grid (Nielsen et al, 2017, Chapter 6.6) and differ among soil types. In the calculations are used a range of C:N values from 10.53 to 15.89 with the lowest value on clay soils and the highest on the most sandy soils. The recommended default value in the IPCC 2006 Guidelines is 15.

### 12.2.6 Cultivation of organic soils

The cultivation of organic soils (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 organic soils is estimated by the Department of Agroecology, Aarhus University. The area of organic soil is divided in areas with >12 % soil organic carbon (SOC) and 6-12 % SOC.

The calculation of the $N_2O$ emission is based on IPCC guidelines (2014), which recommend an emission factor of 13 kg $N_2O$-N per hectare for cropland and 8.2 kg $N_2O$-N per hectare of grassland. These are used for areas with >12 % SOC. For areas with 6-12 % SOC emission of 6.5 and 4.1 kg $N_2O$-N per hectare for cropland and grassland, respectively. Areas of organic soils with no field identification are defined as Grassland, shallow drained, nutrient-rich areas according to the 2013 Wetland Supplement and for these areas are used 1.6 kg $N_2O$-N per hectare >12 % SOC and 0.8 kg $N_2O$-N per hectare 6-12 % SOC.

$$N_2O_{ORG} = AR_i \cdot EF_i \cdot \frac{44}{28} \qquad \text{(Eq. 12.8)}$$

Where:

$N_2O_{ORG}$ = emission of $N_2O$, kg $N_2O$

$AR_i$ = area of organic soil, $i$ land type, ha

$EF_i$ = emission factor, $i$ land type, kg $N_2O$-N per ha

44/28 = conversion from $N_2O$-N to $N_2O$

The emission from cultivation of organic soils has decreased from 2.4 kt $N_2O$ in 1985 to 1.6 kt $N_2O$ in 2015, which is due to the decrease in the cultivated area with organic soils.

Table 12.9 Area and $N_2O$ emission for organic soils, 1985-2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cropland >12 % SOC, ha | 75 168 | 70 992 | 66 816 | 62 640 | 58 464 | 54 288 | 53 538 | 49 650 | 48 232 | 49 248 | 47 763 |
| Grassland >12 % SOC, ha | 21 998 | 20 776 | 19 554 | 18 332 | 17 110 | 16 071 | 15 698 | 17 943 | 18 729 | 18 983 | 18 327 |
| Other >12 % SOC, ha | 0 | 0 | 0 | 0 | 0 | 0 | 940 | 2 384 | 2 817 | 1 348 | 3 289 |
| Cropland 6-12 % SOC, ha | 47 019 | 44 407 | 41 795 | 39 183 | 36 570 | 33 958 | 33 489 | 31 145 | 30 342 | 31 070 | 30 220 |
| Grassland 6-12 % SOC, ha | 13 761 | 12 996 | 12 232 | 11 467 | 10 703 | 10 053 | 9 820 | 11 256 | 11 782 | 11 976 | 11 596 |
| Other 6-12 % SOC, ha | 0 | 0 | 0 | 0 | 0 | 0 | 588 | 1 371 | 1 523 | 477 | 1 583 |
| $N_2O$, kt | 2.39 | 2.26 | 2.12 | 1.99 | 1.86 | 1.73 | 1.70 | 1.64 | 1.62 | 1.65 | 1.61 |

## 12.3 Agricultural soils – indirect emissions

### 12.3.1 Atmospheric deposition

Volatilisation of $NH_3$ and $NO_x$ and the deposition of these gases and products onto soils and the surface of lakes and other water bodies cause $N_2O$ emission. Emission of $N_2O$ is calculated based on all $NH_3$ emission sources; manure applied to soil, inorganic N fertiliser, sewage sludge used as fertiliser, urine and dung deposited during grazing, crops, ammonia treated straw and field burning of agricultural residue and on $NO_x$ emission sources; manure applied to soil, inorganic N fertiliser and sewage sludge.

The emission is calculated as illustrated in Equation 12.8 - i.e. as the total $NH_3$ and $NO_x$ emission multiplied by the IPCC standard value for the emission factor of 0.01 kg $N_2O$-N per kg $NH_3$-N and $NO_x$-N volatilised.

$$N_2O_{dep} = \left(\left(NH_3\text{-}N_i + NO_x\text{-}N_j\right) \cdot EF\right) \cdot \frac{44}{28} \quad \text{(Eq. 12.8)}$$

Where:
$N_2O_{dep}$ = $N_2O$ emission from atmospheric deposition, kg $N_2O$
$NH_3$-$N_i$ = $NH_3$-N volatilised from manure applied to soil, inorganic N fertiliser, sewage sludge used as fertiliser, urine and dung deposited during grazing, crops, ammonia treated straw and field burning of agricultural residue, kg N
$NO_x$-$N_j$ = $NO_3$-N volatilised from manure applied to soil, inorganic N fertiliser and sewage sludge, kg N
EF = emission factor, 0.01 kg $N_2O$-N per kg $NH_3$-N and $NO_x$-N volatilised
44/28 = conversion from $N_2O$-N to $N_2O$

The total $NH_3$ and $NO_x$ emission from all emission sources is shown in Table 12.10 together with the calculated $N_2O$ emission. From 1985 to 2015, the $N_2O$ emission has decreased from 1.09 kt $N_2O$ to 0.51 kt $N_2O$, which equates to a fall of 53 %. As mentioned in Chapter 5 regarding the $NH_3$ emission, this emission reduction is a consequence of environmental policies to reduce the loss of nitrogen to the aquatic recipients.

Table 12.10 Total $NH_3$, $NO_x$ emission and the $N_2O$ emission, 1985 – 2015.

| Emission per year | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $NH_3$ emission, kt $NH_3$-N | 62.0 | 59.4 | 46.6 | 36.6 | 29.2 | 27.9 | 27.0 | 26.6 | 26.9 | 27.0 | 27.4 |
| $NO_x$ emission, kt $NO_x$-N | 7.6 | 7.5 | 6.4 | 5.5 | 5.1 | 4.9 | 5.0 | 4.9 | 5.0 | 4.9 | 5.1 |
| $N_2O$ emission, kt $N_2O$ | 1.09 | 1.05 | 0.83 | 0.66 | 0.54 | 0.52 | 0.50 | 0.49 | 0.50 | 0.50 | 0.51 |
| $CO_2$ emission, million t $CO_2$ eqv. | 0.33 | 0.31 | 0.25 | 0.20 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |

### 12.3.2 Leaching and runoff

Nitrogen, which is transported through the soil, can be transformed to $N_2O$. The IPCC recommends an $N_2O$ emission factor of 0.0075, of which 0.0025 is for leaching to groundwater, 0.0025 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 12.9:

$$N_2O_{leaching} = \left(N_{leach\text{-}ground} \cdot EF_{ground} + N_{leach\text{-}rivers} \cdot EF_{rivers} + N_{leach\text{-}estuatires} \cdot EF_{estuatires}\right) \cdot \frac{44}{28} \quad \text{(Eq. 12.9)}$$

Where:
$N2O_{leaching}$ = emission, kg $N_2O$
N = N leached to ground water, rivers and estuaries, kg N
EF = emission factor for ground water, rivers and estuaries kg $N_2O$-N per kg N
44/28 = conversion from $N_2O$-N to $N_2O$

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 DCA and DCE (see overview of model in Appendix U). 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 from 172 to 159 thousand tonnes N, whereas the N-LES model has estimated the total N leached to be from 163 to 154 thousand tonnes in the same period. An average of the results from the two models is used in the emission inventories.

Data concerning the N leaching to watercourses and to the sea is estimated based on a national model concept called DK-QN developed by Department of Bioscience, Aarhus University as a part of the National Environmental monitoring Program (NOVANA). DK-QN simulates the monthly runoff and nitrogen loading and is developed, based on two other models. These are a groundwater / surface model MIKE-SHE, which describes the national and regional water balance and the interaction flow between groundwater and streams, and the empirical model DK-N, which includes simulations of monthly sources, loads and skinks of total nitrogen. The model DK-QN, has been validated and shows robustness. For a more detailed description, please refer to Windolf et al. (2011).

Since 1985, the amount of nitrogen leached has almost halved as a result of the significant decrease in consumption of inorganic N fertilisers and the improved utilisation of the nitrogen content in animal manure (Table Table 12.12.11). The same trend is reflected in the $N_2O$ emission by a decrease from 2.2 kt $N_2O$ in 1985 to 1.3 kt $N_2O$ in 2015, or 396 kt $CO_2$-eqv. in 2015.

Table 12.11 Leaching of nitrogen and associated emissions, 1985 - 2015.

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N-leaching$_{groundwater}$, kt N | 304 | 267 | 235 | 179 | 160 | 168 | 165 | 161 | 162 | 164 | 166 |
| N-leaching$_{rivers}$, kt N | 128 | 102 | 104 | 95 | 67 | 68 | 73 | 74 | 65 | 80 | 94 |
| N-leaching$_{estuaries}$, kt N | 120 | 100 | 91 | 81 | 56 | 55 | 59 | 59 | 54 | 63 | 78 |
| $N_2O$, kt | 2.17 | 1.84 | 1.69 | 1.39 | 1.11 | 1.14 | 1.17 | 1.15 | 1.11 | 1.20 | 1.33 |
| $CO_2$ eqv. million t | 0.65 | 0.55 | 0.50 | 0.42 | 0.33 | 0.34 | 0.35 | 0.34 | 0.33 | 0.36 | 0.40 |

Figure 12.4 illustrates on the first axis the total amount of nitrogen applied as fertiliser on agricultural land in the form of animal manure, inorganic N-fertiliser, sewage sludge, crop residues and mineralisation, while the second axis show the amount of N leached to the groundwater. It can be seen that the percentage of N leached compared with the total N applied on soil has decreased from 39 % in 1985 to 27 % in 2008 and increased from 2009 to 2011. From 2012 is used an N leaching fraction at 28 % based on an average for the years 2007-2011 due to lack of data.

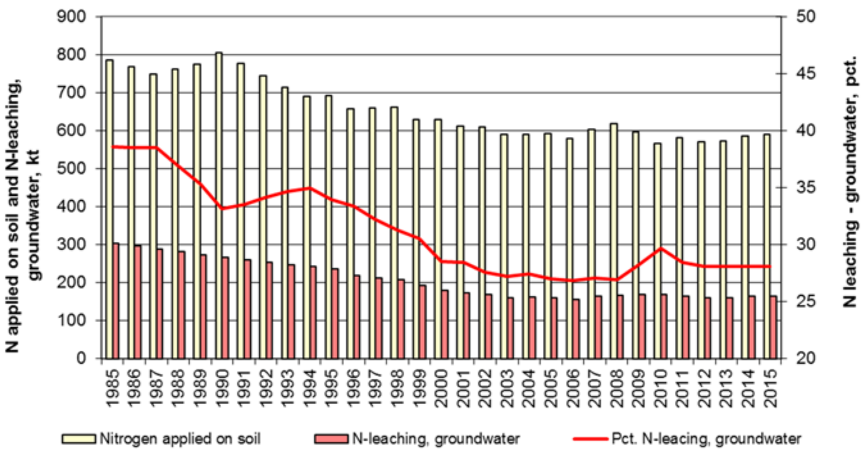



Figure 12.4 Leaching of nitrogen from 1985 to 2015.

# 13 $CO_2$ emission

Emission of $CO_2$ from the agricultural sector comes from three sources; field burning of agricultural residue, liming and inorganic N fertiliser. For calculation etc. of emission from field burning, please refer to Chapter 7. Emission of $CO_2$ from field burning is not reported in the Danish emission inventories, because no cells in Common Reporting Format (CRF) allows to register this emission pollutant.

## 13.1 Liming

The emission of $CO_2$ from liming in Denmark occurs during liming with limestone.

### 13.1.1 Methodological issues

A Tier 1 method as given in IPCC 2006 is used.

$$CO_2 = A_{lime} \cdot EF \qquad \text{(Eq. 13.1)}$$

Where:
$CO_2$ = emission of $CO_2$, kt
$A_{lime}$ = amount of lime, kt $CaCO_3$
EF = emission factor (see Chapter 13.1.3), kt $CO_2$ per kt limestone

### 13.1.2 Activity data

The amount of limestone used is based on the sales statistics. The amount used on the agricultural soils is collected by SEGES (Vestergaard, 2016). The amount of limestone used in private gardens is based on expert judgement (Andersen, 2004, Pers. Comm.) and the same value is used for all years.

### 13.1.3 Emission factors

The emission factor is 4.4 kt $CO_2$ per kt limestone and the same for all years 1985 to 2015. It is based on the molecular weight for $CaCO_3$, $CO_2$ and C.

$$EF = M_{CaCO_3} \cdot M_C \cdot \frac{M_{CO_2}}{M_C}$$

Where:
EF = emission factor for $CO_2$ from liming, kt $CO_2$ per kt limestone
$M_i$ = molecular weight for *i* molecule

### 13.1.4 Emission

The emission of $CO_2$ from liming has overall decreased by 76 % from 1985 to 2015. As shown in Figure 13.1 the main decrease is occurring from 1985 to 1997 and is due to a decrease in the amount of limestone sold.

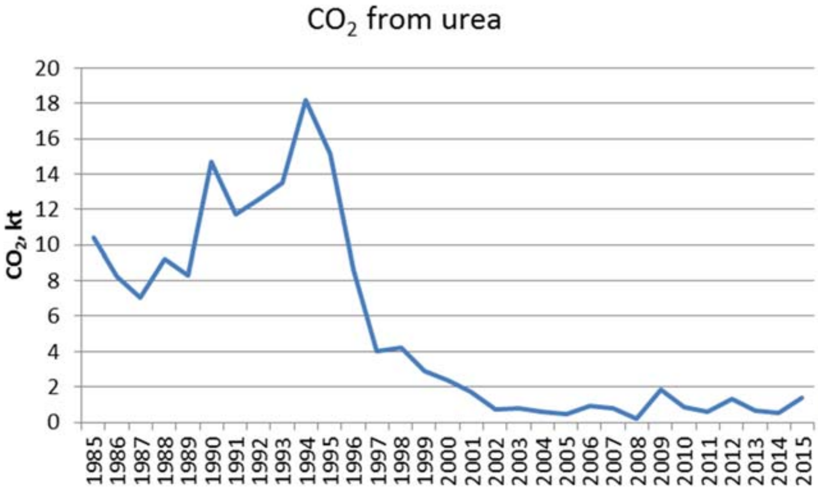



Figure 13.1 $CO_2$ emission from liming, 1985 to 2015.

## 13.2 Fertiliser

### 13.2.1 $CO_2$ from urea

Emission of $CO_2$ from use of urea contributes with less than 1 % of the $CO_2$ emission from the agricultural sector.

A Tier 1 method as given in IPCC 2006 is used.

$$CO_2 = A_{urea} \cdot EF \cdot \frac{44}{12} \quad \text{(Eq. 13.2)}$$

Where:

$CO_2$ = emission of $CO_2$, kt
$A_{urea}$ = amount of urea, kt
EF = emission factor, 0.20 kt C per kt urea

The amount of urea used on agricultural soils is based on sales estimates from the Danish Agricultural Agency (DAA, 2016). The default emission factor of 0.20 t C per t urea given in IPCC 2006 is used.

In Figure 13.2, the emission of $CO_2$ from use of urea is shown. The emission has decreased with 87 % from 1985 to 2015, but the main decrease is occurring from 1990 to 2002. From 2003 to 2015, the emission is almost unaltered. The decrease is due to a decrease in the use of urea.

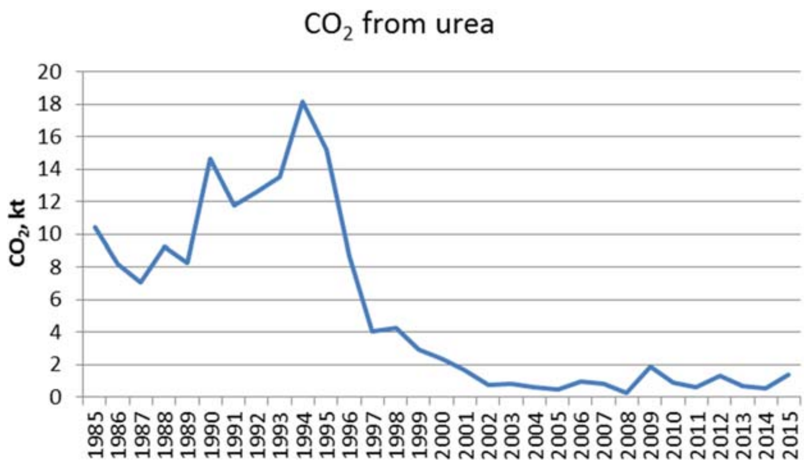



Figure 13.2 Emission of $CO_2$ from use of urea, 1985 to 2015.

### 13.2.2 $CO_2$ from other carbon-containing fertilisers

Use of other carbon-containing fertilisers is in Denmark the use of calcium ammonium nitrate (CAN). The emission of $CO_2$ from CAN contributes with less than 1 % of the $CO_2$ emission from the agricultural sector.

A Tier 1 method as given in IPCC 2006 is used.

$$CO_2 = A_{CAN} \cdot EF \cdot \frac{44}{12} \qquad \text{(Eq. 13.3)}$$

Where:

$CO_2$ = emission of $CO_2$, kg

$A_{CAN}$ = amount of CAN, kg

EF = emission factor, (see Equation 13.4 and 13.5), kg $CO_2$ per kg CAN

The amount of CAN used on agricultural soils is based on sales estimates from the Danish Agricultural Agency (DAA, 2016).

The emission factor is 0.026 kg $CO_2$ per kg CAN and the same for all years 1985 to 2016. It is based on the molecular weight:

$$EF = \left(\frac{\text{kg CaCO}_3}{\text{kg CAN}}/100\right) \cdot M_{CaCO_3} \cdot M_C \cdot \frac{M_{CO_2}}{M_C} \qquad \text{(Eq. 13.4)}$$

$$\frac{\text{kg CaCO}_3}{\text{kg CAN}} = \left(100 - M_{NH_4NO_3}\right)/M_{CaMg(CO_3)_2} \cdot M_{CaCO_3} \cdot 2 \qquad \text{(Eq. 13.5)}$$

Where:

EF Emission factor for $CO_2$ from CAN, kg $CO_2$ per kg CAN

$M_i$ Molecular weight for *i* molecule

Figure 13.3 shows the emission of $CO_2$ from use of CAN. The emission has decreased with 58 % from 1985 to 2015, but the main decrease is occurring from 1989 to 1999. The decrease is due to a decrease in the use of CAN. From 2000 to 2014, the emission is almost unaltered but an increase is taking place from 2014 to 2015 due to an increase in the use of CAN.

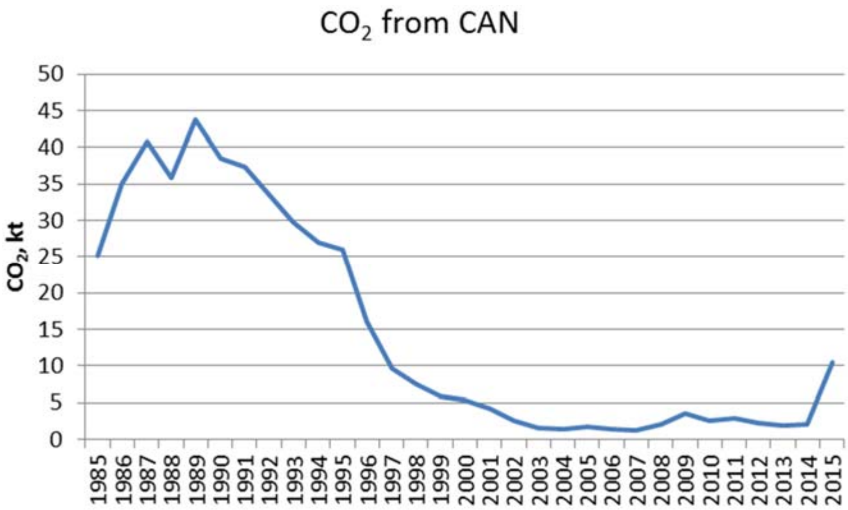



Figure 13.3 Emission of $CO_2$ from use of CAN, 1985 to 2015.

# 14 Quality assurance and quality control

A first step of the development and implementation of a general QA / QC plan for the Danish emission inventories was initiated in 2004, which is described in a manual (Sørensen et al., 2005, Nielsen et al., 2013). The manual describes the concepts of quality work and how to handle quality management by using Critical Control Points and a list of Point of Measurements (PM).

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.

The check of comparability with the reporting of other countries is ensured through the international review processes, where many parameters are compared across countries and compared to the IPCC default. Additionally, Denmark has carried out a project of verification, where the emissions from key categories in the Danish inventories were compared against other countries with similar circumstances. (Fauser et al., 2007 and 2013).

One of the key elements to assess the accuracy of the inventories is estimating the uncertainties of the emission estimates. The procedure for estimating the uncertainties is described in Chapter 15.

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

The first element is the international reviews carried out under the UNFCCC and UNECE. These reviews consist of review teams of internationally appointed experts, who are assigned to review the reporting of the different countries. These review teams consist of experts within all sectors and therefore cover the entire emission inventories. 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 sectorial reports, such as this one. The sectorial reports are externally reviewed by national or international experts in the field.

Statistics Sweden, who is responsible for the Swedish agricultural inventory, reviewed the first version of this report (Mikkelsen et al., 2006). The first updated rapport (Mikkelsen et al., 2011) 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 second updated rapport (Mikkelsen et al., 2013) was reviewed by Heidi Ravnborg from the Danish Environmental Agency. The current report is reviewed by Peter Lund, DCA, Aarhus University, with a specific focus on Chapter 11.

## 14.1 QA/QC plan

The overall framework regarding a QA / QC plan are constructed as six stages, and each stage focus on quality assurance and quality check in different part of the inventory process. A more detailed set up for stage I, II and III are provided, refer to Appendix V.

The QA / QC procedure is divided in six stages as listed below:

Table 14.1 Stages of QA/QC procedure.

| | |
|---|---|
| Stage I | Check of input data<br>- check of data input in IDA are consistent with data from external data suppliers |
| Stage II | Check of IDA data – overall<br>- check of recalculations for total emissions compared with the latest submission<br>- check of total emissions for the total $CO_2$ eqv. and for each compound |
| Stage III | Check of IDA data – specific<br>- check of annual changes of activity data, emission factors, IEF and other important variables as GE, N ex, housing system distribution, grazing days |
| Stage IV | Check by comparing calculation with estimates from other institutions<br>- the total N ex for all livestock production estimated by DCA<br>- the Register for fertilisation controlled by the Danish Agricultural Agency |
| Stage V | Check of data registered in the Common Reporting Format (CRF) reported to UNFCCC and Nomenclature For Reporting (NFR) to UNECE<br>- compare data in CRF or NFR with data from IDA |
| Stage VI | Check of the inventories in general (external review)<br>- check that data is used correctly<br>- check the methodology and the calculations |

**Stage I: Check of input data**

At stage I it is checked that all input data in IDA is consistent with data from the external data suppliers. Data from Statistics Denmark has to be checked for the livestock production, slaughter data for poultry and pigs, check of land use and crop yield. Data input from the DCA has to be checked for feed intake, N excretion, manure production, dry matter content and grazing days. Data from the DAA is checked for distribution of housing systems and the use of nitrogen in inorganic N fertiliser.

**Stage II: Check of IDA data - overall**

Stage II includes checks of the overall calculations in IDA. The first step is to compare the inventory with the last reported emission inventory. In the case where an error cover all time series, it can be difficult to identify this error by checking the changes in inter annual values. Therefore, a check of recalculations is needed.

Next step in stage II is a check of total emissions of $NH_3$, $CH_4$, $N_2O$, NMVOC, $NO_x$, PM and the other compounds, which are related to the field burning of agricultural residues and use of pesticides. For each compound a check of trends of times series 1985-2014 and inter annual changes is provided. Significant jumps or dips from one year to another could indicate an error - otherwise it has to be explained.

### Stage III: Check of IDA data - specific

At stage III, a check of specific variables in IDA is provided for both inter annual changes and trends for the entire time series. Variables includes activity data, emission factors, IEFs and other important key variables such as feed intake, gross energy (GE), N ex and housing systems distribution.

