DANISH EMISSION INVENTORIES FOR AGRICULTURE

Inventories 1985 – 2018

Scientific Report from DCE – Danish Centre for Environment and Energy No. 443 2021

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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 2018 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. Emissions is calculated for both greenhouse gases and air pollutions. The agricultural NH_3 emission from 1985 to 2018 has decreased from 107 kilo tonnes NH_3 to 60 kilo tonnes NH_3, corresponding to a reduction of approximately 44 %. The emission of greenhouse gases in 2018 is estimated at 11.0 million tonnes CO_2 equivalents and reduced from 13.8 million tonnes CO_2 equivalents in 1985. Since 1990, which is the base year of the Kyoto protocol, a reduction of 16 % is obtained.

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

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Preface

On behalf of the Ministry of Environment of Denmark and the Ministry of Climate, Energy and Utilities, 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.

This report has been reviewed by Anders Peter Adamsen, senior scientist at the Department of Engineering, 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 include a detailed description of methods and data used to calculate the emissions from the agricultural sector, and an updated version of DCE Scientific Report No. 250 published in 2017.

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). In this context, the agricultural sector have be understood as defined in the UNFCCC (United Nations Framework Convention on Climate Change), which mean that emissions related to vehicles and other machinery used in the agricultural production are included in the energy sector, while emissions and uptake of carbon in soil are included in the LULUCF sector (Land-Use, and Land-Use Change and Forest).

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 Food, Agriculture and Fisheries. These data include the extent of the livestock production, land use, use of inorganic fertilisers and Danish standards for feed consumption and the content of nitrogen and dry matter in the excreted manure. 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 2018. 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 130 kt (kilo tonnes) NH_3 in 1985 decreasing to 73 kt NH_3 in 2018, corresponding to a reduction of approximately 44 %. 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) and NECD (National Emissions Ceilings Directive). 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.

The agricultural emission of greenhouse gases (GHG) contributes with approximately 23 % of the total GHG from Denmark in 2018. The emission is closely related to the livestock production, and especially the CH_4 emission from the enteric fermentation process, which account for 35 % of the total agricultural GHG emission in 2018, and is mainly related to the cattle production.

The GHG emission from the agricultural sector is estimated to 13.8 million tonnes CO_2 equivalents in 1985 decreasing to 11.0 million tonnes CO_2 equivalents in 2018. Since 1990, which is the base year of the United Nations Framework Convention on Climate Change, the emission has decreased from 13.2 million tonnes CO_2 equivalents and a reduction of 16 % 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 reduction in the amount of inorganic N fertilisers, which is a consequence of improved utilisation of nitrogen in animal manure, mainly 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). Nærværende rapport er en metodebeskrivelse af beregning og anvendt datagrundlag for opgørelse af udledninger fra landbrugssektoren. Denne metodebeskrivelsen opdateres jævnligt, og denne rapport er en opdatering af DCE videnskabelig rapport nr. 250 publiceret i 2017.

Rapporten omfatter en opgørelse af landbrugets emissioner i perioden 1985 – 2018 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). Landbrugssektoren skal i denne sammenhæng forstås, som defineret i UNFCCC (United Nations Framework Convention on Climate Change). Det betyder, at udledninger relateret til køretøjer og øvrigt maskineri er inkluderet i energisektoren, mens udledning og optag af kulstof i jord er inkluderet i LULUCF sektoren (Land-Use, and Land-Use Change and Forest).

Landbrugets emissioner er beregnet på grundlag af en databasebaseret model kaldet IDA, som er en forkortelse af; 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 tørstof- og kvæstofudskillelse 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 hertil. Ammoniakemissionen fra landbrugssektoren er fra perioden 1985 til 2018 faldet fra 130 kilo tons (kt) NH_3 til 73 kt NH_3, svarende til en reduktion på 44 %. 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) og EU direktivet om nationale emissionslofter (NECD). 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 udledning fra handelsgødning, fordi emissionsfaktorerne angivet i EMEP/EEA Guidebook er ændret 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.

Landbrugets emissioner af drivhusgasser (GHG) bidrager med 23 % af den totale GHG-emission fra Danmark i 2018. Størstedelen af emissionen er knyttet til husdyrproduktionen og særligt fra kvægs fordøjelsesprocesser, som bidrager med 35 % af den samlede GHG-emission fra landbruget i 2018.

I 1985 er GHG-emissionen fra landbrugssektoren opgjort til 13,8 mio. tons CO_2-ækvivalenter og er frem til 2018 faldet til 11,0 mio. Siden 1990, som er klimakonventionens basisår, er emissionen faldet fra 13,2 mio. tons CO_2-ækvivalenter, hvilket svarer til en reduktion på 16 %. 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 for at undgå unødigt 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 Food, Agriculture and Fisheries. 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 1985–2018 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. 250 (Albrektsen et al., 2017).

In 2018, 95 % of the total NH_3 emission in Denmark came from the agricultural sector, the remainder 5 % is mainly from transport. It is important to point out that the Danish emission inventory reported under 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)CLRTAP, both includes an adjustment for the NH_3 emission, which covers emission from growing crops and use of inorganic N fertiliser and for NMVOC emission from animals.

In 2018, the agricultural sector contributed 23 % 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 for climate and agricultural conditions. 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 and therefore, over time, changes in estimated emissions can take place to reflect the new knowledge. It is a priority 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 2018, 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 1985-2018

This chapter describes the development in the agricultural emissions of air pollutions and greenhouse gases from 1985 to 2018. 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 UNFCCC related to the Climate Convention and the Kyoto Protocol under the Climate Convention. These, include compound as 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 2018. The main part of the NH_3 emission (95 %) and TSP emission (70 %) is related to the agricultural sector. For the remaining compounds, the agricultural sectors share is in the range from less than 1 % up to 46 %.

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 2018, reported to UNECE, January 2020.

	NH_3	TSP	PM_{10}	$PM_{2.5}$	NMVOC	SO_X	NO_X
National total, kt	77	94	29	16	120	11	106
Agricultural total, kt	73	66	9	1	55	<1	18
Agricultural part of national total, %	95	70	30	8	46	<1	17

2.1.1 NH_3

Approximately 95 % of the total NH_3 emission originates from the agricultural sector and the remainder mainly from transport. Approximately 81 % of the NH_3 emissions from agricultural activities relates to livestock production, the remaining 19 % 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 107 kt NH_3-N in 1985 to 60 kt NH_3-N in 2018, which corresponds to a 44 % 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 decreasing emission from livestock production, which is determined by lower feed costs for the farmers and environmental requirements for the farmer's handling of livestock manure. During 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. Examples are the NPO (Nitrogen, phosphor, organic matter) Action Plan (1986), the Action Plans for the Aquatic Environment (1987, 1998, 2004), the Action Plan for Sustainable Agriculture (1991), the Ammonia Action Plan (2001), the Environmental Approval Act for Livestock Holdings (2007/2011) and the 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.

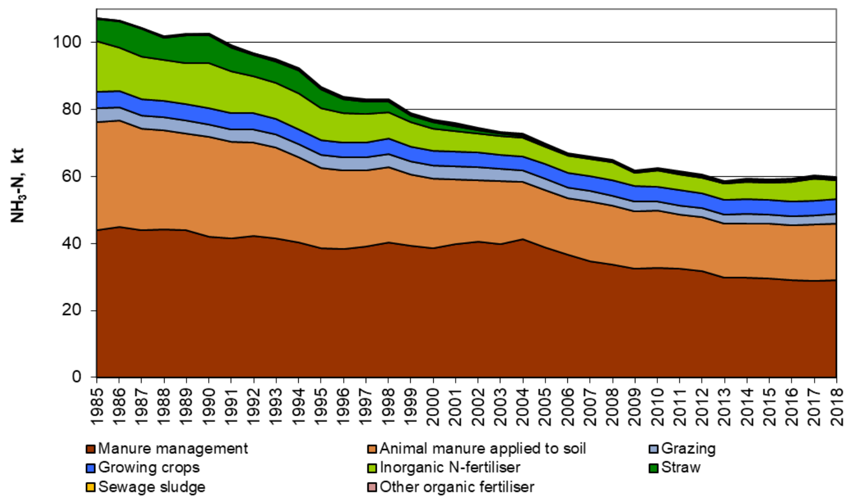

Figure 2.1 NH_3-N emissions in the agricultural sector, 1985 to 2018. Straw includes NH_3 treated straw and field burning of agricultural residues.

In Appendix A, the trend for NH_3 emission from 1985 to 2018 from different sources is expressed in both NH_3-N and NH_3.

NH_3 emission from manure management

In 2018, manure management contributed by 48 % to the total NH_3 emission from agriculture. From 1985 to 2018, the emission from manure management has decreased by 34 %.

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 2018, the contribution from cattle production had increased to 31 % and the swine production accounted for 43 %.

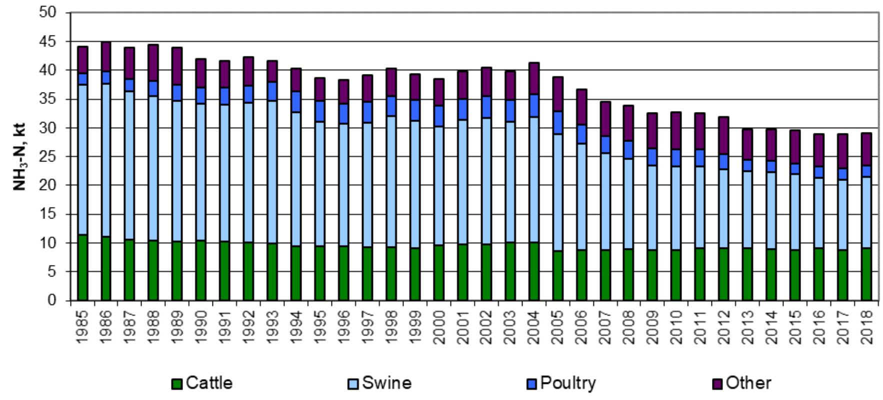

Figure 2.2 NH_3-N emissions from manure management are divided into different livestock categories. 'Other' includes fur bearing animals, horses, sheep, goats and deer.

The emission from manure management decreases from 1985-2018 for both cattle and swine. The emissions from swine has decreased by 53 % despite an increase in the production of fattening pigs from 14.8 million produced in 1985 to 19.2 million in 2018. 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 2018, that figure was considerably lower at 2.99 kg N per fattening pig produced (Lund, 2019). Due to the large contribution from the pig production, the lower level of N-excretion has a significant influence on total agricultural emissions. For cattle, the emissions decreases 20 % mainly due to decrease in number of cattle.

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 2018, 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. 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.

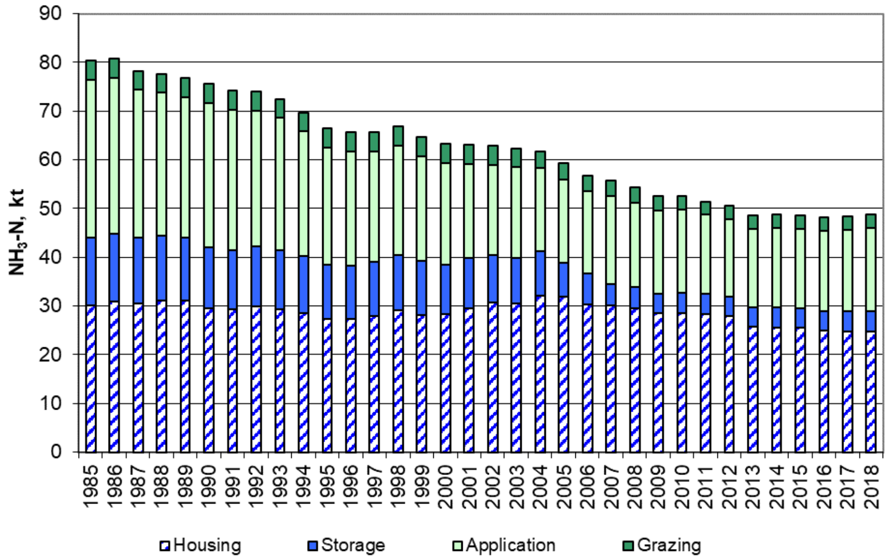

Figure 2.3 NH_3-N emissions from animal manure, 1985 to 2018.

NH_3 emissions from agricultural soils

In 2018, NH_3 emission related to the agricultural soils contributed 52 % to total agricultural emissions, and this mainly stems from animal 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.

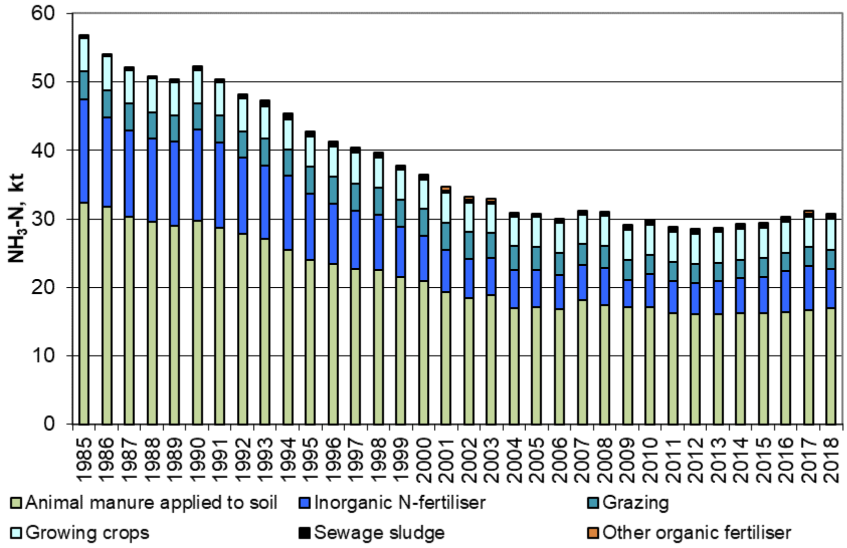

Figure 2.4 NH_3-N emission from animal manure applied to soil, inorganic N fertiliser, grazing, growing crops, sewage sludge and other organic, 1985-2018.

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 2018 is over 40 % lower 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 2018 and the emission shares for PM_{10} and $PM_{2.5}$ are 30 % and 8 %, respectively. For TSP, 88 % of the total agricultural emission is related to field operations in 2018. 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 36 % from field operations, 43 % from livestock and 21 % from field burning.

Figure 2.5 shows PM emission from the agricultural sector from 1985 to 2018 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, 2019). Harvesting and soil cultivation is the predominant source of PM. The decrease in emission from field operations from 2001 to 2002 and increase from 2016 to 2017 is due to changes 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 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.

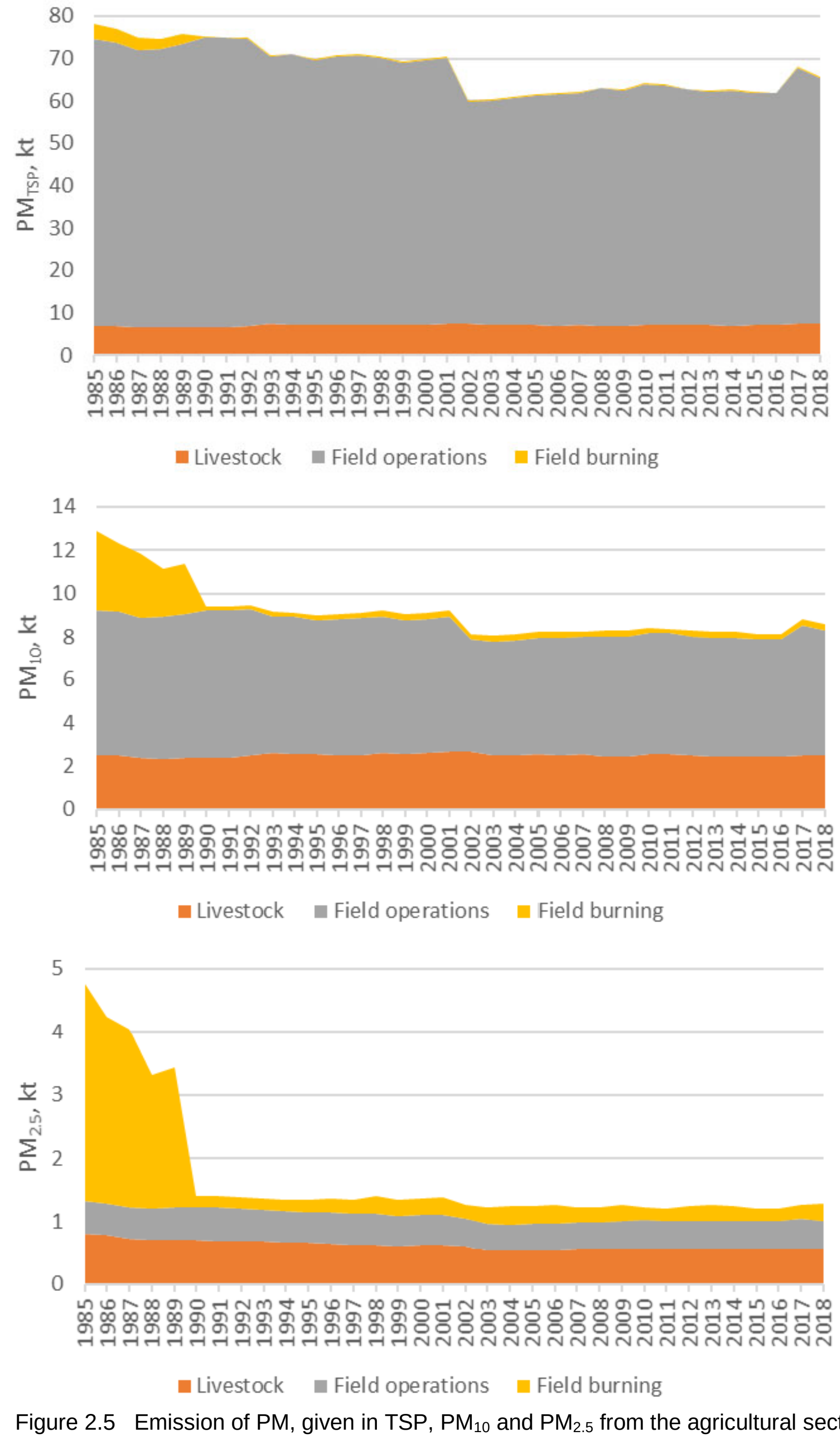

Figure 2.5 Emission of PM, given in TSP, PM_{10} and $PM_{2.5}$ from the agricultural sector, 1985 to 2018.

2.1.3 NMVOC

The NMVOC emission includes emission from livestock, field burning of agricultural residues and from growing crops and grass. Agriculture contributed with 55 kt NMVOC in 2018, corresponding to 46 % of the national NMVOC emission. Of this, emission from livestock contribute with 96 %, crops with 4 % and field burning less than 1 % in 2018. The NMVOC emission form the livestock production is mainly related to dairy cattle, because of silage feeding, which occur a relatively high NMVOC emission.

The emission has decreased from 1990 to 2018, mainly due to decrease in number of cattle.

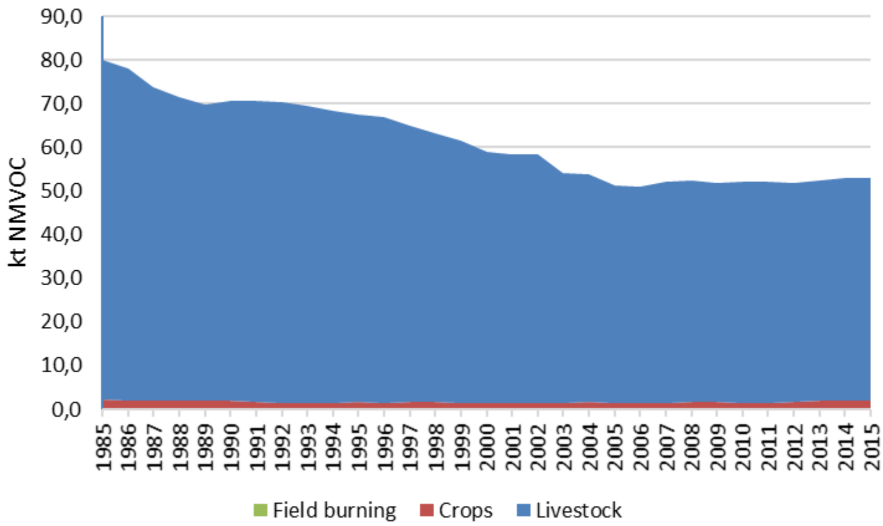

Figure 2.6 Emission of NMVOC from the agricultural sector, 1985-2018.

2.1.4 NO_x

Emission of NO_x, given in NO_2, is estimated for animal manure in housing and storage, inorganic N fertiliser, manure applied to soil, sewage sludge used as fertiliser, other organic fertiliser and from field burning of agricultural residues. Agriculture contributed with 18 kt NO_2 in 2018, corresponding to 17 % of the national NO_2 emission. From 1985, the emission has decreased mainly due to decrease in use of inorganic N fertiliser.

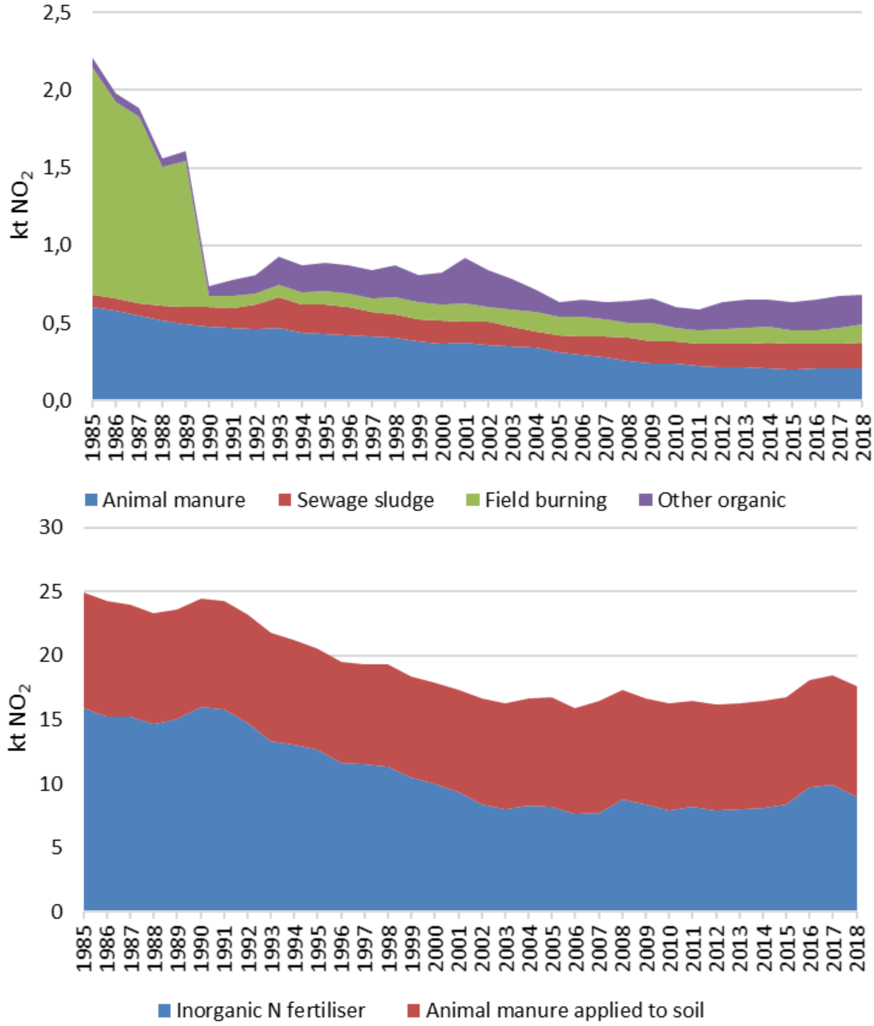

Figure 2.7 NO_2 emission for the agricultural sector, 1985-2018.

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 and HCB also emits from use of pesticides. In 2018, BC, CO, SO_2, heavy metals and dioxin from field burning contributed less than 1 % to the total national emission, while HCB contributed with around 12 %. From 1989 to 1990, all emissions decreased significantly due to the banning of field burning.

2.2 Greenhouse gases

Table 2.3 shows the agricultural contribution of emissions to the national total in 2018. The agricultural emission contribution of N_2O, CH_4 and CO_2 is 89 %, 82 % and 1 %, respectively.

Table 2.3 Emission nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) 2018, reported to UNFCCC, January 2020.

	N_2O	CH_4	CO_2
National total, kt	18	293	34 651
Agricultural total, kt	16	240	244
Agricultural part of national total, %	89	82	1

Table 2.4 shows the development in greenhouse gas emissions calculated in CO_2 eqv. The overall emission in 1985 is estimated to 13 805 kt, decreasing to 11 041 kt in 2018, corresponding to a 20 % 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 16 %, mainly caused by a decrease in the N_2O emission.

Table 2.4 Development in the emission of greenhouse gases, 1985-2018, 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	2015	2016	2017	2018
CH_4	6 363	5 895	6 111	6 006	6 005	5 970	5 896	5 919	5 919	5 990
N_2O	6 710	6 647	5 887	5 393	5 043	4 785	4 840	4 955	5 013	4 807
CO_2	732	619	537	268	222	156	177	217	219	244
Total	13 805	13 161	12 536	11 667	11 270	10 911	10 913	11 090	11 150	11 041

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 2018 is presented in Figure 2.8 and shows a reduction from 255 kt CH_4 in 1985 to 240 kt CH_4 in 2018, corresponding to 6 %. From 1985 to 2018, 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 towards the use of slurry-based housing systems, which have a higher emission factor than systems with solid manure.

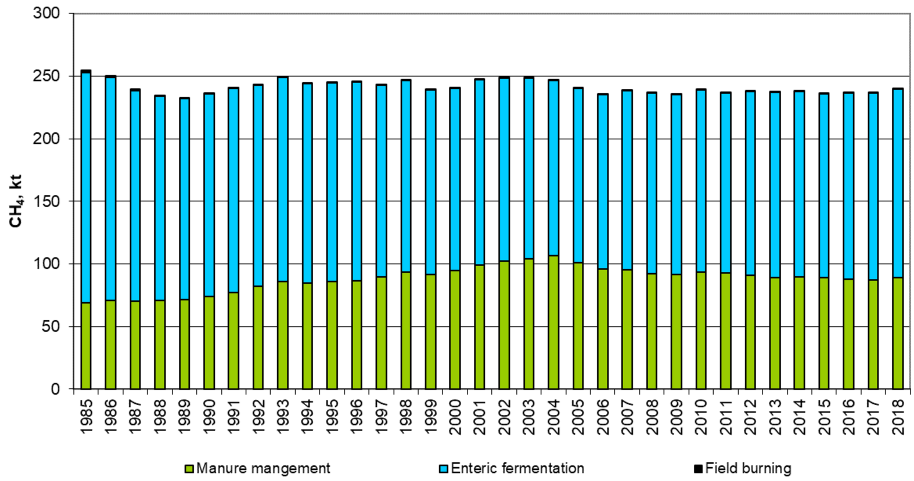

Figure 2.8 CH_4 emission 1985-2018, kt CH_4 per year.

In 2018, approximately 15 % 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 2018 and reveals that the emission has decreased from 22.5 kt N_2O to 16.1 kt N_2O, which corresponds to a 28 % 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 and a lower use of inorganic fertiliser.

Despite the increasing production of swine and poultry, the total amount of excreted nitrogen in manure has decreased from 1985 to 2018, 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.

Last thing, which have to be mentioned due to the reduction of N_2O over time, is the lower emission from cultivation of organic soils, because of a decrease in cultivated hectare of organic soils.

The lower N_2O emission for crop residue in 2018 is a consequence of a very dry summer and thus much lower crop yield than a normal year, which result in a lower nitrogen content in crop residue.

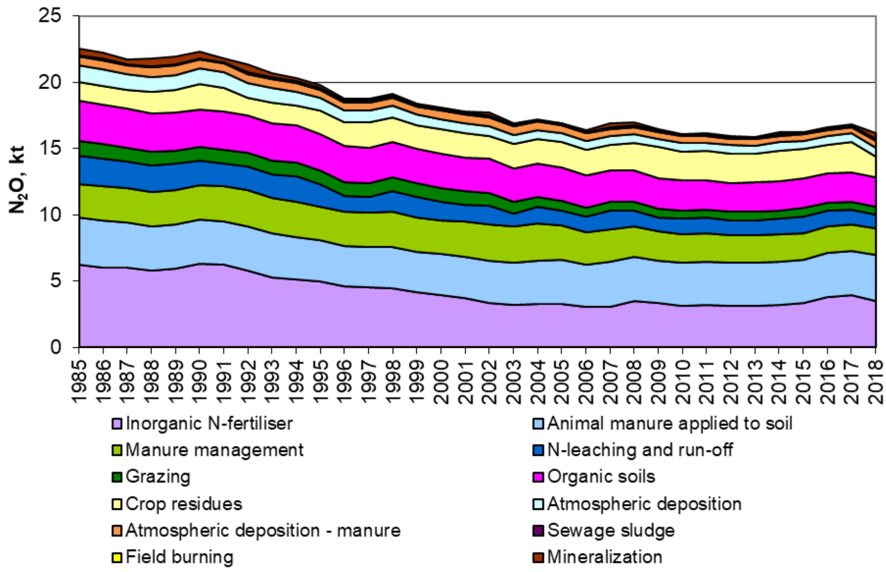

Figure 2.9 Emission of N_2O according to source, 1985-2018.

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 98 % of the agricultural CO_2 emission in 2018. The emission has decreased from 1985 to 2018 from 732 kt CO_2 to 244 kt CO_2, which corresponds to a reduction of 67 %, mainly due to a decrease in the use of lime.

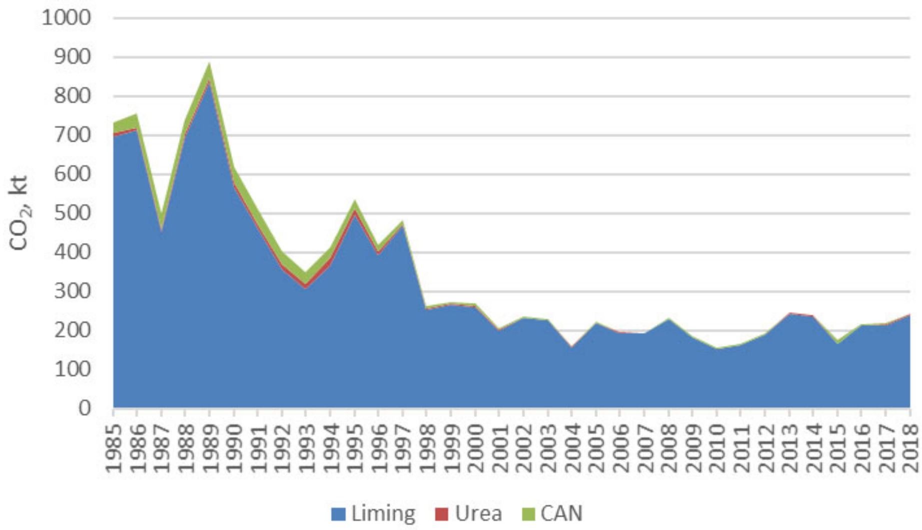

Figure 2.10 Emission of CO_2 from liming, urea and carbon containing fertilisers, 1985-2018.

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.

$$E_{Total} = \sum a_i \cdot EF_i \qquad \text{(Eq. 3.1)}$$

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, 2016 and 2019). National values and methodological approaches are used where these better reflect the Danish agricultural conditions.

3.2 Data references – sources of information

Data input for emission calculations are collected, evaluated and discussed in collaboration with a range of different institutions involved in agricultural research and administration. The organisations include, for example, Statistics Denmark, 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 - emission calculations - responsible for QA/QC - reporting
Statistics Denmark – Agricultural Statistics	www.dst.dk	DSt	- livestock production - milk yield - slaughtering data - export of live animal - poultry - land use - crop production - crop yield
Danish Centre for Food and Agriculture, Aarhus University	http://dca.au.dk/	DCA	- The Danish Normative System (N and dry matter excretion, feeding situation, animal growth) - N content in crops - modelling of data regarding N leaching/runoff - NH_3 emission factors (housing, storage and application)
SEGES – The Danish agricultural advisory service	www.seges.dk	SEGES	- housing type (until 2004) - grazing situation - silage feeding - manure application, time and methods - estimation of extent of field burning of agricultural residue - acidification of slurry (housing, storage and application)
Danish Environmental Protection Agency	www.mst.dk	EPA	- sewage sludge used as fertiliser (until 2004) - industrial waste used as fertiliser - NH_3 emission factor for use NH_3 reducing technology (List of Environmental Technologies) - use of pesticides
The Danish Agriculture Agency	www.lbst.dk	DAA	- inorganic N fertiliser (consumption and type) - housing type (from 2005) - sewage sludge used as fertiliser (from 2005 based on the register for fertilisation) - 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 Integrated Database for Agricultural 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	Sheep and 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, foxes, 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.

