Agriculture in Denmark

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1. A brief description of the agricultural sector - now and 30 years back

1.1. Area

Danish agriculture occupied in 2013 26.278 km^2 (approx. 2.6 million hectares). This represents 62 % of Denmark's total area of 43,094 km^2 (2012). Since 1982, there has been a decline in the cultivated area from approx. 2,900,000 hectares to 2,788,000 hectares in 1990 and 2,669,000 hectares in 2012, representing a reduction of approximately 8 % (4 %.between 1990 and 2012).

1.2. Production and structural development

An overall trend in Danish agriculture is that there are fewer and fewer, but increasingly larger farms. Within the past 30 years, the number of farms has more than halved from just over 100,000 farms in 1982 to about 40,600 in 2012, of which only approximately 30 % are full-time farms. The reduction was most noticeable among full-time farms. This development occurred in parallel with changes in farming methods towards increased mechanization and specialization justified by the agroindustrial complex by demand for high productivity in order to maintain competitiveness in a global market.

The average size of a Danish farm has more than doubled since 1982, from just below 30 hectares to about 66 ha in 2012. In the meantime specialization in livestock production has led to fewer but larger livestock herds. The trend is particularly noticeable for swine holdings where the average herd size has increased from 169 pigs per year and farm in 1982 to almost 3,000 in 2012. Cattle numbers have almost halved over the same period, whereas the average herd size has more than doubled, from 53 to 127 per holding.

In 2012, the annual total in crop production amounts to about 170 million crop units (equivalent to the feeding value of 17 million tonnes grain)[1], over half of which are cereal crops. Approximately 80 % of plant production is used as feed for livestock, mainly pigs and cattle.

Milk production has decreased slightly since the introduction of the milk quota in 1984 and is currently at a total of approximately 4.5 million tonnes. The total number of dairy cows, however, has been almost halved over the period, while yield per cow has almost doubled. In 2012, dairy cows gave on average 9,019 kg of milk annually.

Pig production has increased in number from approx. 9 million in 1990 to 12 million in 2012. In recent years there has been a change in the composition of the pig population, since more piglets are exported to feed outside Denmark. The relative proportion of sows has therefore increased.

(Jordbruget i Danmark, Danmarks Statistik (2014); Notat om økonomi i husdyrproduktionen i Danmark (2010)).

Table 1. Number of animals in Danish agriculture.

	1989	1999	2010	2012
Cattle	2 221 485	1 887 057	1 571 050	1 606 826

[1] One feeding value unit is equivalent to the feeding value of 1 kg of barley, wheat or rye; 1.2 kg oats; 1 kg dry matter from potatoes, beets, carrots or clover; 1.3 kg dry matter from beet tops; 4 kg of straw from wheat, barley or oat or 4.5 kg straw from rye. 100 feeding value units correspond to one crop unit (source: www.den storedanske.dk)

Pigs	9 189 981	11 626 043	13 173 060	12 330 879
Sheep	144 168	142 880	159 626	153 691
Goats	n.a.	n.a.	13 005	9 354
Horses	35 446	40 485	59 735	68 467
Poultry	17 194 203	21 010 135	18 731 331	18 990 746
Fur animals	n.a.	n.a.	2 713 710	2 952 702

The distribution of different soil types and production forms is reflected in the livestock density in different parts of the country, which is highest in Northern and Western Jutland and least on Zealand. Zealand is characterized by a relatively larger share of crop production in general; however roughage production is the highest in Jutland.

The Danish farming emissions are closely linked to livestock – directly in the form of emissions from manure management and ruminant digestion and indirectly in terms of the emissions associated with feed production in Denmark and abroad.

1.3. Employment, demography and consumption

Out of about 40,600 farms (in 2012), approx. 12,000 were full-time farms (where working hours are over 1,665 hours per year) and about 28,000 were part-time farms. Full-time farms accounted thus for approx. 30 % of the farms.

In 2012, 69,643 people were employed in agriculture, forestry and fishery, whereas the total labour force was approx. 2,623,000 people. This means that these sectors employ less than 3 % of the total labour force in Denmark. 43 % of those employed in agriculture, forestry and fishing are 50+ years and 15 % are 67 years or older.

If one considers merely the group of self-employed within these sectors, 69 % are 50+ years and 28 % are 67+ years. This trend of increased age amongst the self-employed within these sectors partly reflects the fact that the land in Denmark has become so expensive and farms have become so large that younger farmers find it very difficult to get established. The Danish Government try to encourage young farmers (up to 40 years) to establish themselves on their own farm by extra financial support.

Furthermore, this development occurred in parallel with declining world prices for agricultural products and thereby decreasing income, which has resulted in a generally poor economy in Danish agriculture, which is largely depending on exports. Although the world market prices are determining for the economy in Danish agriculture, the farmers' income is also affected by the home market and thus on how much the Danes are spending on food. However, "food" takes up relatively ever less in the Danes' budget. In 1985, Danish consumption of food constituted around 22 % of their total spending. 10 years later it was approximately 18 %; 20 years later it had fallen to about 14 %; and today it is down to just below 10 %.

2. Agricultural emissions of greenhouse gases - now and 20 years back

2.1. Domestic emissions

In 2012, Denmark's total emissions (excl. LULUCF) were 51.6 mio. tonnes of CO_2e. When including LULUCF, the emissions were 50.8 mio. tonnes of CO_2e (Energistyrelsen (2014); Eionet (2014)).

In 1990, total emissions (excl. LULUCF) were 68.7 mio. tonnes CO_2e. When including LULUCF, the emissions were then 73.9 mio. tonnes CO_2e.

The total Danish emissions (excl. LULUCF) have fallen approx. 25 % from 1990 to 2012, and approx. 31 % when LULUCF is included (see Figure 1).

After “Energy Industry and Transport”, the agricultural sector is the sector with the highest climate impact.

From 1990 to 2012, emissions from agriculture (from nitrous oxide and methane as defined when Denmark reports its emissions to the UNFCCC) fell from about 12.5 mio. tons CO_2e to about 9.6 mio. tonnes CO2e (excl. LULUCF), which is a decrease of approx. 23 %. When LULUCF is included, emissions from agriculture fell from about 17.6 mio. tonnes CO_2e in 1990 to about 13.1 mio. tonnes CO_2e in 2012, which is a decrease of approx. 25 %.