### Stage IV: Check by comparing calculation with estimates from other institutions

The purpose of stage IV is to verify the calculations in IDA, as far as external data estimations are available. For other purposes DCA for some years calculate the overall N excretion from the total livestock production in DK, which could be compared with the survey given in the emission inventories. Another possibility to check some of the IDA estimations is the information in the fertiliser accounts controlled by DAA. Farmers with more than 10 animal units have to be registered and must keep accounts of the N content in manure, received manure or other organic fertiliser. These comparisons will properly show some differences, which not necessarily indicate an error, but the most important cause of the difference has to be identified.

### Stage V: Check of data registered in CRF and NFR

Stage V primarily focuses on the last reported year and the base year (CRF 1990 / NFR 1985), where all activity data, emissions and IEFs are checked. Furthermore, CRF and NFR sum emissions are checked with sum emissions in IDA. If an error is detected a more detailed check is done to find the reason for the error.

### Stage VI: Check of the inventories in general

General checks of the inventories include considerations of which data input is used, how they are used in the calculations and whether more accurate data are available. The review of this sectorial report addresses these issues and is the most valuable part of the QA of the agricultural sector.

As a part of the report “Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories” (IPCC, 2000) a verification of emission estimates are provided, which include an inter-country comparison for EU15 countries excluding Luxemburg and including Norway and Switzerland and for some verification steps also including Australia, Canada, Japan, Russian Federation and USA (Fauser et al., 2013). The verification covers 1990, 2000 and 2010 emissions, reported in 2012, for 29 Danish verification key categories, identified by a Tier 1 key source analysis. The agricultural sector contributes with 14 of the verification key categories.

For most of the verification categories, the implied emission factor (IEF) show constant time series indicating consistent IEFs from 1990 to 2010 and imply robustness in methodology and underlying data. Comparability of IEF between countries is found for most of the agricultural categories. Some verification categories differ from other countries but can be explained by use of national data, which leads to a larger variation of the IEF values. In general, the Danish IEF is in line with other countries that have comparable agricultural conditions.

# 15 Uncertainties

Uncertainty estimates are based on the methodology described in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and the EMEP/EEA Guidebook (EMEP, 2016). The total uncertainty depends on uncertainty values for activity data and uncertainty values for the emission factor.

## 15.1 Uncertainty values for agricultural air pollutants

### 15.1.1 Activity data

As mentioned before, the main part of the emissions depends on the livestock production, and uncertainties such as number of animals, feeding consumption, normative figures etc. are relatively low. The uncertainties for the most important livestock categories are relatively low e.g. for swine and cattle the uncertainties is estimated to 1.3 % and 0.9 %, respectively. The uncertainty is higher for less important animal groups, e.g. fur bearing animals (3.4 %), poultry, horses and sheep (10.4 %) (DSt, 2017). The uncertainty for number of animals overall is estimated to 2 %.

The allocation of housing system is based on information from the farm nitrogen budgets handled and controlled by the Danish Agricultural Agency. All farmers have to submit the information regarding the housing type annually and the uncertainty is assumed as relatively low.

When it comes to $NH_3$ emission from manure management, the activity data not only includes the number of animals, but also includes estimates for type of housing and thus type of manure, which increase the uncertainty. The uncertainty value is estimated to 5 % - see Table 15.1.

The overall uncertainty for N excretion on grass is estimated to 5 %. Besides the number of animals, the uncertainty depends on the assumed number of days on grass and the N-excretion, which is estimated by SEGES and DCA, Aarhus University. The Danish Normative System for animal excretions is based on data from SEGES, which is the central office for all Danish agricultural advisory services. SEGES engages in a great deal of research as well as the collection of efficiency 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 up to 100 % of fur production are collected annually. These basic feeding plans are used to develop the standard values of the “Danish Normative System”. 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. In the normative standards (Poulsen et al., 2016) uncertainty values are indicated for emission measurements in housing and varies from 15 -25 %, but there are no specified uncertainty estimates for emission factors for storage and application of manure.

The activity data for inorganic N fertiliser depends on the amount of fertiliser sold and the nitrogen content, which is based on information given by the DAA. Uncertainty for this is considered to be low and is estimated to 3 %.

For manure applied to soil the activity data is a combination of number of animals, housing type, N excretion, days on grass and emission factors for $NH_3$ in housings and storage. The combined uncertainty is estimated to 15 %.

An uncertainty of 25 % for the activity for field burning of agricultural residue is used. The uncertainty is a combination of the uncertainty for area of grass for seed production, which has a low uncertainty, amount of burnt straw and yield, which have a high uncertainty.

The uncertainty for activity data regarding use of pesticides with HCB is based on annual sales statistic provided by the Environmental Protection Agency and is considered with relatively low uncertainty; 5 %.

See Table 15.1 for other variables and their uncertainty estimates.

### 15.1.2 Emission factor

The uncertainty regarding the $NH_3$ emission factor from manure management is based on Kai et al (2016) and estimated to 25 %. The uncertainty estimations is based on measurements and model estimations.

The ammonia emission from grazing animals depends on the number of grazing days, the animal type, the temperature and other climatic conditions. No statistics exists on the number of grazing days and are therefore based on an estimated provided of the by SEGES. The uncertainty value is estimated to 25 %.

No uncertainty values for the emission factor regarding the inorganic N-fertiliser are given in the EEA/EMEP guidebook. The Danish inventories assume an uncertainty value of 25 %, which indicated an uncertainty in the translation of the Danish fertiliser types to types specified in the guidebook, but also indicate an uncertainty of the emission factors specified in the guidebook.

The uncertainty regarding the emission from the ammonia emission sources cultivated crops, sewage sludge and ammonia treated straw is all based on the relative few data and therefore assumed to have a high uncertainty estimated to 50 %.

For NMVOC, PM and $NO_x$ the uncertainty for the emission factors is based on EEA/EMEP guidebook.

Uncertainties for field burning are relatively high. The uncertainties for the emission factors for field burning of agricultural residues are based on the EMEP/EEA Guidebook (EMEP, 2016) and Jenkins et al. (1996).

No uncertainty value is provided in EMEP for HCB and PCBs, the uncertainty is assumed to be high and thus estimated to 500 %.

Table 15.1 Variables and uncertainty values, air pollutants.

| NFR code | Compound | Source | Activity data uncertainty | Emission factor uncertainty |
|---|---|---|---|---|
| 3.B | $NH_3$ | Manure management (housing+storage) | 5 % | 25 % |
| 3.Da1 | $NH_3$ | Inorganic fertilisers | 3 % | 25 % |
| 3.Da2a | $NH_3$ | Animal manure applied | 15 % | 25 % |
| 3.Da2b | $NH_3$ | Sewage sludge applied | 15 % | 50 % |
| 3.Da3 | $NH_3$ | Urine and dung deposited by grazing | 5 % | 25 % |
| 3.De | $NH_3$ | Cultivated crops | 2 % | 50 % |
| 3.F | $NH_3$ | Field burning | 25 % | 50 % |
| 3.I | $NH_3$ | $NH_3$ treated straw | 20 % | 50 % |
| 3.B | PM | Manure management | 7 % | 300 % |
| 3.Dc | PM | Cultivation of soils | 10 % | 300 % |
| 3.F | PM | Field burning | 25 % | 50 % |
| 3.B | $NO_x$ | Manure management | 5 % | 100 % |
| 3.Da1 | $NO_x$ | Inorganic fertilisers | 3 % | 400 % |
| 3.Da2a | $NO_x$ | Animal manure applied | 15 % | 400 % |
| 3.Da2b | $NO_x$ | Sewage sludge applied | 15 % | 400 % |
| 3.F | $NO_x$ | Field burning | 25 % | 25 % |
| 3.B | NMVOC | Manure management | 2 % | 300 % |
| 3.De | NMVOC | Cultivated crops | 5 % | 500 % |
| 3.F | NMVOC | Field burning | 25 % | 100 % |

### 15.1.3 Result of the uncertainty calculation

Table 15.2 shows uncertainty values for activity and emission factors and combined and total uncertainties for the air pollutants. The uncertainty estimates are based on the simple Tier 1 approach in the EMEP / CorinAir *Good Practice Guidance for LRTAP Emission Inventories* (Pulles & Aardenne, 2004).

The total uncertainty for the $NH_3$ emission inventories is calculated at ±16 % (see Table 15.2), which is primarily affected by the main emission source manure management. The higher uncertainty values for the field burning of crop residues have only minor effect on the total uncertainty estimate.

A high total uncertainty of around 100 % to 500 % is associated with $NO_x$ emission, NMVOC emission, PM emission and almost all pollutants related to field burning of agricultural residues. The high uncertainty level is due to the emission factors' uncertainty.

Table 15.2 Uncertainty values for air pollutants, 2015.

| Pollutant | NFR category | Emission | Activity data, % | Emission factor, % | Combined uncertainty | Total uncertainty, % |
|---|---|---|---|---|---|---|
| $NO_x$, kt | 3.B Manure management | 0.20 | 5 | 100 | 100 | 191 |
| | 3.Da1 Inorganic N fertilisers | 8.11 | 3 | 400 | 400 | |
| | 3.Da2a Animal manure applied | 8.33 | 15 | 400 | 400 | |
| | 3.Da2b Sewage sludge applied | 0.29 | 15 | 400 | 400 | |
| | 3.F Field burning | 0.11 | 25 | 25 | 35 | |
| CO, kt | 3.F Field burning | 2.61 | 25 | 100 | 103 | 103 |
| NMVOC, kt | 3.B Manure management | 35.68 | 2 | 300 | 300 | 283 |
| | 3.De Cultivated crops | 2.11 | 5 | 500 | 500 | |
| | 3.F Field burning | 0.28 | 25 | 100 | 103 | |
| $SO_2$, kt | 3.F Field burning | 0.01 | 25 | 100 | 103 | 103 |
| $NH_3$, kt | 3.B Manure management | 35.73 | 5 | 25 | 25 | 16 |
| | 3.Da1 Inorganic N fertilisers | 6.10 | 3 | 25 | 25 | |
| | 3.Da2a Animal manure applied | 19.63 | 15 | 25 | 29 | |
| | 3.Da2b Sewage sludge | 0.06 | 15 | 50 | 52 | |
| | 3.Da3 Urine and dung deposited by grazing animals | 1.79 | 5 | 25 | 25 | |
| | 3.De Cultivated crops | 5.40 | 2 | 50 | 50 | |
| | 3.F Field burning | 0.11 | 25 | 50 | 56 | |
| | 3.I Agriculture other(c) | 0.16 | 20 | 50 | 54 | |
| TSP, kt | 3.B Manure management | 6.92 | 7 | 300 | 300 | 268 |
| | 3.Dc Farm-level agricultural operations | 55.04 | 10 | 300 | 300 | |
| | 3.F Field burning | 0.26 | 25 | 50 | 56 | |
| $PM_{10}$, kt | 3.B Manure management | 2.37 | 7 | 300 | 300 | 221 |
| | 3.Dc Farm-level agricultural operations | 5.50 | 10 | 300 | 300 | |
| | 3.F Field burning | 0.26 | 25 | 50 | 56 | |
| $PM_{2.5}$, kt | 3.B Manure management | 0.54 | 7 | 300 | 300 | 172 |
| | 3.Dc Farm-level agricultural operations | 0.46 | 10 | 300 | 300 | |
| | 3.F Field burning | 0.24 | 25 | 50 | 56 | |
| Pb, Mg | 3.F Field burning | 0.04 | 25 | 50 | 56 | 56 |
| Cd, Mg | 3.F Field burning | 0.002 | 25 | 100 | 103 | 103 |
| Hg, Mg | 3.F Field burning | 0.0004 | 25 | 200 | 202 | 202 |
| As, Mg | 3.F Field burning | 0.003 | 25 | 100 | 103 | 103 |
| Cr, Mg | 3.F Field burning | 0.01 | 25 | 200 | 202 | 202 |
| Cu, Mg | 3.F Field burning | 0.00001 | 25 | 200 | 202 | 202 |
| Ni, Mg | 3.F Field burning | 0.01 | 25 | 200 | 202 | 202 |
| Se, Mg | 3.F Field burning | 0.002 | 25 | 100 | 103 | 103 |
| Zn, Mg | 3.F Field burning | 0.001 | 25 | 200 | 202 | 202 |
| Dioxin, g I-Teq | 3.F Field burning | 0.03 | 25 | 500 | 501 | 501 |
| Benzo(a)pyrene, Mg | 3.F Field burning | 0.12 | 25 | 500 | 501 | 501 |
| Benzo(b)fluoranthen, Mg | 3.F Field burning | 0.12 | 25 | 500 | 501 | 501 |
| Benzo(k)fluoranthen, Mg | 3.F Field burning | 0.05 | 25 | 500 | 501 | 501 |
| Indeno(1,2,3 cd)pyrene, Mg | 3.F Field burning | 0.05 | 25 | 500 | 501 | 501 |
| HCB, kg | 3.Df Use of pesticides | 0.03 | 5 | 500 | 500 | 409 |
| | 3.F Field burning | 0.11 | 25 | 500 | 501 | |
| PCB, kg | 3.F Field burning | 0.00002 | 25 | 500 | 501 | 501 |
| BC, kt | 3.F Field burning | 0.02 | 25 | 100 | 103 | 103 |

## 15.2 Uncertainty values for agricultural greenhouse gases

### 15.2.1 Activity data

The activity data regarding $CH_4$ emission from enteric fermentation only depends on number of animals, which is based on very reliable data from Statistics Denmark, thus a low uncertainty at 2 % is used. Activity data for manure management besides number of animals also depends on the housing - and manure type. The uncertainty estimate is assumed to be 5 %.

Uncertainty for $N_2O$ activity data, which depends on the ammonia emission such as manure management, manure applied to soils and the atmospheric deposition reflects the uncertainty value estimated in the ammonia emission inventories (See the combined uncertainty provided in Table 15.2).

Activity regarding crop residue and cultivation of organic soils depends on land use data from Statistics Denmark, which has a low uncertainty. However, activity data also depends on the yield and the crop's N content, which is much more uncertain. An uncertainty value at 25 % and 20 % is used. The same uncertainty level is used for data on the amount of nitrogen leached to groundwater, watercourses and to the sea.

As for the air pollutants, an uncertainty of 25 % for field burning of agricultural residue is used.

### 15.2.2 Emission factor

The uncertainty value for enteric fermentation is in IPCC guidance estimated to 20 %. Uncertainty regarding the emission factor used for manure management depends on the uncertainty for each variable such as manure excretion, distribution of housing type, content of dry matter in manure and use of straw for bedding. National data is used for these variables, which may reduce the uncertainty compared with use of IPCC default value. It is considered that an uncertainty of 20 % is reliable.

A $CH_4$ and $N_2O$ uncertainty for field burning is estimated to 50 %, which is based on IPCC guidelines.

The IPCC default value is used to calculate the uncertainty of the $N_2O$ emission. The uncertainty estimates mentioned in IPCC guidance is very high, from 200 % and for most of the emissions sources up to 500 %. A lower uncertainty value at 100 % is used in the Danish inventories. This could be considered as an underestimation, but on the other hand, an uncertainty on the $N_2O$ estimate of 500% results in a total uncertainty for agricultural greenhouse gases at 120%, which indicate a very uncertain emission inventories.

Table 15.3 Variables and uncertainty values, GHG.

| CRF code | Compound | Source | Activity data | Emission factor |
|---|---|---|---|---|
| 3.A | $CH_4$ | Enteric fermentation | 2 % | 20 % |
| 3.B | $CH_4$ | Manure management | 5 % | 20 % |
| 3.F | $CH_4$ | Field burning | 25 % | 50 % |
| 3.B | $N_2O$ | Manure management | 25 % | 100 % |
| 3.Da1 | $N_2O$ | Inorganic N fertiliser | 3 % | 100 % |
| 3.Da2a | $N_2O$ | Manure applied to soil | 25 % | 100 % |
| 3.Da2b | $N_2O$ | Applied sewage sludge | 15 % | 100 % |
| 3.Da3 | $N_2O$ | Manure applied during grazing | 10 % | 100 % |
| 3.Da4 | $N_2O$ | Crop residue | 25 % | 100 % |
| 3.Da4 | $N_2O$ | Mineralisation | 20 % | 100 % |
| 3.Da6 | $N_2O$ | Organic soils | 20 % | 100 % |
| 3.Db1 | $N_2O$ | Atmospheric deposition | 16 % | 100 % |
| 3.Db2 | $N_2O$ | Leaching | 20 % | 100 % |
| 3.F | $N_2O$ | Field burning | 25 % | 50 % |
| 3.G | $CO_2$ | Liming | 5 % | 100 % |
| 3.H | $CO_2$ | Urea | 3 % | 100 % |
| 3.I | $CO_2$ | CAN | 3 % | 100 % |

### 15.2.3 Result of the uncertainty calculation

Table 15.4 shows the result of Approach 1 uncertainty estimation for 2015, based on the Approach 1 methodology in the 2006 IPCC Guidelines (IPCC, 2006). The overall uncertainty calculation for the agricultural sector based on Approach 1 is estimated to ±19 %.

The lowest uncertainties are seen for $CH_4$ emission from enteric fermentation and manure management and the highest for emission from mineralisation and this pattern is reflected in both calculations.

Table 15.4 Comparison between Approach 1 and Approach 2 uncertainty calculation, 2015.

| Uncertainty | | Approach 1 | |
|---|---|---|---|
| | | Emission, kt $CO_2$ eqv | Uncertainty, % Lower and upper (±) |
| 3 Agriculture total | | 10 472 | 19 |
| 3A Enteric fermentation | $CH_4$ | 3 667 | 20 |
| 3B Manure management | $CH_4$ | 1 918 | 21 |
| | $N_2O$ | 594 | 103 |
| 3B5 Indirect emission | $N_2O$ | 138 | 101 |
| 3D Agricultural Soils | | | |
| 3Da Direct soil emissions | | | |
| 3Da1 Inorganic N fertiliser | $N_2O$ | 953 | 100 |
| 3Da2a Animal manure applied to soils | $N_2O$ | 979 | 103 |
| 3Da2b Sewage sludge applied to soils | $N_2O$ | 13 | 101 |
| 3Da2c Other organic fertiliser applied to soils | $N_2O$ | 21 | 102 |
| 3Da3 Urine and dung deposited by grazing animals | $N_2O$ | 177 | 100 |
| 3Da4 Crop Residues | $N_2O$ | 662 | 103 |
| 3Da5 Mineralisation | $N_2O$ | 4 | 112 |
| 3Da6 Cultivation of organic soils | $N_2O$ | 619 | 102 |
| 3Db Indirect soil emissions | | | |
| 3Db1 Atmospheric deposition | $N_2O$ | 149 | 101 |
| 3Db2 Leaching | $N_2O$ | 396 | 102 |
| 3F Field burning of Agricultural residues | $CH_4$ | 3 | 56 |
| | $N_2O$ | 1 | 56 |
| 3G Liming | $CO_2$ | 166 | 100 |
| 3H Urea application | $CO_2$ | 1 | 100 |
| 3I Other carbon-containing fertilisers | $CO_2$ | 10 | 100 |

# 16 Conclusion

In response to a number of international conventions, Denmark is committed to calculate the Danish emissions to the atmosphere of a range of different pollutants. For the agricultural sector, the emissions includes ammonia ($NH_3$), the greenhouse gases: methane ($CH_4$), nitrous oxide ($N_2O$), carbon dioxide ($CO_2$), the indirect greenhouse gases non-methane volatile organic compounds (NMVOC), particulate matter (PM), nitrogen oxides ($NO_x$) and a series of other pollutants related to the field burning of crop residues (CO, $SO_2$, heavy metals, PAHs, dioxins, HCB and PCBs) and HCB from use of pesticides.

DCE - Danish Centre for Environment and Energy is responsible for providing and reporting the annual emission inventories. In addition to the emission inventories themselves, requirements in the various conventions call for documentation of used calculation methodology. This report, therefore, includes a review of the emissions for the period 1985–2015, a description of the main drivers for the emission trend and a description on how the emission is calculated. The report is an updated version of Scientific Report from DCE – Danish Centre for Environment and Energy No. 108 (Mikkelsen et al., 2013).

## 16.1 Agricultural emissions from 1985 to 2015

In 2015, the agricultural sector contributes 95 % of the total $NH_3$ emission, while the agricultural part of the greenhouse gases are estimated to 21 %. The agricultural emissions is primarily related to the livestock production.

The $NH_3$ emission has decreased from 129 kt $NH_3$ in 1985 and 69 kt $NH_3$ in 2015, corresponding to 46 %.

The agricultural emission of greenhouse gases in 2015 is estimated to 10.4 million tonnes $CO_2$-eqv. and has reduced from 13.3 million tonnes $CO_2$-eqv. in 1985. Since 1990, which is the base year of the United Nations Framework Convention on Climate Change, the emission has decreased to 12.7 million tonnes $CO_2$-eqv. and a reduction of 18 % is obtained.

An active national environmental policy has taken place from the late 1980s, a string of measures have been introduced by action plans to prevent loss of nitrogen from agriculture to the environment with a primary focus on the aquatic environment. The improvement of feed efficiency and nitrogen utilisation in manure has led to a significant decrease in consumption of inorganic N fertiliser. Combined with requirements to the handling of animal manure during storage and application, these are the main drivers for the reduction of both the emission of $NH_3$ and the greenhouse gas $N_2O$. Furthermore, the decrease in number of cattle has led to a reduction in $CH_4$ emission from the enteric fermentation process.