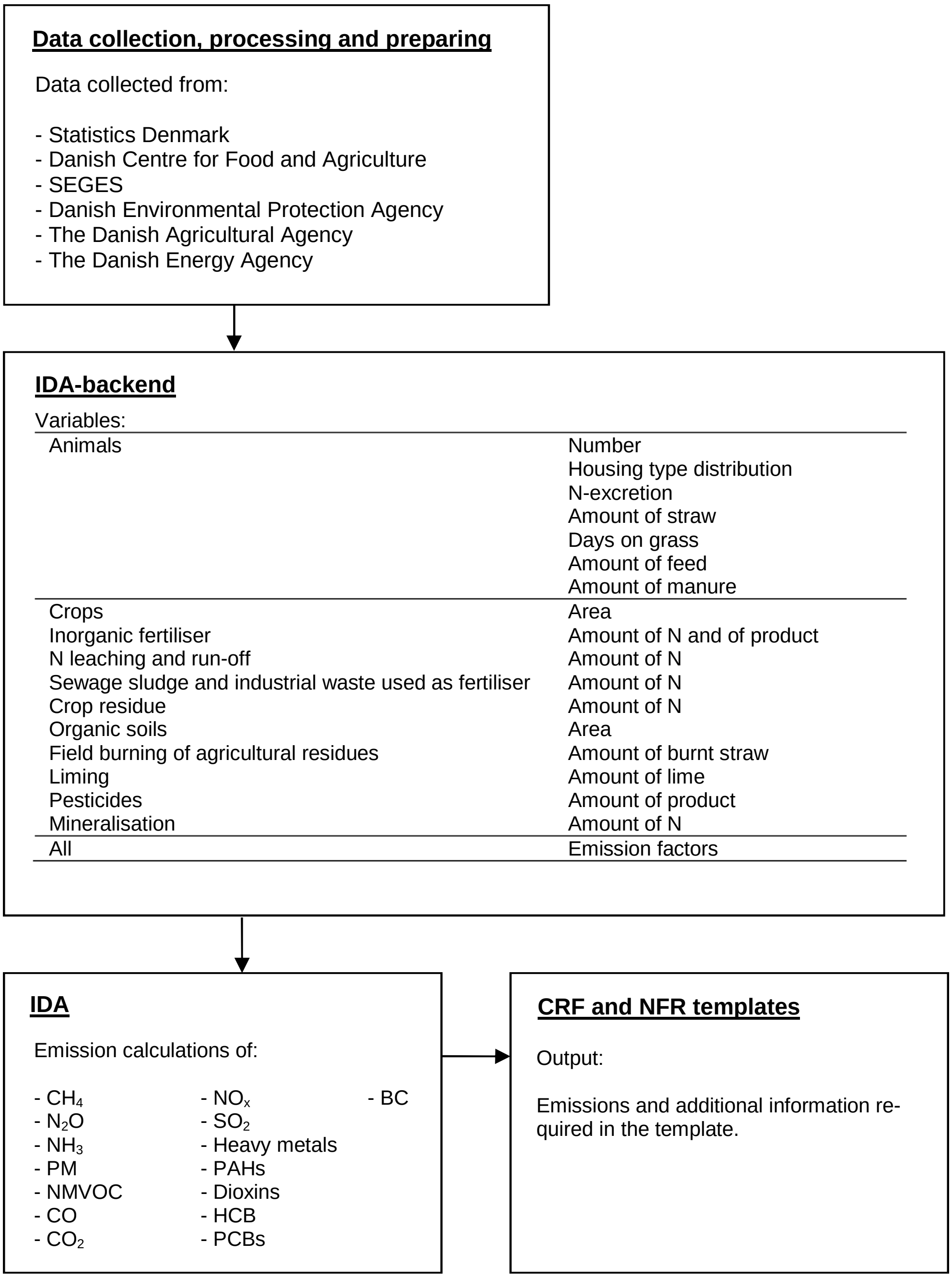

Figure 3.1 Overview of the data process for calculation of agricultural emissions.

4 Livestock population data

The livestock production is the main source of the agricultural emissions. To calculate the agricultural emission, a series of input data is used. Some values are obtained as default values from the IPPC guidelines and the EMEP Guidebook, while 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)
	- Retention time and temperature for slurry in housing/storage and
	- Amount of slurry to biogas production
NMVOC	Silage feeding

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 1985-2018 given in annual average population (AAP), definition in the EMEP / EEA Guidebook (EMEP, 2019).

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 properly underestimate the actual animal population. Therefore, 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 Food, Agriculture and Fisheries 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 number of horses is based on data from SEGES (Clausen, 2018 and Kold, 2019).

The inventories furthermore includes emissions for 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.).

4.1.1 The Danish Normative System

The DCA – Danish Centre for Food and Agriculture provide Danish standards related to feed consumption, excreted volumes, nutrient content of nitrogen, phosphor and potassium, dry matter in manure. The standards are represented for each combination of animal type, housing type and manure type. These standards are all a part of the "Danish Normative System" (Poulsen et al., 2001, Lund et al., 2019), which is used for fertiliser planning and controlled by the authorities. The complexity and dynamics of the system has increased during the years to insure the development of accurate values. Furthermore, the normative system includes emission factors for NH_3, which is based on a combination of measurements and model calculations.

The Danish normative standards are based on practical farming and thus reflect the actual Danish agricultural production conditions. DCA receive data from SEGES, which is the central office for all Danish agricultural advisory services. SEGES carries out a considerable amount of research itself, as well as collecting efficacy reports from the Danish farmers for dairy production, meat production, pig production, etc., to optimise productivity in Danish agriculture. Feeding plans are used to provide values to the Danish Normative System and for dairy cows; the values are based on feeding plans, which covers feed plans from 75-80 % of the Danish dairy production, 40-45 % of the pig production, 80-90 % of the poultry production and approximately 100 % of the fur production. This interest for normative standards for the Danish production is caused by the intensive focus on the possibilities to optimize the feed intake to increase the feed efficiency. The values covering the cattle production can be considered as reliable, even though only 15-18 % of the productions are represented. These values include mainly feeding plans from the farmers with a production efficiency corresponding to a middle level. The farmers with a high productivity level or farmers with a relatively low production level often not depending on SEGES advisory service.

Previously, the normative standards were updated and published every third or fourth year (Laursen, 1987; Laursen, 1994; Poulsen and Kristensen, 1997). From 2001, these standards are updated annually and available to download at the homepage of DCA:
http://anis.au.dk/forskning/sektioner/husdyrernaering-og-fysiologi/normtal/ (October 2020). One of the reports concerning the normative data is published in English in Poulsen and Kristensen (1998) and is available at the homepage of DCA, see list of references.

The normative figures for feed intake and N-excretion are for some livestock categories, e.g. dairy cattle, heifers (2003-2018) 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, 2019). 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.

4.1.2 Cattle

Cattle are divided into six main categories dairy cattle, bull calves, heifer calves, bulls more than 6 months destined for slaughter, heifers more than 6 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	2018
Dairy cattle	12.2	12.5	13.1	14.4	14.0
Heifer calves, 0 - 6 months	9.4	9.4	10.1	10.6	10.8
Heifers, 6 months to calving	8.5	8.6	9.3	9.4	9.5
Bull calves, 0-6 months	4.2	4.0	2.7	2.2	1.9
Bulls, 6 months to slaughter age	6.6	6.2	3.8	3.6	3.6
Suckling cattle	Weight; <400 kg, 400-600 kg and >600 kg				

[1] Source: Nielsen (2019, 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:

$$No._L = No._{DSt} \cdot (1 - J) \qquad \text{(Eq. 4.1a)}$$

$$No._J = No._{DSt} \cdot J \qquad \text{(Eq. 4.1b)}$$

Example for 2018 heifer calves (< ½ year):

$$No._L = 163\ 949 \cdot (1 - 0.108) = 146\ 243$$

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:

$$No._{bulls} = No._{yb} + No._{b} + No._{s} + No._{dis} \quad \text{(Eq. 4.2)}$$

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:

$$No._{bullcalves} = No._{bulls} + No._{vc} \quad \text{(Eq. 4.3)}$$

where:

$No._{bull\ calves}$	= number of bull calves
$No._{bulls}$	= number of bulls
$No._{v\,c}$	= number of veal calves

Example from 2018:

$$No._{bulls} = 56\,200 + 163\,500 + 6\,200 + 2\,160 = 228\,058$$

$$No._{bull\ calves} = 228\,058 + 7\,200 = 235\,258$$

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 12.8 % in 2018 (DSt).

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:

$$Frac = No._{S,DSt} / (No._{D,DSt} + No._{S,DSt}) \quad \text{(Eq. 4.4)}$$

where:

Frac = fraction of suckling cattle
$No._{S, DSt}$ = number of suckling cattle given by DSt
$No._{D, DSt}$ = number of dairy cattle given by DSt

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

Equation 4.5 a) and b):

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

$$No._{B,J} = (No._{B} - No._{B} \cdot Frac) \cdot J \quad \text{(Eq. 4.5b)}$$

where:

$No._{B, L}$ = number of bulls produced, large breed
$No._{B}$ = number of bulls produced
$No._{B, J}$ = number of breed bulls produced, Jersey
Frac = fraction of suckling cattle
J = % of Jersey bulls

Calculation example for 2018:

Table 4.3 Number of bulls, 2018.

	No. of animals, DSt	No. of animals produced	Fraction of suckling cattle	No. of bulls produced	
				Large breed	Jersey
Bull calves < ½ year	127 079	235 258	0.128	231 362	3 896
Bulls > ½ year	131 111	228 058	0.128	220 903	7 155

Suckling cattle

The number for suckling cattle is provided by DSt.

4.1.3 Swine

There are three different main swine categories: sows (including piglets up to 6.6 kg), weaners (6.6 to 31 kg) and fattening pigs (31 to 113 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 2018 was reported as 86 kg (Lund, 2019).

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 2018:

$$No._{fattening} = \left(\frac{1\ 611\ M\ kg}{86\ kg}\right) + 469\ 600 = 19\ 200\ 000 \cong 19.2\ million$$

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 14.0 million in 2018.

Number of weaners produced:

$$No. = No._{fattening} + No._{exported} \qquad \text{(Eq. 4.7)}$$

where:

No. = number of weaners, weight 6.6-31 kg
$No._{fattening}$ = total number of produced fattening pigs
$No._{exported}$ = number of exported living weaners

Example for 2018:

$$No._{weaners} = 19.2\ million + 14.0\ million = 33.2\ million$$

The normative standards for feed intake and excretion values for fattening pigs are in 2018 based on a 113 kg live weight, equivalent to 86 kg slaughter weight (Lund, 2019). 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 2018, the total meat production is estimated at 1 611 million kg meat and the number of living animals exported are 14.0 million (Table 4.4).

Table 4.4 Background data for estimating number of produced fattening pigs and weaners, 2018.

Fattening pigs to slaughter (million kg meat)	
Delivered to slaughterhouse	1 548
Slaughtered for the producer at slaughterhouse	0.1
Slaughtered at home	2
Discarded at slaughterhouse	3
Sow unit (million kg meat)	
Gilt to slaughter	0
Boars	2
Sows	44
Discarded sows at slaughterhouse	11
Total meat production from pigs, million kg meat	1 611
Export of living animals (1 000 s)	
Fattening pigs and animals for breeding	470
Weaners	13 979
No. of produced animal (1 000 s)	
No. of produced fattening pigs	19 200
No. of produced weaners	33 179

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, 2018.

	No. of animal, DSt, 1 000 unit	No. of produced swine, 1 000 unit
Swine (other than sows)	11 736	
Fattening pigs (31-113 kg)		19 200
Weaners (6.6-31 kg)		33 179

4.1.4 Poultry

For poultry, there are four main categories: laying hens, broilers, turkeys and other poultry (geese, ducks, pheasants and ostrich). In the following, estimation of the numbers of animals are 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). Six main production forms for hens are distinguished between – 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 (Lund, 2019). 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 (Lund, 2019)

Below is an example of calculation of the number of free-range hens in 2018 (100 unit):

$$no_{free-range} = \frac{(6 + 8 \cdot 8.7/100) \cdot 1000\,000}{19} / 100 = 3\,524$$

Calculations of number of hens for breeding 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 2018, 100 unit.

	No of hens, 100 unit	%, distribution on production forms	No. of hens, 100 unit
Hens - total	47 972		
- of which egg layers for brooding	8 571		8 571
- of which egg layers	39 401		
Free-range		9	3 524
Organic		32	12 787
Barn		38	14 803
Battery, manure house		20	7 856
Battery, manure tank		1	431

Pullets

The normative figure for pullets is based on the production of 100 pullets. The production time for pullets is 119 days (Lund, 2019), which corresponds to approximately three production cycles during the year (365 / 119 = 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 2018:

$$No._{pu} = 14\ 439 \cdot \frac{365}{119} \cdot \left(\frac{11.3}{100}\right) = 5\ 004$$

Table 4.7 Calculation of the number of pullets produced in 2018,100 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)	14 439	100			
Consumption, floor		55	119	3.067	24 535
Consumption, net		11	119	3.067	5 004
Egg brooding, floor		33	119	3.067	14 747
Number of pullets produced					44 286

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 2018 (in 1 000 unit):

$$No._{po} = 103\ 690 + 500 + 18\ 578 = 122\ 768$$

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, 2018.

	No. of animal, DSt, 1 000 unit	No. of produced animals 1 000 unit
Broilers	12 350	122 768
Turkeys	1 537	643
Ducks	166	478
Geese	4	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 1985-2018. Pheasants are bred for hunting and this is 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 Food, Agriculture and Fisheries 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 2018.

	1985	1995	2000	2005	2010	2015	2016	2017	2018
Ostrich	0	3 333	8 889	3 661	358	91	85	78	98

4.1.5 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 2018, 45 996 horses were listed by DSt, as opposed to 175 000 according to SEGES (Kold, 2019). 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 2018 is based on a new judgement from SEGES, which shows a decrease in number of horses until 2014 and then increase to 2018. Table 4.10 shows the number of horses registered by, respectively, DSt and SEGES.

Table 4.10 Number of horses 1985 to 2018 (1 000 unit).

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
DSt[1]	32	38	18	40	54	60	58	51	52	46
SEGES[2]	140	135	143	150	175	165	155	163	170	175

[1] Agricultural units > 5 ha.

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

4.1.6 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 5 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 mother sheep 1985-2018 (1 000 unit).

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Mother sheep										
DSt[1]	33	77	67	68	79	72	65	66	71	63
CHR[2]	40	92	81	112	126	111	84	83	82	82

[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.

4.1.7 Fur animals

The production of fur animals is calculated as the population of mink, fitchew, 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 2018 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 2018, this had been reduced to 4 %. 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	2015	2016	2017	2018
Tethered housing	85	79	73	46	20	12	7	6	5	4
Loose-housing with beds	14	18	21	43	70	82	87	87	88	89
Deep litter	1	3	6	11	10	6	6	7	7	7

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

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Fully slatted floor	29	50	57	53	53	54	40	0	0	0
Partly slatted floor	30	24	27	36	38	41	58	98	98	98
Solid floor	40	22	11	5	3	2	1	1	1	0
Deep litter	1	4	5	6	6	3	1	1	1	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 2018, 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, 2018.

	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 2018. The emission from manure management contribute 48 % and manure applied to soils 28 % of the total NH_3 emission. The emissions from cultivated crops and inorganic N fertilisers contribute 7 % and 10 %, respectively. The remainder comes from grazing animals (5 %) and the last 2 % is from other sources such as sewage sludge and other organic fertiliser, applied to agricultural land, the field burning of agricultural residues and ammonia treated straw. Description of trend 1985 – 2018 see also Chapter 2.1.1. Appendix A shows the NH_3 emissions from all sources for the period 1985 – 2018.

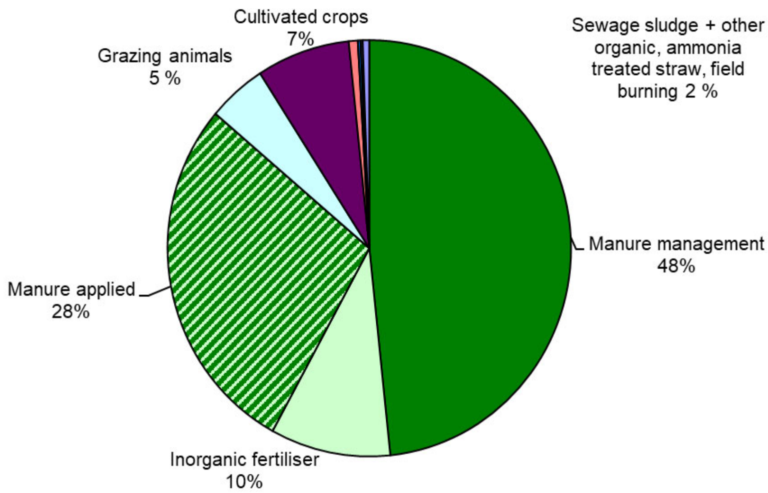

Figure 5.1 NH_3 emissions distributed on sources, 2018.

5.1 Animal manure

5.1.1 Total N and TAN

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

In order to be able to implement the effect of NH_3 reducing measures such as changes in feed composition, 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 is 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 (see Chapter 5.1.3).

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:

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

where:

AM_t = total ammonia emission, kg NH_3-N
AM_h = emission from manure in livestock housing, kg NH_3-N
AM_s = emission from manure storage, kg NH_3-N
AM_{ap} = emission from manure application to fields, kg NH_3-N
AM_g = emission from manure deposited by animals on grass, kg NH_3-N

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. Effect of emission reducing technology in housings, such as acidification of slurry, cooling of manure, heat exchanging etc. is also taken into account (see description in Chapter 5.1.4).

a) $$AM_h = N_h \cdot (100 - AE_i)/100 \cdot EF_h \quad \text{(Eq. 5.2a)}$$

a1) $$N_h = No.\cdot Nex_a \cdot \left(1 - \frac{D_g}{365}\right) \cdot Tech_i \quad \text{(Eq. 5.2b)}$$

b) $$AM_s = N_s \cdot EF_s \quad \text{(Eq. 5.2c)}$$

b1) $$N_s = \left(No.\cdot Nex_h \cdot \left(1 - \frac{D_g}{365}\right) \cdot Tech_i + (N_h \cdot EF_h - AM_h)^1\right) \quad \text{(Eq. 5.2d)}$$

c) $$AM_{ap} = N_{ap} \cdot EF_{ap} \quad \text{(Eq. 5.2e)}$$

c1) $$N_{ap} = \left(No.\cdot Nex_s \cdot \left(1 - \frac{D_g}{365}\right) \cdot Tech_i + Diff + (N_h \cdot EF_h - AM_h - (N_h \cdot EF_h - AM_h) \cdot EF_s)^1\right) \quad \text{(Eq. 5.2f)}$$

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

[1] If $AE_i = 0$ is this factor 0.

where:

N_h = N in housing, kg N
N_s = N in storage, kg N
N_{ap} = N in manure for application, kg N
No. = number of animals
Nex_a = N excretion from animals (normative figures), kg N per head per year
Nex_h = N excretion in housing unit (normative figures), kg N per head per year

Nex_s = N excretion in storage unit (normative figures), kg N 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
$Tech_i$ = share of emission reducing technology *i*
AE_i = abatement efficiency for the emission reducing technology *i*
Diff. = difference between emission estimate for storage in normative figures and inventory estimate, kg N (see below)

The normative figures estimated by DCA cover the N-flow from excretion from animal to the time before application of manure to soil and include emission from housing and storage. The emission factors for storage of slurry in the normative figures is based on storage with full surface crust. But in the emission inventory estimation of the NH_3 emission from storage of slurry three different storage situations is taken into account; storage without cover, with full surface crust and with fixed cover (tent/concrete). This gives a difference in emission from storage and thereby difference in the amount of N in manure applied to soil.

Difference between emission estimate in normative figures and inventory estimate is calculated as:

$$\text{Diff.} = N_s \cdot EF_{s\,norm} - N_s \cdot EF_s \qquad \text{(Eq. 5.3)}$$

Where:

Diff. = difference between emission estimate in normative figures and inventory estimate, kg N
N_s = N in storage (normative figures), kg N
$EF_{s\,norm}$ = emission factor for storage used in estimation of normative figures, % NH_3-N of N
EF_s = emission factor for storage used in inventory estimations, % NH_3-N of N

The emission calculation for fattening pigs in 2018 housed on partly slatted and drained floor is shown below as an example, based on normative figures and emission factors given in Table 5.1. In 2018, 19.2 million fattening pigs were produced (Table 4.5). Of these, 49 % are housed for 365 days a year in housing systems with partly slatted and drained floor.

Table 5.1 Normative figures and emission factors for one produced fattening pigs in 2018 (Lund, 2019).

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
1.96	1.55	1.90	21	2.7	10.69 (slurry)

*The used emissions factors are described in later sections.

Calculation of the emission from fattening pigs housed on partly slatted and drained floor:

$$N_h = (19\,199\,591 \cdot 0.492) \cdot \frac{1.96}{1000} \cdot \left(1 - \frac{0}{365}\right) \cdot 1 = 18\,515\ tonnes\ N$$

$$AM_h = 18\,515 \cdot \frac{21}{100} = 3\,888\ tonnes\ NH_3 - N$$

$$N_s = (19\,199\,591 \cdot 0.492) \cdot \frac{1.55}{1000} \cdot \left(1 - \frac{0}{365}\right) \cdot 1 + \left(18\,515 \cdot \frac{21}{100} - 3\,888\right) = 14\,642\ tonnes\ N$$

$$AM_s = 14\,642 \cdot \frac{2.7}{100} = 395\ tonnes\ NH_3 - N$$

$$Diff = 14\,642 \cdot \frac{2.5}{100} - 14\,642 \cdot \frac{2.7}{100} = -29\ tonnes\ N$$

$$N_{ap} = (19\,199\,591 \cdot 0.492) \cdot \frac{1.90}{1000} \cdot 1 + (-29) + \left(18\,515 \cdot \frac{21}{100} - 3\,888\right) - \left(18\,515 \cdot \frac{21}{100} - 3\,888\right) \cdot \frac{2.7}{100}$$

$$= 17\,918\ tonnes\ N$$

$$AM_{ap} = 17\,918 \cdot \frac{10.69}{100} = 1\,915\ tonnes\ NH_3 - N$$

$$AM_{total} = 3\,888 + 395 + 1\,915 = 6\,198\ tonnes\ NH_3 - N = 7\,526\ tonnes\ NH_3$$

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 excretion 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; Lund, 2019). 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 2018.

For heifers, a change in methodology has taken place. From 1985 to 2002, the normative figures for N ex was provided for each produced animal. This has changed form 2003, where the N ex covers N ex per AAP (annual average population – see definition in section 4.1). For animal categories 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 2018 as well as the NH_3 emission for the different main livestock categories.

5.1.4 Emission reduction technology

Over the past ten to fifteen years, is seen a growing interest in using technology to reduce the ammonia emission in livestock housing. In the inventory estimations are included reduction from cooling of manure in swine housings, acidification in cattle and swine housings, frequent removal of manure in mink housings and use of heat exchanging in housings with broilers.

The environmental technologies are closely related to the expansion of the livestock production. Due to the enlargement of the animal production, the farmer will be met by a statutory environmental requirements implemented in the Environmental Approval Act for Livestock Holdings (BEK nr. 1261 af 29/11/2019 (BEK, 2019)). For some farmers, the emission reducing technology will be chosen as an opportunity to reduce the ammonia emission. The farmers apply for an Environmental Approval for livestock farming and include information on which environmental technologies are planned to be implemented to achieve the reduction of ammonia emission, as well as information regarding the expected reduction effect and the number of animals placed in the housing with the respective environmental technology. This Environmental Approvals Register for livestock farming is administrated by the Danish Environmental Protection Agency. This register also include information on air cleaning system, but these data is still in processing, and thus the reducing effect is not yet included in the inventory.

Information from the Environmental Approval Register are used to estimate the distribution of cooling of manure in swine housings and frequent removal of manure in mink housings.

Estimation of distribution of housings with acidifications are based on information from a distributor of acidification systems combined with information from the Environmental Approval Register.

Distribution of the use of heat exchanging in broiler housings is based on a combination of information from distributors of heat exchanging and subsidy schemes, which include subsidy to installation of heat exchangers.

Below is described the background for estimating the distribution of the included NH_3 reducing technologies in the Danish inventory.

Environmental Approval Register 2007-2016

DCE has received data sets for the Environmental Approval Register for livestock farming for the years 2007 – 2016, which are used to estimate the prevalence of ammonia emission technology in Danish livestock housing. However, it must be emphasized, that the data set covers the Environmental Approvals, which not in all cases necessarily has been implemented. It could be poor financial conditions or other circumstances, which lead to a situation, where the approval is not being realised. Therefore, the Register of Environmental Approvals for livestock farming is inserted in a database, and combined with the Central Husbandry Register (CHR), which is the central register of farms and animals managed by the Ministry of Food, Agriculture and Fisheries of Denmark. A comparison between these two register makes it possible to check each approval with the actual development of the livestock production. In the cases where the CHR register show an expansion of the livestock production contemporary with the Environmental Approval, indicate that the approval are implemented. Around 20 % of all Environmental Approvals includes emission reducing technologies in livestock housing.

The data set for Environmental Approval Register for the years 2007 – 2016 corresponds to approximately 1800 approvals, which includes emission reducing technologies solution in housing. Data processing showed that many farmers have applied more than one approval, which indicate no realization of the first approval. Figure 5.2 shows the percentage distribution of the different reducing technologies for the 1800 farms, and slurry cooling is the most frequently used technology. Particularly the pig production seems to be active regarding use of reducing technology and thus approval for swine accounts for 76 % of all farms, cattle for 17 % and poultry for the remaining 7 %.

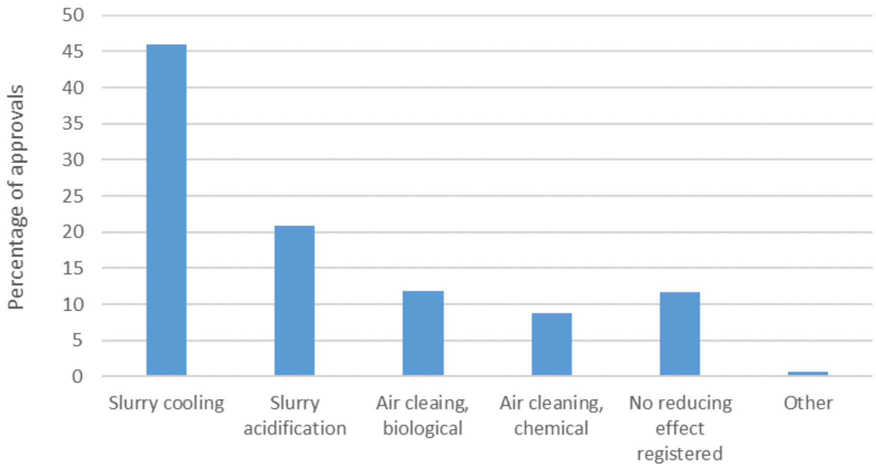

Figure 5.2 Distribution of ammonia reducing technologies in housing based on data from the Environmental Approval Register 2007 – 2016.

The review of Environmental Approval Register 2007-2016 indicate that slurry cooling seems to be the most common choose of ammonia reducing technology for the swine production, while the cattle production primarily use slurry acidification.

Slurry cooling

Cooling of slurry only occur in swine housing. Cooling is not only an advantage for the environment, but also profitably due to the operational cost for energy use, if the heat can be used in other production facilities – e.g. in piglet barns.

The estimation of distribution of slurry cooling is based on data from the Environmental Approval Register. Approximately 600 farmers has an approval, which include a housing system with slurry cooling. A sorting process of the data has been performed, in order to avoid double counting of approvals or avoid counting approvals, which in all probability has not been realized. This sorting process leads to the conclusion, that approximately 460 approvals is considered as implemented. Following assumption is taken in to account during the sorting process:

- It is assumed, that the Environmental Approval is not implemented, if the production has not been increased, or increased by less than 10 %. This is based on the argument, that the farmer does not invest large costs for new technology, if no extension of the production take place.
- The extension of the animal production has to occur within maximum four years after the approval date; otherwise, it is assumed that the approval is not realized.
- Based on the information from the distributors of slurry cooling system, it is assumed that farmers choose to implement slurry cooling system in relation to new housing buildings. Slurry cooling system can principally be established in existing building, but almost never take place in praxis.

- If CHR data shows a production increase above 10 % in year 2017, it is assumed that approvals for year 2014-2016 is realized.

Based on the 460 approvals (CHR numbers), which is considered as realized, the number of swine is summarized for each year, distinguished between three types of swine; fattening pigs, weaners and sows. Table 5.2 shows the estimated number of animals, in housing with slurry cooling system. In 2008, 0.2 million swine is placed in housing with slurry cooling system increasing to 2.2 million swine in 2017.

Table 5.2 Number of produced pigs in housing with slurry cooling based on the data from the Environmental Approval Register.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Fattening pigs	18 428	84 439	194 095	253 899	299 762	342 337	396 743	457 236	529 249	639 288
Weaners	0	124 205	259 149	368 078	512 387	686 390	889 685	1 175 157	1 410 678	1 713 473
Sows	4 140	9 476	17 578	22 899	31 075	42 590	51 514	62 638	69 166	75 294

Estimation of distribution of slurry cooling

Table 5.3 shows the number of animals in housing with slurry cooling system, converted to the percentage of the total livestock production. It shows that slurry cooling most frequently take place in sow housing and for weaners, which confirm the profitably of using the heat in weaners housing. No data is available for 2018, and therefore the slurry cooling system is kept at the same level as 2017.

Table 5.3 Distribution of slurry cooling in housing, percentage of produced pigs.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Fattening pigs	0.1	0.4	0.9	1.2	1.5	1.7	2.0	2.3	2.7	3.4	3.4
Weaners	<0.0	0.4	0.9	1.2	1.7	2.3	2.9	3.7	4.4	5.3	5.3
Sows	0.4	0.9	1.6	2.2	3.1	4.4	5.0	6.1	6.9	7.4	7.4

* No data for 2018 available, therefore maintained the same level as year 2017.

Slurry cooling - NH_3 reducing potential

Reduction potential for the NH_3 emission due to slurry cooling in housing is based on data from the Environmental Approvals. The approvals include information on NH_3 reduction factors for each farm depending on cooling system (temperature), the volume of air exchange in housing and pH level in manure regarding acidification. A weighted average of the NH_3 reduction factor is estimated to 19.6 % and is consistent with the Environmental Technology List (MST, 2020) estimate by 20 %.

Table 5.4 Weighted annually average of NH_3 reduction emission factor for slurry cooling based on the data from the Environmental Approval Register compared with the Environmental Technologies List, %.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average	Tech list*
Cattle/swine	19.6	24.4	21.2	20.0	20.7	20.7	19.5	17.0	17.4	15.9	19.6	20

* Environmental Technologies List (MST, 2020) – the reduction unit is given as Watt per m^2 (28 W/m^2 = 20 % reduction).

Acidification

Information on acidification in Danish livestock housings is provided based on two sources; the Environmental Approval Register and information received from a distributor of acidification systems. Today, only one single company is distributor of acidification systems for housings in Denmark, from where DCE have received information regarding number of sold acidification systems, including information on livestock type (cattle or swine) (JH Agro

A / S, 2017). Both, the Environmental Approvals register and the address sales list is used as background information to estimate the distribution of slurry acidification in Danish livestock housing.

Data from the Environmental Approval Register

The Environmental Approval Register includes slurry acidification in housing for around 270 farms (CHR numbers). Comparison with the data in the CHR register shows an increase of livestock production for 177 farms, within one to four years after the Environmental Approval date. Of these, 103 farms are not included at the distributor list, which indicate that the approval is not realized.