The division into sectors in Figure 1 (which is used when Denmark reports its emissions to the UNFCCC) implies that agricultural consumption of energy for e.g. transport and heating belongs to the sector "Energy Industry and Transport". The agriculture-related share of LULUCF is listed within the LULUCF sector. It is only methane and nitrous oxide, which is listed under "Agriculture". When talking about agriculture's share of the emission of greenhouse gases, contributions related to energy consumption and LULUCF is therefore often neglected.

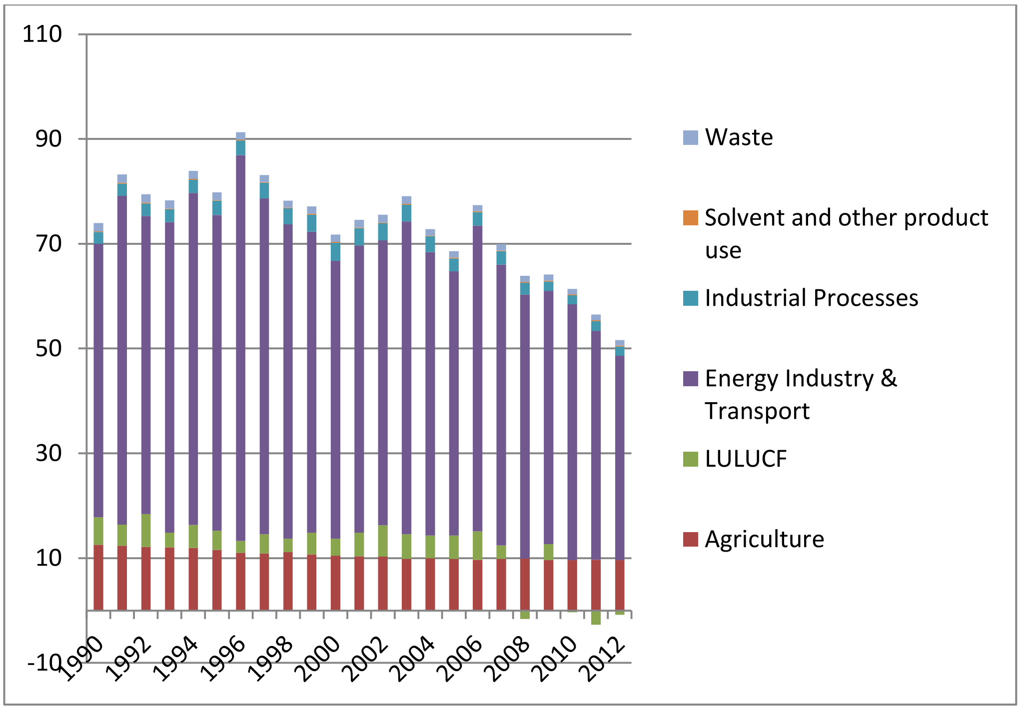


Figure 1. Greenhouse gas emissions in CO_2-equivalents distributed on main sectors and for the time-series (million tonnes CO_2 eqvivalents). DCE 2014a.

In 2012, agriculture thus represented approximately 18 % of Denmark's total emissions according to the official calculations (that is excl. emissions from LULUCF and energy consumption), while the proportion is approx. 32 % when both LULUCF and energy consumption are included (see calculation in section 2.1.3. - 2.1.4.).

Finally, one can then subtract emissions saved related to the production of bioenergy substituting fossil fuels amounting to 2.4 mio. tonnes CO_2e (as demonstrated in section 2.1.6.). The saved emissions correspond to nearly 5 % of Denmark’s total emissions (when emissions related to ILUC is not included).

A calculation to summarize the emissions from agriculture can be stated as follows: N_2O + CH_4 + LULUCF + CO_2 (from energy consumption) – CO_2 (from saved energy consumption) (all in mio. tonnes CO_2e) = 5,4 + 4,2 + 3,4 + 3,5 – 2,4 = 14,1 mio. tonnes CO_2e. A fairly accurate estimation of agriculture’s share of Denmark’s total emissions can therefore be summarized to approx. 28 %.

2.1.1. Nitrous oxide, N_2O

Agriculture is the main source of nitrous oxide emissions (see Figure 2). Nitrous oxide is produced when microorganisms break down and convert various nitrogen-containing compounds. The amount of nitrogen in the soil increases when adding manure, mineral fertilizers, or if growing nitrogen-fixing plants. This increases the risk of the formation of nitrous oxide. Soils with a high content of nitrogen, especially humus-rich soils , can release some nitrous oxide, whether additional nitrogen fertilizer is applied or not. Nitrous oxide is also formed and emitted in the handling and application of manure.

Nitrous oxide emissions from agriculture were 17.4 Gg in 2012 (DCE 2014a), which represents approx. 90 % of the total nitrous oxide emissions (see figure 3). This is equivalent to 5.4 million CO_2e, which corresponds to approx. 11 % of Denmark's total emissions of greenhouse gases (the GWP factor of nitrous oxide is set to 310).