## 16.2 Methodology and documentation

Preparation of the Danish emission inventories are based on the international guidelines EMEP/EEA air pollutant emission inventory guidebook (EMEP 2016 and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). In Denmark, a relatively large amount of data and information is available related to the specific Danish climate and to agricultural production conditions, including livestock populations, housing types, 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 agricultural related research and administration. Especially of relevance are Statistics Denmark, DCA - Danish Centre for Food and Agriculture at Aarhus University and SEGES (agricultural advisory service). Furthermore, the following institutions have been involved: the Danish Environmental Protection Agency, the Danish Agricultural Agency 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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# Appendixes

**A)** Ammonia emission from Danish agriculture 1985 – 2015, kt $NH_3$-N and kt $NH_3$.

| **$NH_3$-N** | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agricultural Sector - total** | **106.06** | **105.29** | **103.14** | **100.61** | **101.27** | **101.39** | **97.78** | **95.47** | **93.48** | **90.74** | **85.15** | **82.14** | **81.50** | **81.42** | **76.80** | **75.06** |
| Manure Management | 44.02 | 44.87 | 43.96 | 44.33 | 43.93 | 42.00 | 41.53 | 42.29 | 41.53 | 40.28 | 38.55 | 38.32 | 39.05 | 40.33 | 38.90 | 38.49 |
| Inorganic N-fertiliser | 15.09 | 12.92 | 12.59 | 12.23 | 12.40 | 13.35 | 12.44 | 11.07 | 10.72 | 10.74 | 9.71 | 8.69 | 8.55 | 8.05 | 7.40 | 6.63 |
| Manure applied to soil | 32.77 | 32.32 | 30.85 | 30.03 | 29.46 | 30.26 | 29.28 | 28.38 | 27.58 | 26.04 | 24.43 | 23.93 | 23.13 | 22.95 | 21.91 | 21.05 |
| Grazing | 2.57 | 2.51 | 2.41 | 2.38 | 2.38 | 2.39 | 2.45 | 2.45 | 2.49 | 2.44 | 2.49 | 2.50 | 2.44 | 2.43 | 2.38 | 2.40 |
| 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 | 4.45 | 4.33 | 4.29 |
| 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 | 0.07 | 0.07 | 0.07 |
| $NH_3$ 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 | 3.05 | 1.71 | 2.03 |
| 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 | 0.10 | 0.09 | 0.09 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agricultural Sector - total** | **73.57** | **72.29** | **71.42** | **70.88** | **68.05** | **65.01** | **64.00** | **63.08** | **59.99** | **60.60** | **59.63** | **58.32** | **56.21** | **56.48** | **56.81** |
| Manure Management | 39.67 | 40.44 | 39.85 | 41.40 | 38.89 | 36.79 | 34.59 | 33.90 | 32.68 | 32.73 | 32.61 | 31.70 | 29.35 | 29.46 | 29.43 |
| Inorganic N fertiliser | 6.14 | 5.68 | 5.43 | 5.55 | 5.37 | 5.02 | 5.18 | 5.47 | 3.74 | 4.54 | 4.58 | 4.35 | 4.60 | 4.64 | 5.02 |
| Manure applied to soil | 19.50 | 18.56 | 18.89 | 17.05 | 17.22 | 16.81 | 18.00 | 17.34 | 17.06 | 17.08 | 16.23 | 16.06 | 16.04 | 16.10 | 16.17 |
| Grazing | 2.44 | 2.36 | 2.11 | 1.94 | 1.82 | 1.72 | 1.63 | 1.64 | 1.57 | 1.54 | 1.49 | 1.51 | 1.53 | 1.52 | 1.48 |
| Crops | 4.33 | 4.33 | 4.32 | 4.34 | 4.40 | 4.40 | 4.33 | 4.46 | 4.65 | 4.45 | 4.46 | 4.45 | 4.43 | 4.49 | 4.45 |
| Sewage sludge used as fertiliser | 0.07 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| $NH_3$ treated straw | 1.33 | 0.77 | 0.66 | 0.43 | 0.21 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| Field burning of agricultural residue | 0.10 | 0.08 | 0.10 | 0.10 | 0.10 | 0.11 | 0.09 | 0.08 | 0.10 | 0.07 | 0.07 | 0.08 | 0.09 | 0.09 | 0.09 |

**A)** *Continued…* kt $NH_3$

| **$NH_3$** | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agricultural Sector - total** | **128.78** | **127.85** | **125.24** | **122.17** | **122.97** | **123.12** | **118.73** | **115.93** | **113.51** | **110.18** | **103.40** | **99.74** | **98.96** | **98.87** | **93.26** | **91.15** |
| Manure Management | 53.45 | 54.49 | 53.38 | 53.83 | 53.34 | 51.00 | 50.42 | 51.36 | 50.42 | 48.91 | 46.81 | 46.53 | 47.42 | 48.97 | 47.24 | 46.74 |
| Inorganic N fertiliser | 18.32 | 15.69 | 15.28 | 14.85 | 15.05 | 16.21 | 15.10 | 13.45 | 13.02 | 13.05 | 11.79 | 10.55 | 10.38 | 9.77 | 8.99 | 8.06 |
| Manure applied to soil | 39.80 | 39.25 | 37.47 | 36.46 | 35.77 | 36.74 | 35.55 | 34.46 | 33.49 | 31.62 | 29.66 | 29.05 | 28.09 | 27.86 | 26.61 | 25.55 |
| Grazing | 3.12 | 3.05 | 2.93 | 2.89 | 2.88 | 2.91 | 2.97 | 2.98 | 3.03 | 2.97 | 3.02 | 3.04 | 2.97 | 2.95 | 2.90 | 2.92 |
| 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 | 5.41 | 5.25 | 5.21 |
| 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 | 0.09 | 0.08 | 0.08 |
| $NH_3$ 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 | 3.70 | 2.08 | 2.47 |
| 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 | 0.12 | 0.12 | 0.11 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agricultural Sector - total** | **89.34** | **87.78** | **86.72** | **86.07** | **82.63** | **78.95** | **77.71** | **76.59** | **72.84** | **73.59** | **72.41** | **70.82** | **68.25** | **68.58** | **68.98** |
| Manure Management | 48.17 | 49.10 | 48.39 | 50.28 | 47.22 | 44.67 | 42.00 | 41.17 | 39.68 | 39.75 | 39.60 | 38.49 | 35.63 | 35.77 | 35.73 |
| Inorganic N fertiliser | 7.45 | 6.90 | 6.60 | 6.74 | 6.52 | 6.09 | 6.29 | 6.64 | 4.55 | 5.51 | 5.56 | 5.28 | 5.59 | 5.64 | 6.10 |
| Manure applied to soil | 23.68 | 22.54 | 22.93 | 20.71 | 20.91 | 20.42 | 21.86 | 21.06 | 20.72 | 20.75 | 19.71 | 19.50 | 19.47 | 19.55 | 19.63 |
| Grazing | 2.97 | 2.86 | 2.56 | 2.36 | 2.21 | 2.09 | 1.99 | 1.99 | 1.90 | 1.87 | 1.81 | 1.84 | 1.86 | 1.85 | 1.79 |
| Crops | 5.25 | 5.26 | 5.24 | 5.27 | 5.34 | 5.34 | 5.26 | 5.41 | 5.65 | 5.41 | 5.42 | 5.40 | 5.37 | 5.45 | 5.40 |
| Sewage sludge used as fertiliser | 0.08 | 0.08 | 0.07 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| $NH_3$ treated straw | 1.62 | 0.94 | 0.80 | 0.53 | 0.26 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| Field burning of agricultural residue | 0.12 | 0.10 | 0.12 | 0.13 | 0.13 | 0.13 | 0.11 | 0.10 | 0.12 | 0.09 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 |

**B)** Development in the emission of greenhouse gases, 1985-2015, measured in kt $CO_2$ equivalents.

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 5 997 | 5 903 | 5 659 | 5 553 | 5 512 | 5 585 | 5 699 | 5 775 | 5 931 | 5 816 | 5 831 | 5 860 | 5 799 | 5 906 | 5 727 | 5 719 |
| $N_2O$ | 6 605 | 6 513 | 6 379 | 6 372 | 6 409 | 6 508 | 6 355 | 6 199 | 6 052 | 5 946 | 5 795 | 5 498 | 5 489 | 5 606 | 5 401 | 5 318 |
| $CO_2$ | 732 | 756 | 500 | 739 | 889 | 619 | 512 | 403 | 350 | 412 | 537 | 418 | 483 | 264 | 274 | 268 |
| Total | 13 333 | 13 172 | 12 539 | 12 663 | 12 810 | 12 712 | 12 566 | 12 377 | 12 332 | 12 175 | 12 163 | 11 776 | 11 771 | 11 775 | 11 402 | 11 305 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 5 887 | 5 903 | 5 893 | 5 838 | 5 682 | 5 574 | 5 648 | 5 586 | 5 555 | 5 633 | 5 579 | 5 588 | 5 556 | 5 590 | 5 524 |
| $N_2O$ | 5 221 | 5 215 | 4 983 | 5 060 | 4 961 | 4 818 | 4 969 | 4 955 | 4 751 | 4 636 | 4 690 | 4 606 | 4 594 | 4 649 | 4 709 |
| $CO_2$ | 207 | 237 | 229 | 160 | 222 | 196 | 194 | 231 | 187 | 156 | 165 | 192 | 246 | 240 | 177 |
| Total | 11 314 | 11 355 | 11 105 | 11 057 | 10 865 | 10 588 | 10 812 | 10 772 | 10 492 | 10 425 | 10 434 | 10 386 | 10 397 | 10 479 | 10 411 |

**C)** Development in the emission of greenhouse gases, 1985-2015, measured in Gg $CO_2$ equivalents, distributed on main sources.

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\underline{CH_4}$ | | | | | | | | | | | | | | | | |
| Enteric fermentation | 4 592 | 4 444 | 4 202 | 4 076 | 4 010 | 4 039 | 4 070 | 4 019 | 4 074 | 3 978 | 3 967 | 3 965 | 3 829 | 3 833 | 3 685 | 3 631 |
| Manure management | 1 362 | 1 422 | 1 422 | 1 451 | 1 474 | 1 544 | 1 627 | 1 754 | 1 854 | 1 836 | 1 861 | 1 892 | 1 967 | 2 070 | 2 039 | 2 085 |
| Field burning | 43 | 37 | 35 | 26 | 28 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| $\underline{N_2O}$ | | | | | | | | | | | | | | | | |
| Crop residue | 421 | 431 | 410 | 471 | 494 | 569 | 541 | 410 | 473 | 459 | 526 | 532 | 557 | 560 | 522 | 547 |
| Atmospheric deposition - soil | 326 | 318 | 311 | 297 | 302 | 313 | 298 | 282 | 275 | 267 | 248 | 234 | 227 | 221 | 204 | 197 |
| Atmospheric deposition - manure management | 207 | 211 | 207 | 208 | 206 | 197 | 195 | 199 | 195 | 189 | 181 | 180 | 183 | 189 | 183 | 181 |
| Manure management | 748 | 770 | 762 | 772 | 778 | 781 | 791 | 816 | 816 | 781 | 755 | 756 | 764 | 790 | 771 | 769 |
| Grazing | 325 | 316 | 302 | 297 | 296 | 298 | 304 | 305 | 312 | 306 | 311 | 313 | 307 | 306 | 300 | 300 |
| Field burning | 13 | 11 | 11 | 8 | 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Inorganic N fertiliser | 1 864 | 1 789 | 1 786 | 1 719 | 1 765 | 1 875 | 1 849 | 1 730 | 1 559 | 1 528 | 1 479 | 1 362 | 1 347 | 1 326 | 1 230 | 1 178 |
| Organic soils | 881 | 871 | 861 | 851 | 842 | 832 | 822 | 812 | 803 | 793 | 783 | 773 | 763 | 754 | 744 | 734 |
| Manure on soil | 1 065 | 1 066 | 1 031 | 1 018 | 1 009 | 1 003 | 998 | 999 | 1 005 | 966 | 937 | 935 | 929 | 947 | 936 | 919 |
| Mineralization | 92 | 82 | 67 | 113 | 106 | 68 | 14 | 87 | 44 | 26 | 28 | 8 | 11 | 10 | 10 | 36 |
| Sewage sludge | 16 | 16 | 17 | 18 | 20 | 22 | 28 | 32 | 44 | 42 | 43 | 43 | 40 | 41 | 38 | 41 |
| Leaching and run-off | 646 | 630 | 614 | 598 | 582 | 549 | 514 | 524 | 525 | 589 | 503 | 361 | 360 | 459 | 462 | 415 |
| $\underline{CO_2}$ | | | | | | | | | | | | | | | | |
| Field burning | 967 | 830 | 789 | 590 | 621 | 49 | 51 | 48 | 53 | 51 | 58 | 57 | 61 | 77 | 73 | 72 |
| Liming | 696 | 712 | 452 | 694 | 837 | 565 | 463 | 357 | 307 | 367 | 496 | 393 | 470 | 252 | 265 | 261 |
| Urea | 10 | 8 | 7 | 9 | 8 | 15 | 12 | 13 | 13 | 18 | 15 | 9 | 4 | 4 | 3 | 2 |
| CAN | 25 | 35 | 41 | 36 | 44 | 38 | 37 | 33 | 30 | 27 | 26 | 16 | 10 | 7 | 6 | 5 |

**C)** *Continued…*

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | | | | | | | | | | | | | | | |
| Enteric fermentation | 3 703 | 3 646 | 3 604 | 3 496 | 3 483 | 3 484 | 3 565 | 3 596 | 3 596 | 3 631 | 3 592 | 3 674 | 3 697 | 3 711 | 3 667 |
| Manure management | 2 180 | 2 255 | 2 286 | 2 339 | 2 195 | 2 086 | 2 080 | 1 987 | 1 956 | 1 999 | 1 984 | 1 911 | 1 856 | 1 877 | 1 854 |
| Field burning | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 |
| $N_2O$ | | | | | | | | | | | | | | | |
| Crop residue | 553 | 522 | 546 | 550 | 588 | 580 | 576 | 614 | 693 | 632 | 653 | 660 | 641 | 694 | 662 |
| Atmospheric deposition - soil | 184 | 173 | 171 | 162 | 161 | 155 | 161 | 162 | 151 | 153 | 150 | 147 | 149 | 149 | 152 |
| Atmospheric deposition – manure management | 186 | 190 | 187 | 194 | 183 | 173 | 162 | 159 | 153 | 154 | 153 | 149 | 138 | 138 | 138 |
| Manure management | 797 | 818 | 808 | 834 | 787 | 728 | 734 | 686 | 641 | 640 | 625 | 612 | 614 | 607 | 594 |
| Grazing | 305 | 292 | 259 | 236 | 219 | 205 | 193 | 194 | 185 | 183 | 179 | 182 | 185 | 183 | 177 |
| Field burning | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Inorganic N fertiliser | 1 094 | 987 | 942 | 968 | 966 | 898 | 911 | 1 032 | 938 | 890 | 923 | 876 | 906 | 875 | 953 |
| Organic soils | 724 | 714 | 705 | 695 | 685 | 675 | 665 | 656 | 646 | 635 | 637 | 627 | 622 | 619 | 619 |
| Manure on soil | 944 | 967 | 965 | 985 | 995 | 962 | 1 018 | 995 | 971 | 975 | 972 | 966 | 973 | 977 | 979 |
| Mineralization | 11 | 87 | 61 | 41 | 25 | 66 | 122 | 66 | 14 | 4 | 21 | 11 | 4 | 14 | 4 |
| Sewage sludge | 51 | 45 | 37 | 29 | 21 | 24 | 23 | 27 | 32 | 29 | 28 | 32 | 33 | 32 | 34 |
| Leaching and run-off | 371 | 418 | 301 | 363 | 331 | 350 | 402 | 364 | 324 | 341 | 348 | 344 | 329 | 359 | 396 |
| $CO_2$ | | | | | | | | | | | | | | | |
| Field burning | 75 | 63 | 75 | 79 | 80 | 81 | 70 | 65 | 77 | 56 | 55 | 64 | 69 | 68 | 67 |
| Liming | 201 | 233 | 226 | 158 | 220 | 194 | 192 | 229 | 181 | 153 | 162 | 188 | 244 | 238 | 166 |
| Urea | 2 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| CAN | 4 | 3 | 2 | 1 | 2 | 1 | 1 | 2 | 4 | 3 | 3 | 2 | 2 | 2 | 10 |

**D)** Number of livestock.

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

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 896 | 864 | 811 | 774 | 759 | 753 | 742 | 712 | 714 | 700 | 702 | 701 | 670 | 669 | 640 | 636 |
| 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 | 1 308 | 1 247 | 1 232 |
| Sheep | 99 | 131 | 148 | 182 | 208 | 230 | 266 | 256 | 221 | 200 | 202 | 235 | 240 | 252 | 264 | 279 |
| Goats | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 8 |
| Horses | 140 | 139 | 138 | 137 | 136 | 135 | 137 | 138 | 140 | 141 | 143 | 144 | 146 | 147 | 149 | 150 |
| Swine[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 | 12 095 | 11 626 | 11 922 |
| Poultry[3] | 15 219 | 15 220 | 15 540 | 15 524 | 17 194 | 16 249 | 15 933 | 19 041 | 19 898 | 19 852 | 19 619 | 19 888 | 18 994 | 18 674 | 21 010 | 21 830 |
| 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 | 2 345 | 2 089 | 2 199 |
| Pheasant | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 |
| Deer | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Ostrich | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.1 | 2.2 | 3.3 | 4.4 | 5.6 | 6.7 | 7.8 | 8.9 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 623 | 610 | 596 | 563 | 564 | 550 | 545 | 558 | 563 | 568 | 565 | 587 | 582 | 563 | 561 |
| Non-dairy cattle[1] | 1 284 | 1 187 | 1 128 | 1 082 | 1 006 | 984 | 1 021 | 1 006 | 977 | 1 003 | 1 003 | 1 020 | 1 032 | 1 001 | 991 |
| Sheep | 297 | 294 | 303 | 310 | 316 | 319 | 309 | 294 | 289 | 278 | 234 | 226 | 221 | 220 | 210 |
| Goats | 9 | 9 | 10 | 11 | 11 | 12 | 13 | 14 | 16 | 16 | 13 | 13 | 13 | 12 | 11 |
| Horses | 155 | 160 | 165 | 170 | 175 | 180 | 185 | 190 | 178 | 165 | 155 | 155 | 150 | 150 | 155 |
| Swine[2] | 12 608 | 12 732 | 12 949 | 13 233 | 13 534 | 13 361 | 13 723 | 12 738 | 12 369 | 13 173 | 12 932 | 12 331 | 12 076 | 12 332 | 12 538 |
| Poultry[3] | 21 236 | 20 580 | 17 844 | 16 649 | 17 633 | 17 425 | 16 741 | 15 406 | 19 676 | 18 731 | 19 319 | 18 991 | 19 431 | 18 348 | 17 523 |
| Fur farming | 2 304 | 2 422 | 2 361 | 2 471 | 2 552 | 2 708 | 2 837 | 2 810 | 2 721 | 2 699 | 2 757 | 2 948 | 3 143 | 3 315 | 3 400 |
| Pheasant | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 | 1 063 |
| Deer | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 10 | 8 | 7 | 8 | 7 | 8 |
| Ostrich | 10.0 | 6.6 | 4.8 | 4.2 | 3.7 | 3.7 | 0.6 | 0.5 | 0.4 | 0.4 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 |

[1]Non-dairy cattle includes calves, bulls, heifers and suckling cattle.

[2]Swine includes sows, weaners and fattening pigs.

[3]Poultry includes hens, pullets, broilers, turkeys, ducks and geese.

**D)** *Continued…*

2) Number of livestock given in produced number of animals, thousands.

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 896 | 864 | 811 | 774 | 759 | 753 | 742 | 712 | 714 | 700 | 702 | 701 | 670 | 669 | 640 | 636 |
| Non-dairy cattle[1] | 3 312 | 3 178 | 2 992 | 2 884 | 2 805 | 2 854 | 2 861 | 2 885 | 2 805 | 2 689 | 2 676 | 2 643 | 2 545 | 2 462 | 2 337 | 2 274 |
| Sheep | 99 | 131 | 148 | 182 | 208 | 230 | 266 | 256 | 221 | 200 | 202 | 235 | 240 | 252 | 264 | 279 |
| Goats | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 8 |
| Horses | 140 | 139 | 138 | 137 | 136 | 135 | 137 | 138 | 140 | 141 | 143 | 144 | 146 | 147 | 149 | 150 |
| Swine[2] | 30 570 | 32 240 | 32 219 | 32 783 | 32 678 | 33 882 | 35 913 | 38 900 | 42 759 | 43 049 | 42 606 | 42 963 | 44 475 | 48 204 | 48 126 | 47 481 |
| Poultry[3] | 94 078 | 93 400 | 92 711 | 99 465 | 106 678 | 108 640 | 113 682 | 123 520 | 129 498 | 139 644 | 135 907 | 129 306 | 132 410 | 139 230 | 150 255 | 146 854 |
| 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 | 2 345 | 2 089 | 2 199 |
| Pheasant | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Deer | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Ostrich | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.1 | 2.2 | 3.3 | 4.4 | 5.6 | 6.7 | 7.8 | 8.9 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 623 | 610 | 596 | 563 | 564 | 550 | 545 | 558 | 563 | 568 | 565 | 587 | 582 | 563 | 561 |
| Non-dairy cattle[1] | 2 286 | 2 220 | 1 373 | 1 359 | 1 246 | 1 210 | 1 261 | 1 267 | 1 212 | 1 224 | 1 257 | 1 220 | 1 238 | 1 211 | 1 197 |
| Sheep | 297 | 294 | 303 | 310 | 316 | 319 | 309 | 294 | 289 | 278 | 234 | 226 | 221 | 220 | 210 |
| Goats | 9 | 9 | 10 | 11 | 11 | 12 | 13 | 14 | 16 | 16 | 13 | 13 | 13 | 12 | 11 |
| Horses | 155 | 160 | 165 | 170 | 175 | 180 | 185 | 190 | 178 | 165 | 155 | 155 | 150 | 150 | 155 |
| Swine[2] | 49 756 | 51 435 | 51 602 | 53 435 | 52 071 | 51 586 | 52 273 | 51 068 | 50 223 | 51 945 | 52 853 | 50 918 | 50 832 | 51 455 | 52 398 |
| Poultry[3] | 149 102 | 148 781 | 143 256 | 144 001 | 135 205 | 117 875 | 118 681 | 120 860 | 119 414 | 128 783 | 128 145 | 123 559 | 126 200 | 123 870 | 123 519 |
| Fur farming | 2 304 | 2 422 | 2 361 | 2 471 | 2 552 | 2 708 | 2 837 | 2 810 | 2 721 | 2 699 | 2 757 | 2 948 | 3 143 | 3 315 | 3 400 |
| Pheasant | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Deer | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 10 | 8 | 7 | 8 | 7 | 8 |
| Ostrich | 10.0 | 6.6 | 4.8 | 4.2 | 3.7 | 3.7 | 0.6 | 0.5 | 0.4 | 0.4 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 |

[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 and geese.

**E)** Housing type distribution in percent, 1985-2015.

**Cattle:**

*Dairy cattle:*

| Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tethered with urine and solid manure | 40.0 | 39.1 | 38.2 | 37.3 | 36.4 | 35.5 | 34.5 | 33.6 | 32.7 | 31.8 | 30.9 | 30.0 | 30.0 | 30.0 | 30.0 | 18.0 |
| Tethered with slurry | 45.0 | 44.7 | 44.5 | 44.2 | 43.9 | 43.6 | 43.4 | 43.1 | 42.8 | 42.5 | 42.3 | 42.0 | 36.0 | 30.0 | 30.0 | 28.0 |
| Loose-holding with beds, solid floor | 4.0 | 3.9 | 3.8 | 3.7 | 3.6 | 3.6 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 6.0 |
| Loose-holding with beds, slatted floor | 9.0 | 9.8 | 10.6 | 11.5 | 12.3 | 12.4 | 12.9 | 13.6 | 13.9 | 14.9 | 15.1 | 15.4 | 17.9 | 20.4 | 20.2 | 29.6 |
| Loose-holding with beds, slatted floor, scrape | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 3.0 | 3.0 | 3.0 |
| Loose-holding with beds, drained floor | 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 | 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 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Deep litter | 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 | 0.0 | 0.0 | 0.0 |
| Deep litter, long eating space, solid floor | 0.5 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 1.0 | 1.5 | 2.0 | 2.0 | 3.0 |
| Deep litter, slatted floor | 0.5 | 0.9 | 1.3 | 1.7 | 2.1 | 2.5 | 2.9 | 3.4 | 3.8 | 4.2 | 4.6 | 5.0 | 6.3 | 7.5 | 7.5 | 7.0 |
| Deep litter, slatted floor, scrape | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.5 | 0.5 | 1.0 |
| Biogas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 1.0 | 1.1 | 1.6 | 1.5 | 2.1 | 2.6 | 3.1 | 3.6 | 3.8 | 4.4 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tethered with urine and solid manure | 15.0 | 12.0 | 8.0 | 6.0 | 6.2 | 6.4 | 6.7 | 5.6 | 4.8 | 4.8 | 3.8 | 3.3 | 3.0 | 2.8 | 2.6 |
| Tethered with slurry | 25.0 | 23.0 | 18.0 | 16.0 | 14.0 | 12.0 | 10.0 | 8.6 | 7.4 | 7.4 | 5.9 | 5.3 | 5.2 | 4.3 | 4.0 |
| Loose-holding with beds, solid floor | 9.0 | 11.0 | 16.0 | 17.0 | 15.8 | 14.6 | 13.4 | 13.7 | 14.1 | 14.1 | 15.5 | 15.3 | 14.1 | 15.0 | 15.2 |
| Loose-holding with beds, slatted floor | 30.9 | 33.2 | 35.0 | 36.6 | 35.8 | 33.8 | 32.3 | 33.6 | 35.1 | 34.9 | 36.1 | 37.8 | 38.9 | 35.9 | 33.2 |
| Loose-holding with beds, slatted floor, scrape | 4.0 | 4.0 | 5.0 | 6.0 | 10.6 | 15.3 | 19.9 | 20.3 | 20.8 | 20.8 | 21.3 | 21.5 | 21.7 | 21.5 | 21.4 |
| Loose-holding with beds, drained floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 0.3 | 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 | 0.6 | 1.3 | 2.1 | 2.4 | 2.6 | 3.3 | 2.7 | 4.0 | 4.4 |
| Deep litter | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.8 | 2.0 | 2.0 | 2.0 | 2.0 | 2.1 | 2.4 | 2.7 | 3.0 | 3.4 |
| Deep litter, long eating space, solid floor | 3.0 | 3.0 | 3.0 | 3.0 | 2.3 | 1.7 | 1.0 | 0.8 | 0.8 | 0.8 | 0.7 | 0.6 | 0.7 | 0.6 | 0.5 |
| Deep litter, slatted floor | 7.0 | 7.0 | 7.0 | 7.0 | 5.4 | 3.8 | 2.2 | 2.1 | 1.8 | 1.8 | 1.5 | 1.4 | 1.5 | 1.3 | 1.4 |
| Deep litter, slatted floor, scrape | 1.0 | 1.0 | 1.0 | 1.0 | 1.4 | 1.5 | 1.8 | 1.6 | 1.4 | 1.4 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 |
| Biogas | 5.1 | 5.8 | 7.0 | 7.4 | 7.6 | 9.1 | 10.0 | 10.0 | 9.4 | 9.6 | 9.5 | 8.1 | 8.5 | 10.7 | 13.0 |