List from distributor

The list received from the acidification system distributer includes 137 addresses, and where possible, CHR number has been identified. This was done by entering address and / or name of owner of the acidification system in CHR at the internet; https: / / chr.fvst.dk. By this process, it was possible to identify CHR number for 125 farms at the list. Remarkably, that 37 of these farms are not registered in the Environmental Approval Register. The farms has bought an acidification system, but same farmers are not reflected in the Environmental Approval Register.

Estimation of distribution of slurry acidification

A comparison between the distributor list and the Environmental Approval Register shows that 88 farms are registered at both lists. Of these, thirteen have no number of animals registered in CHR, and thus an expansion of the livestock production can not be confirmed. The remaining 75 farms, which are included in both, the distributor list and the Environmental Approval Register, are assessed to have implemented acidification system. Also, the farms on the distributor list and with expansion in the livestock production are assessed to have implemented acidification system. The systems are assessed active, at the same year as the increase of the animal production takes place. The number of animals registered on the farms, where it is assessed that acidification system are implemented (75+37 = 112 farms) are used to estimate the distribution of slurry acidification system in Danish livestock housing. The number of animals is based on the number of animals given in the approval or in CHR – see Table 5.5.

Table 5.5 Number of animals in housing with slurry acidification based on the data from the Environmental Approval Register and CHR.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Farms in both list from the distributer and Environmental Approval Register, number from approval/CHR										
Dairy cattle	1 790	5 502	8 209	11 918	13 061	13 135	14 137	16 043	16 532	16 975
Non-dairy cattle	454	997	2 586	5 331	5 531	6 405	6 442	6 589	6 990	6 942
Fattening pigs	16 842	34 349	46 629	80 439	86 142	86 236	100 614	101 329	141 006	141 310
Weaners	0	14 325	34 708	47 191	61 474	62 344	93 766	93 532	96 443	105 349
Sows	0	2 000	2 800	3 346	5 646	7 246	7 246	9 816	10 856	11 531
Farms only in the list from distributer, number from CHR										
Dairy cattle	0	455	748	1 832	2 199	2 165	2 218	2 370	2 490	2 511
Non-dairy cattle	0	925	1 625	3 397	3 914	3 917	4 033	4 310	4 483	4 484
Fattening pigs	19 704	69 306	112 028	124 950	140 571	157 828	165 298	16 682	177 508	170 109
Weaners	15 040	75 350	120 896	200 754	243 995	252 380	249 698	250 753	299 619	338 615
Sows	690	3 962	9 692	9 672	10 395	11 681	11 921	11 791	14 190	14 084

The distribution of acidification systems in housing, given in percentage of number animals, is listed in Table 5.6. The percentage is calculated by dividing the total livestock production (Appendix D) with the number of animals registered in the Environmental Approval Register / CHR (Table 5.5). For 2018, the distribution of animals (in percentage) is set at the same level as 2017, due to lack of data.

Table 5.6 Distribution of slurry acidification in housing, percentage of animals.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Dairy cattle	0.3	1.1	1.6	2.4	2.6	2.6	2.9	3.3	3.3	3.4	3.4
Non-dairy cattle	0.04	0.2	0.3	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0
Fattening pigs	0.2	0.5	0.7	0.9	1.1	1.2	1.3	1.4	1.6	1.7	1.7
Weaners	0.05	0.3	0.5	0.8	1.0	1.1	1.1	1.1	1.2	1.4	1.4
Sows	0.1	0.5	1.1	1.2	1.6	1.9	1.9	2.1	2.5	2.5	2.5

* For 2018, the distribution of animals (in percentage) is set at the same level as 2017 due to lack of data.

Slurry acidification - NH_3 reducing potential

The Environmental Technologies List (MST, 2020) includes reduction factors for a series of NH_3 reduction technologies, among these a reduction factor by 50 % for acidification of cattle slurry and 64 % for acidification of swine slurry. This complies with the information given in the Environmental Approval Register. In each approval, an estimate is given for achieving the reduced emission by using slurry acidification. In Table 5.7 is shown the weighted average of NH_3 reduction factor for each year. For cattle slurry, the reduction factor varies from 46–60 %, while swine slurry varies from 63-70 %. The estimated reduction of NH_3 emission is based on the reduction factors given in Environmental Technologies List.

Table 5.7 Weighted average of NH_3 reduction emission factor for slurry acidification, based on the data from the Environmental Approval Register compared with the Environmental Technologies List, %.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average	Tech list*
Cattle	50.0	48.9	49.6	50.3	48.5	50.3	46.4	50.6	50.0	59.5	50.4	50
Swine	70.0	69.8	69.1	69.7	65.2	65.6	63.1	59.7	68.7	66.1	66.7	64

* Environmental Technologies List (MST, 2020).

Frequent removal of manure regarding mink housing

Frequent removal of manure reduces the emission of NH_3 from housings. A standard mink housing is defined as manure removal by once a week, while a frequent removal of manure minimum two times per week.

Estimation of distribution of frequent removal of manure

The Environmental Approval Register includes approvals for 89 farms (CHR numbers) with mink production in the period 2007-2016. However, the number of approvals is reduced to 60, because information regarding removal of manure (ones a week) and the design of manure system (slurry channel width), shows that 19 farms was considered as standard housing, with no further NH_3 reducing potential. For 2007-2009, no approvals are registered.

Table 5.8 shows the number of mink (breeding females) registered in the Environmental Approval Register with frequent removal of manure for the years 2010-2018 and the percentage of the total production of mink. For 2018, no data is available and therefore the percentage of production with frequent removal of manure is considered at the same level (in percentage) as year 2017.

Table 5.8 Number of breeding female mink in approvals with frequent removal of manure.

Approvals	2010	2011	2012	2013	2014	2015	2016	2017	2018[3]
Number of mink[1], approval for the concerned year	27 360	11 920	49 087	32 499	51 365	61 635	33 099	119 926	-
Total number of mink with frequent removal of manure	27 360	39 280	88 367	120 866	172 231	233 866	266 965	386 891	-
Total number of breeding females, millions[2]	2.70	2.75	2.95	3.12	3.31	3.39	3.25	3.42	3.36
Percentage of production with frequent removal of manure	1.0	1.4	3.0	3.9	5.2	6.9	8.2	11.3	11.3

[1] Mink = breeding female.

[2] Production based on data from Danish Statistic.

[3] For 2018, no data is available. The percentage is maintained as year 2017.

Frequent removal of manure - NH_3 reducing potential

The Environmental Technologies List (MST, 2020) includes reduction factors for frequent removal of manure in mink housings, which are set to a 27 % NH_3 reduction.

Heat exchanging

Installation of heat exchanging in broiler housings have various positive effects; an economic cost saving for heat expense; quick drying of the bedding, which decreases the risk of NH_3 emission and better air quality in the housing, which is of benefit for both animals and humans.

Estimation of distribution of heat exchanging

Estimation of the use of heat exchanging in broiler housings is based on information from the largest distributor of heat exchanging system, which account for approximately 70 % of the marked (Rokkedahl Energy, 2019). DCE has received data for years 2012-2018. In addition to the information from the distributor, the estimation is also based on knowledge from subsidy schemes. Data is received from the Agency of Agriculture and Fisheries. The Danish farmers had the opportunity to apply for funding for activities, with replacing of old equipment to more modern technology, hereunder technology with ammonia reducing technology as heat exchanging, see Table 5.9. Based on the data from the subsidy schemes, it is possible to register the number of farms, which have received confirmation of subsidy and also information of the animal production at these farms.

Both information from the distributor and the subsidy schemes pointed out the same development for the prevalence of heat exchanger.

It is concluded that the information based on the Environmental Approval Register is not reliable in the case of heat exchanging. Data registered in the approvals shows a very limited use of heat exchanging and this underestimate is undoubtedly due to the main reason for installation of heat exchanging is reduction of operational cost. Therefore, an installation of heat exchanging is not necessarily an act that occurs in connection with an expansion of the animal production, and thus not releases an environmental approval.

Table 5.9 Subsidy schemes where subsidy for heat exchanging were possible.

Year	Subsidy schemes	Legislation
2015	Subsidy to investments in new green processes and technology in the main agriculture production	BEK No. 250 of 16 March 2015 (BEK, 2015a)
2014	Subsidy to investments in green processes and technology in the main agriculture production	BEK No. 897 of 21 July 2014 (BEK, 2014)
2013	Subsidy to investments in new green processes and technology in the main agriculture production	BEK No. 569 of 31 May 2013 (BEK, 2013)
2012/2011	Subsidy to projects with investments in new green processes and technology in the main agriculture production	BEK No. 744 of 28 June 2011 (BEK, 2011)
2010	Subsidy to projects with investments in new green processes and technology in the main agriculture production	BEK No. 502 of 11 May 2010 (BEK, 2010)

Based on the data from the main distributor of heat exchanger and the data regarding the subsidy schemes, it is concluded that use of heat exchanging in broiler housing takes place from year 2012. Converted to the percentage of the total production in Denmark, the percentage of broiler production in housing with heat exchanging is estimated to 24 % in 2012 increasing to 90 % in 2017, Table 5.10.

Table 5.10 Distribution of heat exchanging in broiler housings, 1000 animals

Number of produced broilers	2012	2013	2014	2015	2016	2017	2018
With acidification	27 026	57 445	77 658	95 223	99 837	106 493	110 271
Total number of produced broilers	112 459	117 341	115 997	114 738	121 185	118 102	122 768
Percentage of production	24	49	67	83	82	90	90

Heat exchanging - NH_3 reducing potential

In the Environmental Technologies List (MST, 2020) is given a NH_3 reduction factor at 30 % for Rokkedahl heat exchanger, which is a product developed by the main distributor. Information from one of the other distributors of heat exchanger – Big Dutchman – shows a reduction factor of 29 % (LUFA Nord-West, 2012, Big Dutchman, 2019), which mean nearly at the same level as for the Rokkedahl product. A reduction factor of 30 % for all housings with heat exchanging are used.

5.1.5 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 5.11 based on values in the report on normative standards (Poulsen et al., 2001, Kai et al. 2018a). In Appendix J is listed emission factor for housing for all other livestock categories.

Table 5.11 NH_3 emission factors for housing units for cattle, 2018.

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	-	13.5	-	-
	slatted floor and scrape	-	12	-	-
	solid floor	-	20	-	-
	drained floor	-	10.4	-	-
	solid floor with tilt and scrape	-	10.4	-	-
	solid floor with tilt	-	12	-	-
Deep litter	all	-	-	-	6
	+ solid floor	-	-	-	6
	+ slatted floor	-	13.5	-	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 5.12 and are based on normative figures (Poulsen et al., 2001 and Kai et al., 2018b), but adjusted for storage cover.

Table 5.12 NH_3 emission factors for storage units, 2018.

			Urine	Slurry[1]	Solid manure	Deep litter	% of solid manure stored in heap on field
Cattle		Total N*	2	2.0	4	1.1	35
		TAN**	2.2	3.4	-	-	-
Swine	Sows	Total N*	2	2.1	19	6.5	50
		TAN**	2.2	2.7	-	-	-
	Weaners	Total N*	2	2.1	19	9.8	-
		TAN**	2.2	2.7	-	-	-
	Fattening pigs	Total N*	2	2.1	19	9.8	75
		TAN**	2.2	2.7	-	-	-
Poultry	Hens and pullets	Total N*	-	2	7.5	4.8	95
	Broilers	Total N*	-	-	11.5	6.8	85
	Turkeys	Total N*	-	-	-	6.8	-
	Ducks and geese	Total N*	-	-	-	8	-
Fur animals		Total N*	0	1.9	11.5	-	-
		TAN**	0	2.7	-	-	-
Horses, sheep and goats		Total N*	-	-	-	-	3

[1]The emission factors were higher in the previous years (see Appendix K).
*Total N, kg NH3-N per kg N.
**TAN, kg NH3-N per kg TAN (Total Ammonia Nitrogen).

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 (Kai et al., 2018b).

By law, all slurry tanks have to be covered by a fixed cover or a full surface crust in order to reduce NH_3 emission. Birkmose, T. & Hørfarter, R. (2019)

have by a web based tool to machine learning estimated the amount of slurry tanks covered with tent cover in Denmark in 2018. Information about the amount of slurry tanks covered with concrete lid in 2018 is given from the supervisory body for slurry tanks (Anderson, 2019). A survey has been made to estimate the amount of slurry tanks with fixed cover in the years 1985-2018 (Mikkelsen & Albrektsen, 2019). For full surface crust, it can be difficult to establish a natural full surface crust every day all year especially for tank with pig slurry. In 2018, it is assumed that 5 % of the tanks with swine slurry and 2 % of tanks with cattle slurry and fur slurry are incompletely covered.

Emission factors for total N ex housing is based on normative figures (Poulsen et al., 2001), while for TAN is based on Hansen et al. (2008). The emission factor for swine slurry without cover, with surface crust and with fixed cover (tent/concreate) is 9 %, 2 % and 1 % of total-N ex housing and 11.4 %, 2.5 % and 1.3 % of TAN, respectively. For cattle and fur slurry see Appendix K. Calculation examples of NH_3-N emission factor based on TAN for swine, cattle and fur slurry are shown in Equation 5.4.

a) $Emission_{swine\ slurry} = (0.05 \cdot 11.4\%) + (0.71 \cdot 2.5\%) + (0.24 \cdot 1.3\%) = 2.7\ \%$ (Eq. 5.4a)

b) $Emission_{cattle\ slurry} = (0.02 \cdot 10.3\%) + (0.88 \cdot 3.4\%) + (0.10 \cdot 1.7\%) = 3.4\ \%$ (Eq. 5.4b)

c) $Emission_{fur\ slurry} = (0.02 \cdot 1294\%) + (0.69 \cdot 2.9\%) + (0.29 \cdot 1.4\%) = 2.7\ \%$ (Eq. 5.4c)

The emission factors for 2018 for swine (corrected), cattle (corrected) and fur animals are 2.7 %, 3.4 % and 2.7 %, respectively. Emission factors for storage of slurry for all years are shown in Appendix K.

Solid manure

The emission from solid manure is based on normative figures (Kai et al., 2018b). 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 (Kai et al., 2018b). The same correction is made for all animal categories.

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

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. It is assumed that the part of solid manure taken directly from the housing into the field is 65 % from cattle, 25 % from pigs, 50 % from sows, 15 % from broilers and 5 % from hens (Kai et al., 2018b) and this is taken into account. The remaining part of the solid manure is deposited in stockpiles in the field before field application, see Table 5.12.

Denitrification

Table 5.13 lists the emission factors for denitrification of solid manure and deep litter based on normative figures (Poulsen et al., 2001 and Kai et al., 2018b). 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 5.13 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, has to be injected directly into the soil. 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 5.14. 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 13.3 % in 2018, corresponding to a 60 % 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 5.14 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	2015	2016	2017	2018
Liquid manure	Cattle[1]	33.0	34.3	30.3	27.2	14.1	14.4	13.0	13.1	13.3	13.3
	Swine	17.3	17.9	15.3	13.8	11.1	11.1	10.7	10.7	10.7	10.7
Solid manure	Cattle[1]	9.6	7.9	7.5	6.8	6.7	6.4	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

[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_{wm} 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.

$$EF_{wi} = \sum MA_i \cdot EF_i \qquad \text{(Eq. 5.6)}$$

where:

EF_{wm} = weighted emission factor for the given application method, 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 and acidified in housing. Acidified slurry is only applied with the method trailing hoses.

$$\mathrm{EF_{wt}} = EF_{\mathrm{injection}} + (EF_{hoses} - (p_t \cdot (EF_{hoses} - EF_t)) + EF_{broad\ spread} \qquad \text{(Eq. 5.7)}$$

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* (acidification in housings, storage or during application)

$EF_{injection}$ = weighted emission factor for slurry applied with injection / direct incorporation, kg NH_3-N per kg N per year

EF_{hoses} = weighted emission factor for slurry applied with trailing hoses, kg NH_3-N per kg N per year

$EF_{broad\ spread}$ = weighted emission factor for slurry applied with broad spreading, kg NH_3-N per kg N per year

EF_t = emission factor for the technology *t*

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

- spring-winter (bare soil, crops, grass)
- spring-summer (grass)
- late summer-autumn (rape, seed grass)

Application method

- injection / direct incorporation
- trailing hoses
- broad spreading (prohibited for liquid manure from 2003)

Length of time between application to land and incorporation of manure

- 6 or 4 hours
- less than 12 hours
- more than 12 hours
- more than a week

Stage of crop growth

- bare soil
- 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 – 2018 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 5.15.

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 5.15 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).

For cattle, swine, sheep, goats and horses are used default emission factor from EMEP/EEA guidebook (EMEP, 2019). For deer are used same emission factor as for goats. Emission factor for poultry is based on Misselbrook et al. (2000). Poultry droppings is more solid than urine from swine and cattle and therefore the droppings is staying on the top of the soil instead of soaking in to the soil. Emission from outdoor poultry is therefore considered to be higher than (maybe twice) for swine (Jensen, H.B (pers. comm.), 2019, Hansen, M.N. (pers. comm.), 2019a). The emission factors are used for all years.

5.2 Inorganic N fertilisers

The amount of nitrogen (N) applied to soil by use of inorganic N fertiliser is estimated from sales estimates managed by the Danish Agricultural Agency. As part of the QA/QC procedure, the sale statistics is compared with the actually consumption registered in the Danish fertiliser N accounts controlled by The Danish Agricultural Agency, which indicate a difference for the years 2009-2016 and especially a significant difference for 2016 (Figure 5.3). The difference is caused by farmer's import of inorganic fertilisers, which is confirmed by the Danish Agricultural Agency. It is allowed for the farmer to import fertiliser, if the consumption is related to own fields, but not for onward sale. For the years 2009-2016, the comparison shows a higher consumption of fertilisers registered in the Danish fertiliser N accounts. The farmers have no interest in counting a low estimate, which indicates that the N applied registered in the Danish fertiliser N accounts is more reliable for the years 2009-2016. The Danish Agricultural Agency is aware of the situation with farmers import, and for year 2017, the sales statistics include more companies selling inorganic N fertiliser. For the years 1985-2008 and 2017, the use of inorganic N fertiliser is based on the sales statistics. No sales statistic is available for 2018 so the use of inorganic N fertiliser is based on the Danish fertiliser N accounts and the distribution on types of fertiliser is based on the distribution in 2017.

Emission factors are based on the values given in EMEP/EEA Guidebook (EMEP, 2019).

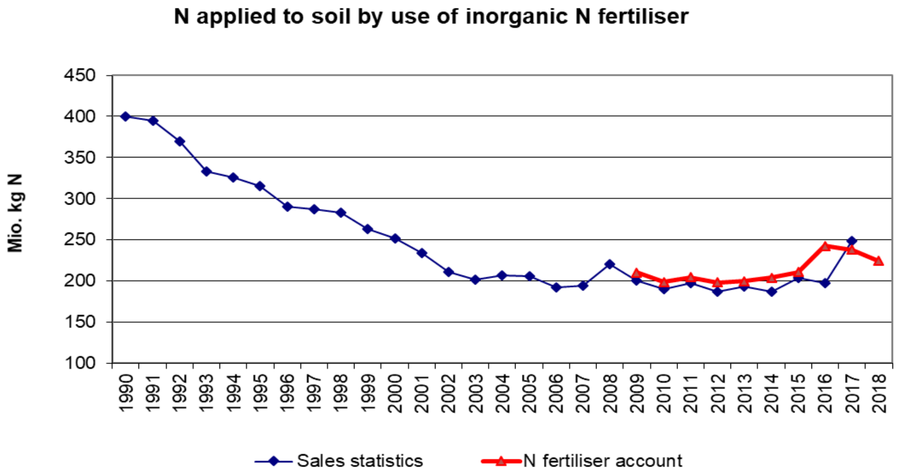

Figure 5.3 N applied from inorganic N fertiliser, sales statistic and N fertiliser account.

The emission from inorganic N fertilisers depends on type as well as amount used. Data for consumption 1985-2018 (Table 5.16) and fertiliser type and nitrogen content for 2018 (Table 5.17) is obtained from the DAA (2018), which is based on the total sale from all fertiliser suppliers.

Table 5.16 Inorganic N fertiliser consumption 1985 – 2018, kt N.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Used in agriculture[1]	398	400	316	251	206	199	211	243	249	224

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

Emission factors for the various fertiliser types are based on the recommendations in the EMEP/EEA Guidebook (EMEP, 2019), see Table 5.17. The same emission factors are applied for all years.

Table 5.17 Consumption and emission factors used for inorganic N fertiliser, 2018.

	Emission factor, % of N in fertiliser	Consumption, kt N
Fertiliser type:		
Calcium nitrate + boron	5.0	0.2
Ammonium sulphate	9.0	7.4
Calcium ammonium nitrate and other nitrate types	0.8	98.4
Ammonium nitrate	1.5	3.1
Liquid ammonia	1.9	5.4
Urea	15.5	0.9
Other single fertilisers	1.0	34.2
Magnesium fertiliser	5.0	0.0
NPK fertiliser	5.0	63.4
Diammonium phosphate (18-20-0)	5.0	2.9
Other NP fertilisers	5.0	7.1
NK fertilisers	1.5	1.3
Total consumption of fertiliser		224[1]
Emission factor - weighted average	2.6	

[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 5.16). This is mainly due to stricter requirements to the utilisation of nitrogen in manure and requirements to handling of manure applied to the soil. Furthermore, changes in the distribution of the different types of fertiliser has taken place and lead to a decreased 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 2.6 % of the total nitrogen used in inorganic N fertiliser is emitted as NH_3 in 2018.

Table 5.18 NH_3-N emission from inorganic N fertilisers and IEF (implied emission factor), 1985 – 2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
NH_3-N, tonnes	15 085	13 351	9 712	6 634	5 367	4 753	5 294	5 912	6 403	5 772
IEF, %	3.8	3.3	3.1	2.6	2.6	2.4	2.5	2.4	2.6	2.6

5.3 Growing 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 5.19 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 2018 the NH_3 emission from growing crops has decreased from approximately 4 900 to 4 500 tonnes of NH_3-N corresponding to a reduction of 9 %, which is due to a decrease in the area with crops.

5.4 Sewage sludge

Some of the sludge from wastewater treatment 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 (2016).

The N content varies from year to year and is usually 4–5 % of the total amount of sludge. The emission factor from EMEP/EEA Guidebook (EMEP, 2019) of 0.13 kg NH_3/kg N applied is used.

Table 5.20 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 5.20 Emission from sewage sludge applied to agricultural land 1985-2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Sewage sludge applied to agricultural soil, kt dry matter	50	78	112	84	57	76	85	84	85	85
N content, %.	4.0	4.0	4.1	4.3	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	2 710	3 622	4 038	3 990	4 053	4 053
NH_3-N emission, tonnes NH_3-N	214	334	496	388	290	388	432	427	434	434

5.5 Other organic fertiliser

Other organic fertiliser includes industrial waste, which is applied as fertiliser to agricultural soil. Information about amounts applied on agricultural soil and the content of nitrogen is obtained from a series of reports published by the Danish Environmental Protection Agency. 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. Farmers with more than 10 animal units[1] is required to indicate the consumption of nitrogen and registered the value to the N fertiliser account, which also is the case for imported or exported N. Amounts in 2002- 2004 are interpolated.

The emission factor from EMEP/EEA Guidebook (EMEP, 2019) of 0.08 kg NH_3/kg N applied is used.

Table 5.21 Activity data emission of NH_3–N from other organic fertiliser, 1985-2018.

		1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
N applied on soil	Tonnes N	1 500	1 529	4 445	5 147	2 359	3 401	4 455	4 914	5 099	4 788
Emission	Tonnes NH_3-N	99	101	293	339	155	224	294	324	336	315

[1] Basically, the Danish animal unit is defined as 100 kg N ex storage from an average housing system. This corresponds to e.g. 0.75 large breed dairy cattle or 39 fattening pigs.

5.6 Ammonia 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. Law banned the NH_3 treatment of straw 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 5.22 shows that since 1985 there have been a considerable decrease in the emission from NH_3 treated straw until the ban in 2006.

Table 5.22 Emission from NH_3 treated straw, 1985-2018, tonnes NH_3-N.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Consumption of NH_3-N	8 300	12 936	8 421	3 131	329	200	200	200	200	200
Emission of NH_3-N	5 395	8 408	5 474	2 035	214	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 inventory, 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 2018 and the emission shares for PM_{10} and $PM_{2.5}$ are 30 % and 8 %, respectively. Most agricultural emissions originate from field operations, contributing with 88 % 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 6.83 kt. Of this, 54 % relates to swine production. The emission from cattle and poultry contributed 19 % and 25 %, respectively.

Table 6.1 shows emission of PM from livestock production 1985 – 2018. 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, decreases from 2005 to 2015 and then increase again, 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, 1985-2018, kt.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
TSP	6.83	6.65	7.14	7.17	7.23	7.22	7.00	7.07	7.33	7.36
PM_{10}	2.48	2.38	2.54	2.61	2.56	2.55	2.41	2.44	2.50	2.51
$PM_{2.5}$	0.81	0.71	0.66	0.63	0.53	0.56	0.55	0.55	0.56	0.56

6.1.1 Calculation method

The estimation of the PM emission is based on the EMEP/EEA Guidebook (EMEP, 2019). The PM emission is calculated using equation 6.1 and thus distinguishes between emission from liquid and solid manure.

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

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 2018 is listed in Table 4.14.

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, 2019). 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	PM_{10}	$PM_{2.5}$
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 14 % from 1985 to 2018 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	2015	2016	2017	2018
TSP	6 772	6 839	6 250	6 238	5 415	5 665	5 490	5 467	6 053	5 795
PM_{10}	510	527	485	479	436	468	457	449	484	456
$PM_{2.5}$	67 720	68 392	62 496	62 382	54 146	56 655	54 903	54 667	60 532	57 952

6.2.1 Calculation method

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

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

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, 2019) 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 again in 2015-2018, 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[d]				
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, 2019) are used for NH_3, NO_x, CO, SO_2, NMVOC, PM, BC, heavy metals and dioxins. 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 1985-2018. 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.

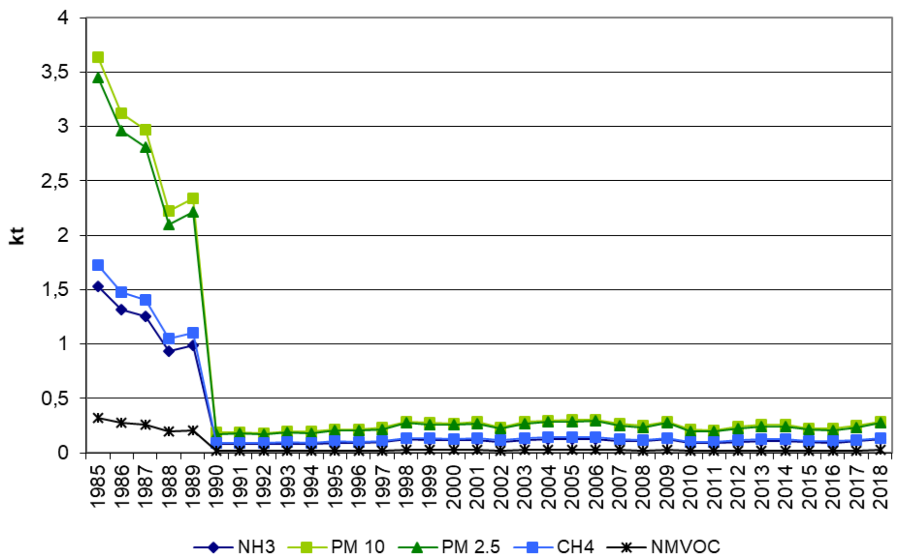

Figure 7.1 Trend of the emission of selected pollutants from field burning of agricultural residues.

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 (emission factors) and Table 7.3. EFs are the same for all years.

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

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

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
CF	= combustion factor

Table 7.1 Parameters for estimating emissions from field burning, 2018.

	Crop production	Fraction burned in fields	Dry matter fraction of residue[a]	Total biomass burned	Combustion factor[b]
	tonnes			kt DM	
Mixed cereals	4 045 400	0.001	0.85	3.44	0.90
Straw from seeds of grass	415 000	0.15	0.85	52.91	0.90

[a] SEGES (2005).
[b] EMEP (2019).

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 (Feidenhans'l, 2009, Pers. Comm.). 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 7.2 shows the emission factor used of all pollutants from field burning of agricultural residues and the emission for the year 2018.

Table 7.2 Emission factors and emissions for the different pollutants from field burning of agricultural residues, 2018.

Pollutant	EF	Unit for EF	Emission 2018	Unit for emission
NH_3	2.4	g per kg DM	0.12	kt
CH_4	2.7	g per kg DM	0.14	kt
N_2O	0.07	g per kg DM	0.004	kt
NO_x	2.3	g per kg DM	0.12	kt
CO	66.7	g per kg DM	3.38	kt
CO_2	1.515	kg per kg DM	76.83	kt
SO_2	0.5	g per kg DM	0.03	kt
NMVOC	0.5	g per kg DM	0.03	kt
PM				
TSP	5.8	g per kg DM	0.29	kt
PM_{10}	5.7	g per kg DM	0.29	kt
$PM_{2.5}$	5.4	g per kg DM	0.27	kt
BC	0.5	g per kg DM	0.03	kt
Metals				
Pb	0.11	mg per kg DM	0.01	t
Cd	0.88	mg per kg DM	0.045	t
Hg	0.14	mg per kg DM	0.0071	t
As	0.0064	mg per kg DM	0.000	t
Cr	0.08	mg per kg DM	0.00	t
Ni	0.052	mg per kg DM	0.00	t
Se	0.02	mg per kg DM	0.001	t
Zn	0.56	mg per kg DM	0.028	t
Cu	0.073	mg per kg DM	0.00370	t
Dioxins	500	ng TEQ per t	0.03	g/TEQ
PAHs				
Benzo(a)pyrene	0.41	mg per kg DM	0.02	t
Benzo(b)fluoranthene	1.14	mg per kg DM	0.06	t
Benzo(k)fluoranthene	0.48	mg per kg DM	0.02	t
Indeno(1,2,3-cd)pyrene	0.67	mg per kg DM	0.03	t
HCB - mixed cereals[1]	0.003	g per t		
HCB - grass seed[1]	0.002	g per t		
HCB			0.12	kg
PCBs - mixed cereals	3	□g TEQ per t		
PCBs - grass seed	0.05	□g TEQ per t		
PCBs			0.00001	kg

[1] See Chapter 7.1.4 for conversion of EF from the unit ha to g per t.

References: EMEP (2019), 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 7.3 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 1990-2018. The emission has decreased significantly from 1990 to 2018 due to decrease in use of pesticides containing HCB.

Table 8.1 Emission of HBC, 1990-2018, kg.

	1990	1995	2000	2005	2010	2015	2016	2017	2018
Pesticides	4.29	3.37	0.34	0.01	0.06	0.04	0.06	0.18	0.18

8.1 Calculation method

The emission is calculated using following equation:

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

Where:

E_{pes} = emission of HCB from pesticides, kg
a_i = amount of effectual substance in the pesticide *i*, kg
EF_i = emission factor for the pesticide *i*, g per tonne

8.2 Activity data

A range of pesticides are used in Denmark. In the period from 1990 to 2018 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, 1990-2018, kg (EPA, 2019).

	1990	1995	2000	2005	2010	2015	2016	2017	2018
Atrazine	91.294	-	-	-	-	-	-	-	-
Chlorothalonil	10.512	10.980	7.340	-	-	-	-	-	-
Clopyralid	16.461	22.587	7.446	5.874	9.122	10.229	11.829	11.049	11.049
Lindane	8.356	-	-	-	-	-	-	-	-
Pichloram	-	-	-	-	723	328	549	3.114	3.114
Simazine	30.234	19.865	23.620	-	-	-	-	-	-

8.3 Emission factors

Emission factors given in EMEP/EEA Guidebook (EMEP, 2019) are used in the calculation of the emissions, see Table 8.3.

Table 8.3 Emission factors for HCB from pesticides, 1990-2018, g per tonnes.

	1990	1995	2000	2005-2018
Atrazine	2.5	-	-	-
Chlorothalonil	300	300	40	-
Clopyralid	2.5	2.5	2.5	2.5
Lindane	100	-	-	-
Pichloram	-	-	-	50
Simazine	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 46 % of the national NMVOC emission in 2018 and is mainly related to emission from animal manure, which accounts for 96 % in 2018.