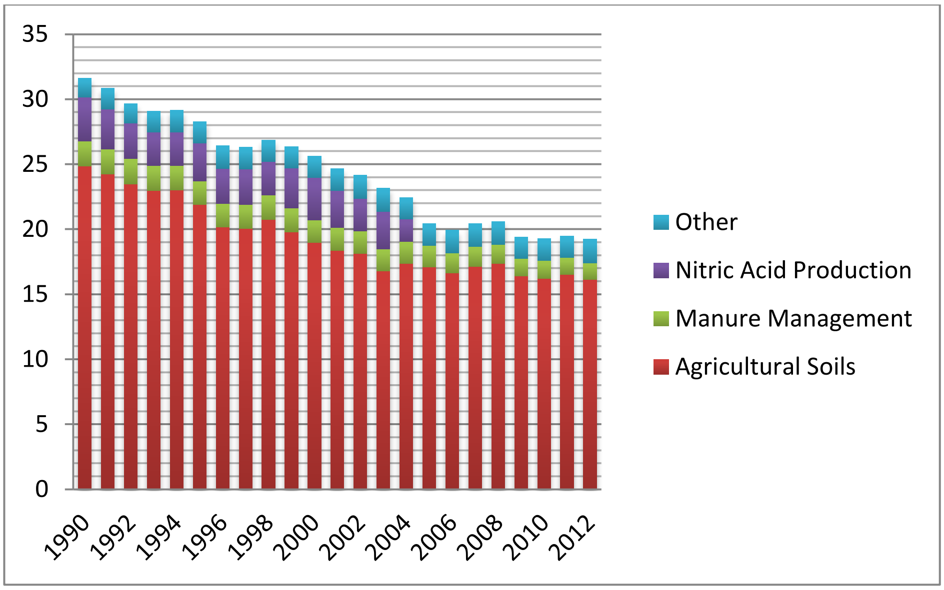


Figure 2. Nitrous oxide emissions in Denmark 1990-2012 in 1000 tonnes. Danish production of nitric acid stopped in 2004 and the emissions from industrial processes is therefore not occurring from 2005 onwards. (DCE 2014 a).

The largest share of nitrous oxide emissions comes from agricultural land. It is especially applied nitrogen from fertilizers and manure and the associated nitrogen leaching that has given and still gives rise to the greatest emissions (DCE48).

Between 1990 and 2003 there was a steady reduction in nitrous oxide emissions from agriculture (in total 30 %), but since 2003 emissions have remained at approximately the same level (see figure 3). The reduction can particularly be related to the lowering of nitrogen standards and improved utilization of the nitrogen in manure, which has resulted in reduced need for chemical fertilizers. Both of these changes are the result of implementation of ammonia emission reduction technology according to the The Danish Action Plans for the Aquatic Environment. A smaller proportion of the reduction is due to manure management and the use of nitrification inhibitors. Over the same period of years the agricultural area decreased with approximately 4 %, which also has also limited the use of nitrogen fertilizer. (DCE48)

2.1.2. Methane, CH_4

Agriculture is the main source of methane emissions (see Figure 3).

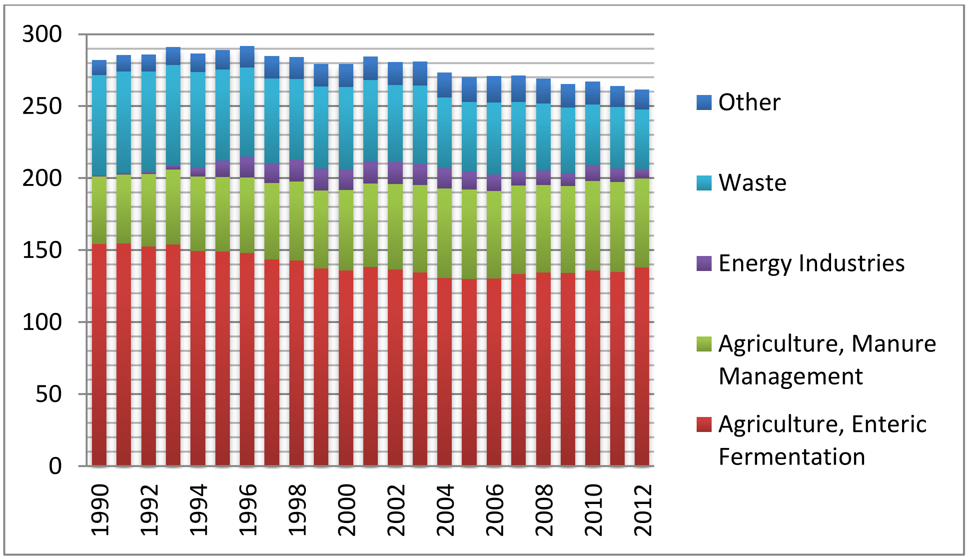


Figure 3. Methane emissions in Denmark 1990-2012 in 1000 tonnes. (DCE 2014a).

The majority of methane emissions in agriculture stems from ruminants. The gas is formed naturally during the digestion process (enteric fermentation). Methane is also formed via anaerobic decomposition of manure.

In 2012, the emissions were approx, 200 Gg (which accounted for almost 77 % of the total CH_4 emissions of approx. 262 Gg). This equivalents to 4.2 million tonnes of CO_2e, representing almost 8 % of Denmark's total emissions of greenhouse gases (the GWP factor of methane is set to 21).

Methane emissions from agriculture have for more than 20 years been approximately 200,000 tons (Figure 4). The emissions from ruminants has dropped slightly, but this decrease is offset by the emissions from the handling of fertilizer that has increased due to the transition from solid manure to (more) slurry.

2.1.3. LULUCF

The LUCUCF sector covers emissions from above-ground and below-ground living and dead biomass as well as carbon stored in the soil. The LULUCF sector alternates from being a net 'sink' and a net source of emissions. Agriculture's share of LULUCF is defined as “Cropland” and “Grassland” (in Figure 4). In years where the LULUCF sector as a whole has been a net sink (as in e.g. 2012), it has been due to forests and forest planting. Agriculture's contribution to LULUCF has been positive throughout the years (see Figure 4).

In 2012, the LULUCF was a net 'sink', with a carbon fixation representing the equivalent to approx. 2 % of total greenhouse gas emissions in Denmark. In that year the forests fixed approx. 4.4 million tonnes of CO_2e, (equivalent to almost 9 % of Denmark’s total emissions) while agricultural land released approx. 3.4 million tonnes of CO_2e equivalent to approx. 7 % of Denmark’s total emissions.