**E)** *Continued…*

*Heifers:*

| Calves, 0-6 mth | Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deep litter (boxes) | 100 | 100 | 100 | 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 | 0 | 0 | 0 |
| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| | Deep litter (boxes) | 89.0 | 84.0 | 83.0 | 80.0 | 85.4 | 90.8 | 96.2 | 96.3 | 96.4 | 96.4 | 96.4 | 96.4 | 96.9 | 96.4 | 96.4 | |
| | Deep litter, solid floor | 11.0 | 16.0 | 17.0 | 20.0 | 14.6 | 9.2 | 3.8 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.1 | 3.6 | 3.6 | |

| 6 mth-calving | Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slatted floor-boxes | 45.0 | 44.0 | 43.0 | 42.0 | 41.0 | 40.0 | 39.0 | 38.0 | 37.0 | 36.0 | 35.0 | 34.0 | 33.0 | 33.0 | 32.0 | 32.0 |
| | Tethered with urine and solid manure | 25.0 | 23.9 | 22.7 | 21.5 | 20.4 | 19.2 | 18.1 | 16.9 | 15.8 | 14.6 | 13.5 | 12.0 | 11.0 | 10.0 | 10.0 | 9.0 |
| | Tethered with slurry | 25.0 | 23.9 | 22.7 | 21.5 | 20.4 | 19.2 | 18.1 | 16.9 | 15.8 | 14.6 | 13.5 | 12.0 | 11.0 | 10.0 | 10.0 | 9.0 |
| | Loose-housing with beds, solid floor | 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 | 0.0 | 0.0 | 0.0 |
| | Loose-housing with beds, slatted floor | 0.0 | 0.7 | 1.5 | 2.2 | 2.9 | 4.0 | 4.4 | 5.2 | 5.9 | 6.7 | 7.4 | 8.0 | 10.0 | 12.0 | 13.0 | 14.0 |
| | Loose-housing with beds, slatted floor, scrape | 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 | 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 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Deep litter | 5.0 | 4.6 | 4.2 | 3.9 | 3.5 | 3.1 | 2.7 | 2.3 | 1.9 | 1.5 | 1.1 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Deep litter, long eating space, solid floor | 0.0 | 0.3 | 0.5 | 0.7 | 1.0 | 1.2 | 1.5 | 1.7 | 1.9 | 2.2 | 2.4 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| | Deep litter, solid floor | 0.0 | 1.8 | 3.7 | 5.6 | 7.4 | 9.0 | 11.1 | 12.9 | 14.8 | 16.6 | 18.5 | 22.0 | 24.0 | 24.0 | 24.0 | 25.0 |
| | Deep litter, slatted floor | 0.0 | 0.7 | 1.5 | 2.2 | 2.9 | 3.7 | 4.4 | 5.2 | 5.9 | 6.7 | 7.4 | 7.0 | 7.0 | 6.0 | 6.0 | 6.0 |
| | Deep litter, slatted floor, scrape | 0.0 | 0.1 | 0.2 | 0.4 | 0.5 | 0.6 | 0.7 | 0.9 | 1.0 | 1.1 | 1.2 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| | Slatted floor-boxes | 31.0 | 30.0 | 30.0 | 29.0 | 32.4 | 35.8 | 39.2 | 37.4 | 34.9 | 35.0 | 31.3 | 29.8 | 28.7 | 27.2 | 25.2 | |
| | Tethered with urine and solid manure | 8.0 | 7.0 | 7.0 | 5.0 | 5.7 | 6.5 | 7.2 | 6.3 | 5.7 | 5.7 | 4.6 | 4.1 | 3.8 | 3.3 | 3.0 | |
| | Tethered with slurry | 8.0 | 7.0 | 7.0 | 5.0 | 4.1 | 3.3 | 2.4 | 2.2 | 2.2 | 2.2 | 1.7 | 1.6 | 1.4 | 1.3 | 1.2 | |
| | Loose-housing with beds, solid floor | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 3.1 | 4.7 | 5.7 | 6.3 | 6.3 | 6.8 | 7.1 | 6.9 | 7.6 | 7.7 | |
| | Loose-housing with beds, slatted floor | 17.0 | 20.0 | 21.0 | 23.0 | 19.3 | 15.7 | 12.0 | 13.8 | 16.2 | 16.2 | 19.0 | 20.4 | 21.2 | 22.2 | 24.2 | |
| | Loose-housing with beds, slatted floor, scrape | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 3.4 | 5.1 | 5.6 | 6.4 | 6.4 | 7.2 | 7.7 | 7.4 | 8.5 | 9.2 | |
| | Loose-holding with beds, solid floor with tilt | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 1.0 | 1.4 | 1.8 | 1.7 | 1.9 | |
| | Deep litter | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 | 15.3 | 22.9 | 22.4 | 21.9 | 21.9 | 21.4 | 21.2 | 22.3 | 21.6 | 21.5 | |
| | Deep litter, long eating space, solid floor | 3.0 | 3.0 | 3.0 | 3.0 | 2.6 | 2.2 | 1.8 | 1.9 | 1.6 | 1.6 | 1.8 | 1.7 | 1.5 | 1.5 | 1.4 | |
| | Deep litter, solid floor | 26.0 | 26.0 | 26.0 | 28.0 | 19.0 | 9.9 | 0.9 | 0.9 | 0.8 | 0.8 | 0.9 | 1.0 | 0.6 | 0.8 | 0.8 | |
| | Deep litter, slatted floor | 5.0 | 5.0 | 5.0 | 5.0 | 3.9 | 2.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.7 | 1.6 | 1.8 | 1.7 | 1.8 | |
| | Deep litter, slatted floor, scrape | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 2.1 | 2.1 | 2.6 | 2.4 | 2.5 | 2.6 | 2.1 | |

**E)** *Continued…*

*Bulls:*

| Calves, 0-6 mth | Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| . | Deep litter (boxes) | 100 | 100 | 100 | 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 | 0 | 0 | 0 |

| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deep litter (boxes) | 90.9 | 86.0 | 82.0 | 77.0 | 83.6 | 90.2 | 96.8 | 97.1 | 97.0 | 97.0 | 96.7 | 96.9 | 97.5 | 96.9 | 96.5 |
| | Deep litter, solid floor | 9.1 | 14.0 | 18.0 | 23.0 | 16.4 | 9.8 | 3.2 | 2.9 | 3.0 | 3.0 | 3.3 | 3.1 | 2.5 | 3.1 | 3.5 |

| 6 mth -440 kg | Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slatted floor-boxes | 45.0 | 44.2 | 43.5 | 42.7 | 41.9 | 41.2 | 40.4 | 39.6 | 38.9 | 38.1 | 37.3 | 36.5 | 35.8 | 35.0 | 34.0 | 33.0 |
| | Tethered with urine and solid manure | 25.0 | 23.9 | 22.9 | 21.8 | 20.7 | 19.6 | 18.5 | 17.5 | 16.4 | 15.3 | 14.2 | 13.2 | 12.1 | 11.0 | 11.0 | 10.0 |
| | Tethered with slurry | 25.0 | 23.9 | 22.9 | 21.8 | 20.7 | 19.6 | 18.5 | 17.5 | 16.4 | 15.3 | 14.2 | 13.2 | 12.1 | 11.0 | 11.0 | 10.0 |
| | Loose-housing with beds, solid floor | 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 | 0.0 | 0.0 | 0.0 |
| | Loose-housing with beds, slatted floor | 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 | 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 | 0.0 | 0.0 | 0.0 | 0.0 | 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 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Deep litter | 5.0 | 4.6 | 4.2 | 3.8 | 3.5 | 3.1 | 2.7 | 2.3 | 1.9 | 1.5 | 1.2 | 0.8 | 0.4 | 0.0 | 0.0 | 0.0 |
| | Deep litter, long eating space, solid floor | 0.0 | 0.3 | 0.5 | 0.8 | 1.1 | 1.3 | 1.6 | 1.9 | 2.1 | 2.4 | 2.7 | 2.9 | 3.2 | 3.0 | 3.0 | 3.0 |
| | Deep litter, solid floor | 0.0 | 2.0 | 4.1 | 6.1 | 8.1 | 10.2 | 12.3 | 14.2 | 16.3 | 18.4 | 20.4 | 22.4 | 24.5 | 27.0 | 29.0 | 33.0 |
| | Deep litter, slatted floor | 0.0 | 0.9 | 1.6 | 2.5 | 3.4 | 4.2 | 5.1 | 5.9 | 6.8 | 7.6 | 8.5 | 9.3 | 10.1 | 11.0 | 10.0 | 9.0 |
| | Deep litter, slatted floor, scrape | 0.0 | 0.2 | 0.3 | 0.5 | 0.6 | 0.8 | 0.9 | 1.1 | 1.2 | 1.4 | 1.5 | 1.7 | 1.8 | 2.0 | 2.0 | 2.0 |

| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slatted floor-boxes | 32.0 | 31.0 | 30.0 | 28.0 | 28.8 | 29.6 | 30.4 | 29.7 | 27.3 | 27.3 | 24.9 | 23.3 | 21.6 | 20.7 | 21.2 |
| | Tethered with urine and solid manure | 9.0 | 8.0 | 8.0 | 7.0 | 6.0 | 5.0 | 4.0 | 3.7 | 3.1 | 3.1 | 2.5 | 2.3 | 2.1 | 1.8 | 1.7 |
| | Tethered with slurry | 9.0 | 8.0 | 8.0 | 7.0 | 5.0 | 3.0 | 1.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.6 | 0.6 | 0.5 | 0.5 |
| | Loose-housing with beds, solid floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.3 | 0.9 |
| | Loose-housing with beds, slatted floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 2.6 | 4.8 | 8.2 | 6.1 | 6.2 |
| | Loose-housing with beds, slatted floor, scrape | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.8 | 3.3 | 4.0 | 4.1 | 2.8 |
| | Loose-holding with beds, solid floor with tilt | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.1 | 0.0 | 0.5 | 0.6 | 0.2 | 1.1 | 1.0 |
| | Deep litter | 0.0 | 0.0 | 0.0 | 0.0 | 18.9 | 37.8 | 56.6 | 57.5 | 60.3 | 60.4 | 58.0 | 57.3 | 56.8 | 58.4 | 57.9 |
| | Deep litter, long eating space, solid floor | 3.0 | 3.0 | 3.0 | 3.0 | 2.3 | 1.6 | 0.9 | 0.9 | 1.1 | 1.1 | 0.9 | 1.2 | 1.1 | 1.1 | 1.4 |
| | Deep litter, solid floor | 37.0 | 41.0 | 45.0 | 48.0 | 33.6 | 19.1 | 4.7 | 4.4 | 4.2 | 4.2 | 3.8 | 3.4 | 3.4 | 3.0 | 3.3 |
| | Deep litter, slatted floor | 8.0 | 7.0 | 5.0 | 6.0 | 4.4 | 2.7 | 1.1 | 1.4 | 1.6 | 1.6 | 1.4 | 1.2 | 1.1 | 1.2 | 1.3 |
| | Deep litter, slatted floor, scrape | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.2 | 1.3 | 1.3 | 1.3 | 1.7 | 1.9 | 0.7 | 1.7 | 1.8 |

**E)** *Continued…*

*Suckling cattle:*

| Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tethered with urine and solid manure | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 9.0 |
| Tethered with slurry | 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 | 0.0 | 0.0 | 0.0 |
| Loose-housing with beds, slatted floor | 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 | 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 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Deep litter | 90.0 | 86.5 | 83.1 | 79.6 | 76.2 | 72.7 | 69.2 | 65.8 | 62.3 | 58.8 | 55.4 | 51.9 | 48.5 | 45.0 | 45.0 | 45.0 |
| Deep litter, long eating space, solid floor | 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 | 0.0 | 0.0 | 0.0 |
| Deep litter, solid floor | 0.0 | 3.5 | 6.9 | 10.4 | 13.8 | 17.3 | 20.8 | 24.2 | 27.7 | 31.2 | 34.6 | 38.1 | 41.5 | 45.0 | 45.0 | 46.0 |
| Deep litter, slatted floor | 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 | 0.0 | 0.0 | 0.0 |
| Deep litter, slatted floor, scrape | 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 | 0.0 | 0.0 | 0.0 |
| Boxes with sloping bedded floor | 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 | 0.0 | 0.0 | 0.0 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tethered with urine and solid manure | 8.0 | 7.0 | 4.0 | 5.0 | 9.2 | 13.5 | 17.7 | 16.0 | 14.9 | 14.9 | 13.4 | 12.6 | 12.0 | 11.1 | 10.4 |
| Tethered with slurry | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 6.3 | 9.4 | 9.2 | 8.6 | 8.6 | 9.7 | 8.9 | 8.2 | 7.6 | 6.9 |
| Loose-housing with beds, slatted floor | 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 | 0.0 | 0.2 |
| Loose-housing with beds, slatted floor, scrape | 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 | 0.0 | 0.3 |
| Deep litter | 44.0 | 43.0 | 44.0 | 43.0 | 50.7 | 58.4 | 66.1 | 67.8 | 68.5 | 69.1 | 68.8 | 70.5 | 72.9 | 73.2 | 74.0 |
| Deep litter, long eating space, solid floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.9 | 1.3 | 1.2 | 1.4 | 1.4 | 1.2 | 1.3 | 1.2 | 1.1 | 1.3 |
| Deep litter, solid floor | 48.0 | 50.0 | 52.0 | 52.0 | 35.3 | 18.6 | 1.9 | 2.2 | 2.7 | 2.7 | 2.7 | 2.8 | 2.6 | 2.8 | 2.8 |
| Deep litter, slatted floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.9 | 1.4 | 1.3 | 1.5 | 1.5 | 1.9 | 1.7 | 1.1 | 1.7 | 1.7 |
| Deep litter, slatted floor, scrape | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.0 | 1.5 | 1.5 | 1.8 | 1.8 | 2.3 | 2.2 | 2.0 | 2.5 | 2.4 |
| Boxes with sloping bedded floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.4 | 0.7 | 0.8 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**E)** *Continued…*

**Swine:**

*Sows:*

| Gastation period | Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deep litter + solid floor | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 1.4 | 2.1 | 2.8 | 3.5 | 4.3 | 5.0 | 5.7 | 6.4 | 7.7 |
| | Deep litter + slatted floor | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 1.4 | 2.1 | 2.8 | 3.5 | 4.3 | 5.0 | 5.7 | 6.4 | 8.3 |
| | Deep litter | 5.0 | 5.4 | 5.8 | 6.2 | 6.6 | 7.0 | 7.4 | 7.7 | 8.2 | 8.6 | 9.7 | 10.7 | 11.8 | 12.8 | 13.9 | 14.3 |
| | Individual housing, partly slatted floor | 49.6 | 50.8 | 52.0 | 53.1 | 54.3 | 55.5 | 56.6 | 56.5 | 56.4 | 56.2 | 55.9 | 55.6 | 55.3 | 55.0 | 54.7 | 51.1 |
| | Individual housing, fully slatted floor | 1.8 | 2.4 | 3.0 | 3.6 | 4.3 | 4.9 | 5.5 | 6.1 | 6.7 | 7.4 | 8.0 | 8.5 | 9.1 | 9.8 | 10.4 | 10.4 |
| | Individual housing, solid floor | 43.6 | 41.2 | 38.8 | 36.5 | 34.0 | 31.6 | 29.3 | 26.9 | 24.5 | 22.2 | 19.4 | 16.6 | 13.8 | 11.0 | 8.2 | 8.2 |
| | Loose housing, partly slatted floor | 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 | 0.0 | 0.0 | 0.0 |
| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| | Deep litter + solid floor | 9.0 | 9.9 | 11.1 | 11.1 | 7.8 | 4.6 | 1.3 | 1.1 | 0.9 | 0.9 | 1.3 | 1.2 | 1.0 | 1.0 | 0.8 | |
| | Deep litter + slatted floor | 9.6 | 11.7 | 13.5 | 13.5 | 12.2 | 10.9 | 9.6 | 9.0 | 8.6 | 8.6 | 8.6 | 8.2 | 8.2 | 7.8 | 7.5 | |
| | Deep litter | 14.7 | 14.9 | 15.2 | 15.2 | 11.2 | 7.1 | 3.1 | 2.8 | 2.5 | 2.5 | 2.0 | 1.9 | 2.2 | 1.9 | 1.9 | |
| | Individual housing, partly slatted floor | 49.4 | 46.7 | 44.0 | 44.0 | 54.0 | 64.0 | 71.1 | 70.4 | 69.0 | 69.0 | 67.5 | 65.8 | 62.6 | 59.7 | 58.0 | |
| | Individual housing, fully slatted floor | 10.1 | 10.0 | 9.8 | 9.8 | 9.8 | 9.7 | 9.7 | 9.7 | 10.0 | 10.0 | 9.7 | 9.1 | 9.6 | 8.1 | 8.0 | |
| | Individual housing, solid floor | 7.2 | 6.8 | 6.4 | 6.4 | 5.0 | 3.7 | 2.3 | 1.6 | 1.0 | 1.0 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| | Loose housing, partly slatted floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.9 | 5.4 | 8.0 | 8.0 | 10.7 | 13.6 | 16.2 | 21.3 | 23.6 | |
| Farrow period | | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| | Individual housing, partly slatted floor | 50.0 | 51.3 | 52.7 | 54.0 | 55.3 | 56.7 | 58.0 | 59.5 | 61.0 | 62.5 | 64.0 | 65.5 | 67.0 | 68.5 | 70.0 | 71.0 |
| | Individual housing, fully slatted floor | 5.0 | 7.5 | 10.0 | 12.5 | 15.0 | 17.5 | 20.0 | 20.6 | 21.3 | 21.9 | 22.5 | 23.1 | 23.8 | 24.4 | 25.0 | 24.0 |
| | Loose housing, solid floor | 45.0 | 41.2 | 37.3 | 33.5 | 29.7 | 25.8 | 22.0 | 19.9 | 17.7 | 15.6 | 13.5 | 11.4 | 9.2 | 7.1 | 5.0 | 5.0 |
| | Loose housing, partly slatted floor | 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 | 0.0 | 0.0 | 0.0 |
| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| | Individual housing, partly slatted floor | 74.0 | 74.9 | 76.6 | 76.6 | 76.8 | 77.0 | 77.2 | 78.1 | 76.9 | 79.6 | 80.0 | 80.9 | 80.1 | 81.3 | 81.3 | |
| | Individual housing, fully slatted floor | 22.0 | 20.9 | 19.5 | 19.5 | 19.2 | 19.0 | 18.7 | 18.6 | 19.7 | 20.4 | 20.0 | 19.1 | 19.9 | 18.7 | 18.7 | |
| | Loose housing, solid floor | 4.0 | 4.2 | 3.9 | 3.9 | 3.1 | 2.2 | 1.4 | 0.9 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Loose housing, partly slatted floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.8 | 2.7 | 2.4 | 2.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| Outdoor | | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| | Outdoor sows (percent of all sows and periods) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.7 | 1.0 | 1.3 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 | 3.0 |
| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| | Outdoor sows (percent of all sows and periods) | 2.6 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.7 | 1.4 | 1.2 | 1.2 | 0.5 | 1.1 | 1.1 | 0.6 | 0.5 | |

**E)** *Continued…*

*Weaners:*

| Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fully slatted floor | 40.0 | 42.9 | 45.7 | 48.6 | 51.4 | 54.3 | 57.1 | 60.0 | 57.1 | 54.3 | 51.4 | 48.6 | 45.7 | 42.9 | 40.0 | 38.0 |
| Partly slatted floor | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 23.6 | 27.2 | 30.7 | 34.3 | 37.9 | 41.4 | 45.0 | 47.0 |
| Solid floor | 35.0 | 32.1 | 29.3 | 26.4 | 23.6 | 20.7 | 17.9 | 15.0 | 13.6 | 12.1 | 10.7 | 9.3 | 7.8 | 6.4 | 5.0 | 5.0 |
| Deep litter (to-climate housings) | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Deep litter + slatted floor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 1.4 | 2.2 | 2.8 | 3.6 | 4.3 | 5.0 | 5.0 |
| Partly slatted and drained floor | 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 | 0.0 | 0.0 | 0.0 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fully slatted floor | 36.0 | 35.0 | 33.0 | 31.0 | 29.1 | 27.3 | 25.4 | 23.0 | 22.0 | 22.0 | 20.2 | 18.7 | 16.5 | 14.8 | 13.4 |
| Partly slatted floor | 49.0 | 50.0 | 52.0 | 54.0 | 57.1 | 60.2 | 63.3 | 66.6 | 67.8 | 67.8 | 69.8 | 71.6 | 74.4 | 74.3 | 75.4 |
| Solid floor | 5.0 | 5.0 | 5.0 | 5.0 | 3.7 | 2.5 | 1.2 | 0.9 | 0.6 | 0.6 | 0.5 | 0.4 | 0.4 | 0.3 | 0.2 |
| Deep litter (to-climate housings) | 5.0 | 5.0 | 5.0 | 5.0 | 4.4 | 3.7 | 3.1 | 2.4 | 1.8 | 1.8 | 1.3 | 1.2 | 1.3 | 1.7 | 1.3 |
| Deep litter + slatted floor | 5.0 | 5.0 | 5.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Partly slatted and drained floor | 0.0 | 0.0 | 0.0 | 0.0 | 5.7 | 6.3 | 7.0 | 7.1 | 7.8 | 7.8 | 8.2 | 8.1 | 7.4 | 8.9 | 9.7 |

**E)** *Continued…*

*Fattening pigs:*

| Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fully slatted floor | 29.0 | 33.4 | 37.9 | 42.3 | 46.7 | 50.1 | 54.2 | 58.7 | 58.2 | 58.3 | 57.7 | 57.1 | 56.9 | 56.6 | 56.5 | 53.9 |
| Partly slatted floor | 30.0 | 28.6 | 27.1 | 25.7 | 24.3 | 22.9 | 21.4 | 20.0 | 21.3 | 22.6 | 23.9 | 25.1 | 26.4 | 27.7 | 29.0 | 31.0 |
| Partly slatted floor (50-75 % solid floor) | 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 | 0.0 | 0.0 | 0.0 |
| Partly slatted floor (25-49 % solid floor) | 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 | 0.0 | 0.0 | 0.0 |
| Solid floor | 40.0 | 36.4 | 32.9 | 29.3 | 25.7 | 22.1 | 18.6 | 15.0 | 13.6 | 12.1 | 10.7 | 9.3 | 7.9 | 6.4 | 5.0 | 5.0 |
| Deep litter | 1.0 | 1.6 | 2.1 | 2.7 | 3.3 | 3.9 | 4.4 | 5.0 | 4.4 | 3.9 | 3.3 | 2.7 | 2.1 | 1.6 | 1.0 | 1.0 |
| Partly slatted floor and partly deep litter | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 1.4 | 2.1 | 2.9 | 3.6 | 4.3 | 5.0 | 5.0 |
| Partly slatted and drained floor | 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 | 0.0 | 0.0 | 0.0 |
| Biogas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.4 | 1.3 | 1.8 | 1.7 | 2.3 | 2.9 | 3.1 | 3.4 | 3.5 | 4.1 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fully slatted floor | 52.6 | 51.3 | 49.2 | 47.3 | 53.0 | 53.0 | 53.0 | 52.9 | 53.8 | 53.8 | 53.2 | 51.5 | 46.4 | 43.7 | 39.8 |
| Partly slatted floor | 33.0 | 34.0 | 35.0 | 38.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Partly slatted floor (50-75 % solid floor) | 0.0 | 0.0 | 0.0 | 0.0 | 6.2 | 6.0 | 5.9 | 7.0 | 7.6 | 7.6 | 7.5 | 7.9 | 8.0 | 8.6 | 8.8 |
| Partly slatted floor (25-49 % solid floor) | 0.0 | 0.0 | 0.0 | 0.0 | 23.0 | 21.2 | 20.8 | 19.5 | 18.0 | 17.9 | 19.1 | 18.3 | 19.6 | 17.8 | 15.5 |
| Solid floor | 4.0 | 4.0 | 4.0 | 3.0 | 3.2 | 3.5 | 3.7 | 2.6 | 1.7 | 1.7 | 1.2 | 1.0 | 1.0 | 0.8 | 0.6 |
| Deep litter | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 3.1 | 4.1 | 3.2 | 2.3 | 2.3 | 1.8 | 1.5 | 1.4 | 1.3 | 1.0 |
| Partly slatted floor and partly deep litter | 5.0 | 5.0 | 5.0 | 5.0 | 3.5 | 2.1 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.6 | 0.6 |
| Partly slatted and drained floor | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 3.9 | 4.9 | 6.1 | 6.8 | 6.8 | 8.2 | 9.8 | 12.9 | 14.8 | 18.7 |
| Biogas | 4.4 | 4.7 | 5.8 | 5.7 | 6.1 | 7.2 | 7.0 | 8.2 | 9.3 | 9.4 | 8.5 | 9.5 | 10.0 | 12.4 | 15.0 |