9.1 Manure management

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

9.1.1 Emission

The trend in NMVOC emission from 1985 to 2019 shows a decrease from 78 kt to 53 kt with the highest fall in the beginning of the period (Figure 9.1). Back in 1985, 84 % of the emission originates from the cattle production, which is decreased to 72 % in 2018. 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. From 2016 to 2018, a small increase of NMVOC from cattle is taken place. 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 2018.

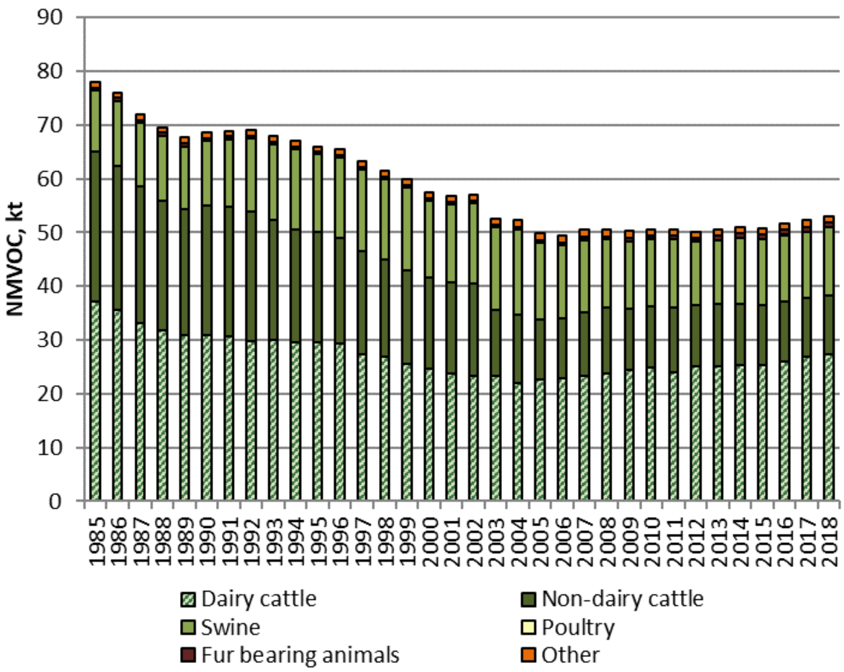

Figure 9.1 Emission of NMVOC from manure management, 1985-2018.

9.1.2 Calculation method

The estimation of NMVOC emissions is based on the EMEP/EEA guidebook (EMEP, 2019). 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.

The calculation of NMVOC emissions is based on the Tier 2 approach. The number of animals is given as the average annual population (AAP).

$$E_{NMVOC} = AAP_i \cdot (E_{NMVOC,silage_{store}} + E_{NMVOC,silage_{feeding}} + E_{NMVOC,house} + E_{NMVOC,manure\_store} + E_{NMVOC,appl} + E_{NMVOC,graz}) \quad \text{(Eq. 9.1)}$$

Where:

E_{NMVOC} = emission of NMVOC, kg
AAP_i = number of animals given in average annual population for the animal category i
$E_{NMVOC,silage\_store}$ = emission of NMVOC from silage storage, kg
$E_{NMVOC,silage\_feeding}$ = emission of NMVOC from silage feeding, kg
$E_{NMVOC,house}$ = emission of NMVOC from housing, kg
$E_{NMVOC,manure\_store}$ = emission of NMVOC from manure storage, kg
$E_{NMVOC,appl}$ = emission of NMVOC from manure application, kg
$E_{NMVOC,graz}$ = emission of NMVOC from grazing, kg

$$E_{NMVOC,silage\_store} = Z \cdot x_{house} \cdot (EF_{NMVOC,silage_{feeding}} \cdot Frac_{silage}) \cdot Frac_{silage\_store} \quad \text{(Eq. 9.2)}$$

$$E_{NMVOC,silage_{feeding}} = Z \cdot x_{house} \cdot \left(EF_{NMVOC,silage_{feeding}} \cdot Frac_{silage}\right) \quad \text{(Eq. 9.3)}$$

$$E_{NMVOC,house} = Z \cdot x_{house} \cdot EF_{NMOVC,house} \quad \text{(Eq. 9.4)}$$

$$E_{NMVOC,manure\_store} = E_{NMVOC,house} \cdot \left(\frac{E_{NH3,storage}}{E_{NH3,house}}\right) \quad \text{(Eq. 9.5)}$$

$$E_{NMVOC,appl} = E_{NMVOC,house} \cdot \left(\frac{E_{NH3,appl}}{E_{NH3,house}}\right) \quad \text{(Eq. 9.6)}$$

$$E_{NMVOC,graz} = Z \cdot (1 - x_{house}) \cdot EF_{NMVOC,graz} \quad \text{(Eq. 9.7)}$$

Where:

Z = for cattle; gross feed intake, MJ. For other animal categories; VS (volatile solids) excreted, kg VS per year
X_{house} = proportion of the year the animals are housed
$Frac_{silage}$ = fraction of silage in the feed composition
$Frac_{silage\_store}$ = proposition of emission from silage storage, 0.25
$EF_{NMVOC,silage\_feeding}$ = emission factor for silage feeding, for cattle, kg NMVOC per MJ, for other animals, kg NMVOC per kg VS
$EF_{NMVOC,house}$ = emission factor for housing, for cattle, kg NMVOC per MJ, for other animals, kg NMVOC per kg VS
$EF_{NMVOC,graz}$ = emission factor for grazing, for cattle, kg NMVOC per MJ, for other animals, kg NMVOC per kg VS
$E_{NH3,house}$ = NH_3 emission from housing, kg NH_3-N
$E_{NH3,storage}$ = NH_3 emission from storage, kg NH_3-N
$E_{NH3,appl}$ = NH_3 emission from application, kg NH_3-N

9.1.3 Activity data

The activity data for the NMVOC emission from manure management is number of animals, see Chapter 4, gross feed intake for cattle and VS excretion for other animal categories, see Chapter 11.

9.1.4 Emission factor

NMVOC emission factors recommended in EMEP/EEA Guidebook (EMEP, 2019), Table 3-11 and 3-12 is used (Table 9.1). All emissions are entered in NFR category 3B, while the notation key IE is used for NFR category 3Da2a and 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/proportion of the year the animals are housed.

Table 9.1 NMVOC emission factors (EMEP (2019), Tier 2).

	EF			Frac	
	Silage feeding	Housing	Grazing	Silage	Silage stored
Dairy Cattle	0.0002	0.0000353	0.0000069	1	0.25
Non-Dairy Cattle	0.0002	0.0000353	0.0000069	1	0.25
Sheep	0.01076	0.001614	0.00002349	0.5	0.25
Swine – sows	0	0.007042	0	0	0.25
Swine – other	0	0.001703	0	0	0.25
Goats	0.01076	0.001614	0.00002349	0.5	0.25
Horses	0.010760	0.001614	0.00002349	0.5	0.25
Laying hens	0	0.005684	0	0	0.25
Broilers	0	0.009147	0	0	0.25
Turkeys	0	0.005684	0	0	0.25
Other poultry	0	0.005684	0	0	0.25
Fur bearing animals	0	0.005684	0	0	0.25

[1] Unit: Cattle: kg NMVOC per MJ, other animal categories: kg NMVOC per kg VS.

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, 2019). The calculation of the NMVOC emission from growing crops is based on emission factors recommended in EMEP/EEA Guidebook (EMEP, 2019).

9.2.1 Emission

The NMVOC emission from cultivated crops is estimated to 2.10 kt in 2018 based on an IEF (implied emission factor) at 0.80 and a cultivated area of 1 118 905 hectares. The IEF varies annually from 0.51 - 0.80 kg NMVOC per hectare (Table 9.2) depending on the allocation of wheat, rye, rape and grass. 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	2015	2016	2017	2018
Total cultivated area, 1000 ha	2 834	2 788	2 726	2 647	2 707	2 646	2 633	2 625	2 634	2 632
IEF, kg per ha	0.66	0.71	0.58	0.56	0.53	0.57	0.80	0.67	0.79	0.80
Emission, kt	1.87	1.99	1.57	1.48	1.42	1.51	2.11	1.75	2.07	2.10

9.2.2 Calculation method

In Table 3-3 in EMEP/EEA Guidebook (EMEP, 2019) 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 9.8 and Table 9.3 for factors:

$$E_{NMVOC} = A \cdot IEF \qquad \text{(Eq. 9.8)}$$

Where:

E_{NMVOC} = emission of NMVOC from agricultural soils, kg (1)
A = total cultivated area, ha (see Table 9.2)
IEF = implied emission factor, kg per ha (2) (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.

$$IEF = \frac{\sum E_i}{\sum ha_i} \qquad \text{(Eq. 9.9)}$$

Where:

IEF = implied emission factor, kg per ha (2)
E_i = emission for the crop *i*, kg (3)
ha_i = area of the crop *i*, ha (4)

$$E_i = EF_i \cdot \text{hours pr day} \cdot \text{days pr year} \cdot Frac_i \cdot DM_i \cdot ha_i \qquad \text{(Eq.9.10)}$$

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* (6)
DM_i = mean dry matter for crop *i*, kg DM per ha (7)
ha_i = area for crop *i*, ha (4)

Table 9.3 Estimation of NMVOC emission factor, 2018.

2015	EF_i [5] (EMEP)	$Frac_i$ [6]	DM_i [7]	Cultivated area[4]	NMVOC emission[3]	IEF[2] – Tier 2 DK
Crop	Kg NMVOC/ kg DM/year		kg DM/ha	ha	Kg/ha/year	kg NMVOC/ha
Wheat	2.60E-08	0.3	7 157	406 774	198 540	
Rye	1.41E-07	0.3	5 602	89 981	186 568	
Rape	2.02E-07	0.3	3 929	145 347	302 572	
Grass land*	1.03E-08	0.5	9 432	476 803	202 894	
Total				1 118 905	890 574[1]	0.80

*Grass land 15 °C.

[1-7] see Eq. 9.8-9.10.

10 NO_x

Emission of NO_x, given in NO_2, 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, sewage sludge and other organic fertiliser (industrial waste). Agriculture accounts for 17 % of the total NO_2 emission in 2018 and the main part occurs from animal manure applied to soil and inorganic N fertiliser.

10.1 Manure management

NO_2 emission from manure management relates to the emissions from housings and account for around 1 % of the agricultural emission of NO_2.

10.1.1 Emission

The NO_2 emission from 1985 to 2018 decreased significantly from 0.6 kt NO_2 to 0.2 kt NO_2 corresponding to a 56 % 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 2018.

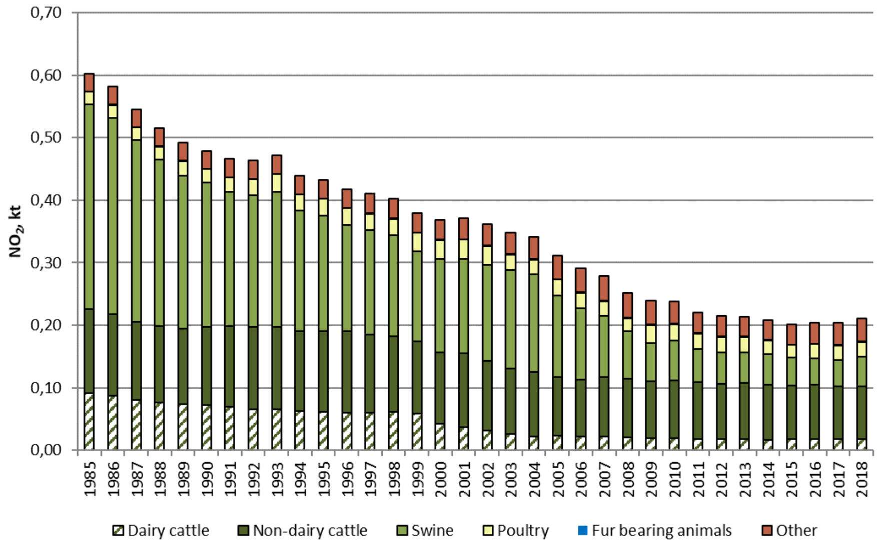

Figure 10.1 NO_2 emission from manure management 1985–2018.

10.1.2 Calculation method

The estimation of NO_2 emission is based on the EMEP/EEA guidebook (EMEP, 2016) Tier 1 and is based on number of animals given as the average annual population (AAP).

$$E_{NO_2} = AAP_i \cdot EF_i \qquad \text{(Eq. 10.1)}$$

Where:

E_{NO2} = emission of NO_2, 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_2 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_2 emission factors (EMEP, 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	0.202
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		0.006
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_2 from manure applied on soils, inorganic N fertiliser, sewage sludge and other organic fertiliser (industrial waste) is estimated and accounts for 49 %, 48 %, 1 % and 1 %, respectively, of the agricultural emission of NO_2.

10.2.1 Emission

The main part of the NO_2 emission from agricultural soils comes from manure applied to soil and use of inorganic N fertiliser. The emission has decreased from 1985 to 2018 by 28 % mainly due to decrease in use of inorganic N fertiliser.

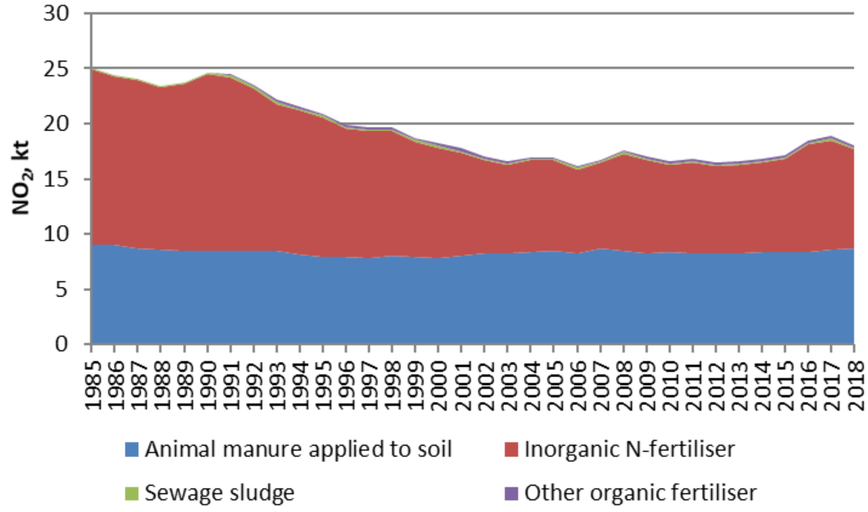

Figure 10.2 NO_2 emission from agricultural soils, 1985-2018.

10.2.2 Calculation method

The emission of NO_x 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 (EMEP, 2019), 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 78 % of the total CH_4 emission in 2018. 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 2018, 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 2018, the emission from enteric fermentation has overall decreased by 7 %, 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 12.8 million in 2018, but this increase is only of minor importance for the total CH_4 emission from enteric fermentation. The emission was 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 % (DSt, 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}) 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:

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

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

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

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

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

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 confirm 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 – 2018, % of gross energy.

Dairy cattle	1990	1991	1995	2000	2002-2018
$Y_{m\ incl.\ beet}$	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 2018

An overview of the most important variables and the implied emission factor (IEF) for 2018 is shown in Table 11.3. 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], 2018.

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	8 082[c]	18.90[d]	18.90	5	6.0	164.69
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 < 6.6 kg	1 472	17.49	17.49	-	0.6	2.75
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	30.00	18.83	100	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	239	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, 2018.

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, 6.6-31 kg	46	16.46	16.46	-	0.6	0.08
Fattening pigs, > 31 kg	226	17.25	17.25	-	0.6	0.43
	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 2018 is estimated to 151 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 2018	Share of total
	kt CH_4	%
Cattle:		
Dairy cattle	92.41	61.32
Heifer calves, < ½ year	3.57	2.37
Heifer, ½ year to calving	25.43	16.87
Bull, calves < ½ year	1.54	1.02
Bulls, ½ year to slaughter	2.76	1.83
Suckling cows	5.77	3.83
Swine:		
Sows incl. piglets < 6.6 kg	2.88	1.91
Weaners, 6.6-31 kg	2.70	1.79
Fattening pigs, > 31 kg	8.17	5.42
Poultry:		
Hens	0.06	0.042
Broilers	0.0016	0.001
Other poultry	0.0004	0.000
Other:		
Horses	3.82	2.53
Sheep	1.04	0.69
Lamps	0.33	0.22
Goats (incl. kids)	0.14	0.09
Deer	0.09	0.06
Mink incl. young	0	0
Total	150.69	100

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 Kai et al. (2018a) and Lund (2019).

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 20 % from 1985 to 2018 and this is from both the cattle and swine production. The emission from swine increased from 1985 to 2004 and decreased subsequently until 2018. 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 2018, 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).

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

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

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

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

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, %

[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.

The ash content in straw is set to 4.5 % (SEGES, 2005). Dry matter content in manure is based on the normative data (Lund, 2019). 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 Lund (2019).

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.

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

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.

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

Table 11.5 Methane conversion factor (MCF) for 2018, %.

Livestock category	Manure type	MCF
Cattle	Slurry	12.4
	Slurry - biogas treated	7.48
	Deep litter > 1 month	17
	Deep litter < 1 month	3
	Solid	2
	Pasture/Range/Paddock	1
Swine	Slurry	13.37
	Slurry - biogas treated	10.38
	Deep bedding weaners	7.2
	Deep bedding fattening	11.4
	Deep bedding sows	14.67
	Solid	3
Fur bearing animals	Slurry	10.14
	Deep litter	3
	Solid	2
Poultry	All types	1.5
	Pasture/Range/Paddock	1
Horses, sheep and goats	Deep litter	1
	Pasture/Range/Paddock	1
Ostich	Solid	2
	Pasture/Range/Paddock	1
Pheasant and deer	Pasture/Range/Paddock	1

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 covered with a fixed cover or have established a surface crust. However, it is difficult to achieve full surface crust 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 surface crust 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 (IPCC, 2006). 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 2018

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[c], 2018.

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	48.39
Heifer calves, < ½ year	0	0.18	2.45
Heifer, ½ year to calving	132 (111)	0.18	14.68
Suckling cows, > 600 kg	224	0.18	22.48
Swine:			
Sows incl. piglets < 7.1 kg	0	0.45	11.80
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	0.45

[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).

Table 11.7b Conversion factors to determine the CH_4 emission from animal manure handling, values per produced animal, 2018.

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	19.24
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	2.46
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.

The total CH_4 emission from manure management 2018 is estimated to 89 kt CH_4 and the main emission originates from the production of dairy cattle and 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 2018	Share of total
	kt CH_4	%
Cattle		
Dairy cattle	27.94	31.5
Heifer calves, < ½ year	0.39	0.4
Heifer, ½ year to calving	6.68	7.5
Bull, calves < ½ year	0.49	0.5
Bulls, ½ year to slaughter	4.38	4.9
Suckling cows	1.87	2.1
Swine:		
Sows, incl. piglets < 6.6 kg	12.34	13.9
Weaners, 6.6-31 kg	7.14	8.0
Fattening pigs, > 31 kg	24.95	28.1
Poultry:		
Hens	0.24	0.3
Broilers	0.30	0.3
Other poultry	0.03	0.03
Other:		
Horses	0.48	0.5
Sheep	0.03	0.0
Lambs	0.01	0.0
Goats (incl. kids)	0.005	0.0
Deer	0.002	0.0
Mink incl. young	1.50	1.7
Total	88.77	

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. 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 include in the inventory, because the anaerobic digested slurry produces lower CH_4 emission from storage and from applied slurry on cultivated soils.

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 a MCF at 10 % for covered and a 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.

The result of the national MCF estimated will first 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 is 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 is also taken into account. The approach use 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 85 % is left on the farms as untreated raw liquid manure and currently (in 2018) 15 % 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. Table 11.9 compares the national MCF values based on IPCC to the new national estimated values.

Table 11.9 Methane conversion factor (MCF) values based on IPCC and from national estimates.

MCF, %	IPCC[a]	2018 Liquid system	2018 Anaerobic digesters
Untreated cattle slurry	10.14	12.40	
Untreated swine slurry	10.35	13.37	
Biogas treated cattle slurry	10.14		7.48
Biogas treated swine slurry	10.35		10.38

[a] Weighted average for covered (MCF 10 %) and uncovered (MCF 17 %) slurry (IPCC, 2006).

The national estimated MCF for untreated swine- and cattle 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 – 2018 for the national estimated MCF for cattle and swine slurry both digested and not digested. The national estimated MCF for not digested slurry for cattle is changing slightly over time, from 12.00 in 1990 and 12.40 in 2018. The MCF for not digested slurry for swine is reduced from 15.25 in 1990 to 13.37 in 2018 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 non-digested cattle slurry in 2018 is estimated to 12.40 % and the MCF for digested cattle slurry is 7.48 %, which corresponds to a 40 % reduction of CH_4 emission. The MCF for not digested swine slurry in 2018 is estimated to 13.37 % and the MCF for digested swine slurry to 10.38 %, which corresponds to a 23 % 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 2018, %.

	1990	1995	2000	2005	2010	2015	2016	2017	2018
Cattle									
MCF for digested cattle slurry	6.49	6.45	7.34	7.33	7.60	7.85	7.53	7.50	7.48
MCF for undigested cattle slurry	12.00	11.89	12.70	12.55	12.56	12.59	12.53	12.49	12.40
Swine									
MCF for digested swine slurry	12.08	11.90	11.60	10.87	11.08	10.98	10.51	10.34	10.38
MCF for undigested swine slurry	15.25	15.11	14.86	14.03	13.93	13.67	13.57	13.42	13.37

11.3.3 Estimation of slurry treated in biogas plants in Denmark

In Denmark, the biogas plants are divided in 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 2018, the Energy Statistics estimated the total energy production based on biogas to 13 414 TJ (DEA, 2019a), and out of this, the manure based biogas plants account for 91 % produced at approximately 33 large-scale plants and 59 farm-level plants. The Energy Statistic provides data annually and thus data from all years 1990 – 2018 is available.

Table 11.11 Biogas production, 2018 (DEA, 2019a).

Facility type	Biogas production, TJ	%
Wastewater treatment	1002	7
Industrial	169	1
Large-scale and farm-scale*	6 666	91
Total	13 414	100

*Include Landfill, which only accounts for approximately 200 TJ (less than 2 % of total biogas production).

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.

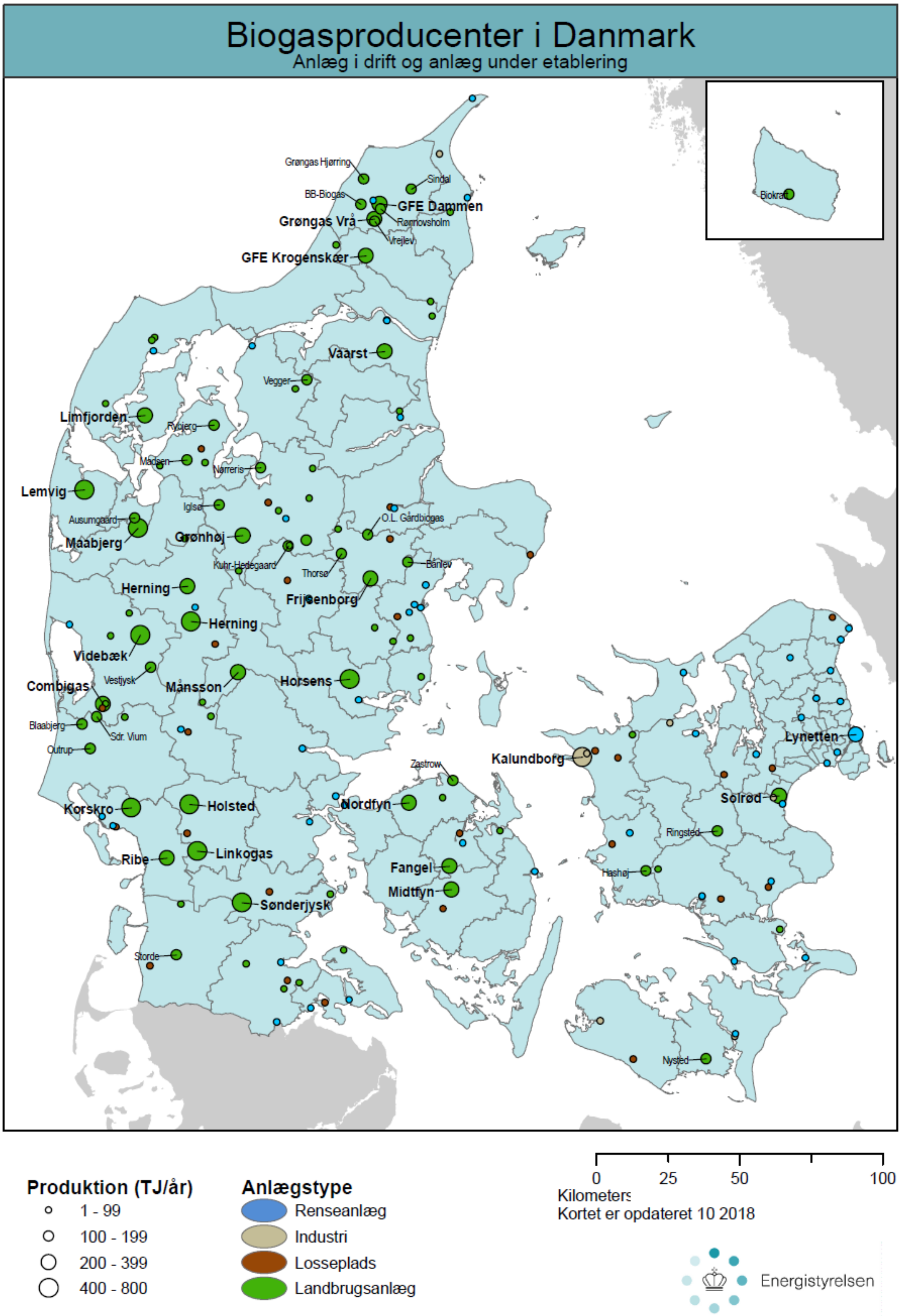

Figure 11.1 Biogas producers in Denmark, 2018 (DEA, 2018c). WWT – waste water treatment.

For year 2015-2018, data for the actual amount and different types of biomass delivered to the biogas plants is available. Data is collected by the Danish Energy Agency (DEA, 2019b), based on reporting from each biogas plant and covers data from all the biggest biogas plants. In the following, these data are referenced as the BIB-register; Biomass Input to Biogas production. The BIB register does not fully cover all biogas plants, but the most important biogas producers, and thus it covers 80-90 % of the total biogas production.

Data regarding the amount of slurry delivered to biogas plants is available for the years 2001, 2015, 2016, 2017 and 2018. Data for year 2001 is based on a single investigation provided by the DEA – the Danish Energy Agency, while the data for year 2015-2018 is based on the BIB – register. For the intervening years, 1990-1999 and 2002-2014, the data for amount of slurry delivered to the biogas production is based on an interpolation, by using the relation between the amount of slurry delivered and the total energy production produced at the biogas plants. The total energy production from biogas plants for all years is based on the Energy Statistics (DEA, 2019a).

In 1990, the biogas production at the large-scale, farm-level and industrial biogas plants is 266 TJ, which correspond to slurry input of 220 kt, increasing to 12 244 TJ and 5 739 kt slurry in 2018.

In 2018, around 15 % of total amount of slurry is delivered to biogas production, 21 % of the total amount of cattle slurry and 11 % for swine slurry.

Table 11.12 Biogas production, 1990-2018.

	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018
Biogas production, TJ[1]											
Total	752	1758	2912	3830	4337	4588	5561	6285	9048	11053	13414
Large-scale, farm-level and industrial biogas plants	266	746	1442	2375	3184	3434	4359	5199	7795	9882	12244
Slurry delivered to biogas plants, kt[2]											
Cattle, swine and mixed	220	617	1192	1779	2076	2038	2503	2884	4142	5263	5739
Percent of total produced slurry	1	2	4	5	6	5	7	8	11	14	15

[1]DEA, 2019a.
[2]DEA, 2019b.

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.

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

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

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, kg 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.

CH_4 emission from manure is estimated on the basis of VS and VS can be divided in VS degradable (VS_d) and VS non-degradable[3] (VS_{nd}). The measured CH_4 emission (Petersen et al., 2016) is measured on manure samples taken inside the barns and thus reflect the emission from both VS_d and VS_{nd}, assuming that the measured CH_4 reflect the average VS_d and VS_{nd} composition in manure. Hence, for CH_4 emissions from barns is used the total amount of VS neglecting short-term changes in the amount of VS_d inside the barn. For manure stored for a longer period, the 'fast' degradation of VS_d has a large impact on the overall emission and it is necessary to distinguish between VS_d and VS_{nd}. So for stored manure the model calculation for VS is divided into VS_d and VS_{nd}.

Emission of CH_4 from barns

$$\mathrm{E}_{d+nd,barns} = \mathrm{VS}_{d+nd,barns} \cdot \mathrm{EF}_{d+nd,barns} \cdot \mathrm{HRT}/365 \qquad \text{(Eq. 11.15)}$$

Where:

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

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

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 (VSnd).

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

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

$$E_{Storage,digested} = VS_{storage,digested} \cdot EF_{storage,digested} \quad \text{(Eq. 11.17)}$$

Where:

$E_{storage,\ digested}$	= emission of CH_4 from storage of digested slurry, kg CH_4
$VS_{storage,\ digested}$	= amount of volatile solids in the slurry digested, see Table 11.14, kg VS
$EF_{storage,\ digested}$	= emission factor for CH_4 for VS, see Table 11.13, g CH_4 per kg VS per year

Table 11.13 Estimated emission factors.

Cattle	
EF_{barns}, g CH_4 per kg VS per year	179.79
$EFd_{storage,\ not\ digested}$, g CH_4 per kg VSd per year	28.08
$EFnd_{storage,\ not\ digested}$, g CH_4 per kg VSnd per year	0.51
$EF_{storage,\ digested}$, g CH_4 per kg VS per year	1.76
Swine	
EF_{barns}, g CH_4 per kg VS per year	563.22
$EFd_{storage,\ not\ digested}$, g CH_4 per kg VSd per year	29.58
$EFnd_{storage,\ not\ digested}$, g CH_4 per kg VSnd per year	0.56
$EF_{storage,\ digested}$, g CH_4 per kg VS per year	1.76

In Table 11.14a-c is shown the estimated CH_4 emission from liquid cattle and swine slurry for the years 1990-2018. 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 10.32 kt CH_4 increasing to 13.69 kt CH_4 in 2018. 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 10.29 kt CH_4 in 1990 and decreased to 9.64 kt CH_4 in 2018. To this comes a small amount from digested manure.

For swine slurry has the total emission inside the barns in 1990 been estimated to 18.71 kt CH_4 in 1990 increasing to 26.37 kt CH_4 in 2018, due to a growing swine production until 2011. To this comes an emission from outdoor storage. This has been estimated to 6.51 kt CH_4 in 1990 and an increase to 10.68 kt CH_4 in 2018. 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	2015	2016	2017	2018
Barns									
Slurry, tonnes VS per year	1 140 939	1 044 346	1 014 726	1 160 046	1 204 501	1 281 868	1 305 683	1 321 646	1 342 416
EF, g CH_4 per kg VS per year	179.79	179.79	179.79	179.79	179.79	179.79	179.79	179.79	179.79
Average HRT, days	18.36	18.48	21.47	21.25	21.17	21.21	21.07	20.97	20.70
EF, g CH_4 per kg VS per year	9.04	9.10	10.58	10.47	10.43	10.44	10.38	10.33	10.20
Emission, kt CH_4 per year	10.32	9.51	10.73	12.14	12.56	13.39	13.55	13.65	13.69
Storage, not digested									
Slurry, not digested, tonnes VSd ab barn	352 702	315 688	293 571	327 969	339 836	356 196	345 984	331 472	330 611
Slurry, not digested, tonnes VSnd ab barn	755 765	676 715	635 045	708 967	734 449	769 883	747 513	715 923	713 487
EF, g CH_4 per kg VSd per year	28.08	28.08	28.08	28.08	28.08	28.08	28.08	28.08	28.08
EF, g CH_4 per kg VSnd per year	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Emission, kt CH_4 per year	10.29	9.21	8.56	9.57	9.91	10.39	10.09	9.67	9.64

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

Swine	1990	1995	2000	2005	2010	2015	2016	2017	2018
Barns									
Slurry, tonnes VS per year	549 494	720 278	819 274	944 522	950 766	930 091	922 126	920 921	950 925
EF, g CH_4 per kg VS per year	563.22	563.22	563.22	563.22	563.22	563.22	563.22	563.22	563.22
Average HRT, days	22.06	21.76	21.22	19.41	19.19	18.62	18.42	18.08	17.97
EF, g CH_4 per kg VS per year	34.04	33.58	32.75	29.95	29.62	28.74	28.42	27.90	27.73
Emission, kt CH_4 per year	18.71	24.19	26.83	28.29	28.16	26.73	26.21	25.69	26.37
Storage, not digested									
Slurry, not digested, tonnes VSd ab barn	215 034	280 411	317 300	371 345	372 827	361 046	348 648	343 780	353 321
Slurry, not digested, tonnes VSnd ab barn	266 669	346 385	389 186	444 931	445 491	428 311	412 520	405 037	415 700
EF, g CH_4 per kg VSd per year	29.58	29.58	29.58	29.58	29.58	29.58	29.58	29.58	29.58
EF, g CH_4 per kg VSnd per year	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Emission, kt CH_4 per year	6.51	8.49	9.60	11.23	11.28	10.92	10.54	10.40	10.68

Table 11.14c Emission estimates for digested biomass.