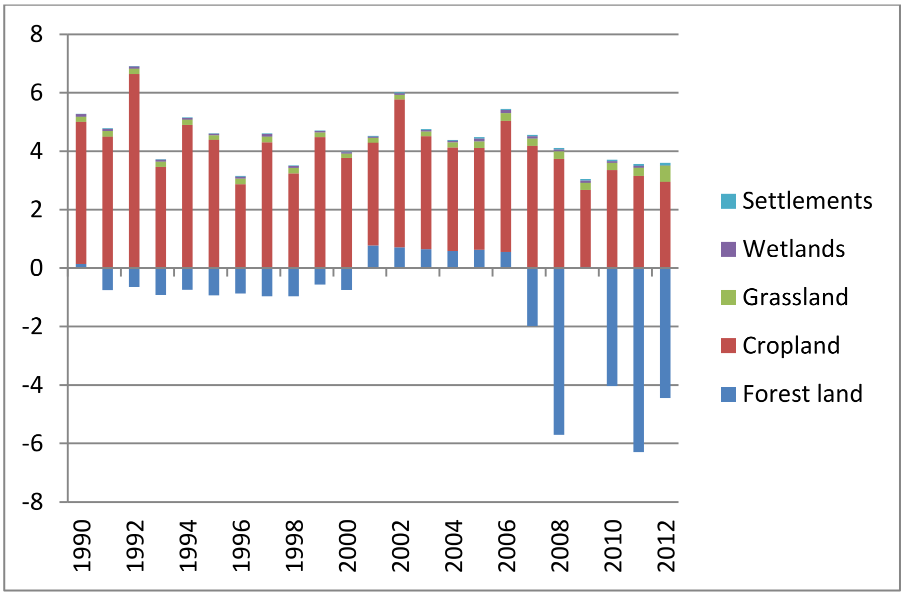


Figure 4. LULUCF in CO2-equivalents distributed on main land uses and time-series (mio. tonnes CO_2 eqvivalents). (Eionet 2014).

Emissions from living and dead biomass on agricultural soils changes from year to year and depend on the climatic conditions (temperature and rainfall) and crop choices in the specific year. The loss from living and dead biomass was in 2012 0.14 million tonnes CO_2e.

Since 1990 there has been a decrease in the total carbon storage in agricultural soils, although it has been prohibited (with some exceptions) to burn straw in the fields since 1990. At the same time, there has been a decrease in the area with organic soils with more than 12 % content of organic carbon. Since 1975, this area has dropped from more than 70,000 ha to below 42,000 ha in 2010. The area with a content of 6-12 % organic carbon in the soil was in same time period reduced from more than 40,000 ha to 30,000 ha. The reason for these changes is the intensive cultivation, since much carbon is lost when the land is drained and ploughed to the extent practiced in Denmark. Thus, in 2012, about 1.35 million CO_2e was lost from the mineral soils and about 1.87 million tonnes of CO_2e was lost from the organic soils.

2.1.4. Emissions from energy consumption

In addition to the above stated agricultural emissions, emissions from energy consumption in both building and machinery should be included.

Table 2. Calculation of emissions from energy consumption in agriculture in 2011 (RE = renewable energy).

	Electricity	Diesel oil	Natural gas	Coal, coke	District Heating	RE	Other	**In total**	Source
Energy consumption, primarily agricultural (TJ)	13,587	20,152	1,455	1,203	1,531	2,313	788	**41,030**	Landbrug & Fødevarer, 2013, table 3
CO_2 (kg / TJ)	55.9	74.0	57.0	100	34.0	0	0	**-**	Energistyrelsen, 2014
Emissions (million tonnes of CO_2)	1.8	1.5	0.1	0.1	0.1	0.0	0.0	**3.5**	

Energy consumption is calculated to be approximately 41 PJ in 2011 (in agriculture and horticulture), of which approximately 13.6 PJ electricity (for heating, stationary machines, etc.), 20.2 PJ diesel (for mobile use) and 2.3 PJ from so-called renewable energy (RE), i.e. straw, wood, waste and biogas (Landbrug & Fødevarer, 2013). The total emissions from energy consumption can be calculated to 3.5 million CO_2e (see Table 2).

2.1.5. Emissions associated with domestic production of fertilizers

Virtually all fertilizers used in Denmark are made abroad (see section 2.2.). According to DCE48 a total of 0.0022 million tonnes CO_2e were emitted from production of "Catalysts / Fertilisers" in Denmark. This emission is recognized under "Industrial Processes" in Figure 1. We do not know exactly what this category covers and whether it is related to agriculture, but as emissions in any case are relatively small, we choose to ignore it.

2.1.6. Avoided emissions through the production of bioenergy

Agriculture supplies energy to the community in the form of straw, biofuels, biogas and energy crops. Part of biogas is derived from waste from other sources than agriculture such as waste and sewage sludge. In the calculations in Table 3, we assume that biogas, which is not derived from landfills (landfill) or sludge, is attributable to agriculture.

With the assumptions below, we can calculate that Danish agriculture produces an amount of energy, which have displaced emissions of approx. 2.4 mio. tons of CO_2, compared to if the energy had to be produced as Danish average (see Table 3).

Table 3: Calculation of avoided CO2 emissions from producing energy of sources from Danish agriculture in 2012. Energistyrelsen, 2014 / DCA101.

	Unit	Electricity	District heating	Transport	**Total**
Straw	TJ	6 331	11 970	0	
Biofuels	TJ	-	1 072	8 642	
Biogas	TJ	2 301	1 504	0	
Energy crops	TJ	476	476	0	
Energy delivery (total)	TJ	9 109	15 022	8 642	
CO_2-content	tons CO_2/TJ	135	36	73	
Displaced CO_2-emission	Mio. tons CO_2	1.2	0.5	0.6	**2.4**

In Table 3, we have made the following assumptions:

• The consumption of straw, biofuels and biogas in industry and households is used for heating. Emissions of CO_2 in the production of heat from these fuels correspond to emission ratios for district heating.

• All biogas produced that does not come from sludge or landfill is aasumed to come from agriculture.

• The annual biomass production for energy crops is 7 t dry matter / ha. The energy content is 16 GJ / tonne of dry matter.

• The production of energy from energy crops is divided equally between electricity and district heating. (This corresponds approximately to the distribution of the energy output from wood products).

• Emissions from indirect land use change (ILUC) related to the production of energy crops (including crops used as additional biomass to biogas production) are not included.