**E)** *Continued…*

**Poultry:**

| Livestock categories | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Free-range hens | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 1.7 | 1.7 | 5.4 | 9.0 | 8.5 | 8.5 | 8.7 | 9.0 |
| Organic hens | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 2.7 | 5.5 | 6.4 | 9.5 | 12.4 | 12.6 |
| Barn hens | 2.2 | 4.2 | 8.6 | 7.4 | 6.4 | 5.4 | 7.6 | 8.5 | 8.6 | 10.7 | 15.4 | 15.4 | 16.4 | 14.2 | 16.6 | 17.1 |
| Battery hens, manure shed | 19.6 | 20.2 | 20.3 | 21.7 | 22.9 | 24.3 | 25.0 | 25.7 | 27.0 | 27.7 | 25.8 | 24.6 | 25.6 | 26.5 | 26.0 | 28.8 |
| Battery hens, manure tank | 14.8 | 14.2 | 13.3 | 13.1 | 13.0 | 12.9 | 12.1 | 11.3 | 10.9 | 10.0 | 8.3 | 7.0 | 6.5 | 5.9 | 5.0 | 4.9 |
| Battery hens, manure cellar | 63.5 | 61.4 | 57.9 | 57.8 | 57.7 | 57.4 | 55.3 | 52.8 | 51.8 | 49.3 | 42.5 | 37.4 | 36.1 | 34.6 | 31.1 | 27.6 |
| Hens for production of brood egg | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Pullet, consumption, net | 22.3 | 21.2 | 20.2 | 19.1 | 18.0 | 17.0 | 15.9 | 14.8 | 13.8 | 12.7 | 11.7 | 10.6 | 9.5 | 8.5 | 7.4 | 7.6 |
| Pullet, consumption, floor | 52.1 | 53.2 | 54.2 | 55.3 | 56.4 | 57.4 | 58.5 | 59.6 | 60.6 | 61.7 | 62.7 | 63.8 | 64.9 | 65.9 | 67.0 | 69.0 |
| Pullet, brood egg, floor | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 23.4 |
| Broilers, (conv. 30 days) | 0 | 0 | 0 | 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 | 0 | 0 | 0 |
| Broilers, (conv. 35 days) | 0 | 0 | 0 | 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 | 100 | 100 | 100 |
| Broilers, (conv. 45 days) | 0 | 0 | 0 | 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 | 0 | 0 | 0 |
| Organic broilers (81 days) | 0 | 0 | 0 | 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 | 50 | 50 | 50 |
| Turkey, female | 50 | 50 | 50 | 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 | 100 | 100 | 100 |
| Geese | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

**E)** *Continued…*

| Livestock categories | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Free-range hens | 9.0 | 8.3 | 9.1 | 7.5 | 7.9 | 5.9 | 5.9 | 5.8 | 6.6 | 6.7 | 7.6 | 6.8 | 4.9 | 4.9 | 6.3 |
| Organic hens | 13.2 | 13.5 | 14.3 | 13.1 | 14.0 | 13.7 | 15.4 | 15.7 | 14.6 | 14.9 | 15.7 | 18.6 | 18.0 | 19.7 | 23.8 |
| Barn hens | 16.4 | 18.1 | 20.2 | 22.8 | 25.3 | 23.5 | 20.4 | 19.0 | 18.8 | 16.7 | 17.2 | 18.6 | 21.3 | 21.3 | 20.6 |
| Battery hens, manure shed | 28.8 | 32.5 | 29.2 | 32.7 | 32.2 | 36.4 | 39.2 | 42.4 | 43.8 | 44.9 | 45.6 | 46.1 | 50.1 | 46.7 | 42.3 |
| Battery hens, manure tank | 4.9 | 4.1 | 4.9 | 4.0 | 4.8 | 6.3 | 7.7 | 8.0 | 7.3 | 7.5 | 8.0 | 5.4 | 5.4 | 3.1 | 3.3 |
| Battery hens, manure cellar | 27.5 | 23.4 | 22.4 | 19.9 | 15.8 | 14.1 | 11.4 | 9.1 | 9.0 | 9.2 | 5.9 | 4.4 | 0.3 | 4.3 | 3.6 |
| Hens for production of brood egg | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Pullet, consumption, net | 7.5 | 6.0 | 7.0 | 5.0 | 5.7 | 6.4 | 7.1 | 6.7 | 7.1 | 7.1 | 19.3 | 31.6 | 17.1 | 22.0 | 18.3 |
| Pullet, consumption, floor | 67.5 | 69.0 | 68.0 | 69.0 | 70.3 | 71.7 | 73.0 | 84.1 | 78.1 | 78.1 | 75.5 | 63.5 | 39.1 | 42.1 | 42.6 |
| Pullet, brood egg, floor | 25.0 | 25.0 | 25.0 | 26.0 | 24.0 | 21.9 | 19.9 | 9.2 | 14.8 | 14.8 | 5.2 | 4.9 | 43.7 | 35.9 | 39.1 |
| Broilers, (conv. 30 days) | 0 | 0 | 0 | 0 | 0.1 | 0.3 | 0.8 | 0.2 | 0.4 | 0.1 | 0.1 | 0.5 | 0.3 | 1.1 | 0.2 |
| Broilers, (conv. 32 days) | 0 | 0 | 0 | 0 | 3.7 | 4.8 | 0.8 | 2.2 | 7.0 | 3.2 | 10.6 | 13.6 | 17.1 | 22.7 | 25.2 |
| Broilers, (conv. 35 days) | 0 | 0 | 0 | 0 | 45.4 | 40.7 | 45.1 | 49.0 | 56.7 | 75.6 | 85.7 | 80.6 | 78.5 | 73.2 | 72.4 |
| Broilers, (conv. 40 days) | 100 | 100 | 100 | 100 | 48.9 | 53.9 | 52.9 | 48.5 | 35.5 | 20.9 | 3.3 | 4.8 | 3.2 | 2.3 | 1.4 |
| Broilers, (conv. 45 days) | 0 | 0 | 0 | 0 | 1.8 | 0.2 | 0.3 | 0.0 | 0.3 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| Broilers, barn (56 days) | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 |
| Organic broilers (81 days) | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.5 | 0.7 | 0.5 | 0.6 |
| Turkey, male | 50 | 50 | 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 | 50 | 50 |
| Ducks | 100 | 100 | 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 | 100 | 100 |

**E)** *Continued…*

**Fur farming:**

| | Housing type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mink | Slurry system | 10.0 | 11.7 | 13.3 | 15.0 | 16.7 | 18.3 | 20.0 | 20.0 | 21.7 | 23.3 | 25.0 | 26.2 | 27.5 | 28.7 | 30.0 | 42.0 |
| | Solid manure and urine | 90.0 | 88.3 | 86.7 | 85.0 | 83.3 | 81.7 | 80.0 | 80.0 | 78.3 | 76.7 | 75.0 | 73.8 | 72.5 | 71.3 | 70.0 | 58.0 |
| Foxes | Slurry system | 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 | 0.0 | 0.0 | 2.0 |
| | Solid manure and urine | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98.0 |

| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mink | Slurry system | 50.0 | 55.0 | 60.0 | 65.0 | 72.7 | 80.5 | 88.2 | 92.2 | 94.8 | 97.3 | 96.5 | 97.2 | 97.9 | 97.4 | 97.8 |
| | Solid manure and urine | 50.0 | 45.0 | 40.0 | 35.0 | 27.3 | 19.5 | 11.8 | 7.8 | 5.2 | 2.7 | 3.5 | 2.8 | 2.1 | 2.6 | 2.2 |
| Foxes | Slurry system | 5.0 | 10.0 | 15.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Solid manure and urine | 95.0 | 90.0 | 85.0 | 70.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

**Horses, sheep, goats, deer, pheasants and ostrich:**

Horses, sheep, goats and ostrich are all housed in deep litter housings all years 1985-2015.

Deer and pheasants are on pasture all years 1985-2015

**F)** Number of grazing days corresponding to the proportion of N in manure deposited on the field during grazing, days per year.

| | 1985-1990 | 1991-2002 | 2003 | 2004 | 2005 | 2006 | 2007-2015 |
|---|---|---|---|---|---|---|---|
| Cattle: | | | | | | | |
| Dairy Cattle | 55 | 55 | 46 | 39 | 32 | 25 | 18 |
| Calves and bulls | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Heifers – feeding days on grass | 165 | 171 | 180 | 168 | 156 | 144 | 132 |
| - actual days on grass* | 165 | 165 | 152 | 141 | 131 | 121 | 111 |
| Suckling Cattle | 184 | 192 | 224 | 224 | 224 | 224 | 224 |

* Actual days on grass are the number of days the heifer is out of the housing. Feeding days on grass is higher than actual days on grass due to a higher feed intake during grazing compared to the period in housing. Feeding days on grass is a conversion of this higher feed intake to days on grass.

**F)** *Continued…*

| | 1985-2015 |
|---|---|
| Swine: | |
| 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 |

**G)** Nitrogen excretion and ammonia emission according to livestock category 1985 – 2015.

1) Nitrogen excretion distributed on livestock groups, tonnes N

| N excretion | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | 168 620 | 164 096 | 156 160 | 151 686 | 150 494 | 150 382 | 148 756 | 144 991 | 143 739 | 138 358 | 137 841 | 137 000 | 131 577 | 129 740 | 124 454 | 123 640 |
| Swine | 117 472 | 120 842 | 117 891 | 116 689 | 113 620 | 112 659 | 113 491 | 117 257 | 121 374 | 114 453 | 107 919 | 107 948 | 111 121 | 117 674 | 116 093 | 114 794 |
| Poultry | 7 427 | 7 758 | 8 054 | 9 055 | 10 178 | 10 315 | 10 322 | 10 942 | 11 711 | 13 037 | 12 263 | 12 019 | 11 946 | 11 793 | 12 226 | 12 167 |
| 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 | 5 815 | 5 874 | 5 934 |
| Sheep | 658 | 868 | 984 | 1 209 | 1 379 | 1 525 | 1 767 | 1 699 | 1 464 | 1 327 | 1 339 | 1 560 | 1 592 | 1 674 | 1 754 | 1 852 |
| Goats | 131 | 129 | 128 | 126 | 124 | 123 | 121 | 119 | 118 | 116 | 114 | 113 | 111 | 127 | 132 | 138 |
| 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 | 10 893 | 9 676 | 10 169 |
| Deer | 144 | 152 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 |
| N excretion total | 310 833 | 311 506 | 301 863 | 299 579 | 297 151 | 292 213 | 290 707 | 291 961 | 291 637 | 281 747 | 273 881 | 273 431 | 272 557 | 277 876 | 270 370 | 268 854 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | 123 674 | 121 427 | 119 046 | 115 876 | 116 110 | 116 299 | 120 384 | 122 619 | 121 284 | 121 796 | 122 009 | 124 662 | 125 425 | 124 411 | 123 162 |
| Swine | 120 662 | 126 730 | 123 749 | 128 946 | 124 864 | 114 064 | 118 096 | 109 939 | 104 498 | 103 365 | 102 963 | 98 448 | 96 408 | 98 155 | 97 644 |
| Poultry | 12 343 | 12 309 | 12 502 | 13 258 | 12 974 | 11 465 | 11 267 | 11 597 | 10 946 | 11 294 | 10 836 | 10 358 | 9 778 | 9 500 | 9 766 |
| Horses | 6 131 | 6 329 | 6 527 | 6 725 | 6 923 | 7 121 | 7 319 | 7 516 | 7 022 | 6 527 | 6 132 | 6 132 | 5 934 | 5 934 | 6 132 |
| Sheep | 1 968 | 1 949 | 2 008 | 2 060 | 2 095 | 2 119 | 2 054 | 1 949 | 1 916 | 1 842 | 1 552 | 1 499 | 1 467 | 1 459 | 1 395 |
| Goats | 155 | 151 | 164 | 176 | 181 | 191 | 198 | 231 | 257 | 262 | 206 | 212 | 214 | 198 | 186 |
| Fur animals | 10 639 | 11 172 | 10 886 | 12 585 | 13 718 | 14 026 | 14 698 | 14 860 | 15 005 | 15 697 | 15 566 | 16 037 | 16 816 | 16 949 | 18 060 |
| Deer | 170 | 158 | 155 | 155 | 154 | 154 | 155 | 153 | 152 | 152 | 129 | 115 | 125 | 118 | 122 |
| N excretion total | 275 742 | 280 226 | 275 037 | 279 782 | 277 019 | 265 439 | 274 171 | 268 865 | 261 079 | 260 935 | 259 392 | 257 463 | 256 168 | 256 722 | 256 467 |

**G)** *Continued…*

2) Ammonia emission from animal manure in housing and storage distributed on livestock groups, tonnes $NH_3$-N

| Ammonia emission | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | 11 367 | 11 126 | 10 639 | 10 373 | 10 333 | 10 394 | 10 278 | 10 037 | 9 896 | 9 508 | 9 450 | 9 424 | 9 250 | 9 309 | 9 023 | 9 627 |
| Swine | 26 084 | 26 578 | 25 681 | 25 181 | 24 271 | 23 813 | 23 721 | 24 229 | 24 830 | 23 162 | 21 574 | 21 312 | 21 666 | 22 687 | 21 854 | 20 616 |
| Poultry | 2 007 | 2 086 | 2 221 | 2 498 | 2 823 | 2 833 | 2 902 | 3 121 | 3 321 | 3 653 | 3 568 | 3 487 | 3 525 | 3 489 | 3 641 | 3 674 |
| Horses | 628 | 623 | 619 | 614 | 610 | 593 | 588 | 582 | 576 | 570 | 563 | 569 | 575 | 581 | 596 | 597 |
| Sheep | 42 | 55 | 63 | 77 | 88 | 98 | 114 | 110 | 96 | 87 | 89 | 95 | 89 | 84 | 80 | 101 |
| Goats | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 8 |
| Fur animals | 3 885 | 4 395 | 4 728 | 5 575 | 5 795 | 4 263 | 3 914 | 4 205 | 2 799 | 3 294 | 3 299 | 3 423 | 3 941 | 4 168 | 3 700 | 3 871 |
| Deer[a] | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Emission total | 44 020 | 44 874 | 43 961 | 44 330 | 43 933 | 42 007 | 41 531 | 42 301 | 41 534 | 40 291 | 38 562 | 38 329 | 39 065 | 40 339 | 38 914 | 38 510 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | 9 793 | 9 773 | 10 040 | 10 100 | 8 605 | 8 751 | 8 723 | 8 965 | 8 829 | 8 809 | 9 068 | 9 084 | 9 071 | 8 847 | 8 782 |
| Swine | 21 379 | 21 975 | 21 143 | 21 826 | 20 424 | 18 557 | 16 919 | 15 772 | 14 802 | 14 542 | 14 398 | 13 432 | 13 000 | 13 148 | 12 917 |
| Poultry | 3 726 | 3 708 | 3 770 | 3 955 | 3 893 | 3 395 | 2 991 | 3 082 | 2 903 | 2 989 | 2 873 | 2 721 | 1 974 | 1 894 | 1 843 |
| Horses | 617 | 637 | 657 | 677 | 697 | 717 | 662 | 679 | 635 | 590 | 554 | 554 | 536 | 536 | 554 |
| Sheep | 107 | 106 | 110 | 113 | 114 | 116 | 101 | 96 | 94 | 91 | 76 | 74 | 72 | 72 | 69 |
| Goats | 9 | 8 | 9 | 10 | 10 | 10 | 10 | 11 | 13 | 13 | 10 | 10 | 11 | 10 | 9 |
| Fur animals | 4 035 | 4 231 | 4 119 | 4 725 | 5 146 | 5 240 | 5 181 | 5 299 | 5 403 | 5 699 | 5 633 | 5 820 | 4 682 | 4 955 | 5 252 |
| Deer[a] | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| Emission total | 39 683 | 40 456 | 39 866 | 41 424 | 38 910 | 36 807 | 34 609 | 33 927 | 32 701 | 32 757 | 32 639 | 31 723 | 29 374 | 29 491 | 29 456 |

[a] All N are deposited on grass

**G)** *Continued…*

3) Ammonia emission from manure distributed on the different parts of the production, tonnes $NH_3$-N

| Ammonia emission | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Housing | 30 077 | 30 937 | 30 574 | 31 177 | 31 076 | 29 516 | 29 243 | 29 996 | 29 224 | 28 544 | 27 336 | 27 284 | 28 009 | 29 079 | 28 138 | 28 416 |
| Storage | 13 935 | 13 927 | 13 374 | 13 137 | 12 838 | 12 470 | 12 262 | 12 279 | 12 284 | 11 721 | 11 198 | 11 023 | 11 042 | 11 254 | 10 779 | 10 078 |
| Application | 32 770 | 32 317 | 30 852 | 30 026 | 29 455 | 30 251 | 29 272 | 28 374 | 27 580 | 26 032 | 24 421 | 23 924 | 23 132 | 22 948 | 21 917 | 21 045 |
| Pasture | 2 565 | 2 503 | 2 402 | 2 368 | 2 361 | 2 378 | 2 430 | 2 434 | 2 478 | 2 426 | 2 469 | 2 491 | 2 441 | 2 440 | 2 401 | 2 404 |
| Emission total | 79 348 | 79 683 | 77 201 | 76 708 | 75 732 | 74 615 | 73 208 | 73 082 | 71 566 | 68 723 | 65 424 | 64 721 | 64 624 | 65 721 | 63 235 | 61 944 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Housing | 29 543 | 30 704 | 30 582 | 32 010 | 31 922 | 30 253 | 30 153 | 29 577 | 28 535 | 28 585 | 28 508 | 27 652 | 25 203 | 25 237 | 25 199 |
| Storage | 10 123 | 9 735 | 9 265 | 9 395 | 6 968 | 6 532 | 4 434 | 4 327 | 4 143 | 4 147 | 4 105 | 4 044 | 4 143 | 4 225 | 4 227 |
| Application | 19 503 | 18 565 | 18 887 | 17 055 | 17 217 | 16 813 | 18 001 | 17 344 | 17 063 | 17 084 | 16 229 | 16 060 | 16 037 | 16 098 | 16 168 |
| Pasture | 2 444 | 2 355 | 2 110 | 1 944 | 1 820 | 1 723 | 1 635 | 1 640 | 1 567 | 1 540 | 1 491 | 1 514 | 1 532 | 1 520 | 1 476 |
| Emission total | 61 614 | 61 359 | 60 845 | 60 403 | 57 927 | 55 322 | 54 223 | 52 888 | 51 307 | 51 356 | 50 333 | 49 270 | 46 915 | 47 079 | 47 070 |

**H)** N ex animal.

| **A) Cattle, large breed** | | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 127.5 | 127.3 | 128.0 |
| 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 | 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 | 39.2 | 39.2 | 39.2 |
| *Continued* | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Dairy cows | Total N | 128.0 | 130.0 | 132.8 | 134.5 | 136.3 | 137.4 | 140.2 | 140.6 | 140.9 | 141.4 | 141.4 | 140.9 | 141.8 | 146.4 | 146.6 | |
| 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 | 24.3 | 24.3 | 23.5 | |
| Heifers[b] | Total N | 39.2 | 39.2 | 39.2 | 39.2 | 43.7 | 48.1 | 52.6 | 52.6 | 52.6 | 50.0 | 50.4 | 50.4 | 50.4 | 50.4 | 50.4 | |

[a] 6 month to slaughter. Kg N per produced animal.

[b] 6 month to calving.

*Continued…*

| **B) Swine** | | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 26.5 | 26.6 | 26.6 |
| Fattening pigs[c] | Total N | 5.1 | 5.0 | 4.9 | 4.9 | 4.8 | 4.5 | 4.3 | 4.0 | 3.8 | 3.5 | 3.3 | 3.3 | 3.2 | 3.2 | 3.2 | 3.1 |
| Weaners[c] | Total N | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 |
| *Continued* | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Sows (incl. piglets) | Total N | 27.2 | 27.2 | 27.2 | 27.2 | 26.5 | 26.0 | 26.4 | 25.8 | 26.0 | 25.1 | 25.1 | 25.6 | 25.2 | 24.8 | 24.2 | |
| Fattening pigs[c] | Total N | 3.1 | 3.3 | 3.2 | 3.2 | 3.2 | 3.0 | 3.1 | 3.0 | 2.9 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | |
| Weaners[c] | Total N | 0.6 | 0.7 | 0.6 | 0.6 | 0.7 | 0.5 | 0.5 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |

[c] per. produced animal.

*Continued…*

| **C) Poultry** | | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 77.0 | 76.9 | 67.1 |
| 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 | 51.3 | 51.3 | 53.3 |
| *Continued* | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Battery hens[d] | Total N | 67.1 | 67.9 | 72.5 | 73.2 | 77.9 | 77.9 | 68.4 | 69.5 | 69.5 | 69.5 | 69.3 | 66.8 | 67.6 | 70.2 | 67.9 | |
| Broilers[e] | Total N | 53.3 | 53.6 | 53.6 | 58.1 | 64.3 | 64.2 | 65.5 | 65.5 | 65.5 | 65.0 | 64.8 | 64.5 | 63.9 | 63.9 | 65.8 | |

[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.

**H)** *Continued…*

| **D) Fur animals** | | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mink (incl. cubs) | Total N | 5.2 | 5.1 | 5.0 | 5.0 | 4.9 | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 |
| *Continued* | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Mink (incl. cubs) | Total N | 4.6 | 4.6 | 4.6 | 5.1 | 5.4 | 5.2 | 5.2 | 5.3 | 5.5 | 5.8 | 5.6 | 5.4 | 5.3 | 5.1 | 5.3 | |

Sources: Laursen (1994), Poulsen & Kristensen (1997), Poulsen et al. (2001), Poulsen (2016).

**l)** TAN ex animal.

| kg per animal | | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle** | | | | | | | | | | |
| Dairy cows | TAN | 66.67 | 67.00 | 65.70 | 65.69 | 67.20 | 65.82 | 65.72 | 66.32 | 66.06 |
| Bulls[a] | TAN | 16.11 | 16.11 | 16.11 | 16.11 | 16.11 | 16.11 | 16.11 | 16.11 | 15.56 |
| Heifers[b] | TAN | 35.86 | 35.86 | 35.86 | 33.49 | 33.85 | 33.85 | 33.85 | 33.85 | 33.85 |
| **Swine** | | | | | | | | | | |
| Sows | TAN | 19.77 | 19.20 | 19.34 | 18.67 | 18.66 | 18.99 | 18.69 | 18.36 | 17.89 |
| Fattening pigs[c] | TAN | 2.04 | 2.03 | 1.96 | 1.87 | 1.86 | 1.88 | 1.88 | 1.93 | 1.90 |
| Weaners[c] | TAN | 0.31 | 0.33 | 0.31 | 0.29 | 0.29 | 0.31 | 0.29 | 0.28 | 0.29 |
| **Fur animals** | | | | | | | | | | |
| Mink | TAN | 3.85 | 3.93 | 4.11 | 4.34 | 4.20 | 4.06 | 3.92 | 3.74 | 3.88 |

[a] 6 month to slaughter. Per produced animal.

[b] 6 month to calving.

[c] per produced animal.

Source: Poulsen (2016).

**J)** Ammonia emission factors for housing units.

| **Swine** | | | Urine | Slurry | Solid manure | Deep litter |
|---|---|---|---|---|---|---|
| | | | TAN | TAN | Total N | Total N |
| | Housing 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 (two-climate housing) | - | 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 |

**J)** *Continued…*

| **Poultry** | | | Solid manure Total N | Deep litter Total N |
|---|---|---|---|---|
| | Housing 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 |
| | | Floor on floor system | 10 | 25 |
| | Battery | Deep pit | 12 | - |
| | | Manure belt | 10 | - |
| Broilers | Conventional | Deep litter | - | 7 |
| | Organic and barn | Deep litter | - | 9 |
| Turkeys, ducks and geese | | Deep litter | - | 20 |

**J)** Continued…

| **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 | 30 | 35 | 20 |
| Horses, sheep and goats | - | - | - | 15 |

**K)** 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] | 2007-2015[4] TAN |
|---|---|---|---|---|---|---|---|
| Swine | | | | | | | |
| 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 – DCA.