Digested biomass	1990	1995	2000	2005	2010	2015	2016	2017	2018
VS, tonnes	10 697	29 950	57 893	108 744	168 171	262 836	286 129	359 253	428 335
EF, g CH_4 per kg VS per year	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76
Emission, kt CH_4 per year	0.02	0.05	0.10	0.19	0.30	0.46	0.50	0.63	0.75

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 20 samples of different types of liquid swine manure and 11 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

Parameters for Arrhenius function

For the CH_4 calculation, a model based on VS quantity and degradability and temperature was used (Sommer et al., 2004). The parameters for Arrhenius function is based on Petersen et al. (2016), Elsgaard et al. (2016) and Maldaner et al. (2018). Equation 11.18 shows the calculation of CH_4 emission form slurry F(T), VSd and $VSnd$ are the proportions of degradable and "non-degradable" VS. The $\ln A$ is the pre-exponential factor (≈ methane production potential) and Ea the activation energy of methanogenesis, while R is the universal gas constant and T is the absolute temperature.

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

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

Where:

F(T)	= the methane production rate, g CH_4 per day
VSd	= the proportions of degradable volatile solids, kg
VSnd	= the proportions of non-degradable volatile solids, kg
b1 and b2	= scaling factors, 1 for VSd and 0.01 for VSnd (dimension-less)
lnA	= the pre-exponential factor (≈ methane production potential), g CH_4 per kg VS_d per h or g CH_4 per kg VS per h (digestate)
Ea	= the activation energy of methanogenesis, J per mol
R	= the gas constant, 8.314 J per mol per K
T	= temperature, K
24	= conversion from hour to day

Ea: An activation energy, Ea, of 81 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).

Ln*A*: The parameter ln*A* reflects a potential for CH_4 production that is influenced by the chemical and biological characteristics of the slurry, which in Petersen et al. (2016) is derived for 20 samples of swine slurry and 11 samples cattle slurry. In average, the observed ln*A* was 31.3 and 31.2 g CH_4 kg-1 VS h-1 for pig and cattle slurry, respectively.

VS – volatile solid: 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.

VSd and VSnd: 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 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 20 swine slurry samples and 11 dairy cattle slurry samples and estimated the VSd. For swine manure they found an average VSd of 51 % (95 % Confidence Interval: 44 – 57 %) and for slurry for dairy cattle a VSd of 33 % (95 % Confidence Interval: 29 – 37 %).

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 %. Møller (2016) has measured the B_0-value of the digestate from the continuous biogasplants to 13.8 m3 CH_4 per kg VS indicating that the major part of the digestate is non-degradeable. Based on the model, which take storage time and temperature into account, the emission factor for $VS_{digested}$ were estimated to 1.76 g CH_4 per kg VS per year.

Table 11.15 shows the parameters used.

Table 11.15 CH_4 emission estimate parameters. Petersen et al. (2016) combined with Elsgaard et al. (2016) and Maldaner et al. (2018).

	Ea, kJ per mol	Ln(A), g CH_4 per kg VS per hour	VSd, %	VSnd, %
Liquid cattle manure	81.0	31.2	33	67
Liquid swine manure	81.0	31.3	51	49
Digestate	81.0	27.9	100	0

Degradation function

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 named 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 1990s 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 2018, days.

	1990	1995	2000	2005	2010	2015	2016	2017	2018
Cattle	18.36	18.48	21.47	21.25	21.17	21.21	21.07	20.97	20.70
Swine	22.06	21.76	21.22	19.41	19.19	18.62	18.42	18.08	17.97

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 11.2). 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.

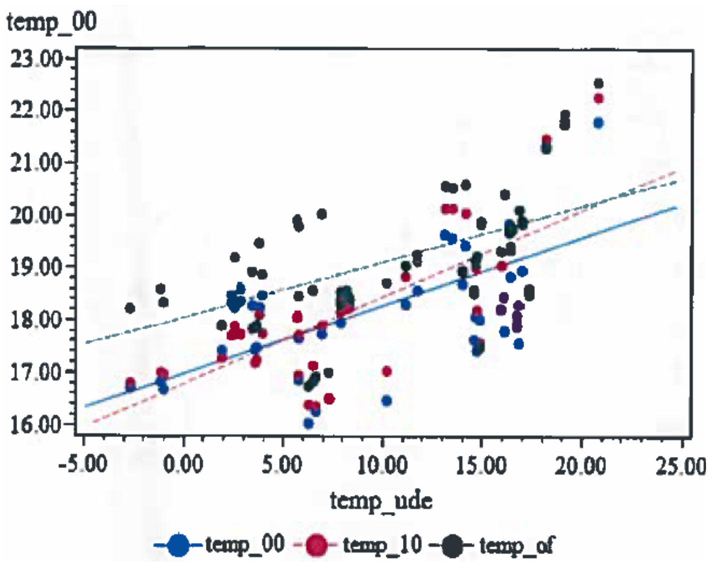

Figure 11.2 Measured slurry temperature in fattening pig slurry channel in different times during the production cycle. The different colours indicate different slurry heights in the slurry channel (Holm, 2015, Pers. Comm.).

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. The manure temperature inside the slurry channels do not follow the air temperature closely (Andersen and Grønkjær, 2020). In 2017 and 2018 temperature, measurements were carried out in one cattle barn in the Southern Denmark and one in the Northern Denmark with logging 2-5 times per day. As Denmark is quite small, these data were combined and converted to a sine-wave representing whole Denmark (Figure 11-3).

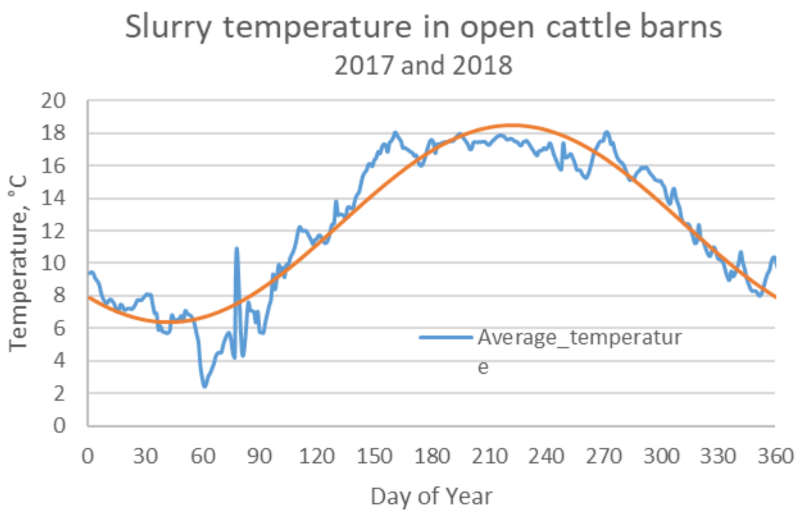

Figure 11.3 Average daily measured slurry temperature in two cattle barns in 2017 and 2018 (Andersen and Grønkjær, 2020).

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

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

R^2 = 0.92

Parameter	Value	Std Error	t-value	95% confidence limits	
a	12.45	0.087	142.64	12.28	12.62
b	6.04	0.098	61.55	5.84	6.23
c	3.97	0.046	86.73	3.89	4.07
d	360.08	4.209	85.55	351.80	368.35

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).

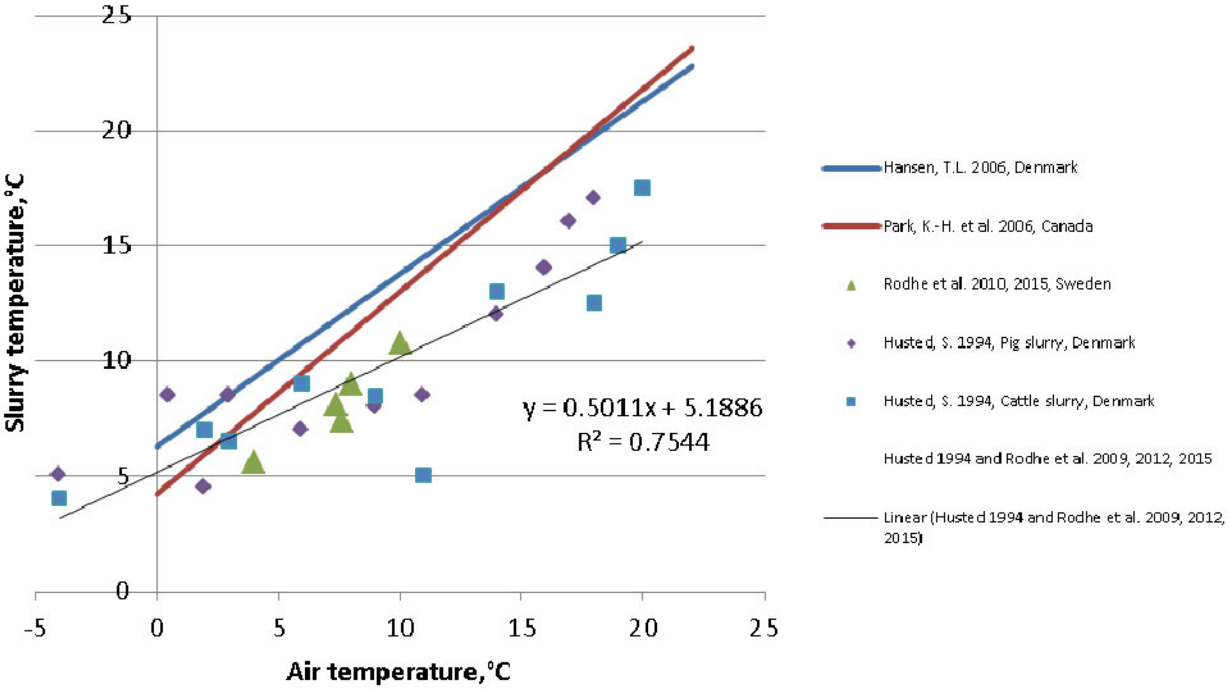

Figure 11.4 Measured and modelled slurry temperatures in outdoor storage tanks.

Manure storage and application to fields

The Ministry of Food, Agriculture and Fisheries 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, 2015b).

It 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 1 February 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.

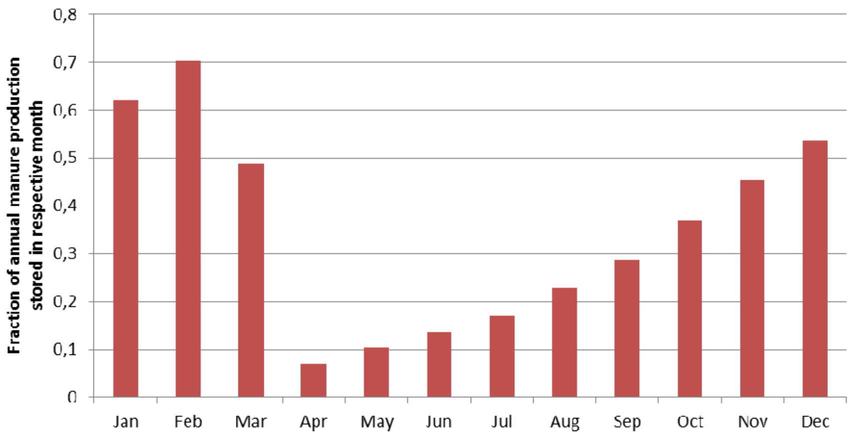

Figure 11.5 The fraction of animal manure stored during different month of the year. The fraction is the share of the total annual manure production corrected for grazing. Small amounts are applied to grass during summer giving a lower increase in the summer months than in the winter period.

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 563.22 g CH_4 per kg VS per year, corresponding to 1.54 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 1.54 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 179.79 g CH_4 per kg VS per year given in Table 3D-26 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 not digested 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 0.51 g CH_4 per kg and for swine slurry the estimation gives 0.56 g CH_4 per kg VS (Table 3D-26).

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 not digested 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 not digested slurry (Dong, 2013, Pers. Comm.).

12 N_2O emission

The agricultural N_2O emissions accounts for 89 % of the total N_2O emission in 2018. 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.

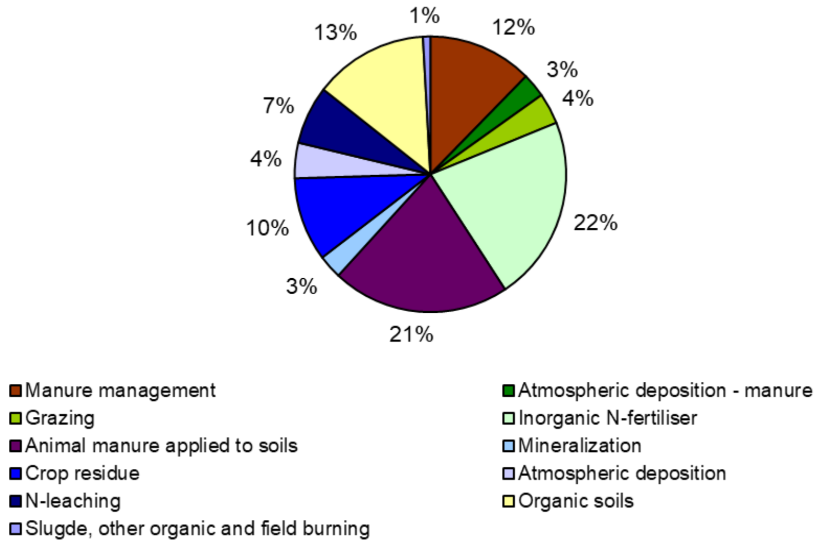

Figure 12.1 Distribution of the N_2O emission in 2018 on sources.

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 2018 of which only 0.5 is related to the indirect emission. The overall emission has decreased with 0.8 kt N2O from 1985 – 2018 corresponding to 25 %. 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 farmers economic benefit of increased feed efficiency and due to environmental requirements.

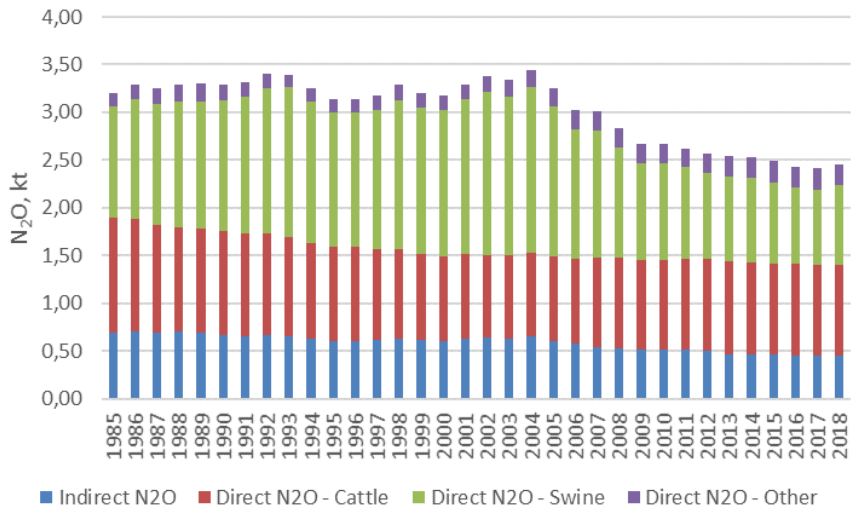

Figure 12.2 N_2O direct and indirect emission from manure management, 1985-2018.

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; Lund, 2019). Under the anaerobic conditions in slurry and urine, the emission of N_2O is considered to be relatively low, while the emission from deep litter systems and solid manure in the housing units is higher. The 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 per kg N ex
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 N_2O, 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)	N_2O emission factor (IPCC default value)
	Kg NH_3-N per kg N	kg N_2O -N per kg N
Inorganic N fertilisers	0.02	0.01[1]
Animal manure applied to soils	0.19*	0.01[1]
Sewage sludge applied to soils	0.02	0.01[1]
Other organic fertilisers applied to soils		0.01[1]
Urine and dung deposited by grazing animals	0.05-0.35[3]	0.01-0.02[1]
Crop residues		0.01[1]
Mineralization/immobilization associated with loss/gain of soil organic matter		0.01[1]
Cultivation of organic soils		0.8-13**[2]

*Varies from year to year, has decreased from 0.28 in 1990.
**Unit: kg N_2O-N per ha.
[1] IPCC (2006).
[2] IPCC (2014).
[3] EMEP (2019).

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 (2018) and the Danish fertiliser N accounts. The consumption of each fertiliser type is shown in Chapter 5, Table 5.17.

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 decreased from 1985 to 2018 (Table 12.3).

Table 12.3 Nitrogen applied as fertiliser to agricultural soils 1985 – 2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
N content in inorganic N fertiliser, kt N	398	400	316	251	206	199	211	243	249	224
N_2O emission, kt N_2O	6,26	6,29	4,96	3,95	3,24	3,13	3,31	3,81	3,91	3,52

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 (Lund, 2019). The total N excretion in housings from 1985 to 2018 has decreased by 11 %, due to improvement of feed efficiency and change in housing systems.

Table 12.4 Nitrogen applied as manure to agricultural soils 1985 – 2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
N-excretion, housing, kt N	274	258	239	235	251	239	235	236	240	243
N in manure applied on soil, kt N	225	212	197	195	212	208	209	210	214	217
N_2O emission, kt N_2O	3.54	3.33	3.10	3.06	3.33	3.27	3.28	3.30	3.36	3.41

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 – 2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Nitrogen in sewage sludge, t N	2 000	3 115	4 635	3 625	2 710	3 622	4 038	3 990	4 053	4 053
N_2O emission, kt N_2O	0.03	0.05	0.07	0.06	0.04	0.06	0.06	0.06	0.06	0.06

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 – 2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Nitrogen in industrial waste, t N	1 500	1 529	4 445	5 147	2 359	3 401	4 455	4 914	5 099	4 788
N_2O emission, kt N_2O	0.02	0.02	0.07	0.08	0.04	0.05	0.07	0.08	0.08	0.08

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 2018, due to a fall in grazing days for the large dairy cattle farms.

Table 12.7 Nitrogen excreted on grass 1985 – 2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
N excretion, grass, kt N	37	34	35	34	26	22	21	21	21	21
N_2O emission, kt	1.09	1.00	1.05	1.01	0.73	0.61	0.59	0.60	0.59	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 IPCC 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.

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

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

$$N_{crop\ residue} = N_{Above\ ground} + N_{Below\ ground} \quad \text{(Eq. 12.5)}$$

Where:

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

$$N_{Above\ ground} = area_i \cdot \left(\left(\left(harvest_i \cdot DRY_i / Frac_{renev,i} / area_i\right) \cdot slope_i + intercept_i\right) \cdot N_{AG,i}\right) \quad \text{(Eq. 12.6)}$$

Where:

$N_{Above\ ground}$	= 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
$Frac_{renev}$	= 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)
N_{AG}	= N content of above ground residue, kg N per kg DM

$$N_{below\ ground} = area_i \cdot \left(\left(harvest_i \cdot DRY_i / Frac_{renev,i} / area_i\right) \cdot R_{BG-BIO} \cdot N_{BG}\right) \quad \text{(Eq. 12.7)}$$

Where:

$N_{Below\ ground}$	= 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
$Frac_{renev}$	= fraction of total area of crop type i that is renewed annually
R_{BG-BIO}	= ratio of below-ground residues to above-ground biomas, kg DM per kg DM
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 (SEGES, 2005), 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 101 million kg N in 2018, which is mainly a result of a lower amount of harvest straw.

Table 12.8 N content in crop residue, million kg N, 1985-2018.

	1986	1990	1995	2000	2005	2010	2015	2016	2017	2018
Total N in crop residue	120.0	145.8	132.5	134.1	140.2	149.9	155.1	150.3	161.7	117.4
N in harvested straw	30.0	24.2	20.1	17.4	14.6	14.8	13.6	13.9	15.7	16.3
N in crop residue	89.9	121.6	112.4	116.7	125.6	135.1	141.5	136.4	146.0	101.1

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 and 2018 the spring and summer was extremely dry, which lower the yield.

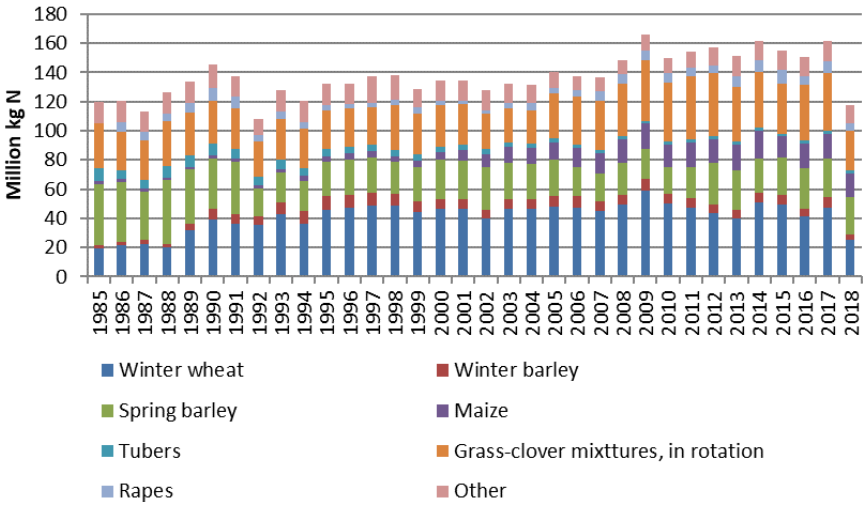

Figure 12.3 Total N in crop residue, 1985 – 2018.

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 Resilient Organic Matter (ROM) 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 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.

C-TOOL is subdivided into 44 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. A C:N-ratio of 10, which is common in the fertilised Danish agricultural soils are used for all soil types. 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.

N_2O emissions from cultivation of organic soils are based on the area of organic soils of cropland, grassland and areas with no field identification, which are defined as grassland, shallow drained, nutrient-rich areas according to the 2013 Wetlands Supplement (IPCC, 2014). These areas are subdivided in areas with >12 % of soil organic carbon (SOC) and 6-12 % SOC. The Danish definition of organic soils are >10 % organic matter equivalent to app. 6 % SOC. It was defined in 1975 (Madsen et al., 1992). Agricultural soils in use under Danish conditions will normally have a carbon content of 1.5-3 % SOC (Taghizadeh-Toosi et al., 2014). This is the equilibrium state with a degradation condition and crop residue input. Drained land under agricultural use will therefore evidently approach a C content of 1.5-3 %. It is therefore assumed that the 6-12 % SOC soils will have losses of CO_2, N_2O and CH_4. Almost all measurements in the literature is performed on soils having >12 % OC. The areas with >12 % of SOC are multiplied by the default emission factor from Table 2.5 of the 2013 Wetland Supplement, IPCC (2014), which for >12 % SOC is 13 kg per ha cropland, 8.2 kg per ha deep-drained, nutrient-rich grassland and 1.6 kg per ha shallow-drained, nutrient-rich grassland. It has not been able to find any solid documentation for areas with 6-12 % SOC, so it is chosen to use 50 % of the values for soils having >12 % SOC, i.e. 6.5, 4.1 and 0.8 kg per ha, respectively.

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

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 3.01 kt N_2O in 1985 to 2.19 kt N_2O in 2018, which is due to the decrease in the cultivated area with organic soils.

Table 12.9 Area and N_2O emission for organic soils, 1985-2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Cropland, >12 % SOC	70 918	67 025	63 131	59 237	55 343	51 449	49 026	47 527	45 970	44 999
Grassland, >12 % SOC	35 552	33 600	31 647	29 695	27 743	25 791	24 188	25 392	27 058	27 838
SN grassland*, >12 % SOC	0	0	0	0	0	0	1 440	2 881	4 424	5 395
Cropland, 6-12 % SOC	91 857	89 076	86 296	83 515	80 734	77 954	75 550	74 467	73 330	72 364
Grassland, 6-12 % SOC	25 855	25 072	24 289	23 507	22 724	21 941	21 073	21 872	22 975	23 493
SN grassland*, 6-12 % SOC	0	0	0	0	0	0	1 511	2 562	3 680	4 645
N_2O, kt	3.01	2.87	2.74	2.60	2.46	2.32	2.23	2.21	2.20	2.19

*SN grassland - shallow drained, nutrient-rich grassland.

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 and other organic matter 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, sewage sludge and other organic matter fertiliser.

The emission is calculated as illustrated in Equation 12.9 - 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.

$$N_2O_{dep} = \left(\left(NH_3\text{-}N_i + NO_x\text{-}N_j\right) \cdot EF\right) \cdot \frac{44}{28} \qquad \text{(Eq. 12.9)}$$

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 and other organic matter 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 2018 the N_2O emission has decreased from 1.25 kt N_2O to 0.67 kt N_2O, which equates to a fall of 46 %. 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 – 2018.

Emission per year	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
NH_3 emission, kt NH_3-N	63.4	60.7	48.3	38.6	31.0	30.0	29.6	30.5	31.3	31.0
NO_x emission, kt NO_x-N	16.3	16.1	13.6	11.9	11.0	10.8	11.2	12.0	12.3	11.7
N_2O emission, kt N_2O	1.25	1.21	0.97	0.79	0.66	0.64	0.64	0.67	0.69	0.67
CO_2 emission, M t CO_2 eqv.	0.37	0.36	0.29	0.24	0.20	0.19	0.19	0.20	0.20	0.20

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 12.10:

$$N_2O_{leaching} = \left(N_{leach\text{-}ground} \cdot EF_{ground} + N_{leach\text{-}rivers} \cdot EF_{rivers} + N_{leach\text{-}estuatires} \cdot EF_{estuatires}\right) \cdot \frac{44}{28} \quad \text{(Eq. 12.10)}$$

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, rivers and estuaries 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 2003-2011 to be from 149-174 thousand tonnes N, whereas the N-LES model has estimated the total N leached to be from 161-170 thousand tonnes in the same period. An average of the results from the two models is used in the emission inventories. From 2012 to 2017, data from N-LES is used. For 2018 no model estimations are available therefore are the N leaching from ground water based on an average for 2015-2017.

Data concerning the N leaching to rivers and estuaries are based on data from NOVANA (National Monitoring program of the Water Environment and Nature) received from the Department of Bioscience, Aarhus University (Windorf et al., 2011, Windorf, 2013, Thodsen, 2019). NOVANA is a monitoring program, which includes monitoring of the ecologic, physic and chemical condition of water areas and transport of water and a range of substances, including N, to lakes and the sea (Wiberg-Larsen et al., 2010). These studies include measurements from 223 monitoring stations in all parts of Denmark and they have been carried out since the early 1990s.

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 1.1 kt N_2O in 2018, or 329 kt CO_2 eqv. in 2018.

Table 12.11 Leaching of nitrogen and associated emissions, 1985 - 2018.

	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
N $leaching_{groundwater}$, kt N	304	267	235	179	162	167	153	164	157	153
N $leaching_{rivers}$, kt N	128	102	104	95	67	68	94	80	76	74
N $leaching_{estuaries}$, kt N	120	100	91	81	56	55	77	62	64	54
N_2O, kt	2,17	1,84	1,69	1,39	1,12	1,14	1,27	1,20	1,17	1,11
CO_2 eqv.,Mio. t	0,65	0,55	0,50	0,42	0,33	0,34	0,38	0,36	0,35	0,33

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, other organic fertiliser (industrial waste), 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 24 % in 2017. For 2018 is used an N leaching fraction at 25 % based on an average for the years 2015-2017 due to lack of data.

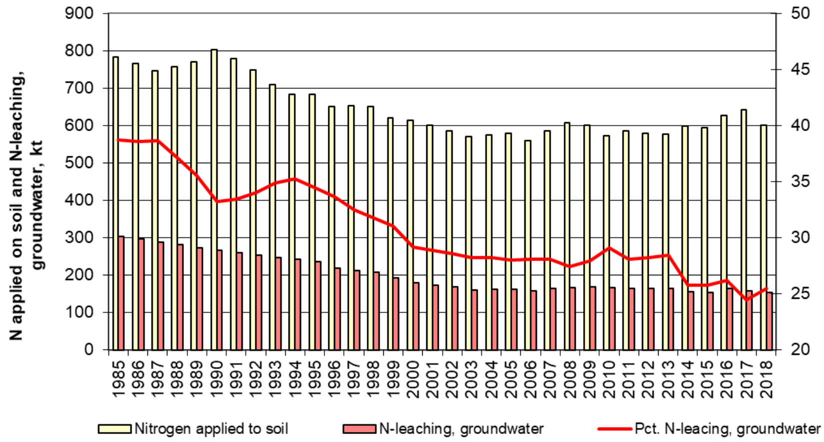

Figure 12.4 Leaching of nitrogen from 1985 to 2018.

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.

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

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 (Hansen, 2019b). 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 2018. 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 66 % from 1985 to 2018. As shown in Figure 13.1, the main decrease is occurring from 1985 to 1997 and is due to a change in fertiliser practice with increase in use of manure as fertiliser and decrease in use of inorganic N fertiliser. When ammonium nitrogen (inorganic N) is used as fertiliser and a loss of nitrogen from the soil is occurring, it causes an acidification of the soil and use of liming could be necessary to even out pH in the soil (Knudsen, 2004).

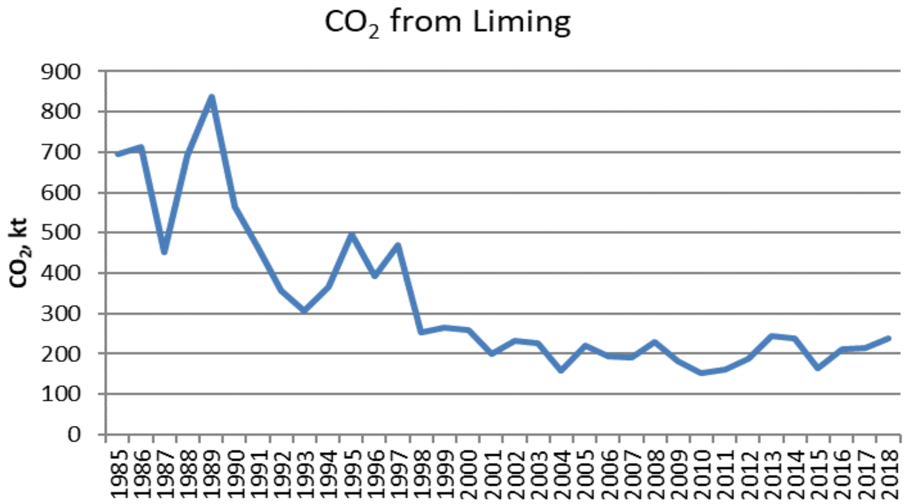

Figure 13.1 CO_2 emission from liming, 1985 to 2018.

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.

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

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, 2018). For 2018, no sales statistic is available and the amount of urea is based on N from the Danish fertiliser accounts combined with the distribution of fertiliser types in 2017. The default emission factor of 0.20 t C per t urea given in IPCC 2006 is used.

Figure 13.2 shows the emission of CO_2 from use of urea. The emission has decreased with 87 % from 1985 to 2018, but the main decrease is occurring from 1990 to 2002. From 2003 to 2018, the emission is almost unaltered. The decrease is due to a decrease in the use of urea.