2.2. Foreign emissions

In addition to the domestic emissions, it is also necessary to include emissions associated with imported inputs, especially emissions from the production of imported feed, fertilizer, pesticides and possibly also machines etc. if we want to have an accurate picture of the climate impact of Danish agricultural production. The two main categories are fertilizers and livestock feed. For example, the production of imported fertilizers is a source of emissions of both CO_2 and N_2O. Agricultural consumption of N, P and K was in 2011/2012 (as pure nutrients): 187,024 tonnes N, 12,804 tonnes P and 42,616 tonnes K. The related emissions have not been calculated, but it is estimated that the emissions related to the production of nitrogen fertilizer are between 3 and 8 ton CO2e/ton N.

However, here we only include emissions related to imported livestock feed. Furthermore, regarding livestock feed, we only include the primary crop, soya.

CONCITO (2014) estimates the greenhouse gas impact of Danish imports of soybeans, which are primarily used for animal feed, to about 6 million tonnes of CO_2e. (CONCITO estimates in their calculations net average emissions in the production of soy to approx. 3.8 kg CO_2e / kg of soy cake when indirect land use change is included).

3. Agricultural emissions of ammonia - now and 20 years back

Agriculture is the largest source of ammonia emissions, with a contribution of 96 % of the total emissions. Most of the emissions are related to livestock production where ammonia is released from manure in animal housing, from the storage and spreading of manure and from grazing animals. The remaining 15-20 % comes from the spreading of fertilizers, growing plants, ammonia treated straw, field burning of crop residues and use of sewage sludge as fertilizer on the fields.

The EU Nitrate Directive is implemented in Denmark through regulation of fertilization, including fixed maximum nitrogen allocations and requirements regarding the use of manure. The ‘manure regulation’ lays down a number of rules for storage and application of manure, which intends to reduce emissions and leaching of nitrogen (Bekendtgørelse om erhvervsmæssigt dyrehold, husdyrgødning, ensilage m.v., 2013).

Rules for both slurry as solid dung are applied in relation to storage:
• There are requirements for the size of slurry tanks as well as the dunghill area. The capacity should normally correspond to at least 9 months' supply of manure/dung.
• Slurry containers must not be placed closer than 100 meters to open streams and lakes (larger than 100 m^2). Containers shall be made of durable materials, which can resist penetration form moisture. Slurry tanks must be strong enough to withstand impact from machines in connection with pumping, stirring and draining.
• Slurry tanks must be covered with either: 1) a fixed cover e.g. a tent; 2) a natural floating layer, e.g. straw. If not covered ammonia-reducing technology should be applied.
• Some slurry tanks must always have a fixed cover. This applies if they are built closer than 300 meters from neighboring dwellings or certain types of habitats.
• Dunghill sites must be built following special regulations, e.g. constructed from a material that moisture cannot penetrate. The dung stack should usually be covered with a breathable material.

Rules for application of manure and sewage sludge:
• Animal manure applied to non-vegetated areas must be tilled into the soil as soon as possible and within 6 hours.
• Spreading must not be done in a way which induces a risk that the fertilizer can be washed into drains, streams or lakes, for example in the case of heavy rain or thawing.
• Application of liquid manure and degassed plant biomass has to be done by trailing hoses, injection or the like.
• Application onto black soil and permanent grass must be done with injection or with pretreated slurry.
• From harvest to February 1, liquid manure may only be spread on selected crop types (fields with winter rape and some meadows).

• The maximum amount of manure allowed to be spread amount to the manure from 2.3 livestock units per. hectare.

There is also legislation on nitrogen standards for various crops as well as requirements on plant cover/cover crops that can absorb excess nitrogen. (Bekendtgørelse af lov om jordbrugets anvendelse af gødning og om plantedække, 2013).

Agricultural emissions of ammonia decreased from 124 Gg in 1990 to 73 Gg in 2012, representing a reduction of 41 % (see figure 5). The reduction is achieved through a series of policies over the period intended to reduce losses of nitrogen to the aquatic environment. A number of action plans have contributed to this: NPO Action Plan (nitrogen, phosphorus and organic matter) in 1986; the Water Environment Plans 1987, 1998 and 2004; Action Plan for Sustainable Agriculture from 1991 and the Ammonia Action Plan from 2001. These plans have resulted in better nitrogen utilization in animal production (and hence less emissions per unit of production - especially in the production of fattening pigs), reduced nitrogen loss from the manure and better utilization of the nitrogen in manure along with a decrease in the use of fertilizers. Together, these actions and the associated laws and regulations have reduced total ammonia emissions significantly.

The decrease in emissions is primarily related to: better utilization of nitrogen from both manure and mineral fertilizers and improved feed utilization in swine production. Following the Livestock Regulation (BEK, 2002), ammonia treatment of straw has been banned since August 2004. Furthermore, a ban on spreading manure on fields in winter, a ban on broad spreading of slurry and requirements to grow nitrogen-fixing crops have been introduced.