[5] Hansen et al., 2008.

**L)** Correction for lack of cover on manure heaps.

| | Emission factor $NH_3$-N in % of N ex housing-total | Solid manure 2007-2015 |
|---|---|---|
| **Cattle** | | |
| No cover | 5% | 50% |
| Full cover | 3% | 50% |
| **Emission under storage** | | **4%** |
| **Swine** | | |
| No cover | 25% | 50% |
| Full cover | 13% | 50% |
| **Emission under storage** | | **19%** |
| **Hens** | | |
| No cover | 10% | 50% |
| Full cover | 5% | 50% |
| **Emission under storage** | | **7.5%** |
| **Broilers** | | |
| No cover | 15% | 50% |
| Full cover | 8% | 50% |
| **Emission under storage** | | **11,5%** |
| **Fur animals** | | |
| No cover | 15% | 50% |
| Full cover | 8% | 50% |
| **Emission under storage** | | **11.5%** |
| **Horses, sheep and goats** | | |
| No cover | 5% | 50% |
| Full cover | 3% | 50% |
| **Emission under storage** | | **4%** |

**M)** Estimate of how liquid and solid manure has been handled in practice, 1985-2015.

**Cattle and other livestock except from swine:**

*Liquid manure:*

| 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 |
| | Injection | Hours | | | | | | | | | | | | | | | | |
| - | March | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| - | April | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| + | March | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | April | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | Summer, grass injection | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| - | Summer, before winter rape | 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 |
| - | Autumn | 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 | 2.2 | 3.3 | 4.4 | 5.6 | 6.7 | 7.8 | 8.9 | 10.0 | 9.1 |
| - | April | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 1.1 | 1.7 | 2.2 | 2.8 | 3.3 | 3.9 | 4.4 | 5.0 | 4.5 |
| + | March | < week | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 6 |
| + | April | < week | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 13 |
| + | May | < week | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 3 | 5 | 7 | 8 | 10 | 11 | 12 | 13 |
| + | Summer | < week | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 4 | 4 | 4 |
| - | Summer | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 |
| + | Autumn | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| - | Autumn | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 0 |
| | Broad spreading | | | | | | | | | | | | | | | | | |
| - | Winter-spring | < 12 | 26 | 27 | 28 | 29 | 30 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 18.3 | 16.7 | 15.0 | 13.6 |
| - | Winter-spring | > 12 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5.0 | 5.0 | 5.0 | 4.5 |
| - | Winter-spring | < week | 15 | 15 | 15 | 15 | 15 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 18.3 | 16.7 | 15.0 | 13.6 |
| + | Spring-summer | < week | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 2.0 | 2.0 | 2.0 | 1.8 |
| + | Late summer-autumn | < week | 7 | 7 | 7 | 7 | 7 | 7 | 6.2 | 5.3 | 4.5 | 3.7 | 2.8 | 2 | 1.7 | 1.3 | 1.0 | 0.9 |
| - | Late summer-autumn | < 12 | 2.4 | 2.8 | 3.2 | 3.6 | 4.0 | 4.4 | 4.2 | 3.9 | 3.7 | 3.5 | 3.2 | 3 | 2.7 | 2.3 | 2.0 | 1.8 |
| - | Late summer-autumn | > 12 | 7.6 | 7.2 | 6.8 | 6.4 | 6.0 | 5.6 | 5.0 | 4.4 | 3.8 | 3.2 | 2.6 | 2 | 1.7 | 1.3 | 1.0 | 0.9 |
| - | Late summer-autumn | < week | 29 | 28 | 27 | 26 | 25 | 24 | 20 | 16 | 12 | 8 | 4 | 0 | 0 | 0 | 0 | 0 |
| | | Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

-: indicate bare soil, +: indicate growth.

**M)** *Continued…*

| Crop stage | Application time | Lying time | Percent of N ex storage per manure type | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| | Injection | Hours | | | | | | | | | | | | | | | |
| - | March | 0 | 5 | 8 | 11 | 21 | 20 | 20 | 20 | 21 | 21 | 21 | 25 | 25 | 25 | 25 | 25 |
| - | April | 0 | 5 | 8 | 12 | 21 | 21 | 20 | 20 | 21 | 21 | 21 | 30 | 30 | 30 | 30 | 30 |
| + | March | < week | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 3 | 3 | 8 | 6 | 6 | 6 | 4 |
| + | April | < week | 0 | 0 | 0 | 0 | 2 | 3 | 4 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| + | Summer, grass injection | 0 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 10 | 15 | 15 | 15 | 15 |
| - | Summer, before winter rape | 0 | 0 | 0 | 1 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 3 | 3 | 3 | 3 | 3 |
| + | Autumn | 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 |
| | Hose application | | | | | | | | | | | | | | | | |
| - | March | 4 | 10 | 10 | 14 | 8 | 8 | 6 | 5 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| - | April | 4 | 5 | 5 | 4 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| + | March | < week | 7 | 7 | 7 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 6 | 6 | 6 | 8 |
| + | April | < week | 18 | 17 | 15 | 10 | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 6 | 6 | 6 | 6 |
| + | May | < week | 18 | 17 | 15 | 10 | 9 | 9 | 9 | 9 | 9 | 9 | 7 | 5 | 5 | 5 | 5 |
| + | Summer | < week | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | Summer | 4 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 |
| + | Autumn | < week | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 |
| - | Autumn | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Broad spreading | | | | | | | | | | | | | | | | |
| - | Winter-spring | < 12 | 6 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Winter-spring | > 12 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Winter-spring | < week | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | Spring-summer | < week | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | Late summer-autumn | < week | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | < 12 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | > 12 | 0.5 | 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 |
| | | Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

-: indicate bare soil, +: indicate growth.

**M)** *Continued…*
*Solid manure:*

| 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 |
| | Broad spreading | | | | | | | | | | | | | | | | | |
| - | Winter-spring | 4 | 13 | 16 | 19 | 22 | 25 | 26 | 26 | 27 | 28 | 29 | 29 | 30 | 32 | 33 | 35 | 38 |
| - | Winter-spring | 6 | 18 | 16 | 14 | 12 | 10 | 11 | 11 | 12 | 13 | 14 | 14 | 15 | 15 | 15 | 15 | 14 |
| - | Winter-spring | < week | 19 | 18 | 17 | 16 | 15 | 14 | 14 | 13 | 12 | 11 | 11 | 10 | 10 | 10 | 10 | 9 |
| + | Spring-summer | < week | 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 |
| - | Late summer-autumn | 4 | 13 | 16 | 19 | 22 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 26 |
| - | Late summer-autumn | 6 | 13 | 11 | 9 | 7 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| - | Late summer-autumn | < week | 24 | 23 | 22 | 21 | 20 | 19 | 19 | 18 | 17 | 16 | 16 | 15 | 13 | 12 | 10 | 9 |
| | | Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

| *Continued…* | | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Broad spreading | | | | | | | | | | | | | | | | |
| - | Winter-spring | 4 | 49 | 54 | 54 | 56 | 57 | 59 | 60 | 60 | 60 | 60 | 70 | 70 | 70 | 70 | 70 |
| - | Winter-spring | 6 | 14 | 15 | 15 | 14 | 14 | 13 | 12 | 12 | 12 | 12 | 20 | 20 | 20 | 20 | 20 |
| - | Winter-spring | < week | 10 | 11 | 11 | 11 | 10 | 9 | 9 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 0 |
| + | Spring-summer | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 |
| + | Late summer-autumn | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | 4 | 18 | 13 | 15 | 15 | 16 | 16 | 17 | 17 | 17 | 17 | 5 | 5 | 5 | 5 | 5 |
| - | Late summer-autumn | 6 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | < week | 6 | 5 | 4 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

-: indicate bare soil, +: indicate growth.

**M)** *Continued…*

**Swine:**

*Liquid manure:*

| 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 |
| | Injection | Hours | | | | | | | | | | | | | | | | |
| - | March | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| - | April | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| + | March | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | April | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | Summer, grass injection | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Summer, before winter rape | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| + | Autumn | 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 |
| | Hose application | | | | | | | | | | | | | | | | | |
| - | March | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 10 | 7 |
| - | April | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 5 | 5 | 6 | 7 | 5 | 7 |
| + | March | < week | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 6 | 6 |
| + | April | < week | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 3 | 6 | 6 | 9 | 10 | 12 | 13 | 14 |
| + | May | < week | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 6 | 6 | 9 | 10 | 12 | 13 | 14 |
| + | Summer | < week | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| - | Summer | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 |
| + | Autumn | < week | 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 |
| | Broad spreading | | | | | | | | | | | | | | | | | |
| - | Winter-spring | < 12 | 26 | 27 | 28 | 29 | 30 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 18 | 17 | 15 | 13.6 |
| - | Winter-spring | > 12 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4.5 |
| - | Winter-spring | < week | 15 | 15 | 15 | 15 | 15 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 18 | 17 | 15 | 13.6 |
| + | Spring-summer | < week | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 2 | 1.8 |
| + | Late summer-autumn | < week | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 5.3 | 4.5 | 4 | 3 | 2 | 2 | 1 | 1 | 0.9 |
| - | Late summer-autumn | < 12 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 3.9 | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 1.8 |
| - | Late summer-autumn | > 12 | 8 | 7 | 7 | 6 | 6 | 6 | 5 | 4.4 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 0.9 |
| - | Late summer-autumn | < week | 29 | 28 | 27 | 26 | 25 | 24 | 20 | 16 | 12 | 8 | 4 | 0 | 0 | 0 | 0 | 0 |
| | | Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

-: indicate bare soil, +: indicate growth.

**M)** *Continued…*

| Crop status | Application time | Lying time | Percent of N ex storage per manure type | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| | Injection | Hours | | | | | | | | | | | | | | | |
| - | March | 0 | 5 | 8 | 6 | 6 | 7 | 7 | 8 | 10 | 10 | 10 | 14 | 14 | 14 | 14 | 14 |
| - | April | 0 | 6 | 8 | 7 | 7 | 7 | 8 | 8 | 9 | 9 | 9 | 11 | 11 | 11 | 11 | 11 |
| + | March | < week | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| + | April | < week | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| + | Summer, grass injection | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | Summer, before winter rape | 0 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 5 | 5 | 5 | 5 |
| + | Autumn | 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 |
| | Hose application | | | | | | | | | | | | | | | | |
| - | March | 4 | 7 | 7 | 9 | 8 | 7 | 6 | 4 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| - | April | 4 | 8 | 8 | 9 | 8 | 7 | 6 | 4 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| + | March | < week | 11 | 11 | 13 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| + | April | < week | 16 | 15 | 20 | 23 | 28 | 30 | 32 | 32 | 32 | 32 | 33 | 33 | 33 | 33 | 33 |
| + | May | < week | 16 | 15 | 21 | 23 | 18 | 14 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| + | Summer | < week | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| - | Summer | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| + | Autumn | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 |
| - | Autumn | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| | Broad spreading | | | | | | | | | | | | | | | | |
| - | Winter-spring | < 12 | 6 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Winter-spring | > 12 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Winter-spring | < week | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | Spring-summer | < week | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | Late summer-autumn | < week | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | < 12 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | > 12 | 0.5 | 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 |
| | | Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

-: indicate bare soil, +: indicate growth.

**M)** *Continued…*

*Solid manure:*

| 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 |
| | Broad spreading | | | | | | | | | | | | | | | | | |
| - | Winter-spring | 4 | 13 | 16 | 19 | 22 | 25 | 26 | 26 | 27 | 28 | 29 | 29 | 30 | 32 | 33 | 35 | 37.7 |
| - | Winter-spring | 6 | 18 | 16 | 14 | 12 | 10 | 11 | 11 | 12 | 13 | 14 | 14 | 15 | 15 | 15 | 15 | 13.6 |
| - | Winter-spring | < week | 19 | 18 | 17 | 16 | 15 | 14 | 14 | 13 | 12 | 11 | 11 | 10 | 10 | 10 | 10 | 9.1 |
| + | Spring-summer | < week | 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 |
| - | Late summer-autumn | 4 | 13 | 16 | 19 | 22 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25.9 |
| - | Late summer-autumn | 6 | 13 | 11 | 9 | 7 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4.5 |
| - | Late summer-autumn | < week | 24 | 23 | 22 | 21 | 20 | 19 | 19 | 18 | 17 | 16 | 16 | 15 | 13 | 12 | 10 | 9.1 |
| | | Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

| *Continued…* | | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Broad spreading | | 49 | 54 | 54 | 56 | 57 | 59 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| - | Winter-spring | 4 | 14 | 15 | 15 | 14 | 14 | 13 | 12 | 12 | 12 | 12 | 16 | 16 | 16 | 16 | 16 |
| - | Winter-spring | 6 | 10 | 11 | 11 | 11 | 10 | 9 | 9 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 0 |
| - | Winter-spring | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 |
| + | Spring-summer | < week | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| + | Late summer-autumn | < week | 18 | 13 | 15 | 15 | 16 | 16 | 17 | 17 | 17 | 17 | 19 | 19 | 19 | 19 | 19 |
| - | Late summer-autumn | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | 6 | 6 | 5 | 4 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| - | Late summer-autumn | < week | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | | Total | 49 | 54 | 54 | 56 | 57 | 59 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |

-: indicate bare soil, +: indicate growth.

**N)** Emission of particular matter, 1985-2015.

**TSP**

| kt TSP | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal category | | | | | | | | | | | | | | | | |
| Dairy cattle | 1.11 | 1.07 | 1.01 | 0.97 | 0.95 | 0.95 | 0.94 | 0.90 | 0.91 | 0.89 | 0.90 | 0.90 | 0.86 | 0.85 | 0.81 | 0.86 |
| Non-dairy cattle | 1.27 | 1.21 | 1.13 | 1.09 | 1.06 | 1.07 | 1.04 | 1.03 | 1.00 | 0.94 | 0.91 | 0.91 | 0.87 | 0.86 | 0.81 | 0.79 |
| Sheep | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| Goats | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| Horses | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 |
| Swine | 2.90 | 2.97 | 2.94 | 2.92 | 2.91 | 3.01 | 3.10 | 3.31 | 3.65 | 3.44 | 3.49 | 3.42 | 3.59 | 3.84 | 3.69 | 3.78 |
| Laying hens | 1.06 | 1.06 | 0.96 | 1.04 | 1.03 | 1.08 | 0.96 | 1.07 | 1.05 | 1.32 | 1.16 | 1.20 | 1.07 | 0.93 | 0.95 | 0.93 |
| Broilers | 0.34 | 0.34 | 0.38 | 0.37 | 0.43 | 0.39 | 0.40 | 0.50 | 0.54 | 0.48 | 0.50 | 0.52 | 0.50 | 0.52 | 0.60 | 0.64 |
| Turkeys | 0.034 | 0.046 | 0.025 | 0.024 | 0.034 | 0.026 | 0.036 | 0.035 | 0.058 | 0.050 | 0.050 | 0.044 | 0.063 | 0.052 | 0.048 | 0.050 |
| Other poultry | 0.053 | 0.048 | 0.044 | 0.044 | 0.054 | 0.045 | 0.047 | 0.044 | 0.042 | 0.051 | 0.059 | 0.039 | 0.037 | 0.040 | 0.044 | 0.033 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TSP total | 6.83 | 6.82 | 6.57 | 6.55 | 6.57 | 6.65 | 6.60 | 6.98 | 7.31 | 7.24 | 7.14 | 7.10 | 7.06 | 7.17 | 7.03 | 7.17 |

| *Continued…* | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal category | | | | | | | | | | | | | | | |
| Dairy cattle | 0.86 | 0.85 | 0.87 | 0.85 | 0.87 | 0.87 | 0.88 | 0.90 | 0.92 | 0.92 | 0.93 | 0.96 | 0.96 | 0.92 | 0.92 |
| Non-dairy cattle | 0.81 | 0.76 | 0.48 | 0.47 | 0.45 | 0.46 | 0.49 | 0.49 | 0.48 | 0.48 | 0.49 | 0.49 | 0.50 | 0.49 | 0.49 |
| Sheep | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.003 | 0.003 |
| Goats | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0005 | 0.0005 | 0.0005 | 0.0006 | 0.0006 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0004 |
| Horses | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Swine | 3.99 | 4.03 | 4.10 | 4.18 | 4.27 | 4.21 | 4.32 | 4.01 | 3.90 | 4.15 | 4.07 | 3.87 | 3.79 | 3.88 | 3.85 |
| Laying hens | 0.89 | 0.87 | 0.93 | 0.91 | 0.98 | 0.74 | 0.79 | 0.94 | 0.84 | 0.99 | 1.08 | 1.05 | 1.09 | 1.05 | 1.08 |
| Broilers | 0.62 | 0.61 | 0.49 | 0.45 | 0.48 | 0.52 | 0.47 | 0.39 | 0.59 | 0.51 | 0.50 | 0.50 | 0.53 | 0.49 | 0.44 |
| Turkeys | 0.050 | 0.049 | 0.036 | 0.050 | 0.057 | 0.036 | 0.046 | 0.049 | 0.054 | 0.054 | 0.044 | 0.051 | 0.032 | 0.027 | 0.027 |
| Other poultry | 0.040 | 0.045 | 0.039 | 0.038 | 0.035 | 0.038 | 0.021 | 0.023 | 0.019 | 0.018 | 0.017 | 0.017 | 0.011 | 0.009 | 0.010 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TSP total | 7.35 | 7.30 | 7.03 | 7.05 | 7.23 | 6.96 | 7.12 | 6.90 | 6.90 | 7.22 | 7.21 | 7.04 | 7.00 | 6.97 | 6.92 |

**N)** *Continued…*

**$PM_{10.}$**

| kt $PM_{10}$ | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal category | | | | | | | | | | | | | | | | |
| Dairy cattle | 0.51 | 0.49 | 0.46 | 0.44 | 0.44 | 0.44 | 0.43 | 0.41 | 0.42 | 0.41 | 0.41 | 0.41 | 0.39 | 0.39 | 0.37 | 0.40 |
| Non-dairy cattle | 0.59 | 0.56 | 0.52 | 0.50 | 0.49 | 0.49 | 0.48 | 0.47 | 0.46 | 0.43 | 0.42 | 0.42 | 0.40 | 0.39 | 0.37 | 0.37 |
| Sheep | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 |
| Goats | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Horses | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Swine | 0.87 | 0.89 | 0.89 | 0.89 | 0.89 | 0.92 | 0.95 | 1.02 | 1.14 | 1.06 | 1.07 | 1.05 | 1.10 | 1.24 | 1.19 | 1.22 |
| Laying hens | 0.22 | 0.22 | 0.20 | 0.22 | 0.22 | 0.23 | 0.20 | 0.23 | 0.22 | 0.28 | 0.24 | 0.25 | 0.22 | 0.19 | 0.20 | 0.20 |
| Broilers | 0.17 | 0.17 | 0.19 | 0.19 | 0.22 | 0.20 | 0.20 | 0.25 | 0.27 | 0.24 | 0.25 | 0.26 | 0.25 | 0.26 | 0.30 | 0.32 |
| Turkeys | 0.03 | 0.05 | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | 0.03 | 0.06 | 0.05 | 0.05 | 0.04 | 0.06 | 0.05 | 0.05 | 0.05 |
| Other poultry | 0.05 | 0.05 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.05 | 0.06 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $PM_{10}$ total | 2.48 | 2.46 | 2.37 | 2.34 | 2.37 | 2.38 | 2.38 | 2.49 | 2.63 | 2.55 | 2.54 | 2.51 | 2.50 | 2.61 | 2.56 | 2.61 |

| *Continued…* | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal category | | | | | | | | | | | | | | | |
| Dairy cattle | 0.39 | 0.39 | 0.40 | 0.39 | 0.40 | 0.40 | 0.40 | 0.42 | 0.42 | 0.43 | 0.43 | 0.44 | 0.44 | 0.43 | 0.42 |
| Non-dairy cattle | 0.37 | 0.35 | 0.22 | 0.22 | 0.21 | 0.21 | 0.23 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.22 | 0.22 |
| Sheep | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Goats | 0.0001 | 0.0001 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| Horses | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Swine | 1.28 | 1.29 | 1.31 | 1.34 | 1.37 | 1.35 | 1.39 | 1.28 | 1.23 | 1.32 | 1.30 | 1.23 | 1.20 | 1.22 | 1.19 |
| Laying hens | 0.19 | 0.18 | 0.20 | 0.19 | 0.21 | 0.15 | 0.17 | 0.20 | 0.18 | 0.21 | 0.23 | 0.22 | 0.23 | 0.22 | 0.23 |
| Broilers | 0.31 | 0.30 | 0.24 | 0.23 | 0.24 | 0.26 | 0.24 | 0.19 | 0.30 | 0.26 | 0.25 | 0.25 | 0.26 | 0.25 | 0.22 |
| Turkeys | 0.05 | 0.05 | 0.04 | 0.05 | 0.06 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 | 0.03 | 0.03 | 0.03 |
| Other poultry | 0.04 | 0.05 | 0.04 | 0.04 | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $PM_{10}$ total | 2.68 | 2.65 | 2.49 | 2.50 | 2.56 | 2.49 | 2.53 | 2.43 | 2.46 | 2.55 | 2.52 | 2.48 | 2.45 | 2.42 | 2.37 |

**N)** *Continued…*

**PM$_{2,5}$.**

| kt PM$_{2,5}$ | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal category | | | | | | | | | | | | | | | | |
| Dairy cattle | 0.33 | 0.32 | 0.30 | 0.29 | 0.28 | 0.28 | 0.28 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.26 | 0.25 | 0.24 | 0.26 |
| Non-dairy cattle | 0.38 | 0.36 | 0.34 | 0.32 | 0.31 | 0.32 | 0.31 | 0.30 | 0.29 | 0.28 | 0.27 | 0.27 | 0.26 | 0.25 | 0.24 | 0.23 |
| Sheep | 0.0002 | 0.0002 | 0.0003 | 0.0003 | 0.0004 | 0.0004 | 0.0005 | 0.0005 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0005 | 0.0005 | 0.0005 |
| Goats | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00004 | 0.00004 | 0.00004 |
| Horses | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Swine | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.05 | 0.05 |
| Laying hens | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| Broilers | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Turkeys | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Other poultry | 0.007 | 0.006 | 0.006 | 0.006 | 0.007 | 0.006 | 0.006 | 0.006 | 0.005 | 0.007 | 0.008 | 0.005 | 0.005 | 0.005 | 0.006 | 0.004 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PM$_{2,5}$ total | 0.81 | 0.79 | 0.74 | 0.72 | 0.71 | 0.71 | 0.70 | 0.69 | 0.69 | 0.67 | 0.66 | 0.66 | 0.64 | 0.64 | 0.61 | 0.63 |

| *Continued…* | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal category | | | | | | | | | | | | | | | |
| Dairy cattle | 0.26 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.27 | 0.27 | 0.28 | 0.28 | 0.29 | 0.29 | 0.28 | 0.28 |
| Non-dairy cattle | 0.24 | 0.23 | 0.14 | 0.14 | 0.13 | 0.14 | 0.15 | 0.15 | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.14 |
| Sheep | 0.0006 | 0.0005 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0005 | 0.0005 | 0.0005 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 |
| Goats | 0.00004 | 0.00004 | 0.00005 | 0.00005 | 0.00005 | 0.00006 | 0.00006 | 0.00007 | 0.00007 | 0.00007 | 0.00006 | 0.00006 | 0.00006 | 0.00006 | 0.00005 |
| Horses | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Swine | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 |
| Laying hens | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Broilers | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 |
| Turkeys | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 |
| Other poultry | 0.005 | 0.006 | 0.005 | 0.005 | 0.004 | 0.005 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PM$_{2,5}$ total | 0.63 | 0.62 | 0.54 | 0.53 | 0.53 | 0.53 | 0.54 | 0.54 | 0.55 | 0.56 | 0.55 | 0.57 | 0.56 | 0.55 | 0.54 |