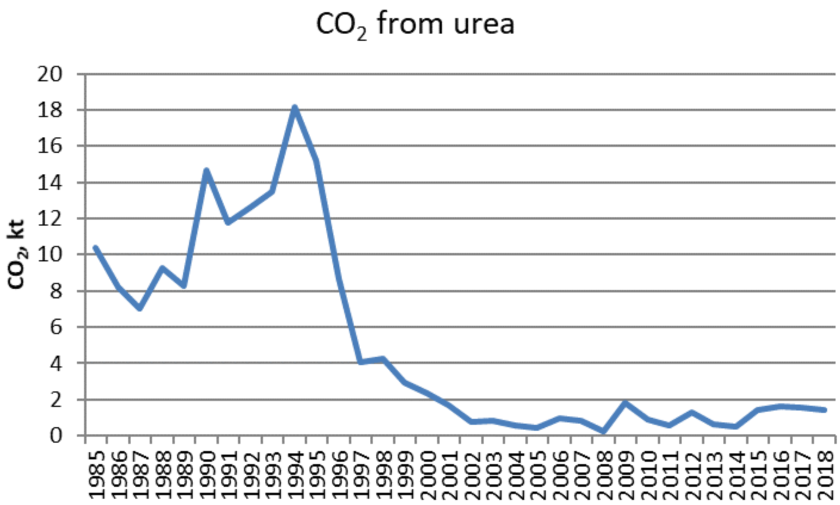

Figure 13.2 Emission of CO_2 from use of urea, 1985 to 2018.

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.

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

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, 2018). For 2018, no sales statistic is available and the amount of CAN is based on N from the Danish fertiliser accounts combined with the distribution of fertiliser types in 2017.

The emission factor is 0.026 kg CO_2 per kg CAN and the same for all years 1985 to 2018. It is based on the molecular weight:

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

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

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 89 % from 1985 to 2018, but the main decrease is occurring from 1989 to 1999. The decrease is due to decrease in the use of CAN. From

2000 to 2014 and 2016-2018 the emission is almost unaltered but an increase is seen in 2015 due to an increase in the use of CAN.

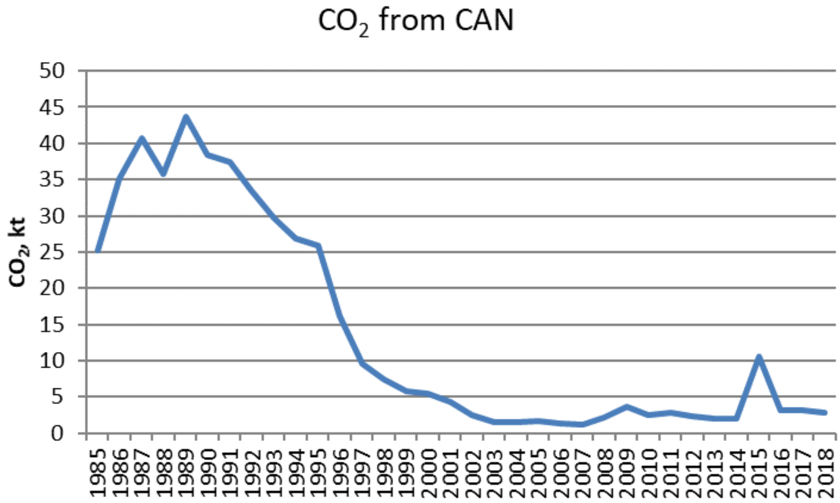

Figure 13.3 Emission of CO_2 from use of CAN, 1985 to 2018.

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 a lot of parameters are compared across countries and also compared to the IPCC default. Additionally Denmark has carried out a project of verification, where the emissions from key categories in the Danish 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.

The first version of this report (Mikkelsen et al., 2006) was reviewed by Statistics Sweden, who is responsible for the Swedish agricultural inventory. 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 third updated rapport (Albrektsen et al., 2017) was reviewed by senior scientist Peter Lund, Department of animal science, Aarhus University, with a specific focus on Chapter 11. The current report is reviewed by Anders Peter Adamsen, senior scientist at the Department of Engineering, Aarhus University.

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** - check of data input in IDA are consistent with data from external data suppliers
Stage II	**Check of IDA data – overall** - check of recalculations for total emissions compared with the latest submission - check of total emissions for the total CO_2 eqv. and for each compound
Stage III	**Check of IDA data – specific** - 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** - the total N ex for all livestock production estimated by DCA - 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** - compare data in CRF or NFR with data from IDA
Stage VI	**Check of the inventories in general (external review)** - check that data is used correctly - 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 have 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 Danish Agricultural Agency: distribution of housing systems and the use of nitrogen in inorganic N fertiliser is checked.

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 1985-2018 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, this is compared with the estimated values in the emission inventory (Nielsen et al., 2020).

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 have to 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 2013, 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, 2019). 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 (DAA). 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 (Lund, 2019) uncertainty values are indicated for emission measurements in housing and varies from 15 -25 %, but there is 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. (2018a and 2018b) 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 estimate 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 EMEP/EEA 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 EMEP/EEA 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, 2019) 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.Da2c	NH_3	Other organic fertiliser	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.Da2c	NO_x	Other organic fertiliser	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, 2018.

Pollutant	NFR category	Emission	Activity data, %	Emission factor, %	Combined uncertainty	Total uncertainty, %
NH_3, kt	3B Manure management	35.13	5	25	25	16
	3Da1 Inorganic N-fertilizers	7.01	3	25	25	
	3Da2a Animal manure applied	20.55	15	25	29	
	3Da2b Sewage sludge	0.53	15	50	52	
	3Da2c Other organic fertiliser	0.38	15	50	52	
	3Da3 Grazing animals	3.42	5	25	25	
	3De Cultivated crops	5.44	2	50	50	
	3F Field burning	0.12	25	50	56	
	3I Agriculture other	0.16	20	50	54	
TSP, kt	3B Manure management	7.36	7	300	300	267
	3Dc Agricultural operations	57.95	10	300	300	
	3F Field burning	0.29	25	50	56	
PM_{10}, kt	3B Manure management	2.51	7	300	300	221
	3Dc Aagricultural operations	5.80	10	300	300	
	3F Field burning	0.29	25	50	56	
$PM_{2,5}$, kt	3B Manure management	0.56	7	300	300	168
	3Dc Agricultural operations	0.46	10	300	300	
	3F Field burning	0.27	25	50	56	
NMVOC, kt	3B Manure management	53.01	2	300	300	289
	3De Cultivated crops	2.10	5	500	500	
	3F Field burning	0.03	25	100	103	
NO_x, kt	3B Manure management	0.21	5	100	100	273
	3Da1 Inorganic N fertilisers	8.97	3	400	400	
	3Da2a Animal manure applied	8.68	15	400	400	
	3Da2b Sewage sludge	0.16	15	400	400	
	3Da2c Other organic fertiliser	0.19	15	400	400	
	3F Field burning	0.12	25	25	35	
HCB, kg	3Df Use of pesticides	0.18	5	500	500	361
	3F Field burning	0.12	25	500	501	
PCB, kg	3F Field burning	0.00	25	500	501	501
SO_2, kt	3F Field burning	0.03	25	100	103	103
BC, kt	3F Field burning	0.03	25	100	103	103
CO, kt	3F Field burning	3.38	25	100	103	103
Pb, t	3F Field burning	0.006	25	50	56	56
Cd, t	3F Field burning	0.04	25	100	103	103
Hg, t	3F Field burning	0.01	25	200	202	202
As, t	3F Field burning	0.0003	25	100	103	103
Cr, t	3F Field burning	0.004	25	200	202	202
Cu, t	3F Field burning	0.004	25	200	202	202
Ni, t	3F Field burning	0.003	25	200	202	202
Se, t	3F Field burning	0.001	25	100	103	103
Zn, t	3F Field burning	0.03	25	200	202	202
Dioxin, g I-Teq	3F Field burning	0.03	25	500	501	501
(a)*, t	3F Field burning	0.02	25	500	501	501
(b)*, t	3F Field burning	0.06	25	500	501	501
(k)*, t	3F Field burning	0.02	25	500	501	501
(1,2,3 cd)*, t	3F Field burning	0.03	25	500	501	501

*(a) - Benzo(a)pyrene, (b) - Benzo(b)fluoranthen, (k) - Benzo(k)fluoranthen, (1,2,3 cd) - Indeno(1,2,3 cd)pyrene.

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 and feeding consumption, number of animals 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 very uncertain emission inventories.

Table 15.3 Variables and uncertainty values, GHG.

CRF code	Compound	Source	Activity data uncertainty	Emission factor uncertainty
3.A	CH_4	Enteric fermentation	2 %	20 % (IPCC, 2006 p 10.33)
3.B	CH_4	Manure management	5 %	20 %
3.B	N_2O	Manure management	25 %	100 % (IPCC 2006, Table 10.21)
3.B5	N_2O	Atmospheric deposition	16 %	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.Da2c	N_2O	Other organic fertiliser	20 %	100 %
3.Da3	N_2O	Manure applied during grassing	10 %	100 %
3.Da4	N_2O	Crop residue	25 %	100 %
3.Da4	N_2O	Mineralization	50 %	100 %
3.Da6	N_2O	Histosols	20 %	100 %
3.Db1	N_2O	Atmospheric deposition	16 % (2018)	100 %
3.Db2	N_2O	Leaching	20 %	100 %
3.F	N_2O	Field burning	25 %	50 %
3.F	CH_4	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 2018, 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 Uncertainty calculation, 2018.

		Emission, kt CO_2 eqv.	Uncertainty, % Lower and upper (±)
3 Agriculture total		11 042	19
3A Enteric fermentation	CH_4	3 767	20
3B Manure management		2 952	26
	CH_4	2 219	21
	N_2O	597	103
3B5 Indirect emission	N_2O	136	101
3D Agricultural Soils		4 073	41
3Da Direct soil emissions		3 543	48
3Da1 Inorganic N fertiliser	N_2O	1 050	100
3Da2a Animal manure applied to soils	N_2O	1 016	103
3Da2b Sewage sludge applied to soils	N_2O	19	101
3Da2c Other organic fertiliser applied to soils	N_2O	22	102
3Da3 Urine and dung deposited by grazing animals	N_2O	175	100
3Da4 Crop Residues	N_2O	473	103
3Da5 Mineralisation	N_2O	135	112
3Da6 Cultivation of organic soils	N_2O	652	102
3Db Indirect soil emissions		530	74
3Db1 Atmospheric deposition	N_2O	200	101
3Db2 Leaching	N_2O	329	102
3F Field burning of Agricultural residues		4	45
	CH_4	3	56
	N_2O	1	56
3G Liming	CO_2	240	100
3H Urea application	CO_2	2	100
3I Other carbon containing fertilisers	CO_2	3	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 1985–2018, 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. 250 (Albrektsen et al., 2017).

16.1 Agricultural emissions from 1985 to 2018

In 2018, the agricultural sector contributes 95 % of the total NH_3 emission, while the agricultural part of the greenhouse gases are estimated to 23 %. The agricultural emissions is primarily related to the livestock production.

The NH_3 emission has decreased from 130 kt NH_3 in 1985 and 73 kt NH_3 in 2018, corresponding to 44 %.

The agricultural emission of greenhouse gases in 2018 is estimated to 11.0 million tonnes CO_2 eqv. and is reduced from 13.8 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 is decreased to 13.2 million tonnes CO_2 eqv. and a reduction of 16 % 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 2019) 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 IPCC Guidelines and the EMEP/EEA Guidebook.

References

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Appendixes

A) Ammonia emission from Danish agriculture 1985 – 2018, kt NH_3-N and kt NH_3.

NH_3-N	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Agricultural Sector - total	**107.40**	**106.59**	**104.41**	**101.88**	**102.56**	**102.66**	**99.13**	**96.90**	**95.12**	**92.36**	**86.84**	**83.87**
Manure Management	44.02	44.87	43.96	44.33	43.93	42.00	41.52	42.29	41.52	40.28	38.55	38.32
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
Manure applied to soil	32.29	31.82	30.36	29.53	28.95	29.72	28.74	27.84	27.04	25.52	23.95	23.45
Grazing animals	4.12	4.02	3.88	3.83	3.81	3.81	3.86	3.88	3.94	3.88	3.94	3.98
Cultivated 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
Sewage sludge used as fertiliser	0.21	0.21	0.22	0.25	0.30	0.33	0.34	0.41	0.53	0.48	0.50	0.49
NH_3 treated straw	5.40	6.63	7.36	5.98	7.42	8.41	7.13	6.33	6.25	6.68	5.47	4.18
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
Other organic	0.10	0.10	0.10	0.10	0.10	0.10	0.18	0.20	0.30	0.30	0.30	0.31
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agricultural Sector - total	**83.19**	**83.17**	**78.82**	**77.08**	**75.91**	**74.47**	**73.38**	**72.69**	**69.78**	**66.89**	**65.98**	**65.09**
Manure Management	39.07	40.35	39.21	38.50	39.82	40.45	39.76	41.31	38.80	36.70	34.55	33.81
Inorganic N fertiliser	8.55	8.05	7.40	6.63	6.14	5.68	5.43	5.55	5.37	5.02	5.18	5.47
Manure applied to soil	22.66	22.46	21.45	20.84	19.32	18.46	18.84	17.01	17.17	16.84	18.06	17.40
Grazing animals	3.94	3.96	3.94	3.95	4.02	3.90	3.61	3.42	3.29	3.18	3.08	3.11
Cultivated crops	4.48	4.45	4.33	4.29	4.33	4.33	4.32	4.34	4.40	4.40	4.33	4.46
Sewage sludge used as fertiliser	0.43	0.40	0.39	0.39	0.38	0.39	0.34	0.29	0.29	0.33	0.37	0.41
NH_3 treated straw	3.69	3.05	1.71	2.04	1.34	0.78	0.66	0.43	0.21	0.13	0.13	0.13
Field burning of agricultural residue	0.08	0.10	0.09	0.09	0.10	0.08	0.10	0.10	0.10	0.11	0.09	0.08
Other organic	0.30	0.34	0.29	0.34	0.48	0.40	0.32	0.24	0.16	0.19	0.18	0.23
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018		
Agricultural Sector - total	**61.87**	**62.59**	**61.45**	**60.58**	**58.72**	**59.25**	**59.20**	**59.45**	**60.25**	**59.98**		
Manure Management	32.56	32.61	32.46	31.81	29.76	29.78	29.59	28.98	28.90	28.99		
Inorganic N fertiliser	3.93	4.75	4.76	4.60	4.75	5.07	5.29	5.91	6.40	5.77		
Manure applied to soil	17.11	17.12	16.23	16.07	16.12	16.24	16.24	16.40	16.72	16.93		
Grazing animals	2.94	2.84	2.71	2.74	2.74	2.72	2.70	2.76	2.79	2.82		
Cultivated crops	4.45	4.45	4.46	4.45	4.43	4.49	4.45	4.45	4.45	4.48		
Sewage sludge used as fertiliser	0.38	0.39	0.39	0.40	0.41	0.44	0.43	0.43	0.43	0.43		
NH_3 treated straw	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	0.07	0.07	0.08	0.09	0.09	0.08	0.08	0.09	0.10		
Other organic	0.26	0.22	0.23	0.29	0.30	0.29	0.29	0.32	0.34	0.32		

A) *Continued…* kt NH_3.

NH_3	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Agricultural Sector - total	**130.42**	**129.43**	**126.79**	**123.71**	**124.54**	**124.65**	**120.37**	**117.66**	**115.51**	**112.15**	**105.45**	**101.84**
Manure Management	53.45	54.49	53.38	53.83	53.35	51.00	50.42	51.35	50.42	48.91	46.81	46.54
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
Manure applied to soil	39.21	38.64	36.86	35.85	35.16	36.08	34.90	33.80	32.84	30.99	29.08	28.48
Grazing animals	5.00	4.89	4.72	4.65	4.63	4.62	4.69	4.71	4.79	4.71	4.78	4.84
Cultivated 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
Sewage sludge used as fertiliser	0.26	0.26	0.27	0.30	0.36	0.40	0.42	0.50	0.64	0.58	0.60	0.59
NH_3 treated straw	6.55	8.05	8.94	7.26	9.01	10.21	8.66	7.69	7.59	8.12	6.65	5.07
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
Other organic	0.12	0.12	0.12	0.12	0.12	0.12	0.22	0.24	0.36	0.36	0.36	0.37
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agricultural Sector - total	**101.02**	**100.99**	**95.71**	**93.60**	**92.17**	**90.42**	**89.11**	**88.27**	**84.74**	**81.23**	**80.12**	**79.04**
Manure Management	47.44	49.00	47.61	46.75	48.36	49.12	48.28	50.16	47.11	44.56	41.96	41.06
Inorganic N fertiliser	10.38	9.77	8.99	8.06	7.45	6.90	6.60	6.74	6.52	6.09	6.29	6.64
Manure applied to soil	27.52	27.28	26.05	25.31	23.46	22.42	22.88	20.66	20.85	20.45	21.93	21.12
Grazing animals	4.78	4.80	4.79	4.80	4.88	4.74	4.39	4.16	3.99	3.86	3.74	3.77
Cultivated crops	5.44	5.41	5.25	5.21	5.25	5.26	5.24	5.27	5.34	5.34	5.26	5.41
Sewage sludge used as fertiliser	0.52	0.49	0.48	0.47	0.46	0.47	0.41	0.35	0.35	0.40	0.45	0.49
NH_3 treated straw	4.49	3.71	2.08	2.47	1.62	0.94	0.80	0.53	0.26	0.16	0.16	0.16
Field burning of agricultural residue	0.10	0.12	0.12	0.11	0.12	0.10	0.12	0.13	0.13	0.13	0.11	0.10
Other organic	0.36	0.41	0.35	0.41	0.58	0.48	0.39	0.29	0.19	0.23	0.22	0.28
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018		
Agricultural Sector - total	**75.13**	**76.01**	**74.62**	**73.56**	**71.31**	**71.95**	**71.89**	**72.19**	**73.15**	**72.83**		
Manure Management	39.54	39.60	39.42	38.63	36.14	36.16	35.93	35.18	35.10	35.20		
Inorganic N fertiliser	4.78	5.77	5.78	5.59	5.77	6.16	6.43	7.18	7.77	7.01		
Manure applied to soil	20.77	20.79	19.70	19.52	19.57	19.72	19.72	19.91	20.30	20.56		
Grazing animals	3.57	3.45	3.29	3.33	3.33	3.30	3.28	3.35	3.39	3.42		
Cultivated crops	5.41	5.41	5.42	5.40	5.37	5.45	5.40	5.41	5.40	5.44		
Sewage sludge used as fertiliser	0.46	0.47	0.48	0.49	0.49	0.54	0.52	0.52	0.53	0.53		
NH_3 treated straw	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	0.09	0.09	0.10	0.11	0.11	0.09	0.09	0.10	0.12		
Other organic	0.32	0.27	0.28	0.35	0.37	0.35	0.36	0.39	0.41	0.38		

B) Development in the emission of greenhouse gases, 1985-2018, measured in kt CO_2 equivalents.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
CH_4	6 363	6 256	5 991	5 870	5 824	5 895	6 004	6 071	6 223	6 098	6 111	6 136
N_2O	6 710	6 615	6 471	6 483	6 534	6 647	6 485	6 351	6 160	6 043	5 887	5 578
CO_2	732	756	500	739	889	619	512	403	350	412	537	418
Total	13 805	13 626	12 962	13 092	13 246	13 161	13 001	12 826	12 733	12 553	12 536	12 132

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CH_4	6 067	6 172	5 981	6 006	6 179	6 207	6 216	6 162	6 005	5 889	5 956	5 907
N_2O	5 579	5 686	5 483	5 393	5 302	5 274	5 043	5 128	5 043	4 883	5 041	5 053
CO_2	483	264	274	268	207	237	229	160	222	196	194	231
Total	12 128	12 122	11 738	11 667	11 688	11 718	11 488	11 449	11 270	10 969	11 191	11 191

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
CH_4	5 889	5 970	5 918	5 949	5 925	5 943	5 896	5 919	5 919	5 990
N_2O	4 903	4 785	4 819	4 756	4 727	4 840	4 840	4 955	5 013	4 807
CO_2	187	156	165	192	246	240	177	217	219	244
Total	10 979	10 911	10 901	10 897	10 898	11 024	10 913	11 090	11 150	11 041

C) Development in the emission of greenhouse gases, 1985-2018, measured in Gg CO_2 equivalents, distributed on main sources.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
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
Manure management	1 727	1 774	1 754	1 768	1 786	1 854	1 931	2 050	2 146	2 118	2 141	2 168
Field burning	43	37	35	26	28	2	2	2	2	2	3	3
N_2O												
Crop residue	421	431	410	471	494	569	541	410	473	459	526	532
Atmospheric deposition - soil	373	364	357	341	347	359	344	327	319	310	290	274
Atmospheric deposition - manure management	208	212	208	209	207	198	196	199	196	190	182	181
Manure management	325	316	302	297	296	298	304	305	312	306	311	313
Grazing	748	770	762	772	778	781	791	816	815	780	754	755
Field burning	13	11	11	8	9	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
Organic soils	897	889	881	873	865	856	848	840	832	823	815	807
Manure on soil	1 054	1 055	1. 020	1 007	997	991	986	987	992	954	925	923
Mineralization	144	130	104	169	173	148	83	179	93	62	58	26
Sewage sludge	16	16	17	18	20	22	28	32	44	42	43	43
Leaching and run-off	646	630	614	598	582	549	514	524	525	589	503	361
CO_2												
Field burning	967	830	789	590	621	49	51	48	53	51	58	57
Liming	696	712	452	694	837	565	463	357	307	367	496	393
Urea	10	8	7	9	8	15	12	13	13	18	15	9
CAN	25	35	41	36	44	38	37	33	30	27	26	16

C) *Continued…*

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CH_4												
Enteric fermentation	3 829	3 833	3 685	3 631	3 703	3 646	3 604	3 496	3 483	3 484	3 565	3 596
Manure management	2 235	2 336	2 293	2 373	2 472	2 559	2 608	2 662	2 518	2 401	2 388	2 308
Field burning	3	3	3	3	3	3	3	4	4	4	3	3
N_2O												
Crop residue	557	560	522	547	553	522	546	550	588	580	576	614
Atmospheric deposition - soil	267	261	243	236	223	211	208	199	197	191	198	200
Atmospheric deposition – manure management	184	190	185	181	188	191	187	194	183	173	163	159
Manure management	307	306	300	300	305	292	259	236	219	205	193	194
Grazing	763	789	769	767	795	816	807	833	787	728	734	687
Field burning	1	1	1	1	1	1	1	1	1	1	1	1
Inorganic N fertiliser	1 347	1 326	1 230	1 178	1 094	987	942	968	966	898	911	1 032
Organic soils	799	790	782	774	766	758	749	741	733	725	716	708
Manure on soil	916	934	922	913	938	963	964	984	993	960	1 016	994
Mineralization	38	28	29	39	19	70	42	29	19	43	100	65
Sewage sludge	40	41	38	41	51	45	37	29	24	28	29	34
Leaching and run-off	360	459	462	415	371	418	301	363	334	352	403	365
CO_2												
Field burning	61	77	73	72	75	63	75	79	80	81	70	65
Liming	470	252	265	261	201	233	226	158	220	194	192	229
Urea	4	4	3	2	2	1	1	1	0	1	1	0
CAN	10	7	6	5	4	3	2	1	2	1	1	2

C) *Continued…*

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
CH_4										
Enteric fermentation	3 596	3 631	3 590	3 672	3 694	3 695	3 667	3 717	3 731	3 767
Manure management	2 290	2 337	2 325	2 275	2 228	2 246	2 226	2 200	2 185	2 219
Field burning	3	2	2	3	3	3	3	3	3	3
N_2O										
Crop residue	693	632	653	660	641	694	663	639	684	473
Atmospheric deposition - soil	189	191	187	185	186	189	191	199	204	200
Atmospheric deposition – manure management	153	153	153	150	140	140	139	136	136	136
Manure management	185	183	178	181	184	183	177	178	176	175
Grazing	644	643	629	616	618	614	604	589	586	597
Field burning	1	1	1	1	1	1	1	1	1	1
Inorganic N fertiliser	985	931	958	928	936	955	988	1 136	1 165	1 050
Organic soils	700	692	676	659	667	660	663	659	656	652
Manure on soil	970	974	971	964	970	974	976	984	1 003	1 016
Mineralization	25	12	33	27	13	44	18	35	12	135
Sewage sludge	35	33	34	38	39	40	40	42	43	41
Leaching and run-off	323	340	348	348	332	347	380	358	348	329
CO_2										
Field burning	77	56	55	64	69	68	59	59	66	77
Liming	181	153	162	188	244	238	166	212	214	240
Urea	2	1	1	1	1	1	1	2	2	1
CAN	4	3	3	2	2	2	10	3	3	3

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	2001
Dairy cattle	896	864	811	774	759	753	742	712	714	700	702	701	670	669	640	636	623
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	1 284
Sheep	99	131	148	182	208	230	266	256	221	200	202	235	240	252	264	279	297
Goats	8	8	8	8	8	7	7	7	7	7	7	7	7	8	8	8	9
Horses	140	139	138	137	136	135	137	138	140	141	143	144	146	147	149	150	155
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	12 608
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	21 236
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	2 304
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	1 063
Deer	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11
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	10.0

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Dairy cattle	610	596	563	564	550	545	558	563	568	565	587	582	563	561	572	570	575
Non-dairy cattle[1]	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	997	975	965
Sheep	294	303	310	316	319	309	294	289	278	234	226	221	220	210	207	204	205
Goats	9	10	11	11	12	13	14	16	16	13	13	13	12	11	11	11	10
Horses	160	165	170	175	180	185	190	178	165	155	155	150	150	155	163	170	175
Swine[2]	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	12 383	12 308	12 781
Poultry[3]	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	18 503	21 484	21 246
Fur farming	2 422	2 361	2 471	2 552	2 708	2 837	2 810	2 721	2 699	2 757	2 948	3 123	3 308	3 388	3 251	3 416	3 363
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	1 063
Deer	10	10	10	10	10	10	10	9	10	8	7	8	7	8	7	7	8
Ostrich	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	0.1	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	2001
Dairy cattle	896	864	811	774	759	753	742	712	714	700	702	701	670	669	640	636	623
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	2 286
Sheep	99	131	148	182	208	230	266	256	221	200	202	235	240	252	264	279	297
Goats	8	8	8	8	8	7	7	7	7	7	7	7	7	8	8	8	9
Horses	140	139	138	137	136	135	137	138	140	141	143	144	146	147	149	150	155
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	49 756
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	149 102
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	2 304
Pheasant	2	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	11
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	10.0

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Dairy cattle	610	596	563	564	550	545	558	563	568	565	587	582	563	561	572	570	575
Non-dairy cattle[1]	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	1 194	1 176	1 170
Sheep	294	303	310	316	319	309	294	289	278	234	226	221	220	210	207	204	205
Goats	9	10	11	11	12	13	14	16	16	13	13	13	12	11	11	11	10
Horses	160	165	170	175	180	185	190	178	165	155	155	150	150	155	163	170	175
Swine[2]	51 435	51 602	53 435	52 071	51 586	52 273	51 068	50 223	51 945	52 846	50 916	50 836	51 556	52 391	52 920	51 835	53 423
Poultry[3]	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	131 247	127 725	133 134
Fur farming	2 422	2 361	2 471	2 552	2 708	2 837	2 810	2 721	2 699	2 757	2 948	3 123	3 308	3 388	3 251	3 416	3 363
Pheasant	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Deer	10	10	10	10	10	10	10	9	10	8	7	8	7	8	7	7	8
Ostrich	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	0.1	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, 1985-2018.