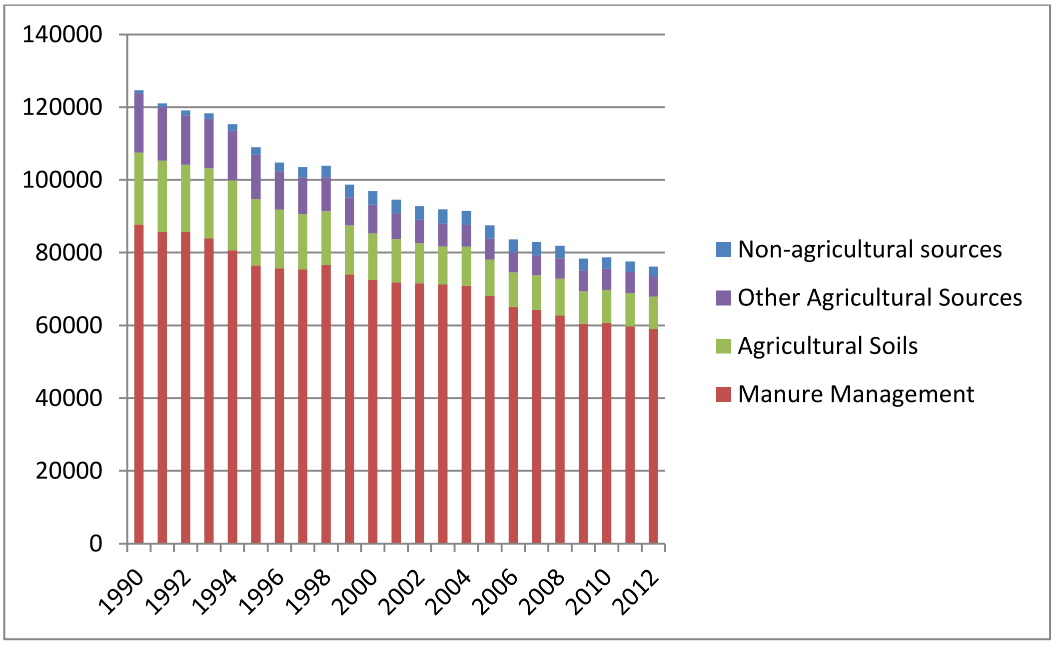


Figure 5. Emissions of ammonia in tonnes NH_3. The category "Non-agricultural Sources" include all emissions from the following sectors: Energy (including Mobile sources), Industry and Waste. The category "Other Agricultural Sources" is comprised of: Crops, Field Burning, Sewage Sludge, Ammonia Treate Straw.(DCE 2014b).

Manure was in 2012 responsible for some 80 % of total agricultural ammonia emissions. In 1990, it was responsible for 71 %. Since 1990, the emissions from manure have decreased by 33 % (see Figure 6).

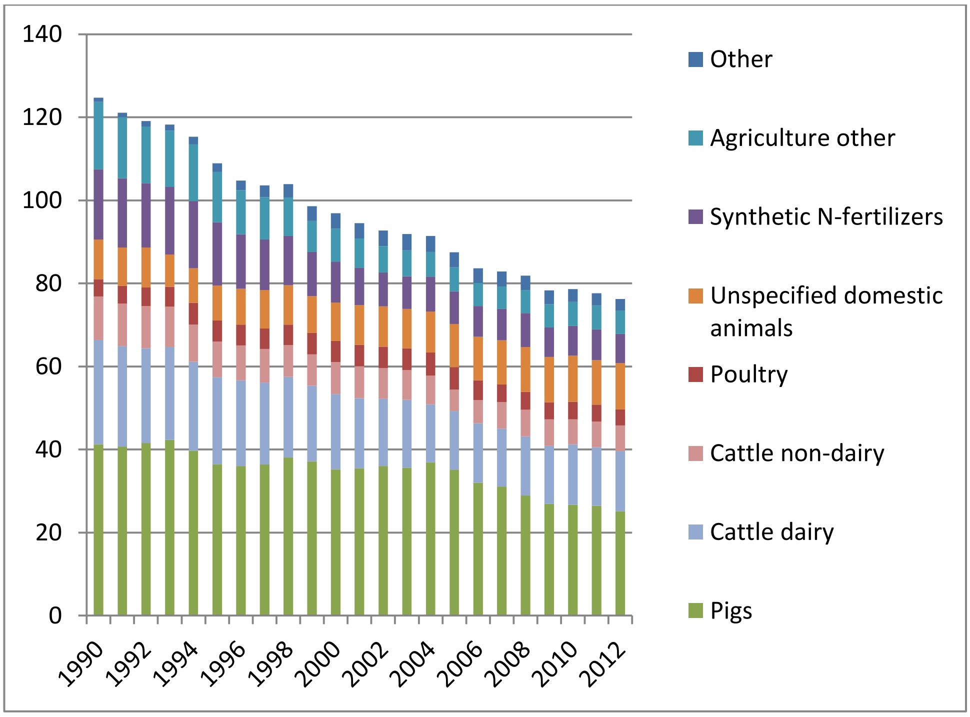


Figure 6. The annual ammonia emissions from the main livestock categories. Same total but other brake down than Figure 5.

Most of the emissions come from cattle and pigs (see Figure 6). In 1990 cattle production was responsible for 29 % and pigs for 33 % of total emissions.

In 2012, the share of cattle had fallen to 27 % (19 % from dairy / 8 % non-dairy), while the contribution from the pig production was still at 33 %. The contribution of emissions from mineral fertilizers has declined since 1990. It is noteworthy that the total emissions from pigs fell by 39 % between 1990 and 2012 despite a significant growth in pig production from 9.2 million pigs in 1989 to 12.3 million in 2009 (Table 1). One of the main reasons for this is a significantly increased efficiency in feed intake.

According to the Gothenburg Protocol, Denmark must reduce NH_3 emissions by 24 % over the period 2005-2020.

Currently, a revision of the NEC (National Emission Ceilings Directive) is negotiated at the EU level. The Commission has proposed a 24% and 37% reduction for Denmark by 2020 and 2030 respectively compared to the base year 2005 (Claus Torp 2014).

The reason for keeping Denmark's reduction target fixed at 24 % is DCE's projection for emissions of NH_3 (DCE 7, 2012). DCE's projection was based on applicable regulatory and political agreements, i.e. the Green Growth agreement from 2009 (with follow-up in 2010 requiring a general reduction of ammonia by approval of livestock farms), the Nitrates Directive, the Habitats Directive (with specific ceilings of deposition), NEC Directive, the Livestock Approval Act (application of liquid manure on black soil and grassland permitted only when incorporated into the soil) (Kirsten Brosbøl, 2014).

However, DCE made a new projection in 2013, which shows that Denmark would only reduce emissions by 15 % compared to the base year with current regulatory and political agreements (DCE 81, 2013). The difference between projections for 2012 and 2013 is primarily due to an increase in the expected number of animals, and changes in the number of buildings with NH_3-reducing technology. DCE 81 (2013) provides no real justification for the increase in the expected number of animals, but the reduction in expected number of stables with NH_3-reducing technologies is attributed to the economic recession.

4. Future emissions of greenhouse gases

4.1. Business as usual

The report *Projections of Greenhouse Gases 2011-2035* (DCE48) provides guidance for emissions of greenhouse gases from Danish agriculture based on the policies and measures that already were adopted by September 2012 (personal communication with Ole-Kenneth Nielsen). This can be considered a business as usual scenario (BAU). However, this scenario goes further in biogas production than what is actually decided, assuming that 75 % of the slurry will be anaerobically digested to biogas, while the current politically agreed intention (from Energiaftalen 2012) is that up to 50 % of the manure should be used for biogas production.