**O)** Area of cultivated

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 328 501 | 342 612 | 386 583 | 295 267 | 431 306 | 522 171 | 507 031 | 567 311 | 608 673 | 559 619 |
| Spring wheat | 10 035 | 10 353 | 10 942 | 12 851 | 13 197 | 10 777 | 11 684 | 15 193 | 10 687 | 12 740 |
| Wheat, total | 338 536 | 352 964 | 397 525 | 308 118 | 444 502 | 532 949 | 518 715 | 582 504 | 619 360 | 572 359 |
| Rye | 125 918 | 119 939 | 135 505 | 80 280 | 99 961 | 108 545 | 79 622 | 88 178 | 78 273 | 87 937 |
| Winter barley | 59 509 | 60 504 | 61 412 | 44 085 | 81 899 | 139 468 | 140 195 | 151 328 | 174 568 | 182 087 |
| Spring barley | 1 034 213 | 1 017 599 | 881 700 | 1 110 203 | 905 689 | 761 647 | 795 382 | 759 064 | 534 883 | 517 670 |
| Barley, total | 1 093 722 | 1 078 103 | 943 112 | 1 154 288 | 987 588 | 901 115 | 935 577 | 910 392 | 709 451 | 699 756 |
| Oats | 36 410 | 20 843 | 18 063 | 39 958 | 26 495 | 20 212 | 21 462 | 27 646 | 28 165 | 39 757 |
| Triticale etc | 6 013 | 6 499 | 4 756 | 4 121 | 3 053 | 3 741 | 3 176 | 3 207 | 2 659 | 3 565 |
| Cereals, total | 1 600 599 | 1 578 349 | 1 498 962 | 1 586 764 | 1 561 601 | 1 566 562 | 1 558 552 | 1 611 927 | 1 437 908 | 1 403 374 |
| Pulses | 126 836 | 144 595 | 203 604 | 146 927 | 122 572 | 114 354 | 98 876 | 118 123 | 120 295 | 100 883 |
| Seed potatoes | 0 | 0 | 0 | 5 171 | 5 590 | 5 885 | 7 603 | 9 494 | 8 369 | 6 467 |
| Potatoes for manufacturing | 0 | 0 | 0 | 14 842 | 16 914 | 22 694 | 24 951 | 30 703 | 26 003 | 22 553 |
| Potatoes for human consumption | 0 | 0 | 0 | 13 145 | 11 015 | 10 999 | 10 934 | 13 485 | 12 137 | 9 782 |
| Potatoes | 30 384 | 30 710 | 29 604 | 33 158 | 33 519 | 39 579 | 43 487 | 53 682 | 46 509 | 38 803 |
| Sugar beets | 72 760 | 69 777 | 67 072 | 67 714 | 66 833 | 66 119 | 64 758 | 65 185 | 66 421 | 66 019 |
| Fodder beets | 124 782 | 120 466 | 113 052 | 110 184 | 107 369 | 102 347 | 93 170 | 80 979 | 70 993 | 60 380 |
| Root crops, total | 227 926 | 220 953 | 209 728 | 211 057 | 207 721 | 208 044 | 201 415 | 199 846 | 183 923 | 165 202 |
| Winter rape, excl non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape, non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape | 34 040 | 17 328 | 36 523 | 27 043 | 77 932 | 159 869 | 202 973 | 117 786 | 136 832 | 95 710 |
| Spring rape, excl non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring rape, non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring rape, total | 182 780 | 208 667 | 213 093 | 171 489 | 152 048 | 110 230 | 76 185 | 62 658 | 27 003 | 73 628 |
| Rape, total | 216 821 | 225 995 | 249 616 | 198 532 | 229 980 | 270 099 | 279 158 | 180 444 | 163 835 | 169 338 |
| Flax | 473 | 0 | 7 771 | 1 914 | 1 446 | 1 365 | 733 | 785 | 470 | 889 |
| Other seeds for industrial use | 2 992 | 4 501 | 2 791 | 2 556 | 1 880 | 821 | 428 | 135 | 246 | 683 |
| Seeds for industrial use, total | 220 287 | 230 496 | 260 390 | 203 002 | 233 306 | 272 285 | 280 319 | 181 364 | 164 551 | 170 910 |
| Seeds for sowing | 47 042 | 44 555 | 57 487 | 58 201 | 69 412 | 51 743 | 49 729 | 51 667 | 56 150 | 52 794 |

**O)** Area of cultivated, *Continued…*

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|
| Lucerne | 4 189 | 4 742 | 4 555 | 4 608 | 6 373 | 8 494 | 10 810 | 10 838 | 11 650 | 10 629 |
| Maize for green fodder | 20 374 | 24 715 | 24 967 | 16 607 | 17 106 | 18 735 | 19 164 | 20 245 | 26 187 | 31 269 |
| Cereals and pulses for green fodder | 50 629 | 55 220 | 47 416 | 52 819 | 50 104 | 47 772 | 53 621 | 63 761 | 68 015 | 77 696 |
| Pulses, fodder cabbage etc. | 3 532 | 2 701 | 2 815 | 3 056 | 2 335 | 2 584 | 2 969 | 2 667 | 1 814 | 2 610 |
| 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 |
| Grass and green fodder in rotation, total | 356 582 | 351 097 | 327 080 | 333 122 | 328 372 | 326 400 | 336 694 | 352 580 | 394 774 | 452 575 |
| Vegetables grown in the open, excl peas for canning | 7 282 | 7 491 | 7 013 | 7 613 | 7 143 | 7 314 | 6 987 | 7 642 | 6 442 | 6 530 |
| Peas for canning | 11 194 | 11 716 | 7 456 | 7 949 | 8 992 | 8 791 | 8 716 | 8 723 | 8 977 | 6 103 |
| Vegetables grown in the open, total | 18 476 | 19 207 | 14 469 | 15 562 | 16 135 | 16 105 | 15 703 | 16 365 | 15 418 | 12 633 |
| Bulbs and flowers | 362 | 574 | 324 | 411 | 368 | 323 | 291 | 382 | 353 | 253 |
| Apples | 3 615 | 3 338 | 3 172 | 3 105 | 2 772 | 2 726 | 2 462 | 3 006 | 2 209 | 2 061 |
| Pears | 444 | 367 | 383 | 417 | 344 | 351 | 497 | 436 | 438 | 328 |
| Strawberries | 1 364 | 1 372 | 1 330 | 1 198 | 1 188 | 1 096 | 1 049 | 992 | 1 018 | 947 |
| Sour cherries | 1 791 | 0 | 1 675 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sweet cherries | 182 | 0 | 109 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cherries, total | 1 973 | 1 674 | 1 784 | 0 | 0 | 0 | 0 | 0 | 2 022 | 2 441 |
| Black current | 773 | 0 | 844 | 0 | 0 | 0 | 0 | 0 | 1 919 | 2 351 |
| Other fruits and berries | 519 | 1 341 | 445 | 3 033 | 3 245 | 3 719 | 3 936 | 4 541 | 649 | 537 |
| Fruits and berries, total | 8 689 | 8 091 | 7 958 | 7 753 | 7 549 | 7 892 | 7 944 | 8 975 | 8 255 | 8 665 |
| Nursery area | 3 521 | 3 347 | 3 410 | 3 260 | 3 350 | 3 471 | 3 409 | 3 117 | 3 485 | 3 892 |
| Horticultural crops, total | 31 047 | 31 219 | 26 161 | 26 985 | 27 402 | 27 792 | 27 347 | 28 839 | 27 512 | 25 442 |
| Permanent grass land out of rotation | 220 564 | 214 446 | 210 480 | 216 775 | 219 085 | 217 235 | 212 030 | 207 932 | 197 229 | 316 668 |
| Set aside with grass | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Christmas trees | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other crops and fallow land | 3 217 | 3 199 | 3 831 | 3 769 | 4 656 | 3 861 | 4 694 | 4 047 | 156 217 | 3 326 |
| Other crops | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fallow land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total agricultural area | 2 834 100 | 2 818 910 | 2 797 723 | 2 786 603 | 2 774 128 | 2 788 276 | 2 769 657 | 2 756 327 | 2 738 559 | 2 691 174 |

**O)** Area of cultivated, *Continued…*

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 600 341 | 669 495 | 671 570 | 666 826 | 611 437 | 611 183 | 624 198 | 564 819 | 651 023 | 650 114 |
| Spring wheat | 6 324 | 4 712 | 13 264 | 6 383 | 7 944 | 7 977 | 8 506 | 10 930 | 12 587 | 15 755 |
| Wheat, total | 606 666 | 674 207 | 684 835 | 673 209 | 619 381 | 0 | 0 | 575 749 | 663 610 | 665 869 |
| Rye | 95 720 | 75 495 | 88 320 | 103 171 | 49 180 | 50 472 | 65 059 | 46 205 | 32 666 | 31 430 |
| Winter barley | 185 419 | 197 545 | 176 416 | 162 039 | 150 508 | 144 514 | 146 219 | 116 840 | 129 750 | 121 978 |
| Spring barley | 528 872 | 565 693 | 562 578 | 497 796 | 550 680 | 586 574 | 591 088 | 701 795 | 575 487 | 571 359 |
| Barley, total | 714 292 | 763 238 | 738 994 | 659 836 | 701 188 | 0 | 0 | 818 635 | 705 237 | 693 337 |
| Oats | 25 530 | 26 396 | 30 059 | 28 614 | 25 784 | 44 448 | 59 498 | 54 725 | 49 064 | 54 588 |
| Triticale etc | 5 286 | 5 839 | 13 058 | 29 153 | 52 216 | 54 546 | 41 948 | 36 130 | 36 735 | 40 414 |
| Cereals, total | 1 447 494 | 1 545 175 | 1 555 265 | 1 493 983 | 1 447 749 | 1 499 714 | 1 536 516 | 1 531 443 | 1 487 312 | 1 485 639 |
| Pulses | 74 178 | 69 158 | 95 256 | 106 051 | 65 762 | 35 590 | 31 964 | 40 184 | 31 356 | 26 593 |
| Seed potatoes | 6 600 | 6 645 | 5 426 | 4 827 | 4 606 | 4 522 | 4 757 | 3 414 | 3 359 | 5 079 |
| Potatoes for manufacturing | 24 756 | 24 876 | 23 794 | 21 969 | 22 376 | 22 642 | 21 620 | 20 484 | 20 461 | 19 392 |
| Potatoes for human consumption | 11 000 | 11 690 | 10 096 | 8 705 | 10 964 | 11 524 | 11 809 | 13 754 | 12 226 | 16 578 |
| Potatoes | 42 356 | 43 210 | 39 316 | 35 502 | 37 946 | 0 | 0 | 37 651 | 36 046 | 41 050 |
| Sugar beets | 67 771 | 69 732 | 69 495 | 65 698 | 62 898 | 59 167 | 56 323 | 57 806 | 49 600 | 48 745 |
| Fodder beets | 52 927 | 41 347 | 37 414 | 32 188 | 22 917 | 17 577 | 13 302 | 9 953 | 7 991 | 6 233 |
| Root crops, total | 163 055 | 154 289 | 146 225 | 133 387 | 123 761 | 115 433 | 107 811 | 105 410 | 93 637 | 96 027 |
| Winter rape, excl non food | 84 844 | 54 298 | 67 490 | 83 865 | 86 383 | 63 677 | 54 743 | 59 921 | 83 675 | 109 833 |
| Winter rape, non food | 23 229 | 13 871 | 5 727 | 6 406 | 18 392 | 17 501 | 16 203 | 17 640 | 18 532 | 10 448 |
| Winter rape | 108 073 | 68 169 | 73 217 | 90 272 | 104 775 | 0 | 0 | 77 561 | 102 207 | 120 281 |
| Spring rape, excl non food | 33 411 | 25 711 | 25 884 | 18 551 | 26 708 | 12 181 | 3 760 | 3 074 | 1 634 | 851 |
| Spring rape, non food | 10 589 | 11 413 | 4 413 | 3 056 | 8 327 | 5 765 | 3 901 | 3 122 | 2 502 | 494 |
| Spring rape, total | 44 001 | 37 124 | 30 297 | 21 607 | 35 035 | 0 | 0 | 6 196 | 4 136 | 1 345 |
| Rape, total | 152 074 | 105 293 | 103 514 | 111 879 | 139 810 | 0 | 0 | 83 758 | 106 343 | 121 626 |
| Flax | 1 195 | 3 438 | 3 461 | 3 871 | 10 698 | 5 029 | 1 422 | 221 | 117 | 113 |
| Other seeds for industrial use | 931 | 100 | 52 | 0 | 7 | 21 | 17 | 47 | 28 | 16 |
| Seeds for industrial use, total | 154 200 | 108 831 | 107 027 | 115 751 | 150 515 | 104 175 | 80 047 | 84 025 | 106 488 | 121 755 |
| Seeds for sowing | 61 556 | 60 964 | 61 212 | 84 515 | 80 979 | 78 949 | 84 958 | 71 040 | 87 193 | 90 781 |

**O)** Area of cultivated, *Continued…*

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|
| Lucerne | 10 099 | 11 145 | 7 342 | 6 850 | 5 514 | 5 245 | 3 451 | 3 566 | 3 946 | 4 147 |
| Maize for green fodder | 36 583 | 41 652 | 42 701 | 46 992 | 48 452 | 61 493 | 78 814 | 95 741 | 118 267 | 129 317 |
| Cereals and pulses for green fodder | 87 893 | 58 997 | 101 124 | 115 657 | 117 782 | 118 763 | 113 504 | 112 469 | 110 089 | 102 041 |
| Pulses, fodder cabbage etc. | 2 964 | 1 082 | 411 | 673 | 622 | 585 | 843 | 48 | 52 | 61 |
| Grass and clover in rotation | 238 384 | 257 398 | 235 285 | 249 128 | 238 107 | 246 656 | 240 320 | 218 000 | 211 950 | 196 375 |
| Grass and green fodder in rotation, total | 375 923 | 370 274 | 386 863 | 419 300 | 410 478 | 432 741 | 436 932 | 429 823 | 444 303 | 431 941 |
| Vegetables grown in the open, excl peas for canning | 7 055 | 7 041 | 6 251 | 6 084 | 6 157 | 6 479 | 6 015 | 6 066 | 6 396 | 6 656 |
| Peas for canning | 5 529 | 3 758 | 3 124 | 3 962 | 4 172 | 4 149 | 3 441 | 2 689 | 3 386 | 2 979 |
| Vegetables grown in the open, total | 12 583 | 10 798 | 9 374 | 10 046 | 10 329 | 0 | 0 | 8 755 | 9 783 | 9 635 |
| Bulbs and flowers | 332 | 255 | 180 | 156 | 194 | 175 | 160 | 148 | 150 | 128 |
| Apples | 1 658 | 1 854 | 1 697 | 1 660 | 1 623 | 1 679 | 1 783 | 1 574 | 1 624 | 1 673 |
| Pears | 545 | 469 | 430 | 555 | 431 | 441 | 469 | 420 | 457 | 439 |
| Strawberries | 1 135 | 983 | 1 095 | 983 | 991 | 984 | 1 066 | 788 | 805 | 899 |
| Sour cherries | 0 | 0 | 2 505 | 2 490 | 2 626 | 2 639 | 2 569 | 2 558 | 2 615 | 2 380 |
| Sweet cherries | 0 | 0 | 89 | 101 | 130 | 163 | 134 | 113 | 152 | 133 |
| Cherries, total | 2 654 | 2 823 | 2 594 | 2 591 | 2 756 | 0 | 0 | 2 671 | 2 767 | 2 513 |
| Black current | 1 827 | 1 783 | 1 531 | 1 280 | 1 411 | 1 492 | 1 850 | 1 939 | 2 028 | 1 976 |
| Other fruits and berries | 548 | 543 | 523 | 435 | 472 | 612 | 576 | 584 | 648 | 756 |
| Fruits and berries, total | 8 367 | 8 457 | 7 874 | 7 505 | 7 683 | 0 | 0 | 7 976 | 8 330 | 7 816 |
| Nursery area | 3 437 | 3 298 | 3 261 | 2 997 | 2 925 | 2 866 | 2 817 | 2 600 | 2 626 | 2 503 |
| Horticultural crops, total | 24 719 | 22 808 | 20 689 | 20 703 | 21 132 | 21 678 | 20 880 | 19 478 | 20 889 | 20 522 |
| Permanent grass land out of rotation | 207 122 | 192 851 | 167 600 | 156 260 | 159 530 | 166 261 | 173 702 | 177 546 | 177 635 | 172 536 |
| Set aside with grass | 216 493 | 190 701 | 147 400 | 141 432 | 182 905 | 191 295 | 201 817 | 204 721 | 206 584 | 196 972 |
| Christmas trees | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other crops and fallow land | 1 308 | 982 | 477 | 468 | 1 236 | 1 146 | 940 | 1 834 | 2 309 | 2 538 |
| Other crops | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fallow land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total agricultural area | 2 726 048 | 2 716 034 | 2 688 014 | 2 671 850 | 2 644 048 | 2 646 982 | 2 675 566 | 2 665 507 | 2 657 706 | 2 645 304 |

**O)** Area of cultivated, *Continued…*

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 666 512 | 682 080 | 683 764 | 638 724 | 716 472 | 743 911 | 724 487 | 588 724 | 542 051 | 651 530 | 608 733 |
| Spring wheat | 12 223 | 10 257 | 7 906 | 10 716 | 9 379 | 13 753 | 20 221 | 30 981 | 28 803 | 16 910 | 12 641 |
| Wheat, total | 678 735 | 692 337 | 691 670 | 649 440 | 725 851 | 757 663 | 744 708 | 619 705 | 570 854 | 668 441 | 621 374 |
| Rye | 28 474 | 29 755 | 30 047 | 30 975 | 42 197 | 51 336 | 56 097 | 57 537 | 88 181 | 104 093 | 125 540 |
| Winter barley | 139 855 | 161 241 | 168 824 | 126 516 | 141 270 | 142 560 | 130 882 | 104 214 | 110 853 | 145 209 | 114 178 |
| Spring barley | 562 991 | 527 158 | 457 408 | 580 879 | 443 183 | 425 510 | 471 143 | 623 447 | 578 675 | 490 533 | 524 952 |
| Barley, total | 702 845 | 688 398 | 626 232 | 707 395 | 584 453 | 568 070 | 602 025 | 727 661 | 689 528 | 635 743 | 639 131 |
| Oats | 58 261 | 60 288 | 55 563 | 71 873 | 53 381 | 41 907 | 42 304 | 51 010 | 53 488 | 34 830 | 37 797 |
| Triticale etc | 42 518 | 42 036 | 41 646 | 45 526 | 54 977 | 50 192 | 45 472 | 39 263 | 32 730 | 31 667 | 30 054 |
| Cereals, total | 1 510 833 | 1 512 814 | 1 445 158 | 1 505 210 | 1 460 859 | 1 469 168 | 1 490 606 | 1 495 177 | 1 434 781 | 1 474 773 | 1 453 896 |
| Pulses | 15 819 | 11 353 | 5 639 | 4 910 | 6 332 | 10 349 | 7 109 | 6 252 | 7 912 | 8 793 | 12 229 |
| Seed potatoes | 5 094 | 4 032 | 4 654 | 4 380 | 4 551 | 5 189 | 5 151 | 6 535 | 4 957 | 5 302 | 5 851 |
| Potatoes for manufacturing | 19 110 | 18 712 | 20 880 | 20 018 | 17 728 | 16 637 | 18 948 | 21 322 | 21 217 | 21 562 | 22 012 |
| Potatoes for human consumption | 16 278 | 15 210 | 15 689 | 17 981 | 15 787 | 16 312 | 16 433 | 13 764 | 14 218 | 15 753 | 13 716 |
| Potatoes | 40 482 | 37 954 | 41 224 | 42 379 | 38 067 | 38 138 | 40 532 | 41 622 | 40 392 | 42 617 | 41 579 |
| Sugar beets | 47 439 | 41 653 | 39 301 | 36 182 | 37 674 | 39 074 | 39 945 | 42 893 | 38 680 | 35 859 | 25 004 |
| Fodder beets | 4 974 | 4 035 | 3 819 | 5 206 | 5 257 | 4 118 | 3 985 | 4 562 | 5 736 | 6 708 | 5 188 |
| Root crops, total | 92 895 | 83 642 | 84 343 | 83 768 | 80 998 | 81 331 | 84 462 | 89 077 | 84 809 | 85 183 | 71 771 |
| Winter rape, excl non food | 87 530 | 97 559 | 148 559 | 172 606 | 160 326 | 163 436 | 150 402 | 124 449 | 173 746 | 164 221 | 192 535 |
| Winter rape, non food | 21 742 | 24 389 | 30 253 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape | 109 271 | 121 948 | 178 812 | 172 606 | 160 326 | 163 436 | 150 402 | 124 449 | 173 746 | 164 221 | 192 535 |
| Spring rape, excl non food | 1 282 | 1 064 | 404 | 388 | 613 | 1 372 | 1 818 | 2 467 | 1 371 | 1 375 | 699 |
| Spring rape, non food | 2 859 | 1 456 | 626 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring rape, total | 4 141 | 2 521 | 1 030 | 388 | 613 | 1 372 | 1 818 | 2 467 | 1 371 | 1 375 | 699 |
| Rape, total | 113 412 | 124 469 | 179 842 | 172 994 | 160 940 | 164 808 | 152 220 | 126 915 | 175 117 | 165 595 | 193 234 |
| Flax | 98 | 212 | 59 | 211 | 134 | 90 | 39 | 16 | 29 | 100 | 6 |
| Other seeds for industrial use | 60 | 145 | 113 | 198 | 706 | 823 | 854 | 541 | 583 | 897 | 752 |
| Seeds for industrial use, total | 113 571 | 124 840 | 180 072 | 173 580 | 161 779 | 165 721 | 153 113 | 127 472 | 175 729 | 166 592 | 193 992 |
| Seeds for sowing | 96 122 | 103 941 | 87 262 | 82 058 | 90 112 | 66 655 | 66 122 | 75 529 | 79 616 | 77 825 | 74 512 |

**O)** Area of cultivated, *Continued…*

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lucerne | 4 575 | 3 982 | 3 682 | 3 756 | 5 366 | 6 405 | 6 926 | 4 715 | 3 715 | 3 814 | 2 579 |
| Maize for green fodder | 131 027 | 135 245 | 144 869 | 159 030 | 168 917 | 172 168 | 173 693 | 183 570 | 182 935 | 183 370 | 177 908 |
| Cereals and pulses for green fodder | 75 512 | 63 998 | 60 348 | 52 251 | 55 848 | 62 845 | 56 672 | 54 333 | 58 945 | 61 100 | 56 621 |
| Pulses, fodder cabbage etc. | 43 | 20 | 31 | 19 | 0 | 26 | 0 | 0 | 0 | 0 | 0 |
| Grass and clover in rotation | 253 007 | 270 840 | 262 429 | 300 251 | 305 476 | 320 914 | 329 135 | 326 797 | 320 131 | 312 536 | 255 623 |
| Grass and green fodder in rotation, total | 464 164 | 474 084 | 471 359 | 515 306 | 535 607 | 562 358 | 566 426 | 569 415 | 565 725 | 560 820 | 492 732 |
| Vegetables grown in the open, excl peas for canning | 6 432 | 7 089 | 7 077 | 7 456 | 7 726 | 8 043 | 8 209 | 7 382 | 7 675 | 9 209 | 8 331 |
| Peas for canning | 2 999 | 2 841 | 2 741 | 3 592 | 3 737 | 2 677 | 2 935 | 2 837 | 2 209 | 2 505 | 2 749 |
| Vegetables grown in the open, total | 9 430 | 9 930 | 9 817 | 11 048 | 11 462 | 10 720 | 11 144 | 10 219 | 9 884 | 11 714 | 11 080 |
| Bulbs and flowers | 127 | 141 | 161 | 293 | 101 | 92 | 71 | 86 | 46 | 31 | 39 |
| Apples | 1 751 | 1 645 | 1 812 | 1 797 | 1 730 | 1 684 | 1 550 | 1 703 | 1 563 | 1 484 | 1 501 |
| Pears | 416 | 413 | 465 | 442 | 372 | 357 | 336 | 344 | 299 | 308 | 317 |
| Strawberries | 1 091 | 1 277 | 1 135 | 1 144 | 983 | 1 137 | 1 160 | 1 185 | 1 119 | 1 455 | 1 227 |
| Sour cherries | 1 977 | 1 967 | 2 006 | 1 757 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sweet cherries | 155 | 162 | 161 | 193 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cherries, total | 2 132 | 2 128 | 2 167 | 1 950 | 1 864 | 1 743 | 1 466 | 1 401 | 1 380 | 1 317 | 1 059 |
| Black current | 2 000 | 1 846 | 1 855 | 2 071 | 1 848 | 1 935 | 2 041 | 1 855 | 2 167 | 1 719 | 1 121 |
| Other fruits and berries | 848 | 774 | 887 | 889 | 913 | 927 | 1 031 | 1 006 | 1 047 | 1 308 | 1 102 |
| Fruits and berries, total | 8 237 | 8 083 | 8 322 | 8 294 | 7 723 | 7 797 | 7 596 | 7 508 | 7 604 | 7 611 | 6 348 |
| Nursery area | 2 318 | 2 275 | 2 255 | 2 519 | 1 827 | 1 521 | 1 041 | 1 247 | 1 199 | 1 061 | 2 270 |
| Horticultural crops, total | 20 113 | 20 429 | 20 556 | 22 154 | 21 114 | 20 130 | 19 852 | 19 060 | 18 733 | 20 417 | 19 737 |
| Permanent grass land out of rotation | 192 968 | 189 384 | 196 630 | 189 962 | 191 529 | 199 859 | 186 652 | 200 413 | 195 484 | 192 617 | 254 770 |
| Set aside with grass | 175 200 | 167 502 | 153 570 | 70 662 | 5 699 | 9 874 | 4 367 | 5 018 | 9 123 | 4 930 | 4 501 |
| Christmas trees | 0 | 0 | 0 | 0 | 18 281 | 19 521 | 17 609 | 20 593 | 18 928 | 23 461 | 22 101 |
| Other crops and fallow land | 25 551 | 22 518 | 18 173 | 20 285 | 51 665 | 41 435 | 43 906 | 36 782 | 37 126 | 36 943 | 33 058 |
| Other crops | 0 | 0 | 0 | 0 | 18 556 | 16 569 | 23 217 | 17 230 | 20 010 | 20 091 | 11 013 |
| Fallow land | 0 | 0 | 0 | 0 | 33 108 | 24 866 | 20 689 | 19 551 | 17 116 | 16 853 | 22 045 |
| Total agricultural area | 2 707 236 | 2 710 507 | 2 662 761 | 2 667 895 | 2 623 975 | 2 646 400 | 2 639 944 | 2 644 631 | 2 627 817 | 2 652 026 | 2 632 947 |