Cattle:

Dairy cattle:

Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	15.0
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	25.0
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	9.0
Loose holding with beds, slatted floor	9.0	9.8	10.6	11.5	12.3	12.3	12.7	13.5	13.7	14.7	14.8	15.0	17.5	19.8	19.6	28.9	30.1
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	4.0
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	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	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	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	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	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	1.0
Biogas	0.0	0.0	0.0	0.0	0.0	0.8	1.2	1.2	1.8	1.7	2.4	3.0	3.5	4.2	4.4	5.1	5.9

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Tethered with urine and solid manure	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	2.4	2.0	1.7
Tethered with slurry	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	3.5	3.0	2.6
Loose holding with beds, solid floor	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	14.9	14.9	15.5
Loose holding with beds, slatted floor	32.5	34.3	36.1	35.5	33.6	32.4	34.0	35.7	35.8	37.3	39.0	40.4	38.0	36.3	32.1	28.0	26.3
Loose holding with beds, slatted floor, scrape	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	21.9	21.5	21.7
Loose holding with beds, drained floor	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	0.0	0.0	0.0
Loose holding with beds, solid floor with tilt	0.0	0.0	0.0	0.0	0.0	0.6	1.3	2.1	2.4	2.6	3.3	2.7	4.0	4.4	4.7	5.3	5.4
Deep litter	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	4.0	4.4	4.7
Deep litter, long eating space, solid floor	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	0.6	0.7	0.6
Deep litter, slatted floor	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	1.2	1.3	1.2
Deep litter, slatted floor, scrape	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	0.9	0.8	0.8
Biogas	6.5	7.7	7.9	7.9	9.3	9.9	9.6	8.8	8.7	8.3	6.9	7.0	8.6	9.9	13.8	18.1	19.5

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	2001
	Deep litter (boxes)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	89.0
	Deep litter, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.0
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Deep litter (boxes)	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	96.6	96.6	96.5
	Deep litter, solid floor	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	3.4	3.4	3.5

6 mth-calving	Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	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	31.0
	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	8.0
	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	8.0
	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	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	17.0
	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	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	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	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	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	26.0
	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	5.0
	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	2.0
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Slatted floor-boxes	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	24.0	22.0	20.3
	Tethered with urine and solid manure	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	2.6	2.4	2.1
	Tethered with slurry	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	1.3	1.1	1.0
	Loose housing with beds, solid floor	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	8.1	8.6	8.8
	Loose housing with beds, slatted floor	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	25.4	25.8	27.6
	Loose housing with beds, slatted floor, scrape	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	9.0	9.5	9.5
	Loose holding with beds, solid floor with tilt	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	1.9	2.6	2.6
	Deep litter	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	21.9	22.1	22.1
	Deep litter, long eating space, solid floor	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	1.4	1.5	1.6
	Deep litter, solid floor	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	0.8	0.9	0.9
	Deep litter, slatted floor	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	1.7	1.8	1.5
	Deep litter, slatted floor, scrape	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	1.9	1.7	2.0

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	2001
.	Deep litter (boxes)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90.9
	Deep litter, solid floor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.1

		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Deep litter (boxes)	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	96.5	96.6	96.2
	Deep litter, solid floor	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	3.5	3.4	3.8

6 mth -440 kg	Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	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	32.0
	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	9.0
	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	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	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	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	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	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	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	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	37.0
	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	8.0
	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	2.0

		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Slatted floor-boxes	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	19.8	18.9	18.4
	Tethered with urine and solid manure	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	1.4	1.3	1.1
	Tethered with slurry	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	0.4	0.3	0.3
	Loose housing with beds, solid floor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.9	1.4	3.1	4.2
	Loose housing with beds, slatted floor	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	7.5	8.8	10.5
	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	2.8	3.3	4.0	4.1	2.8	2.7	2.7	3.2
	Loose holding with beds, solid floor with tilt	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	1.1	1.0	1.2
	Deep litter	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	58.4	56.6	54.6
	Deep litter, long eating space, solid floor	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	1.4	1.5	1.4
	Deep litter, solid floor	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	2.2	2.3	2.4
	Deep litter, slatted floor	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	1.7	2.1	1.6
	Deep litter, slatted floor, scrape	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	2.0	1.4	1.1

E) *Continued…*

Suckling cattle:

Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	8.0
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	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	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	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	44.0
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	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	48.0
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	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	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	0.0

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Tethered with urine and solid manure	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	9.9	9.2	8.6
Tethered with slurry	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	6.3	6.4	6.3
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	0.2	0.5	0.6	0.7
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	0.3	0.6	0.7	0.8
Deep litter	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	73.9	74.5	74.9
Deep litter, long eating space, solid floor	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	1.4	1.3	1.3
Deep litter, solid floor	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	2.9	3.1	3.1
Deep litter, slatted floor	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	2.1	1.9	1.9
Deep litter, slatted floor, scrape	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	2.4	2.3	2.4
Boxes with sloping bedded floor	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	0.0	0.0	0.0

E) *Continued…*

Swine:

Sows:

Gestation period	Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	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	9.0
	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	9.6
	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	14.7
	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	49.4
	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	10.1
	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	7.2
	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	0.0
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Deep litter + solid floor	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	0.8	0.9	0.7
	Deep litter + slatted floor	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	7.3	7.3	6.8
	Deep litter	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	1.9	1.8	2.5
	Individual housing, partly slatted floor	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	55.3	59.5	57.9
	Individual housing, fully slatted floor	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	7.4	0.0	0.0
	Individual housing, solid floor	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	0.1	0.2	0.3
	Loose housing, partly slatted floor	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	27.2	30.3	31.8
Farrow period		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	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	74.0
	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	22.0
	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	4.0
	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	0.0
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Individual housing, partly slatted floor	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	81.7	82.2	83.2
	Individual housing, fully slatted floor	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	18.3	17.8	16.8
	Loose housing, solid floor	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	0.0	0.0	0.0
	Loose housing, partly slatted floor	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	0.0	0.0	0.0
Outdoor		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	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	2.6
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Outdoor sows (percent of all sows and periods)	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	0.6	0.7	0.8

E) *Continued…*
Weaners:

Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	36.0
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	49.0
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	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	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	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	0.0

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Fully slatted floor	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	0.0	0.0	0.0
Partly slatted floor	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	76.9	78.8	78.6
Solid floor	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	0.2	0.2	0.2
Deep litter (to-climate housings)	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	1.1	1.0	2.0
Deep litter + slatted floor	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	0.0	0.0	0.0
Partly slatted and drained floor	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	21.8	20.0	19.2

E) *Continued…*

Fattening pigs:

Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Fully slatted floor	29.0	33.4	37.9	42.3	46.7	49.9	54.0	58.6	58.0	58.2	57.4	56.8	56.5	56.2	56.1	53.5	52.1
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	33.0
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	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	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	4.0
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	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	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	0.0
Biogas	0.0	0.0	0.0	0.0	0.0	1.2	1.6	1.4	2.0	1.8	2.6	3.2	3.5	3.8	3.9	4.5	4.9

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Fully slatted floor	50.9	48.8	47.1	53.0	53.0	53.0	52.9	53.8	53.8	53.2	51.5	46.4	43.7	39.8	0.0	0.0	0.0
Partly slatted floor	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	0.0	0.0	0.0
Partly slatted floor (50-75 % solid floor)	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	9.3	10.1	10.6
Partly slatted floor (25-49 % solid floor)	0.0	0.0	0.0	23.0	21.3	21.1	20.0	18.8	19.0	20.4	19.9	21.6	20.6	19.4	15.1	18.8	17.6
Solid floor	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	0.6	0.5	0.4
Deep litter	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	0.9	0.8	0.8
Partly slatted floor and partly deep litter	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	0.5	0.6	0.7
Partly slatted and drained floor	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	57.1	49.7	49.2
Biogas	5.1	6.2	5.9	6.1	7.1	6.7	7.7	8.5	8.3	7.2	7.9	8.0	9.6	11.1	16.5	19.5	20.7

E) *Continued…*

Poultry:

Livestock categories	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	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	13.2
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	16.4
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	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	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	27.5
Aviary	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.5	0.7	0.2	0.0	0.2
Hens for production of brood egg	100	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	7.5
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	67.5
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	25.0
Broilers, (conv. 30 days)	0	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	0
Broilers, (conv. 35 days)	0	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	100
Broilers, (conv. 45 days)	0	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	0
Organic broilers (81 days)	0	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	50
Turkey, female	50	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	100
Geese	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

E) *Continued…*

Livestock categories	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Free range hens	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	6.1	7.4	8.7
Organic hens	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	25.8	27.9	31.9
Barn hens	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	27.3	35.3	37.7
Battery hens, manure shed	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	36.5	26.4	20.6
Battery hens, manure tank	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	2.6	1.3	1.1
Battery hens, manure cellar	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	1.8	1.7	0.0
Aviary	0.2	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
Hens for production of brood egg	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Pullet, consumption, net	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	20.5	15.8	11.3
Pullet, consumption, floor	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	50.8	52.7	55.4
Pullet, brood egg, floor	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	28.7	31.5	33.3
Broilers, (conv. 30 days)	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	1
Broilers, (conv. 32 days)	0	0	0	4	5	1	2	7	3	11	14	17	23	25	39	52	57
Broilers, (conv. 35 days)	0	0	0	45	41	45	49	57	76	86	81	79	73	72	56	41	34
Broilers, (conv. 40 days)	100	100	100	49	54	53	49	36	21	3	5	3	2	1	4	4	5
Broilers, (conv. 45 days)	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1
Broilers, barn (56 days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Organic broilers (81 days)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Turkey, male	50	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	50
Ducks	100	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	100

E) *Continued…*

Fur farming:

	Housing type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	10.0	11.7
	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	90.0	88.3
Foxes	Slurry system	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Solid manure and urine	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mink	Slurry system	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	98.1	98.0	98.2
	Solid manure and urine	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	1.9	2.0	1.8
Foxes	Slurry system	10.0	15.0	30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Solid manure and urine	90.0	85.0	70.0	100	100	100	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 1985-2018.

Deer and pheasants are on pasture all years 1985-2018.

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	2007-2018
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…*

	1985-2018
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 – 2018.

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	2001
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	123 674
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	120 662
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	12 343
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	6 131
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	1 968
Goats	131	129	128	126	124	123	121	119	118	116	114	113	111	127	132	138	155
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	10 639
Deer	144	152	160	160	160	160	160	160	160	160	160	160	160	160	160	160	170
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	275 742

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cattle	121 427	119 046	115 876	116 110	116 299	120 384	122 619	121 284	121 796	121 905	124 553	125 306	124 270	123 162	126 394	127 694	129 845
Swine	126 730	123 749	128 946	124 864	114 064	118 096	109 939	104 498	103 365	102 957	98 447	96 412	98 253	97 681	95 259	96 226	98 069
Poultry	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	10 317	10 009	10 442
Horses	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	6 429	6 725	6 923
Sheep	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	1 374	1 356	1 360
Goats	151	164	176	181	191	198	231	257	262	206	212	214	198	186	186	186	171
Fur animals	11 172	10 886	12 585	13 718	14 026	14 698	14 860	15 005	15 696	15 566	16 037	16 710	16 912	17 996	17 487	18 722	17 181
Deer	158	155	155	154	154	155	153	152	152	129	115	125	118	122	117	113	123
N excretion total	280 226	275 037	279 782	277 019	265 439	274 171	268 865	261 079	260 934	259 282	257 352	255 947	256 643	256 439	257 563	261 032	264 114

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	2001
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	9 793
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	22 125	20 616	21 524
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	3 726
Horses	628	623	619	614	610	593	588	582	576	570	563	569	575	581	596	597	617
Sheep	36	47	54	66	75	83	97	93	80	72	73	85	87	91	96	101	107
Goats	7	7	7	7	7	7	7	7	6	6	6	6	6	7	7	8	8
Fur animals	3 891	4 404	4 739	5 589	5 812	4 277	3 928	4 220	2 810	3 307	3 314	3 439	3 960	4 189	3 720	3 880	4 046
Deer[a]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emission total	44 019	44 872	43 959	44 329	43 932	42 000	41 520	42 289	41 519	40 278	38 549	38 323	39 070	40 354	39 209	38 503	39 823

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cattle	9 773	10 040	10 100	8 605	8 751	8 723	8 963	8 822	8 799	9 049	9 154	9 163	8 944	8 847	9 150	8 848	9 084
Swine	21 975	21 049	21 727	20 326	18 465	16 892	15 686	14 699	14 450	14 296	13 590	13 219	13 400	13 109	12 198	12 166	12 366
Poultry	3 708	3 770	3 955	3 893	3 395	2 991	3 082	2 903	2 989	2 876	2 662	2 058	1 950	1 876	2 007	1 930	2 018
Horses	637	657	677	697	717	662	679	635	590	554	554	536	536	554	581	608	626
Sheep	106	110	113	114	116	101	96	94	91	76	74	72	72	69	68	67	67
Goats	8	9	10	10	10	10	11	13	13	10	10	11	10	9	9	9	8
Fur animals	4 243	4 122	4 729	5 151	5 246	5 176	5 293	5 397	5 679	5 602	5 764	4 702	4 870	5 124	4 963	5 277	4 824
Deer[a]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emission total	40 451	39 757	41 310	38 797	36 700	34 555	33 811	32 562	32 610	32 464	31 809	29 762	29 781	29 588	28 975	28 904	28 992

[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	2001
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	29 543
Storage	13 942	13 936	13 385	13 152	12 856	12 483	12 276	12 294	12 295	11 734	11 213	11 039	11 061	11 276	11 071	10 087	10 279
Application	32 291	31 821	30 358	29 526	28 952	29 717	28 739	27 836	27 045	25 524	23 949	23 453	22 663	22 465	21 449	20 845	19 316
Pasture	4 116	4 024	3 884	3 829	3 810	3 805	3 864	3 876	3 941	3 877	3 939	3 984	3 938	3 957	3 943	3 954	4 017
Emission total	80 426	80 717	78 202	77 684	76 694	75 522	74 122	74 001	72 505	69 679	66 437	65 761	65 670	66 776	64 601	63 302	63 156

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Housing	30 704	30 582	32 010	31 922	30 253	30 141	29 559	28 494	28 522	28 421	27 832	25 694	25 628	25 529	24 879	24 752	24 768
Storage	9 748	9 175	9 300	6 875	6 447	4 413	4 252	4 068	4 088	4 043	3 978	4 067	4 152	4 059	4 096	4 152	4 224
Application	18 460	18 843	17 012	17 174	16 844	18 058	17 397	17 106	17 120	16 227	16 074	16 119	16 240	16 237	16 397	16 716	16 930
Pasture	3 904	3 614	3 423	3 288	3 181	3 083	3 105	2 942	2 843	2 712	2 741	2 738	2 720	2 701	2 757	2 788	2 819
Emission total	62 815	62 215	61 745	59 258	56 725	55 696	54 313	52 610	52 573	51 404	50 625	48 619	48 741	48 526	48 130	48 408	48 741

H) N ex animal, kg N per animal.

A) Cattle, large breed		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	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	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	39.2
Continued		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Dairy cows	Total N	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	150.7	155.5	158.8
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	23.5	23.5	23.5	23.5
Heifers[b]	Total N	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	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	2001
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	27.2
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	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	0.6
Continued		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sows (incl. piglets)	Total N	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	23.9	24.1	23.8
Fattening pigs[c]	Total N	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	2.9	3.0	3.0
Weaners[c]	Total N	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	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	2001
Battery hens[d]	Total N	72.2	72.2	72.2	72.2	72.2	74.4	76.6	78.8	81.0	83.2	85.4	85.4	85.4	85.4	85.4	84.9	84.9
Broilers[e]	Total N	48.4	48.4	48.4	48.4	48.4	49.8	51.3	52.8	54.3	55.7	57.2	57.2	57.2	57.2	57.2	56.9	56.9
Continued		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Battery hens[d]	Total N	85.7	85.0	84.1	91.2	91.2	86.4	86.8	86.8	86.8	81.8	81.1	79.5	83.1	77.7	77.7	77.7	77.7
Broilers[e]	Total N	57.4	56.9	56.3	61.1	61.1	57.9	58.2	58.2	58.2	54.8	54.4	53.3	55.7	52.1	52.1	52.1	52.1

[d] pr. 100 animal.

[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	2001
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	4.6
Continued		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mink (incl. cubs)	Total N	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	5.4	5.5	5.1

Sources: Laursen (1994), Poulsen & Kristensen (1997), Poulsen et al. (2001), Lund (2019).

I) TAN ex animal.

kg per animal		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cattle													
Dairy cows	TAN	66.67	67.00	65.70	65.69	67.20	65.82	65.72	66.32	66.06	68.56	70.54	72.61
Bulls[a]	TAN	16.11	16.11	16.11	16.11	16.11	16.11	16.11	16.11	15.56	15.56	15.56	15.56
Heifers[b]	TAN	35.86	35.86	35.86	33.49	33.85	33.85	33.85	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	17.66	17.80	17.50
Fattening pigs[c]	TAN	2.04	2.03	1.96	1.87	1.86	1.88	1.88	1.93	1.90	1.87	2.00	1.96
Weaners[c]	TAN	0.31	0.33	0.31	0.29	0.29	0.31	0.29	0.28	0.29	0.28	0.28	0.28
Fur animals													
Mink	TAN	3.85	3.93	4.11	4.34	4.20	4.06	3.92	3.74	3.88	3.94	4.02	3.74

[a] 6 month to slaughter. Per produced animal.

[b] 6 month to calving.

[c] per produced animal.

Source: Lund (2019).

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	% NH_3-N loss of TAN ex animal		% NH_3-N 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	-	26	-	-
		Partly slatted floor	-	13	-	-
	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	% NH_3-N 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	-	10
	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
	% NH_3-N loss of TAN ex animal		% NH_3-N loss of N ex animal	
Fur animals	35	30	35	20
Horses, sheep and goats	-	-	-	15

K) Correction for lack of surface crust / fixed cover on slurry tanks.

	Emission factor[1]	**Emissions factor[2]**	**1985-1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	NH_3-N % of total-N	NH3-N % of TAN							Total N						
Swine															
No cover	9%	11.4%	40%	40%	40%	40%	40%	40%	20%	20%	10%	5%	5%	5%	5%
Surface crust	2%	2.5%	60%	60%	59%	59%	58%	58%	77%	76%	86%	90%	90%	89%	88%
Fixed cover	1%	1.3%	0%	0%	1%	1%	2%	2%	3%	4%	4%	5%	5%	6%	7%
Emission during storage			4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	3.4%	3.4%	2.7%	2.3%	2.3%	2.3%	2.3%
Cattle															
No cover	6%	10.3%	20%	20%	20%	20%	20%	20%	5%	5%	5%	2%	2%	2%	2%
Surface crust	2%	3.4%	80%	80%	80%	79%	79%	78%	93%	92%	92%	96%	96%	96%	96%
Fixed cover	1%	1.7%	0%	0%	0%	1%	1%	2%	2%	3%	3%	2%	2%	2%	2%
Emission during storage			2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.2%	2.2%	2.2%	2.1%	2.1%	2.1%	2.1%
Fur animals															
No cover	9%	12.9%	20%	20%	20%	20%	20%	20%	5%	5%	5%	2%	2%	2%	2%
Surface crust	2%	2.9%	80%	80%	80%	80%	80%	80%	95%	95%	95%	98%	98%	97%	95%
Fixed cover	1%	1.4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	3%
Emission during storage			3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	2.4%	2.4%	2.4%	2.1%	2.1%	2.1%	2.1%
			2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
									TAN						
Swine															
No cover	9%	11.4%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
Surface crust	2%	2.5%	87%	86%	85%	85%	84%	83%	82%	81%	79%	76%	74%	71%	
Fixed cover	1%	1.3%	8%	9%	10%	10%	11%	12%	13%	14%	17%	19%	22%	24%	
Emission under storage			2.9%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.7%	2.7%	2.7%	2.7%	
Cattle															
No cover	6%	10.3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	
Surface crust	2%	3.4%	95%	95%	95%	95%	95%	94%	94%	94%	93%	91%	90%	88%	
Fixed cover	1%	1.7%	3%	3%	3%	3%	3%	4%	4%	4%	6%	7%	9%	10%	
Emission under storage				3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.4%	3.4%	3.4%	3.4%	
Fur animals															
No cover	9%	12.9%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	
Surface crust	2%	2.9%	94%	92%	91%	89%	88%	86%	85%	83%	80%	76%	73%	69%	
Fixed cover	1%	1.4%	5%	6%	8%	9%	11%	12%	14%	15%	19%	22%	26%	29%	
Emission under storage			3.0%	3.0%	3.0%	3.0%	2.9%	2.9%	2.9%	2.9%	2.8%	2.8%	2.7%	2.7%	

[1] Poulsen et al., 2001. [2] 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 2007-2018
Cattle		
No cover	5%	50%
Full cover	3%	50%
Emission during storage		**4%**
Swine		
No cover	25%	50%
Full cover	13%	50%
Emission during storage		**19%**
Hens		
No cover	10%	50%
Full cover	5%	50%
Emission during storage		**7.5%**
Broilers		
No cover	15%	50%
Full cover	8%	50%
Emission during storage		**11,5%**
Fur animals		
No cover	15%	50%
Full cover	8%	50%
Emission during storage		**11.5%**
Horses, sheep and goats		
No cover	5%	50%
Full cover	3%	50%
Emission during storage		**4%**

M) Handling of liquid and solid manure in relation to application to soil, 1985-2018.

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	2001
	Injection	Hours																	
-	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5
-	April	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	3	5
+	March	< week	0	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	0
+	Summer. grass injection	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	3
-	Summer. before winter rape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hose application																		
-	March	4	0	0	0	0	0	0	1.1	2.2	3.3	4.4	5.6	6.7	7.8	8.9	10	9.1	10
-	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	4.5	5
+	March	< week	0	0	0	0	0	0	1	1	2	3	3	4	5	5	6	6	7
+	April	< week	0	0	0	0	0	0	2	3	3	5	6	8	9	11	12	13	18
+	May	< week	0	0	0	0	0	0	1	3	3	5	7	8	10	11	12	13	18
+	Summer	< week	0	0	0	0	0	0	1	2	3	3	4	5	5	4	4	4	4
-	Summer	4	0	0	0	0	0	0	1	1	2	2	3	3	3	2	2	2	3
+	Autumn	< week	0	0	0	0	0	0	0	1	2	3	3	4	4	4	4	4	5
-	Autumn	4	0	0	0	0	0	0	0	1	1	1	2	2	1	1	0	0	0
	Broad spreading																		
-	Winter-spring	< 12	26	27	28	29	30	26	25	24	23	22	21	20	18.3	16.7	15	13.6	6
-	Winter-spring	> 12	5	5	5	5	5	5	5	5	5	5	5	5	5.0	5	5	4.5	2
-	Winter-spring	< week	15	15	15	15	15	20	20	20	20	20	20	20	18.3	16.7	15	13.6	6
+	Spring-summer	< week	8	8	8	8	8	8	7	6	5	4	3	2	2.0	2	2	1.8	1
+	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	0.9	0.5
-	Late summer-autumn	< 12	2.4	2.8	3.2	3.6	4	4.4	4.2	3.9	3.7	3.5	3.2	3	2.7	2.3	2	1.8	1
-	Late summer-autumn	> 12	7.6	7.2	6.8	6.4	6	5.6	5	4.4	3.8	3.2	2.6	2	1.7	1.3	1	0.9	0.5
-	Late summer-autumn	< week	29	28	27	26	25	24	20	16	12	8	4	0	0.0	0	0	0	0
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

-: indicate bare soil. +: indicate growth.

M) *Continued…*

Crop stage	Application time	Lying time	Percent of N ex storage per manure type																
			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Injection	Hours																	
-	March	0	8	11	21	20	20	20	21	21	21	25	25	25	25	25	25	25	25
-	April	0	8	12	21	21	20	20	21	21	21	30	30	30	30	30	30	30	30
+	March	< week	0	0	0	1	2	3	3	3	3	8	6	6	6	4	4	4	4
+	April	< week	0	0	0	2	3	4	4	4	4	0	0	0	0	0	0	0	0
+	Summer. grass injection	0	4	4	5	5	6	6	7	7	7	10	15	15	15	15	15	15	15
-	Summer. before winter rape	0	0	1	6	6	7	7	7	7	7	3	3	3	3	3	3	3	3
+	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hose application																		
-	March	4	10	14	8	8	6	5	3	3	3	0	0	0	0	0	0	0	0
-	April	4	5	4	2	2	1	1	1	1	1	0	0	0	0	0	0	0	0
+	March	< week	7	7	5	5	5	4	4	4	4	5	6	6	6	8	8	8	8
+	April	< week	17	15	10	9	9	9	9	9	9	8	6	6	6	6	6	6	6
+	May	< week	17	15	10	9	9	9	9	9	9	7	5	5	5	5	5	5	5
+	Summer	< week	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
-	Summer	4	3	5	5	5	5	5	5	5	5	0	0	0	0	0	0	0	0
+	Autumn	< week	5	5	4	4	4	4	4	4	4	2	2	2	2	2	2	2	2
-	Autumn	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Broad spreading																		
-	Winter-spring	< 12	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Winter-spring	> 12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Winter-spring	< week	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Spring-summer	< week	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	< 12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	> 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	100	100	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	2001
	Broad spreading																		
-	Winter-spring	4	13	16	19	22	25	26	26	27	28	29	29	30	32	33	35	38	49
-	Winter-spring	6	18	16	14	12	10	11	11	12	13	14	14	15	15	15	15	14	14
-	Winter-spring	< week	19	18	17	16	15	14	14	13	12	11	11	10	10	10	10	9	10
+	Spring-summer	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	4	13	16	19	22	25	25	25	25	25	25	25	25	25	25	25	26	18
-	Late summer-autumn	6	13	11	9	7	5	5	5	5	5	5	5	5	5	5	5	5	3
-	Late summer-autumn	< week	24	23	22	21	20	19	19	18	17	16	16	15	13	12	10	9	6
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Continued…			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Broad spreading																		
-	Winter-spring	4	54	54	56	57	59	60	60	60	60	70	70	70	70	70	70	70	70
-	Winter-spring	6	15	15	14	14	13	12	12	12	12	20	20	20	20	20	20	20	20
-	Winter-spring	< week	11	11	11	10	9	9	9	9	9	0	0	0	0	0	0	0	0
+	Spring-summer	< week	0	0	0	0	0	0	0	0	0	5	5	5	5	5	5	5	5
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	4	13	15	15	16	16	17	17	17	17	5	5	5	5	5	5	5	5
-	Late summer-autumn	6	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	< week	5	4	4	3	3	2	2	2	2	0	0	0	0	0	0	0	0
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

-: 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	2001
	Injection	Hours																	
-	March	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	5
-	April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	6
+	March	< week	0	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	0
+	Summer. grass injection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
-	Summer. before winter rape	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2
+	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hose application																		
-	March	4	0	0	0	0	0	0	1	1	2	3	4	5	6	6	10	7	7
-	April	4	0	0	0	0	0	0	1	2	3	3	5	5	6	7	5	7	8
+	March	< week	0	0	0	0	0	0	1	1	2	3	4	4	5	5	6	6	11
+	April	< week	0	0	0	0	0	0	1	3	3	6	6	9	10	12	13	14	16
+	May	< week	0	0	0	0	0	0	1	4	4	6	6	9	10	12	13	14	16
+	Summer	< week	0	0	0	0	0	0	1	1	2	3	3	4	4	4	4	4	5
-	Summer	4	0	0	0	0	0	0	1	1	2	2	3	3	3	2	2	2	3
+	Autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	4	0	0	0	0	0	0	1	2	3	3	5	5	4	3	2	2	3
	Broad spreading																		
-	Winter-spring	< 12	26	27	28	29	30	26	25	24	23	22	21	20	18.3	16.7	15	13.6	6
-	Winter-spring	> 12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4.5	2
-	Winter-spring	< week	15	15	15	15	15	20	20	20	20	20	20	20	18.3	16.7	15	13.6	6
+	Spring-summer	< week	8	8	8	8	8	8	7	6	5	4	3	2	2	2	2	1.8	1
+	Late summer-autumn	< week	7	7	7	7	7	7	6	5	5	4	3	2	1.7	1.3	1	0.9	1
-	Late summer-autumn	< 12	2	3	3	4	4	4	4	4	4	3	3	3	2.7	2.3	2	1.8	1
-	Late summer-autumn	> 12	8	7	7	6	6	6	5	4	4	3	3	2	1.7	1.3	1	0.9	1
-	Late summer-autumn	< week	29	28	27	26	25	24	20	16	12	8	4	0	0	0	0	0	0
		Total	100	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																
			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Injection	Hours																	
-	March	0	8	6	6	7	7	8	10	10	10	14	14	14	14	14	14	14	14
-	April	0	8	7	7	7	8	8	9	9	9	11	11	11	11	11	11	11	11
+	March	< week	0	0	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2
+	April	< week	0	0	0	0	2	3	3	3	3	3	3	3	3	3	3	3	3
+	Summer. grass injection	0	2	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
-	Summer. before winter rape	0	2	1	1	2	2	2	2	2	2	5	5	5	5	5	5	5	5
+	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Autumn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hose application																		
-	March	4	7	9	8	7	6	4	2	2	2	0	0	0	0	0	0	0	0
-	April	4	8	9	8	7	6	4	3	3	3	0	0	0	0	0	0	0	0
+	March	< week	11	13	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
+	April	< week	15	20	23	28	30	32	32	32	32	33	33	33	33	33	33	33	33
+	May	< week	15	21	23	18	14	13	13	13	13	13	13	13	13	13	13	13	13
+	Summer	< week	5	3	3	3	3	3	2	2	2	1	1	1	1	1	1	1	1
-	Summer	4	3	3	3	3	3	3	3	3	3	0	0	0	0	0	0	0	0
+	Autumn	< week	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2
-	Autumn	4	3	3	3	3	3	3	3	3	3	0	0	0	0	0	0	0	0
	Broad spreading																		
-	Winter-spring	< 12	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Winter-spring	> 12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Winter-spring	< week	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Spring-summer	< week	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	< 12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	> 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	100	100	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	2001
	Broad spreading																		
-	Winter-spring	4	13	16	19	22	25	25.7	26.4	27.1	27.9	28.6	29.3	30	31.7	33.3	35	37.7	49
-	Winter-spring	6	18	16	14	12	10	10.7	11.4	12.1	12.9	13.6	14.3	15	15	15	15	13.6	14
-	Winter-spring	< week	19	18	17	16	15	14.3	13.6	12.9	12.1	11.4	10.7	10	10	10	10	9.1	10
+	Spring-summer	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	4	13	16	19	22	25	25	25	25	25	25	25	25	25	25	25	25.9	18
-	Late summer-autumn	6	13	11	9	7	5	5	5	5	5	5	5	5	5	5	5	4.5	3
-	Late summer-autumn	< week	24	23	22	21	20	19.3	18.6	17.9	17.1	16.4	15.7	15	13.3	11.7	10	9.1	6
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Continued…			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Broad spreading																		
-	Winter-spring	4	54	54	56	57	59	60	60	60	60	60	60	60	60	60	60	60	60
-	Winter-spring	6	15	15	14	14	13	12	12	12	12	16	16	16	16	16	16	16	16
-	Winter-spring	< week	11	11	11	10	9	9	9	9	9	0	0	0	0	0	0	0	0
+	Spring-summer	< week	0	0	0	0	0	0	0	0	0	5	5	5	5	5	5	5	5
+	Late summer-autumn	< week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	4	13	15	15	16	16	17	17	17	17	19	19	19	19	19	19	19	19
-	Late summer-autumn	6	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	Late summer-autumn	< week	5	4	4	3	3	2	2	2	2	0	0	0	0	0	0	0	0
		Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

-: indicate bare soil. +: indicate growth.

N) Emission of particular matter. 1985-2018.

TSP.

kt TSP	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	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	0.81
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	0.005
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	0.0004
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	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	3.99
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	0.89
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	0.62
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	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	0.040
Other	0	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	7.35

Continued…	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Animal category																	
Dairy cattle	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	0.94	0.93	0.94
Non-dairy cattle	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	0.48	0.47	0.47
Sheep	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	0.003	0.003	0.003
Goats	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	0.0004	0.0004	0.0004
Horses	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	0.04	0.04	0.04
Swine	4.03	4.10	4.18	4.27	4.21	4.32	4.01	3.90	4.15	4.07	3.87	3.79	3.87	3.93	3.88	3.85	4.00
Laying hens	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	1.16	1.39	1.31
Broilers	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	0.47	0.53	0.49
Turkeys	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	0.038	0.028	0.029
Other poultry	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	0.005	0.015	0.011
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TSP total	7.30	7.03	7.05	7.23	6.96	7.12	6.90	6.90	7.22	7.21	7.04	7.00	6.96	7.00	7.07	7.33	7.36

N) *Continued…*

PM$_{10}$.

kt PM_{10}	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	0.39
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	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	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	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	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	1.28
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	0.19
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	0.31
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	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	0.04
Other	0	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	2.68

Continued…	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Animal category																	
Dairy cattle	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	0.43	0.43	0.43
Non-dairy cattle	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	0.22	0.22	0.22
Sheep	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	0.001	0.001	0.001
Goats	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	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	0.02	0.02
Swine	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	1.23	1.22	1.20	1.24
Laying hens	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	0.24	0.29	0.28
Broilers	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	0.23	0.27	0.25
Turkeys	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	0.04	0.03	0.03
Other poultry	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	0.00	0.01	0.01
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM_{10} total	2.65	2.49	2.50	2.56	2.49	2.53	2.43	2.46	2.55	2.52	2.48	2.45	2.41	2.41	2.44	2.50	2.51

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	2001
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	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	0.24
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	0.0006
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	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	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	0.06
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	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	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	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	0.005
Other	0	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	0.63

Continued…	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Animal category																	
Dairy cattle	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	0.28	0.28	0.28
Non-dairy cattle	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	0.14	0.14	0.14
Sheep	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	0.0004	0.0004	0.0004
Goats	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	0.00005	0.00005	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	0.01	0.01
Swine	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	0.05	0.05	0.06
Laying hens	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	0.02	0.02	0.02
Broilers	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	0.02	0.03	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	0.00	0.00	0.01	0.01	0.01
Other poultry	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	0.001	0.002	0.001
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM$_{2.5}$ total	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	0.55	0.55	0.56	0.56

O) Area of cultivated, ha.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Winter wheat	328 501	342 612	386 583	295 267	431 306	522 171	507 031	567 311	608 673	559 619	600 341	669 495
Spring wheat	10 035	10 353	10 942	12 851	13 197	10 777	11 684	15 193	10 687	12 740	6 324	4 712
Wheat, total	338 536	352 964	397 525	308 118	444 502	532 949	518 715	582 504	619 360	572 359	606 666	674 207
Rye	125 918	119 939	135 505	80 280	99 961	108 545	79 622	88 178	78 273	87 937	95 720	75 495
Winter barley	59 509	60 504	61 412	44 085	81 899	139 468	140 195	151 328	174 568	182 087	185 419	197 545
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	528 872	565 693
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	714 292	763 238
Oats	36 410	20 843	18 063	39 958	26 495	20 212	21 462	27 646	28 165	39 757	25 530	26 396
Triticale etc	6 013	6 499	4 756	4 121	3 053	3 741	3 176	3 207	2 659	3 565	5 286	5 839
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	1 447 494	1 545 175
Pulses	126 836	144 595	203 604	146 927	122 572	114 354	98 876	118 123	120 295	100 883	74 178	69 158
Seed potatoes	0	0	0	5 171	5 590	5 885	7 603	9 494	8 369	6 467	6 600	6 645
Potatoes for manufacturing	0	0	0	14 842	16 914	22 694	24 951	30 703	26 003	22 553	24 756	24 876
Potatoes for human consumption	0	0	0	13 145	11 015	10 999	10 934	13 485	12 137	9 782	11 000	11 690
Potatoes	30 384	30 710	29 604	33 158	33 519	39 579	43 487	53 682	46 509	38 803	42 356	43 210
Sugar beets	72 760	69 777	67 072	67 714	66 833	66 119	64 758	65 185	66 421	66 019	67 771	69 732
Fodder beets	124 782	120 466	113 052	110 184	107 369	102 347	93 170	80 979	70 993	60 380	52 927	41 347
Root crops, total	227 926	220 953	209 728	211 057	207 721	208 044	201 415	199 846	183 923	165 202	163 055	154 289
Winter rape, excl non food	0	0	0	0	0	0	0	0	0	0	84 844	54 298
Winter rape, non food	0	0	0	0	0	0	0	0	0	0	23 229	13 871
Winter rape	34 040	17 328	36 523	27 043	77 932	159 869	202 973	117 786	136 832	95 710	108 073	68 169
Spring rape, excl non food	0	0	0	0	0	0	0	0	0	0	33 411	25 711
Spring rape, non food	0	0	0	0	0	0	0	0	0	0	10 589	11 413
Spring rape, total	182 780	208 667	213 093	171 489	152 048	110 230	76 185	62 658	27 003	73 628	44 001	37 124
Rape, total	216 821	225 995	249 616	198 532	229 980	270 099	279 158	180 444	163 835	169 338	152 074	105 293
Flax	473	0	7 771	1 914	1 446	1 365	733	785	470	889	1 195	3 438
Other seeds for industrial use	2 992	4 501	2 791	2 556	1 880	821	428	135	246	683	931	100
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	154 200	108 831
Seeds for sowing	47 042	44 555	57 487	58 201	69 412	51 743	49 729	51 667	56 150	52 794	61 556	60 964