The trend towards larger farms with higher productivity, compared with today's average is in this scenario expected to continue. This is expected to lead to increased production efficiency, improved feed efficiency and better use of nitrogen in livestock manure – all measures that reduce emissions. Furthermore establishing biogas plants is expected to an extent, which, as mentioned earlier, goes further than already agreed goals. The expectation is also that strengthened environmental requirements at both Danish and EU level will help to reduce emissions, including some change from annual crops to pastures. On the other hand, there is also an expectation of trends that will increase emissions, for example a continued deterioration of the organic material in the soil and increased methane emissions due to increased milk production. Furthermore, it is pointed out that the import / export conditions will continue to play a crucial role.

In this chapter, the new IPCC factors for GWP, i.e. 298 CO_2e for N_2O and 25 CO_2e of CH_4, are used as it describes a future situation. Therefore, the figure for nitrous oxide is lower than with the previously used conversion factor for nitrous oxide (section 2.1.1.), while the figure for methane is higher than with the previously used conversion factor for methane (section 2.1.2). The 2012 figures are as follows with the previously used conversion factors: approx. 5.4 million tonnes CO_2e for nitrous oxide and approx. 4.2 million tonnes of CO_2e for methane. With the new conversion factors the figures are approx. 5.3 million tonnes CO_2e for nitrous oxide and approx. 4.9 million tonnes of CO_2e for methane.

Million tonnes CO2 ekv. /year	1990	2000	2010	2011	2012
N_2O	7,90	6,10	5,16	5,19	5,26
CH_4	5,05	4,82	4,94	4,88	4,87
LULUCF (Cropland og grassland)	5,05	3,79	3,37	3,56	3,54
Total (N_2O + CH_4 + LULUCF)	**18,00**	**14,71**	**13,47**	**13,62**	**13,67**

Table 4. Historical and current emissions of greenhouse gases from Danish agriculture (DCE48).

Million tonnes CO2 ekv./ year	2015	2020	2025	2030
N_2O	4,96	4,74	4,68	4,61
CH_4	4,76	4,72	4,79	4,86
LULUCF (Cropland og grassland)	3,52	3,45	3,42	3,35
Total (N_2O + CH_4 + LULUCF)	**13,24**	**12,92**	**12,89**	**12,82**

Table 5. Future emissions according to the scenario described until 2030 (DCE48).

4.1.1. Nitrous oxide, N_2O

The historic reductions in nitrous oxide emissions ((as described in Section 2.1.1.) are achieved mainly as a result of the lowered nitrogen standards and improved manure management as well as improved nitrogen utilization in animal manure (which has resulted in reduced use of mineral fertilizers and reduced nitrogen leaching). At the same time the agricultural area has decreased by more approx. 4 %.

In the BAU scenario, it is expected that in the future the largest reductions will be achieved through continued improvements in manure management and thus increased / improved manure application. As a consequence there will be a continued decline in the use of mineral fertilizers, which at the same time will reduce emissions related to nitrogen leaching. The current trend in relation to the reduction of the agricultural area is expected to continue; particularly organic soils are expected to be removed from production. No changes in nitrogen standards are assumed in this scenario. The decrease in nitrous oxide emissions from 1990 to 2010 is in the scenario (DCE48) expected to continue but at a slower pace. The expected result of the projected initiatives would reduce nitrous oxide emissions by around 13 %, i.e. a decrease from 5.3 million tonnes CO_2e in 2012 to 4.6 million tonnes CO_2e in 2030.

The reduction is mainly related to the following:

- Improved manure management, such as:
    - more nitrogen retained in the manure during storage and incl. reduced ammonia volatilization from the stables
    - cooling of pig slurry in the stables, covering the slurry containers, covering of solid manure
    - a high proportion of slurry is processed to biogas (75 %)
- A decrease in the use of mineral fertilizers (which is primarily attributable to the reduction of agricultural area, and the improved nitrogen efficiency from manure due to better manure management)
- Reduced nitrogen leaching (which is primarily attributable to the reduced use of mineral fertilizers)
- Increased withdrawal of organic soils from cultivation (drained peat soils with at least 12 % organic matter in the plough layer).