**P)** Number of operations; soil cultivation, harvesting, cleaning and drying

a) Soil cultivation

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Spring wheat | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Rye | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Winter barley | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Spring barley | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Oats | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| Triticale etc | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Seed potatoes | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 |
| Potatoes for manufacturing | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Potatoes for human consumption | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Sugar beets | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Fodder beets | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Winter rape, excl non food | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Winter rape, non food | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Spring rape, excl non food | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Spring rape, non food | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Flax | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| Other seeds for industrial use | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| Seeds for sowing | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 |
| Lucerne | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| Maize for green fodder | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Cereals and pulses for green fodder | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Pulses, fodder cabbage etc. | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Grass and clover in rotation | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Peas for canning | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Permanent grass land out of rotation | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |

a) Soil cultivation, *Continued…*

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 10 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Spring wheat | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Rye | 9 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| Winter barley | 8 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Spring barley | 8 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Oats | 7.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 6 | 6 | 6 | 6 | 6 |
| Triticale etc | 9 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| Seed potatoes | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 16.5 | 20.5 | 19 | 19 | 19 | 19 | 19 |
| Potatoes for manufacturing | 15 | 16 | 17 | 17 | 17 | 17 | 17 | 17 | 19 | 22 | 19 | 19 | 19 | 19 | 19 |
| Potatoes for human consumption | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 17 | 20 | 16 | 16 | 16 | 16 | 16 |
| Sugar beets | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Fodder beets | 11 | 11 | 11 | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Winter rape, excl non food | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Winter rape, non food | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Spring rape, excl non food | 8 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 7 |
| Spring rape, non food | 8 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 7 |
| Flax | 8.5 | 7 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 8 | 8 | 8 | 8 | 8 | 8 |
| Other seeds for industrial use | 8.5 | 7 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 8 | 8 | 8 | 8 | 8 | 8 |
| Seeds for sowing | 4.7 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.6 | 3.6 |
| Lucerne | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| Maize for green fodder | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| Cereals and pulses for green fodder | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Pulses, fodder cabbage etc. | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Grass and clover in rotation | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Peas for canning | 8 | 6 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| Permanent grass land out of rotation | 3.2 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |

b) Harvesting

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Rye | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Winter barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Oats | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Triticale etc | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Seed potatoes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Potatoes for manufacturing | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Potatoes for human consumption | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sugar beets | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Fodder beets | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Winter rape, excl non food | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Winter rape, non food | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring rape, excl non food | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring rape, non food | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Flax | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Other seeds for industrial use | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Seeds for sowing | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lucerne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maize for green fodder | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Cereals and pulses for green fodder | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Pulses, fodder cabbage etc. | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Grass and clover in rotation | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Peas for canning | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Permanent grass land out of rotation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

b) Harvesting, *Continued…*

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Rye | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Winter barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Oats | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Triticale etc | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Seed potatoes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Potatoes for manufacturing | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Potatoes for human consumption | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sugar beets | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Fodder beets | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Winter rape, excl non food | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Winter rape, non food | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring rape, excl non food | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring rape, non food | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Flax | 1 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| Other seeds for industrial use | 1 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| Seeds for sowing | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lucerne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maize for green fodder | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Cereals and pulses for green fodder | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Pulses, fodder cabbage etc. | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Grass and clover in rotation | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Peas for canning | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Permanent grass land out of rotation | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

c) Cleaning

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Rye | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Winter barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Oats | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Triticale etc | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Seed potatoes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Potatoes for manufacturing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Potatoes for human consumption | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sugar beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fodder beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape, excl non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape, non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring rape, excl non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring rape, non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Flax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other seeds for industrial use | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Seeds for sowing | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lucerne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maize for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cereals and pulses for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pulses, fodder cabbage etc. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grass and clover in rotation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peas for canning | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Permanent grass land out of rotation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

c) Cleaning, *Continued…*

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring wheat | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Rye | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Winter barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Spring barley | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Oats | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Triticale etc | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Seed potatoes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Potatoes for manufacturing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Potatoes for human consumption | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Sugar beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fodder beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape, excl non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape, non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring rape, excl non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring rape, non food | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Flax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other seeds for industrial use | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Seeds for sowing | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lucerne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maize for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cereals and pulses for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pulses, fodder cabbage etc. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grass and clover in rotation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peas for canning | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Permanent grass land out of rotation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

d) Drying

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring wheat | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Rye | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Winter barley | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring barley | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Oats | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Triticale etc | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Seed potatoes | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Potatoes for manufacturing | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Potatoes for human consumption | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Sugar beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fodder beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape, excl non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Winter rape, non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring rape, excl non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring rape, non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Flax | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Other seeds for industrial use | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Seeds for sowing | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Lucerne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maize for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cereals and pulses for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pulses, fodder cabbage etc. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grass and clover in rotation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peas for canning | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Permanent grass land out of rotation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

d) Drying, *Continued…*

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring wheat | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Rye | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Winter barley | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring barley | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Oats | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Triticale etc | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Seed potatoes | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Potatoes for manufacturing | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Potatoes for human consumption | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Sugar beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fodder beets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter rape, excl non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Winter rape, non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring rape, excl non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Spring rape, non food | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Flax | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Other seeds for industrial use | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Seeds for sowing | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Lucerne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maize for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cereals and pulses for green fodder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pulses, fodder cabbage etc. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grass and clover in rotation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peas for canning | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Permanent grass land out of rotation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Q)** 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 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $NH_3$ | kt | 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 | 0.12 | 0.12 | 0.11 |
| $CH_4$ | kt | 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 | 0.14 | 0.13 | 0.13 |
| $N_2O$ | kt | 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 | 0.004 | 0.003 | 0.003 |
| $NO_x$ | kt | 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 | 0.12 | 0.12 | 0.11 |
| CO | kt | 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 | 2.98 | 2.83 | 2.79 |
| $CO_2$ | kt | 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 | 76.60 | 72.77 | 71.68 |
| $SO_2$ | kt | 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 | 0.02 | 0.01 | 0.01 |
| NMVOC | kt | 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 | 0.32 | 0.30 | 0.30 |
| PM | | | | | | | | | | | | | | | | | |
| TSP | kt | 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 | 0.29 | 0.28 | 0.27 |
| $PM_{10}$ | kt | 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 | 0.29 | 0.28 | 0.27 |
| $PM_{2.5}$ | kt | 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 | 0.28 | 0.26 | 0.26 |
| BC | kt | 0.32 | 0.27 | 0.26 | 0.19 | 0.20 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 |
| Metals | | | | | | | | | | | | | | | | | |
| Pb | t | 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 | 0.04 | 0.04 | 0.04 |
| Cd | t | 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 | 0.002 | 0.002 | 0.002 |
| Hg | t | 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 | 0.0004 | 0.0004 | 0.0004 |
| As | t | 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 | 0.003 | 0.003 | 0.003 |
| Cr | t | 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 | 0.011 | 0.011 | 0.010 |
| Ni | t | 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 | 0.009 | 0.009 | 0.008 |
| Se | t | 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 | 0.002 | 0.002 | 0.002 |
| Zn | t | 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 | 0.001 | 0.001 | 0.001 |
| Cu | t | 0.0002 | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00002 | 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 | 0.03 | 0.03 | 0.03 |
| PAH | | | | | | | | | | | | | | | | | |
| Benzo(a)pyrene | t | 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 | 0.14 | 0.13 | 0.13 |
| Benzo(b)fluoranthene | t | 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 | 0.14 | 0.13 | 0.13 |
| Benzo(k)fluoranthene | t | 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 | 0.05 | 0.05 | 0.05 |
| Indeno(1,2,3-cd)pyrene | t | 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 | 0.05 | 0.05 | 0.05 |
| HCB | kg | 2.22 | 1.90 | 1.80 | 1.33 | 1.40 | 0.08 | 0.08 | 0.08 | 0.09 | 0.08 | 0.10 | 0.09 | 0.10 | 0.12 | 0.12 | 0.12 |
| PCB | kg | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.00002 | 0.00002 | 0.00001 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 |

**Q)** *Continued…*

| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $NH_3$ | kt | 0.12 | 0.10 | 0.12 | 0.13 | 0.13 | 0.13 | 0.11 | 0.10 | 0.12 | 0.09 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 |
| $CH_4$ | kt | 0.13 | 0.11 | 0.13 | 0.14 | 0.14 | 0.14 | 0.13 | 0.12 | 0.14 | 0.10 | 0.10 | 0.11 | 0.12 | 0.12 | 0.12 |
| $N_2O$ | kt | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.004 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| $NO_x$ | kt | 0.12 | 0.10 | 0.12 | 0.13 | 0.13 | 0.13 | 0.11 | 0.10 | 0.12 | 0.09 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 |
| CO | kt | 2.93 | 2.44 | 2.93 | 3.07 | 3.12 | 3.16 | 2.73 | 2.53 | 2.98 | 2.17 | 2.15 | 2.47 | 2.67 | 2.63 | 2.61 |
| $CO_2$ | kt | 75.33 | 62.66 | 75.33 | 78.98 | 80.14 | 81.30 | 70.35 | 65.15 | 76.64 | 55.89 | 55.32 | 63.57 | 68.71 | 67.65 | 67.10 |
| $SO_2$ | kt | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| NMVOC | kt | 0.31 | 0.26 | 0.31 | 0.33 | 0.33 | 0.34 | 0.29 | 0.27 | 0.32 | 0.23 | 0.23 | 0.26 | 0.29 | 0.28 | 0.28 |
| PM | | | | | | | | | | | | | | | | |
| TSP | kt | 0.29 | 0.24 | 0.29 | 0.30 | 0.31 | 0.31 | 0.27 | 0.25 | 0.29 | 0.21 | 0.21 | 0.24 | 0.26 | 0.26 | 0.26 |
| $PM_{10}$ | kt | 0.29 | 0.24 | 0.29 | 0.30 | 0.31 | 0.31 | 0.27 | 0.25 | 0.29 | 0.21 | 0.21 | 0.24 | 0.26 | 0.26 | 0.26 |
| $PM_{2.5}$ | kt | 0.27 | 0.23 | 0.27 | 0.29 | 0.29 | 0.30 | 0.26 | 0.24 | 0.28 | 0.20 | 0.20 | 0.23 | 0.25 | 0.25 | 0.24 |
| BC | kt | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Metals | | | | | | | | | | | | | | | | |
| Pb | t | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 |
| Cd | t | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Hg | t | 0.0004 | 0.0003 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0003 | 0.0004 | 0.0003 | 0.0003 | 0.0003 | 0.0004 | 0.0004 | 0.0004 |
| As | t | 0.003 | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.003 |
| Cr | t | 0.011 | 0.009 | 0.011 | 0.011 | 0.012 | 0.012 | 0.010 | 0.009 | 0.011 | 0.008 | 0.008 | 0.009 | 0.010 | 0.010 | 0.010 |
| Ni | t | 0.009 | 0.007 | 0.009 | 0.009 | 0.009 | 0.009 | 0.008 | 0.008 | 0.009 | 0.007 | 0.006 | 0.007 | 0.008 | 0.008 | 0.008 |
| Se | t | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| Zn | t | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Cu | t | 0.00001 | 0.00001 | 0.00001 | 0.00002 | 0.00002 | 0.00002 | 0.00001 | 0.00001 | 0.00002 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| Dioxin | g I-TEQ | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 |
| PAH | | | | | | | | | | | | | | | | |
| Benzo(a)pyrene | t | 0.14 | 0.12 | 0.14 | 0.15 | 0.15 | 0.15 | 0.13 | 0.12 | 0.14 | 0.10 | 0.10 | 0.12 | 0.13 | 0.12 | 0.12 |
| Benzo(b)fluoranthene | t | 0.14 | 0.11 | 0.14 | 0.14 | 0.14 | 0.15 | 0.13 | 0.12 | 0.14 | 0.10 | 0.10 | 0.11 | 0.12 | 0.12 | 0.12 |
| Benzo(k)fluoranthene | t | 0.05 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 |
| Indeno(1,2,3-cd)pyrene | t | 0.05 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| HCB | kg | 0.12 | 0.10 | 0.12 | 0.13 | 0.13 | 0.13 | 0.11 | 0.11 | 0.12 | 0.09 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 |
| PCB | kg | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 |

**R)** Gross energy per kg DM for dairy cattle, 1985-2015, MJ per kg DM

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MJ per kg DM | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MJ per kg DM | 18.7 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 |

**S)** Feeding plans - average feeding level.

| Winter feeding plans | | Feeding code | Pct. dm | Pct. Crude protein | Pct. Raw fat | Pct. Raw ashes | Pct. Carbon-hydrates | FU per kg dm | kg feed per day | MJ per day | MJ per FU |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AgriFish (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** |
| **Swine:** | 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** |

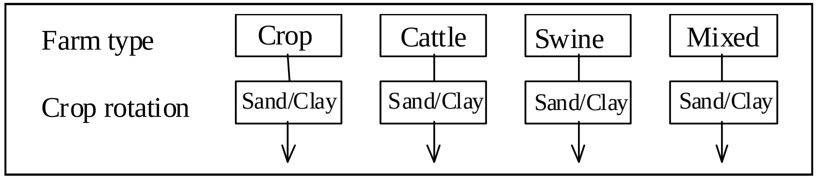
**T)** National MCF for liquid manure, 1985-2015

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle - untreated liquid manure | 4.85 | 4.85 | 4.85 | 4.85 | 4.85 | 4.85 | 4.83 | 4.86 | 4.82 | 4.79 | 4.76 | 4.73 | 4.87 | 5.00 | 4.99 | 5.03 |
| Cattle - biogas treated liquid manure | 2.68 | 2.68 | 2.68 | 2.68 | 2.68 | 2.68 | 2.66 | 2.69 | 2.65 | 2.63 | 2.61 | 2.57 | 2.72 | 2.86 | 2.86 | 2.88 |
| Swine - untreated liquid manure | 15.19 | 15.19 | 15.19 | 15.19 | 15.19 | 15.19 | 15.23 | 15.26 | 15.20 | 15.14 | 15.12 | 15.08 | 15.05 | 14.99 | 14.94 | 14.94 |
| Swine - biogas treated liquid manure | 11.94 | 11.94 | 11.94 | 11.94 | 11.94 | 11.94 | 11.97 | 11.98 | 11.90 | 11.82 | 11.79 | 11.73 | 11.70 | 11.62 | 11.55 | 11.55 |
| Fur bearing animals - liquid manure | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 11.40 | 10.35 | 10.35 |

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle - untreated liquid manure | 5.02 | 5.03 | 4.99 | 5.00 | 4.92 | 4.88 | 4.91 | 4.92 | 4.89 | 4.88 | 4.90 | 4.91 | 5.00 | 4.88 | 4.82 |
| Cattle - biogas treated liquid manure | 2.87 | 2.87 | 2.83 | 2.84 | 2.77 | 2.73 | 2.75 | 2.76 | 2.77 | 2.75 | 2.77 | 2.85 | 2.93 | 2.78 | 2.62 |
| Swine - untreated liquid manure | 14.88 | 14.89 | 14.89 | 14.84 | 14.18 | 14.20 | 14.17 | 14.08 | 14.13 | 14.14 | 14.07 | 14.00 | 13.95 | 13.93 | 13.92 |
| Swine - biogas treated liquid manure | 11.48 | 11.49 | 11.49 | 11.43 | 10.70 | 10.73 | 10.70 | 10.60 | 10.66 | 10.66 | 10.59 | 10.52 | 10.46 | 10.39 | 10.25 |
| Fur bearing animals - liquid manure | 10.35 | 10.35 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 | 10.14 |

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

**Basic DAISY calculations of N-leaching**




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

38.000 combinations

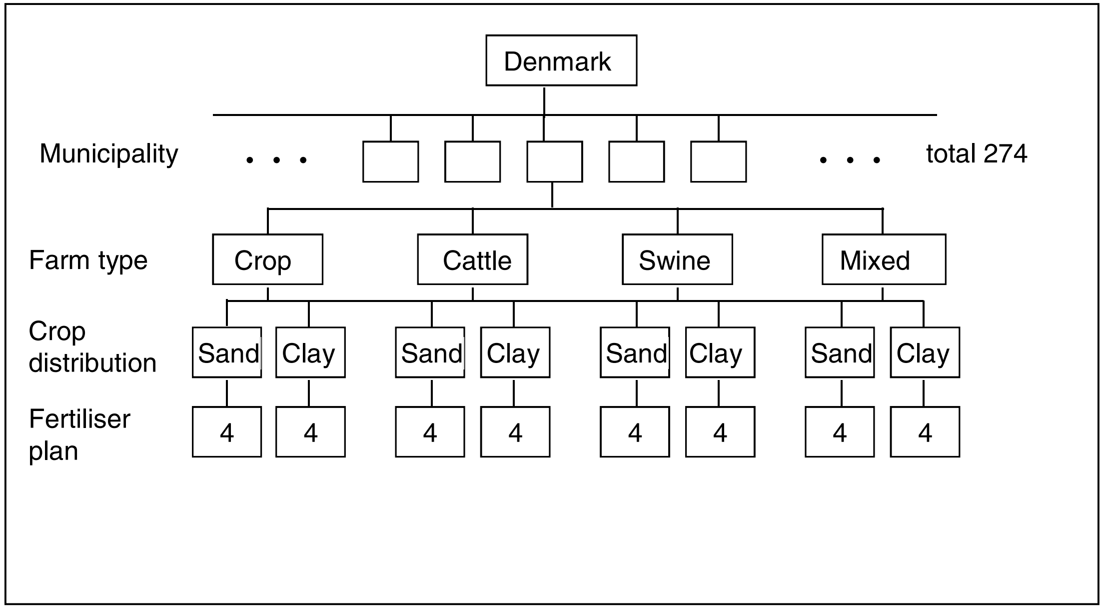
Data base
Calculation for all combinations for each of 4 climate year
Calculation for 12 combinations for each year in an 11 years period (1989-2001).

**N-LES calculations**

Model calculations for the crop rotations and fertiliser 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

**Up scaling by the SKEP model**

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



**V)** QA/QC procedure, stage I – III.

| Stage I: Check of input data | Variable | Reference |
|---|---|---|
| Livestock production | - number of animal | DSt |
| | - slaughter data | |
| Normative figures | - N-excretion | DCA |
| | - use of straw | |
| | - amount of manure | |
| | - feed intake | |
| | - milk yield | |
| Housing types | - distribution | DAAS + DAFA |
| Grazing days | | DAAS |
| Crops | - land use | DSt |
| | - crop yield | |
| | - crop production | |
| Synthetic fertiliser | - N-content | DAFA |
| | - fertiliser types | |
| N-leaching | - amount of nitrogen leached | DCE |
| Atmospheric deposition | - all $NH_3$ emission sources | DCE – $NH_3$ inventory |
| Sewage sludge and industrial waste | - Amount of sludge applied to soils | EPA + DAFA |
| **Stage II: Check of IDA data – overall** | **Emission source** | **Variable** |
| Recalculation | - $CO_2$ eqv. total emission | - compared with latest submission |
| | - $CH_4$, $N_2O$, NMVOC | |
| | - emission from field burning | |
| Time series | - $CO_2$ eqv. total emission | - trends |
| | - $CH_4$, $N_2O$, NMVOC | - jumps and dips |
| | - emission from field burning | |
| **Stage III: Check of IDA data – specific** | **Emission source** | **Variable** |
| $CH_4$ | - enteric fermentation | - IEF (jumps and dips) |
| | | - Ym (dairy cattle + heifer) |
| | | - GE |
| $CH_4$ | - manure management | - IEF (jumps and dips) |
| | | - VS |
| | | - biogas |
| $N_2O$ | - manure management | - trends (jumps and dips) |
| | | - IEF |
| | | - biogas |
| $N_2O$ | - synthetic fertiliser | - trends (jumps and dips) |
| | | - IEF |
| $N_2O$ | - animal waste applied to soil | - trends (jumps and dips) |
| | | - IEF |
| $N_2O$ | - N-fixing crops | - trends (jumps and dips) |
| | | - IEF |
| $N_2O$ | - crop residue | - trends (jumps and dips) |
| | | - IEF |
| $N_2O$ | - pasture, range and paddock | - trends (jumps and dips) |
| | | - IEF |
| $N_2O$ | - atmospheric deposition | - trends (jumps and dips) |
| | | - IEF |
| $N_2O$ | - N-leaching and run-off | - trends (jumps and dips) |
| | | - IEF |
| $N_2O$ | - sewage sludge + industrial waste | - trends (jumps and dips) |
| | | - IEF |
| NMVOC | - crops | - trends (jumps and dips) |

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# DANISH EMISSION INVENTORIES FOR AGRICULTURE

Inventories 1985 - 2015

Regulations in international conventions obligate Denmark to prepare annual emission inventories and document the methodologies used to calculate emissions. The responsibility for preparing the emission inventories for agriculture is undertaken by the Danish Centre for Environment and Energy (DCE), Aarhus University, Denmark. This report contains a description of the emissions from the agricultural sector from 1985 to 2015 and includes a detailed description of methods and data used to calculate the emissions, which is based on international guidelines as well as national methodologies. The emissions are calculated by using an Integrated Database model for Agricultural emissions (IDA). IDA covers all aspects of the agricultural inputs and estimates both greenhouse gases and air pollutants, methane ($CH_4$), nitrous oxide ($N_2O$), ammonia ($NH_3$), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and other pollutants, which mainly are related to the field burning of agricultural residue such as NOx, $CO_2$, CO, $SO_2$, heavy metals, dioxins, PAHs, HCB and PCBs. The largest contribution to agricultural emissions originates from livestock production, which is dominated by production of cattle and swine. The agricultural $NH_3$ emission from 1985 to 2015 has decreased from 128 800 tonnes NH3 to 69 000 tonnes $NH_3$, corresponding to a reduction of approximately 46 %. The emission of greenhouse gases in 2015 is estimated at 10.4 million tonnes $CO_2$ equivalents and reduced from 13.2 million tonnes $CO_2$ equivalents in 1985. Since 1990, which is the base year of the Kyoto protocol a reduction of 18 % is obtained. Improvements in feed efficiency, the utilisation of nitrogen in livestock manure and a significant decrease in the consumption of inorganic N-fertiliser are the most important explanations for the reduction of $NH_3$. This has furthermore resulted in a significant reduction of $N_2O$ emission, which is the main reason for a considerable decline in the total greenhouse gas.

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