O) Area of cultivated. *Continued…*

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Lucerne	4 189	4 742	4 555	4 608	6 373	8 494	10 810	10 838	11 650	10 629	10 099	11 145
Maize for green fodder	20 374	24 715	24 967	16 607	17 106	18 735	19 164	20 245	26 187	31 269	36 583	41 652
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	87 893	58 997
Pulses, fodder cabbage etc.	3 532	2 701	2 815	3 056	2 335	2 584	2 969	2 667	1 814	2 610	2 964	1 082
Grass and clover in rotation	277 857	263 719	247 327	256 032	252 453	248 815	250 129	255 069	287 109	330 370	238 384	257 398
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	375 923	370 274
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	7 055	7 041
Peas for canning	11 194	11 716	7 456	7 949	8 992	8 791	8 716	8 723	8 977	6 103	5 529	3 758
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	12 583	10 798
Bulbs and flowers	362	574	324	411	368	323	291	382	353	253	332	255
Apples	3 615	3 338	3 172	3 105	2 772	2 726	2 462	3 006	2 209	2 061	1 658	1 854
Pears	444	367	383	417	344	351	497	436	438	328	545	469
Strawberries	1 364	1 372	1 330	1 198	1 188	1 096	1 049	992	1 018	947	1 135	983
Sour cherries	1 791	0	1 675	0	0	0	0	0	0	0	0	0
Sweet cherries	182	0	109	0	0	0	0	0	0	0	0	0
Cherries, total	1 973	1 674	1 784	0	0	0	0	0	2 022	2 441	2 654	2 823
Black current	773	0	844	0	0	0	0	0	1 919	2 351	1 827	1 783
Other fruits and berries	519	1 341	445	3 033	3 245	3 719	3 936	4 541	649	537	548	543
Fruits and berries, total	8 689	8 091	7 958	7 753	7 549	7 892	7 944	8 975	8 255	8 665	8 367	8 457
Nursery area	3 521	3 347	3 410	3 260	3 350	3 471	3 409	3 117	3 485	3 892	3 437	3 298
Horticultural crops, total	31 047	31 219	26 161	26 985	27 402	27 792	27 347	28 839	27 512	25 442	24 719	22 808
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	207 122	192 851
Set aside with grass	0	0	0	0	0	0	0	0	0	0	216 493	190 701
Christmas trees	0	0	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	1 308	982
Other crops	0	0	0	0	0	0	0	0	0	0	0	0
Fallow land	0	0	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	2 726 048	2 716 034

O) Area of cultivated. *Continued…*

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Winter wheat	671 570	666 826	611 437	611 183	624 198	564 819	651 023	650 114	666 512	682 080	683 764	638 724
Spring wheat	13 264	6 383	7 944	7 977	8 506	10 930	12 587	15 755	12 223	10 257	7 906	10 716
Wheat, total	684 835	673 209	619 381	0	0	575 749	663 610	665 869	678 735	692 337	691 670	649 440
Rye	88 320	103 171	49 180	50 472	65 059	46 205	32 666	31 430	28 474	29 755	30 047	30 975
Winter barley	176 416	162 039	150 508	144 514	146 219	116 840	129 750	121 978	139 855	161 241	168 824	126 516
Spring barley	562 578	497 796	550 680	586 574	591 088	701 795	575 487	571 359	562 991	527 158	457 408	580 879
Barley, total	738 994	659 836	701 188	0	0	818 635	705 237	693 337	702 845	688 398	626 232	707 395
Oats	30 059	28 614	25 784	44 448	59 498	54 725	49 064	54 588	58 261	60 288	55 563	71 873
Triticale etc	13 058	29 153	52 216	54 546	41 948	36 130	36 735	40 414	42 518	42 036	41 646	45 526
Cereals, total	1 555 265	1 493 983	1 447 749	1 499 714	1 536 516	1 531 443	1 487 312	1 485 639	1 510 833	1 512 814	1 445 158	1 505 210
Pulses	95 256	106 051	65 762	35 590	31 964	40 184	31 356	26 593	15 819	11 353	5 639	4 910
Seed potatoes	5 426	4 827	4 606	4 522	4 757	3 414	3 359	5 079	5 094	4 032	4 654	4 380
Potatoes for manufacturing	23 794	21 969	22 376	22 642	21 620	20 484	20 461	19 392	19 110	18 712	20 880	20 018
Potatoes for human consumption	10 096	8 705	10 964	11 524	11 809	13 754	12 226	16 578	16 278	15 210	15 689	17 981
Potatoes	39 316	35 502	37 946	0	0	37 651	36 046	41 050	40 482	37 954	41 224	42 379
Sugar beets	69 495	65 698	62 898	59 167	56 323	57 806	49 600	48 745	47 439	41 653	39 301	36 182
Fodder beets	37 414	32 188	22 917	17 577	13 302	9 953	7 991	6 233	4 974	4 035	3 819	5 206
Root crops, total	146 225	133 387	123 761	115 433	107 811	105 410	93 637	96 027	92 895	83 642	84 343	83 768
Winter rape, excl non food	67 490	83 865	86 383	63 677	54 743	59 921	83 675	109 833	87 530	97 559	148 559	172 606
Winter rape, non food	5 727	6 406	18 392	17 501	16 203	17 640	18 532	10 448	21 742	24 389	30 253	0
Winter rape	73 217	90 272	104 775	81 178	70 947	77 561	102 207	120 281	109 271	121 948	178 812	172 606
Spring rape, excl non food	25 884	18 551	26 708	12 181	3 760	3 074	1 634	851	1 282	1 064	404	388
Spring rape, non food	4 413	3 056	8 327	5 765	3 901	3 122	2 502	494	2 859	1 456	626	0
Spring rape, total	30 297	21 607	35 035	17 946	7 661	6 196	4 136	1 345	4 141	2 521	1 030	388
Rape, total	103 514	111 879	139 810	99 125	78 608	83 758	106 343	121 626	113 412	124 469	179 842	172 994
Flax	3 461	3 871	10 698	5 029	1 422	221	117	113	98	212	59	211
Other seeds for industrial use	52	0	7	21	17	47	28	16	60	145	113	198
Seeds for industrial use, total	107 027	115 751	150 515	104 175	80 047	84 025	106 488	121 755	113 571	124 840	180 072	173 580
Seeds for sowing	61 212	84 515	80 979	78 949	84 958	71 040	87 193	90 781	96 122	103 941	87 262	82 058

O) Area of cultivated. *Continued…*

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Lucerne	7 342	6 850	5 514	5 245	3 451	3 566	3 946	4 147	4 575	3 982	3 682	3 756
Maize for green fodder	42 701	46 992	48 452	61 493	78 814	95 741	118 267	129 317	131 027	135 245	144 869	159 030
Cereals and pulses for green fodder	101 124	115 657	117 782	118 763	113 504	112 469	110 089	102 041	75 512	63 998	60 348	52 251
Pulses. fodder cabbage etc.	411	673	622	585	843	48	52	61	43	20	31	19
Grass and clover in rotation	235 285	249 128	238 107	246 656	240 320	218 000	211 950	196 375	253 007	270 840	262 429	300 251
Grass and green fodder in rotation. total	386 863	419 300	410 478	432 741	436 932	429 823	444 303	431 941	464 164	474 084	471 359	515 306
Vegetables grown in the open, excl peas for canning	6 251	6 084	6 157	6 479	6 015	6 066	6 396	6 656	6 432	7 089	7 077	7 456
Peas for canning	3 124	3 962	4 172	4 149	3 441	2 689	3 386	2 979	2 999	2 841	2 741	3 592
Vegetables grown in the open, total	9 374	10 046	10 329	0	0	8 755	9 783	9 635	9 430	9 930	9 817	11 048
Bulbs and flowers	180	156	194	175	160	148	150	128	127	141	161	293
Apples	1 697	1 660	1 623	1 679	1 783	1 574	1 624	1 673	1 751	1 645	1 812	1 797
Pears	430	555	431	441	469	420	457	439	416	413	465	442
Strawberries	1 095	983	991	984	1 066	788	805	899	1 091	1 277	1 135	1 144
Sour cherries	2 505	2 490	2 626	2 639	2 569	2 558	2 615	2 380	1 977	1 967	2 006	1 757
Sweet cherries	89	101	130	163	134	113	152	133	155	162	161	193
Cherries, total	2 594	2 591	2 756	0	0	2 671	2 767	2 513	2 132	2 128	2 167	1 950
Black current	1 531	1 280	1 411	1 492	1 850	1 939	2 028	1 976	2 000	1 846	1 855	2 071
Other fruits and berries	523	435	472	612	576	584	648	756	848	774	887	889
Fruits and berries, total	7 874	7 505	7 683	0	0	7 976	8 330	7 816	8 237	8 083	8 322	8 294
Nursery area	3 261	2 997	2 925	2 866	2 817	2 600	2 626	2 503	2 318	2 275	2 255	2 519
Horticultural crops, total	20 689	20 703	21 132	21 678	20 880	19 478	20 889	20 522	20 113	20 429	20 556	22 154
Permanent grass land out of rotation	167 600	156 260	159 530	166 261	173 702	177 546	177 635	172 536	192 968	189 384	196 630	189 962
Set aside with grass	147 400	141 432	182 905	191 295	201 817	204 721	206 584	196 972	175 200	167 502	153 570	70 662
Christmas trees	0	0	0	0	0	0	0	0	0	0	0	0
Other crops and fallow land	477	468	1 236	1 146	940	1 834	2 309	2 538	25 551	22 518	18 173	20 285
Other crops	0	0	0	0	0	0	0	0	0	0	0	0
Fallow land	0	0	0	0	0	0	0	0	0	0	0	0
Total agricultural area	2 688 014	2 671 850	2 644 048	2 646 982	2 675 566	2 665 507	2 657 706	2 645 304	2 707 236	2 710 507	2 662 761	2 667 895

O) Area of cultivated. *Continued…*

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Winter wheat	716 472	743 911	724 487	588 724	542 051	651 530	608 733	568 815	579 495	406 774
Spring wheat	9 379	13 753	20 221	30 981	28 803	16 910	12 641	16 253	13 982	32 793
Wheat, total	725 851	757 663	744 708	619 705	570 854	668 441	621 374	585 068	593 477	439 567
Rye	42 197	51 336	56 097	57 537	88 181	104 093	125 540	98 977	108 749	89 981
Winter barley	141 270	142 560	130 882	104 214	110 853	145 209	114 178	111 653	126 959	81 931
Spring barley	443 183	425 510	471 143	623 447	578 675	490 533	524 952	598 008	546 412	707 690
Barley, total	584 453	568 070	602 025	727 661	689 528	635 743	639 131	709 662	673 371	789 621
Oats	53 381	41 907	42 304	51 010	53 488	34 830	37 797	51 725	56 740	80 153
Triticale etc	54 977	50 192	45 472	39 263	32 730	31 667	30 054	21 257	20 192	20 850
Cereals, total	1 460 859	1 469 168	1 490 606	1 495 177	1 434 781	1 474 773	1 453 896	1 466 687	1 452 529	1 420 173
Pulses	6 332	10 349	7 109	6 252	7 912	8 793	12 229	14 864	20 627	33 983
Seed potatoes	4 551	5 189	5 151	6 535	4 957	5 302	5 851	5 550	6 557	7 048
Potatoes for manufacturing	17 728	16 637	18 948	21 322	21 217	21 562	22 012	25 543	27 250	28 786
Potatoes for human consumption	15 787	16 312	16 433	13 764	14 218	15 753	13 716	12 793	13 230	12 801
Potatoes	38 067	38 138	40 532	41 622	40 392	42 617	41 579	43 885	47 038	48 635
Sugar beets	37 674	39 074	39 945	42 893	38 680	35 859	25 004	34 550	33 114	39 369
Fodder beets	5 257	4 118	3 985	4 562	5 736	6 708	5 188	4 336	4 583	4 006
Root crops, total	80 998	81 331	84 462	89 077	84 809	85 183	71 771	82 771	84 735	92 009
Winter rape, excl non food	160 326	163 436	150 402	124 449	173 746	164 221	192 535	163 749	176 829	144 254
Winter rape, non food	0	0	0	0	0	0	0	0	0	0
Winter rape	160 326	163 436	150 402	124 449	173 746	164 221	192 535	163 749	176 829	144 254
Spring rape, excl non food	613	1 372	1 818	2 467	1 371	1 375	699	536	860	1 094
Spring rape, non food	0	0	0	0	0	0	0	0	0	0
Spring rape, total	613	1 372	1 818	2 467	1 371	1 375	699	536	860	1 094
Rape, total	160 940	164 808	152 220	126 915	175 117	165 595	193 234	164 285	177 688	145 347
Flax	134	90	39	16	29	100	6	56	107	0
Other seeds for industrial use	706	823	854	541	583	897	401	1 086	857	1 123
Seeds for industrial use, total	161 779	165 721	153 113	127 472	175 729	166 592	193 640	165 427	178 652	146 471
Seeds for sowing	90 112	66 655	66 122	75 529	79 616	77 825	74 512	72 835	82 251	102 860

O) Area of cultivated. *Continued…*

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Lucerne	5 366	6 405	6 926	4 715	3 715	3 814	2 579	1 923	1 939	1 372
Maize for green fodder	168 917	172 168	173 693	183 570	182 935	183 370	177 908	178 540	165 338	177 678
Cereals and pulses for green fodder	55 848	62 845	56 672	54 333	58 945	61 100	56 621	60 461	48 686	50 878
Pulses, fodder cabbage etc.	0	26	0	0	0	0	0	0	0	0
Grass and clover in rotation	305 476	320 914	329 135	326 797	320 131	312 536	255 623	269 983	272 185	264 146
Grass and green fodder in rotation. total	535 607	562 358	566 426	569 415	565 725	560 820	492 732	510 907	488 148	494 075
Vegetables grown in the open, excl peas for canning	7 726	8 043	8 209	7 382	7 675	9 209	8 331	8 812	9 576	9 779
Peas for canning	3 737	2 677	2 935	2 837	2 209	2 505	2 749	3 241	3 430	3 136
Vegetables grown in the open, total	11 462	10 720	11 144	10 219	9 884	11 714	11 080	12 053	13 006	12 914
Bulbs and flowers	101	92	71	86	46	31	39	28	51	55
Apples	1 730	1 684	1 550	1 703	1 563	1 484	1 501	1 490	1 471	1 677
Pears	372	357	336	344	299	308	317	317	333	305
Strawberries	983	1 137	1 160	1 185	1 119	1 455	1 227	1 186	1 275	1 269
Sour cherries	0	0	0	0	0	0	0	0	0	0
Sweet cherries	0	0	0	0	0	0	0	0	0	0
Cherries. total	1 864	1 743	1 466	1 401	1 380	1 317	1 059	1 047	870	639
Black current	1 848	1 935	2 041	1 855	2 167	1 719	1 121	755	588	541
Other fruits and berries	913	927	1 031	1 006	1 047	1 308	1 124	1 240	1 026	1 202
Fruits and berries, total	7 723	7 797	7 596	7 508	7 604	7 611	6 348	6 036	5 562	5 633
Nursery area	1 827	1 521	1 041	1 247	1 199	1 061	2 270	2 009	1 977	1 974
Horticultural crops, total	21 114	20 130	19 852	19 060	18 733	20 417	19 737	20 126	20 596	20 576
Permanent grass land out of rotation	191 529	199 859	186 652	200 413	195 484	192 617	254 770	225 620	234 680	212 657
Set aside with grass	5 699	9 874	4 367	5 018	9 123	4 930	4 501	6 079	5 461	9 253
Christmas trees	18 281	19 521	17 609	20 593	18 928	23 461	22 101	20 908	21 603	23 693
Other crops and fallow land	51 665	41 435	43 906	36 782	37 126	36 943	33 058	38 868	42 007	76 702
Other crops	18 556	16 569	23 217	17 230	20 010	20 091	11 013	11 011	10 205	9 578
Fallow land	33 108	24 866	20 689	19 551	17 116	16 853	22 045	27 857	31 802	67 124
Total agricultural area	2 623 975	2 646 400	2 639 944	2 644 631	2 627 817	2 652 026	2 632 947	2 625 093	2 631 289	2 632 453

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	2001
Winter wheat	10	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	6
Rye	9	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	8
Spring barley	8	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	7.5
Triticale etc.	9	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	14.5
Potatoes for manufacturing	15	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	15
Sugar beets	12	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	11
Winter rape, excl non food	9	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	9
Spring rape, excl non food	8	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	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	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	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	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	2.6
Maize for green fodder	8	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	8
Pulses. fodder cabbage etc.	8	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	5
Peas for canning	8	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	3.2

a) Soil cultivation. *Continued…*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Winter wheat	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	10	10
Spring wheat	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7
Rye	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	9	9
Winter barley	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	8	8
Spring barley	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7
Oats	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	6	6	6	6	6	6	6	6
Triticale etc	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	10	10
Seed potatoes	14.5	14.5	14.5	14.5	14.5	14.5	14.5	16.5	20.5	19	19	19	19	19	19	19	19
Potatoes for manufacturing	16	17	17	17	17	17	17	19	22	19	19	19	19	19	19	20	20
Potatoes for human consumption	15	15	15	15	15	15	15	17	20	16	16	16	16	16	16	16	16
Sugar beets	12	12	12	12	12	12	12	12	12	12	12	12	12	13	13	14	14
Fodder beets	11	11	10	10	10	11	11	11	11	11	11	11	11	11	11	12	12
Winter rape, excl non food	8	9	9	9	9	9	9	9	9	9	9	9	9	10	10	10	10
Winter rape, non food	8	9	9	9	9	9	9	9	9	9	9	9	9	10	10	10	10
Spring rape, excl non food	6	6	6	6	6	6	6	6	7	7	7	7	7	5	5	5	5
Spring rape, non food	6	6	6	6	6	6	6	6	7	7	7	7	7	5	5	5	5
Flax	7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8	8	8	8	8	7.5	7.5	7.5	7.5
Other seeds for industrial use	7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8	8	8	8	8	7.5	7.5	7.5	7.5
Seeds for sowing	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.9	5.5	5.5	5.5	5.5
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	2.6
Maize for green fodder	8	8	8	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Cereals and pulses for green fodder	7	7	7	7	7	7	6	6	6	6	6	6	6	6	6	6	6
Pulses, fodder cabbage etc.	7	7	7	7	7	7	6	6	6	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	4	4	4	4	4
Peas for canning	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7
Permanent grass land out of rotation	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.2	1.2	1.2	1.2	1.2

b) Harvesting.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Winter wheat	1	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	1
Rye	1	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	1
Spring barley	1	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	1
Triticale etc.	1	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	1
Potatoes for manufacturing	1	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	1
Sugar beets	1	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	2
Winter rape, excl non food	1	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	1
Spring rape, excl non food	1	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	1
Flax	1	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	1
Seeds for sowing	1	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	0
Maize for green fodder	1	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	2
Pulses, fodder cabbage etc.	2	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	2
Peas for canning	1	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	1

b) Harvesting. *Continued…*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Winter wheat	1	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	1
Rye	1	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	1
Spring barley	1	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	1
Triticale etc.	1	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	1
Potatoes for manufacturing	1	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	1
Sugar beets	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fodder beets	2	2	2	1	1	1	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	1	1
Winter rape, non food	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spring rape, excl non food	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1
Spring rape, non food	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1
Flax	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1	1	1	1	1	1	1
Other seeds for industrial use	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	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	1
Lucerne	0	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	1
Cereals and pulses for green fodder	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
Pulses, fodder cabbage etc.	1	1	1	1	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	2
Peas for canning	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Permanent grass land out of rotation	0	0	0	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	2001
Winter wheat	1	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	1
Rye	1	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	1
Spring barley	1	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	1
Triticale etc.	1	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	1
Potatoes for manufacturing	0	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	1
Sugar beets	0	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	0
Winter rape, excl non food	0	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	0
Spring rape, excl non food	0	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	0
Flax	0	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	0
Seeds for sowing	1	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	0
Maize for green fodder	0	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	0
Pulses, fodder cabbage etc.	0	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	0
Peas for canning	1	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	1

c) Cleaning. *Continued…*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Winter wheat	1	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	1
Rye	1	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	1
Spring barley	1	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	1
Triticale etc.	1	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	0	0	0	0	0	0	0	0
Potatoes for manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Potatoes for human consumption	1	1	0	0	0	0	0	0	0	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	0
Fodder beets	0	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	0
Winter rape, non food	0	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	0
Spring rape, non food	0	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	0
Other seeds for industrial use	0	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	1
Lucerne	0	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	0
Cereals and pulses for green fodder	0	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	0
Grass and clover in rotation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peas for canning	1	1	1	1	1	0	0	0	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	1	1

d) Drying.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	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	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	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	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	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	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	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	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	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	0.5
Sugar beets	0	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	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	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	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	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	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	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	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	0.5
Lucerne	0	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	0
Cereals and pulses for green fodder	0	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	0
Grass and clover in rotation	0	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	0.5
Permanent grass land out of rotation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

d) Drying. *Continued…*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	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	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	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	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	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	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	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	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	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	0.5
Sugar beets	0	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	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	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	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	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	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	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	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	0.5
Lucerne	0	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	0
Cereals and pulses for green fodder	0	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	0
Grass and clover in rotation	0	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	0.5
Permanent grass land out of rotation	0	0	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	2001
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	0.12
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	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	0.003
NO_x	kt	1.47	1.26	1.20	0.90	0.94	0.07	0.08	0.07	0.08	0.08	0.09	0.09	0.09	0.12	0.11	0.11	0.11
CO	kt	42.55	36.56	34.73	25.96	27.32	2.15	2.23	2.13	2.33	2.25	2.54	2.53	2.68	3.37	3.20	3.16	3.32
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	75.33
SO_2	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	0.02
NMVOC	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	0.02
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	0.29
PM_{10}	kt	3.64	3.12	2.97	2.22	2.34	0.18	0.19	0.18	0.20	0.19	0.22	0.22	0.23	0.29	0.27	0.27	0.28
$PM_{2.5}$	kt	3.45	2.96	2.81	2.10	2.21	0.17	0.18	0.17	0.19	0.18	0.21	0.20	0.22	0.27	0.26	0.26	0.27
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	0.02
Metals																		
Pb	t	0.07	0.06	0.06	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Cd	t	0.561	0.482	0.458	0.343	0.360	0.028	0.029	0.028	0.031	0.030	0.034	0.033	0.035	0.044	0.042	0.042	0.044
Hg	t	0.089	0.077	0.073	0.054	0.057	0.005	0.005	0.004	0.005	0.005	0.005	0.005	0.006	0.007	0.007	0.007	0.007
As	t	0.004	0.004	0.003	0.002	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	t	0.051	0.044	0.042	0.031	0.033	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004
Ni	t	0.033	0.029	0.027	0.020	0.021	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.003
Se	t	0.013	0.011	0.010	0.008	0.008	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	t	0.357	0.307	0.292	0.218	0.229	0.018	0.019	0.018	0.020	0.019	0.021	0.021	0.022	0.028	0.027	0.026	0.028
Cu	t	0.047	0.040	0.038	0.028	0.030	0.002	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.004	0.004	0.003	0.004
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	0.03
PAH																		
(a)[1]	t	0.26	0.22	0.21	0.16	0.17	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
(b)[1]	t	0.73	0.62	0.59	0.44	0.47	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.06	0.05	0.05	0.06
(k)[1]	t	0.31	0.26	0.25	0.19	0.20	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
(1,2,3)[1]	t	0.43	0.37	0.35	0.26	0.27	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
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	0.12
PCB	kg	0.002	0.002	0.002	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[1] (a) Benzo(a)pyrene (b) Benzo(b)fluoranthene (k) Benzo(k)fluoranthene (1,2,3) Indeno(1.2.3-cd)pyrene

Q) *Continued…*

		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NH_3	kt	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	0.09	0.09	0.10	0.12
CH_4	kt	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	0.11	0.10	0.12	0.14
N_2O	kt	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	0.003	0.003	0.004
NO_x	kt	0.10	0.11	0.12	0.12	0.12	0.11	0.10	0.12	0.08	0.08	0.10	0.10	0.10	0.09	0.09	0.10	0.12
CO	kt	2.76	3.32	3.48	3.53	3.58	3.10	2.87	3.37	2.46	2.44	2.80	3.02	2.98	2.62	2.58	2.90	3.38
CO_2	kt	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	59.45	58.65	65.96	76.83
SO_2	kt	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	0.02	0.02	0.03
NMVOC	kt	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	0.02	0.02	0.03
<u>PM</u>																		
TSP	kt	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	0.23	0.22	0.25	0.29
PM_{10}	kt	0.24	0.28	0.30	0.30	0.31	0.26	0.25	0.29	0.21	0.21	0.24	0.26	0.25	0.22	0.22	0.25	0.29
$PM_{2.5}$	kt	0.22	0.27	0.28	0.29	0.29	0.25	0.23	0.27	0.20	0.20	0.23	0.24	0.24	0.21	0.21	0.24	0.27
BC	kt	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	0.02	0.02	0.03
<u>Metals</u>																		
Pb	t	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cd	t	0.036	0.044	0.046	0.047	0.047	0.041	0.038	0.045	0.032	0.032	0.037	0.040	0.039	0.035	0.034	0.038	0.045
Hg	t	0.006	0.007	0.007	0.007	0.008	0.007	0.006	0.007	0.005	0.005	0.006	0.006	0.006	0.005	0.005	0.006	0.007
As	t	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	t	0.003	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.003	0.003	0.003	0.004	0.004	0.003	0.003	0.003	0.004
Ni	t	0.002	0.003	0.003	0.003	0.003	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
Se	t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	t	0.023	0.028	0.029	0.030	0.030	0.026	0.024	0.028	0.021	0.020	0.023	0.025	0.025	0.022	0.022	0.024	0.028
Cu	t	0.003	0.004	0.004	0.004	0.004	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004
Dioxin	g I-TEQ	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	0.02	0.02	0.03	0.03
<u>PAH</u>																		
(a)[1]	t	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
(b)[1]	t	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.06	0.04	0.04	0.05	0.05	0.05	0.04	0.04	0.05	0.06
(k)[1]	t	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
(1,2,3)[1]	t	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
HCB	kg	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	0.10	0.10	0.11	0.12
PCB	kg	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[1] (a) Benzo(a)pyrene (b) Benzo(b)fluoranthene (k) Benzo(k)fluoranthene (1,2,3) Indeno(1.2.3-cd)pyrene

R) Gross energy per kg DM for dairy cattle. 1985-2018. MJ per kg DM.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	18.7

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
MJ per kg DM	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	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**

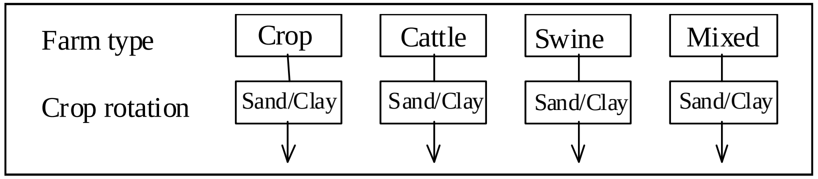
T) National MCF for liquid manure. 1985-2018.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cattle - untreated liquid manure	12.00	12.00	12.00	12.00	12.00	12.00	11.98	12.06	11.99	11.92	11.89	11.83	12.22	12.57	12.57	12.70	12.70
Cattle - biogas treated liquid manure	6.49	6.49	6.49	6.49	6.49	6.49	6.48	6.57	6.51	6.46	6.45	6.40	6.81	7.20	7.19	7.34	7.33
Swine - untreated liquid manure	15.25	15.25	15.25	15.25	15.25	15.25	15.28	15.30	15.22	15.15	15.11	15.06	15.02	14.93	14.86	14.86	14.79
Swine - biogas treated liquid manure	12.08	12.08	12.08	12.08	12.08	12.08	12.11	12.12	12.02	11.93	11.90	11.83	11.79	11.69	11.60	11.60	11.52
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	10.35

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cattle - untreated liquid manure	12.73	12.69	12.72	12.55	12.55	12.68	12.71	12.59	12.56	12.61	12.57	12.79	12.61	12.59	12.53	12.49	12.40
Cattle - biogas treated liquid manure	7.41	7.40	7.46	7.33	7.36	7.51	7.58	7.58	7.60	7.68	7.84	8.12	8.00	7.85	7.53	7.50	7.48
Swine - untreated liquid manure	14.81	14.81	14.76	14.03	14.02	13.99	13.89	13.93	13.93	13.87	13.79	13.74	13.69	13.67	13.57	13.42	13.37
Swine - biogas treated liquid manure	11.59	11.63	11.61	10.87	10.94	10.96	10.90	11.02	11.08	11.10	11.11	11.11	11.15	10.98	10.51	10.34	10.38
Fur bearing animals - liquid manure	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	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

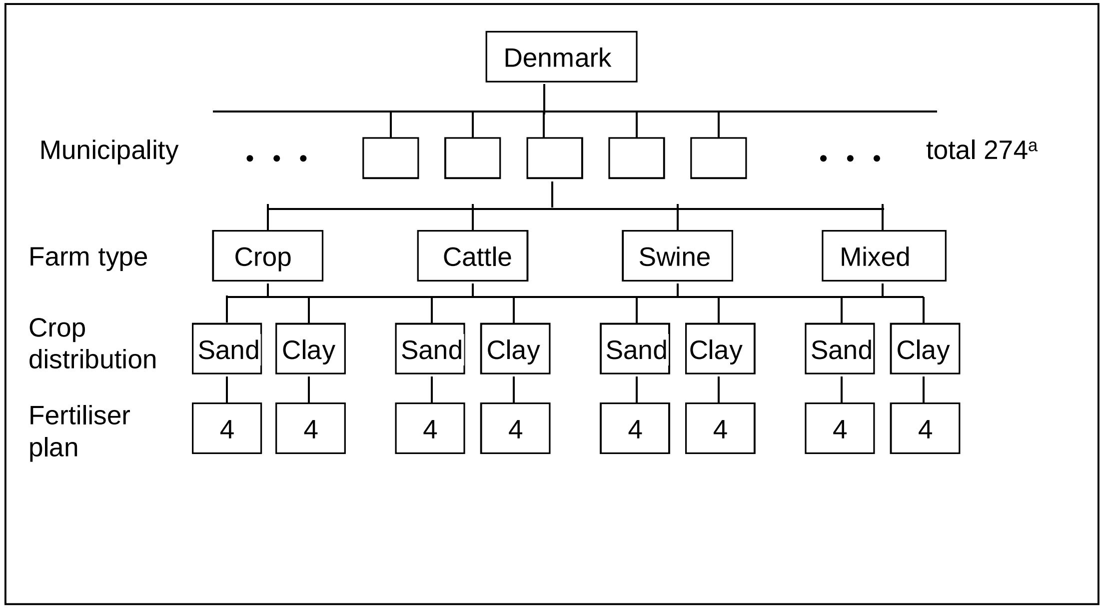
Data base
Calculation for all combinations for each of 4 climate year
Calculation for 12 combinations for each year in an 11 years period (1989-2001).

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

Upscaling by the SKEP model

In the up scaling of DAISY calculations a climate normalisation and yield correction is made
[a] former municipality division



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	SEGES + DAA
Grazing days		SEGES
Crops	- land use	DSt
	- crop yield	
	- crop production	
Synthetic fertiliser	- N content	DAA
	- 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 + DAA
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)

DANISH EMISSION INVENTORIES FOR AGRICULTURE

Inventories 1985 – 2018

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 2018 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. Emissions is calculated for both greenhouse gases and air pollutions. The agricultural NH_3 emission from 1985 to 2018 has decreased from 107 kilo tonnes NH_3 to 60 kilo tonnes NH_3, corresponding to a reduction of approximately 44 %. The emission of greenhouse gases in 2018 is estimated at 11.0 million tonnes CO_2 equivalents and reduced from 13.8 million tonnes CO_2 equivalents in 1985. Since 1990, which is the base year of the Kyoto protocol, a reduction of 16 % is obtained

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