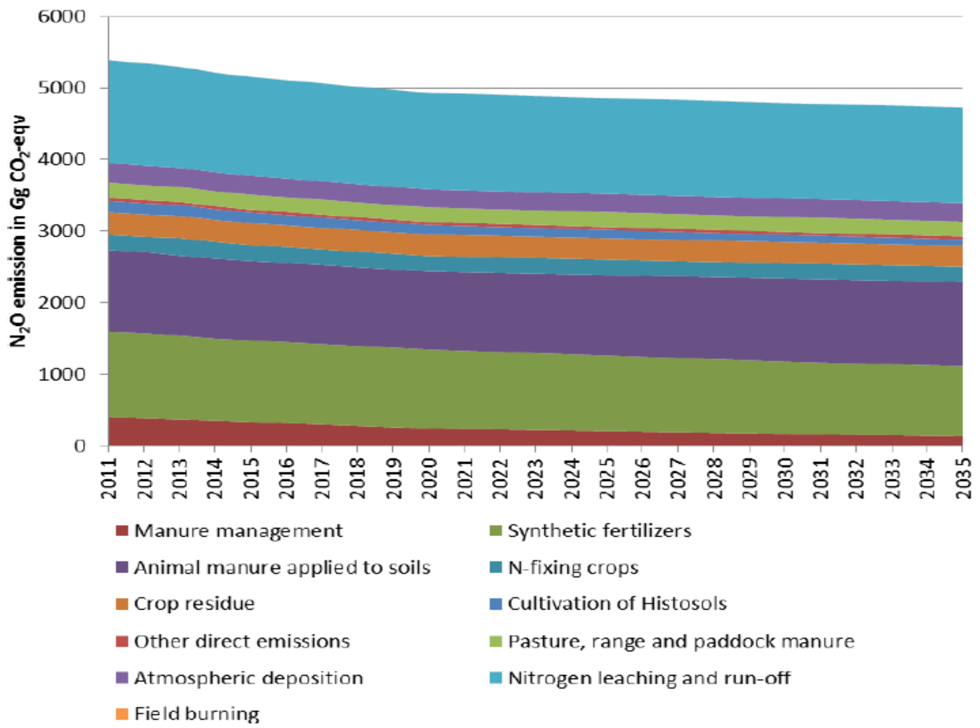
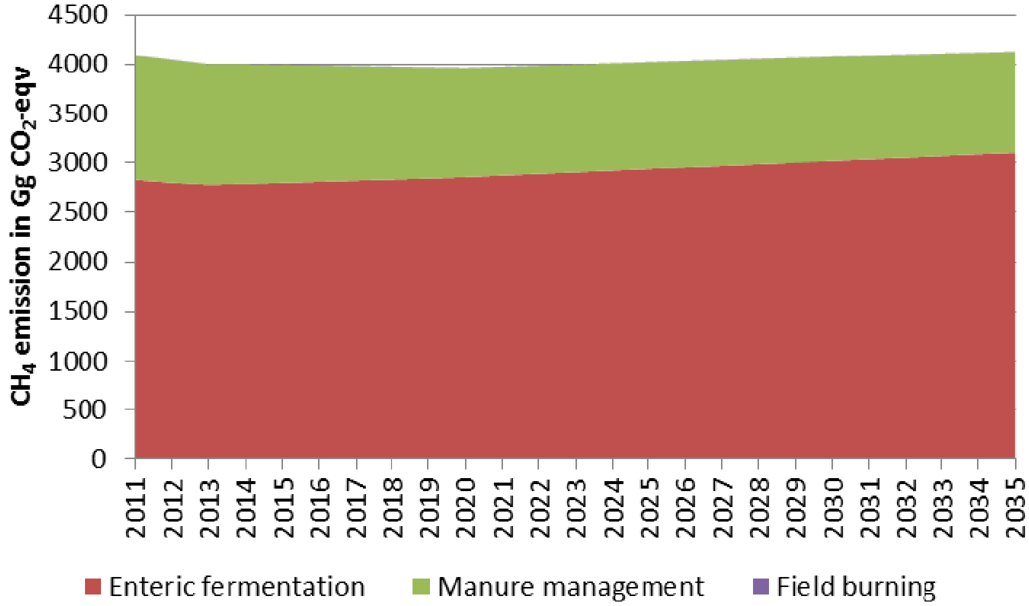


Figure 7. Projected N2O emission from the agricultural sector, given in CO_2 equivalents. (DCE48).

Figure 7 shows that the largest reductions are achieved by continued improvements in manure management in parallel with the continued decline in the use of mineral fertilizers; this will at the same time reduce GHG emissions related to nitrogen leaching. In addition some reductions are achieved when more organic soils (histosols) are taken out of production.

4.1.2. Methane, CH_4

As described in in Section 2.1.2., the total historical emissions of methane from agriculture remained virtually constant over the period 1990-2012. However, this includes some changes, namely that emissions from ruminants has decreased slightly due to a decrease in the number of dairy cattle, but this reduction is off-set by emissions from manure management that has increased due to the transition from solid manure to (more) slurry.



Figur 8. Projected CH_4 emission from the agricultural sector, given CO_2 equivalents. (DCE48).

In the future, total methane emissions are expected remain relatively unchanged until 2035 (see Figure 8). The underlying expectation is mainly based on three assumptions:

- The number of dairy cattle is expected to be unchanged from 2013 to 2035. This will, by continuously increasing milk yields per cow (achieved through increased feed consumption) lead to rising emissions from cows' digestion. (Until 2013, EU's milk quota determined the total production of milk; dairy cow numbers therefore decreased as the yield per cow increased. After the termination of the quota system, it is expected that the total milk production will increase. An increase in milk production per cow of 1.5 % per year until 2020 is expected, and after 2020 1.25 % per year).
- Methane emissions from the handling of manure have increased from 1990 to 2010 due to changes in housing systems towards more slurry-based systems. From 2020, it is expected that the manure of all dairy cattle can be handled as slurry.
- The reduced emissions that result from digestion of manure to biogas is assumed to have a significant impact in relation to emissions from manure handling (see Figure 8). In this scenario (DCA48) it is assumed that approximately 75 % of the manure will be anaerobically digested, reducing the total methane emissions in this scenario. If this implementation of biogas production from slurry is not completed, the reduction in CH_4 emissions from manure management will be lower and the total CH_4 emissions is therefore likely to be increased by 2030compared to current emissions.

4.1.3. LULUCF

As described in Section 2.1.3., historic reductions related to agriculture's emissions from LULUCF is mainly due to reduction of the cultivated area (in rotation with annual crops), the ban on field burning of straw (introduced in 1990), and probably also to extremely low content of organic material in many soils that it in itself has led to reduced emissions. Alongside these reductions, however, there has been a continued degradation of the organic material in the farmland on both mineral and organic soils - a trend that is expected to continue.

It is expected that in the future the annual loss from the mineral soils will be in the same order of magnitude as currently while the annual emissions from organic soils will be slightly reduced, which is a consequence of the progressively reduced content of organic matter in the organic soils.

It is estimated that there will still be a continued annual loss resulting in the release of approximately 1.35 million tonnes CO_2e from the mineral soils. This loss depends on the temperature and the yields, as well as on the amount of manure, straw and other crop residues that is removed to be used for other purposes. Furthermore, emissions from organic soils must be added; these are expected to be slightly lower than the current 1.87 million tonnes CO_2e per year.

In DCE48 it is assumed that there will be a shift from land in rotation to perennial grassland, termination of cultivation of some organic soils, and that there is a re-establishment of wetlands on agricultural land which will absorb carbon as it is expected that continued plant growth will occur in some of these wetlands (in the order of about 40,000 ha (in addition to the buffer zones)). The latter removals are reported under “Wetlands” in Figure 4, and are thus not included in Table 5.

50,000 hectares were set aside for uncultivated 10 meter wide buffer zones (that may not be plowed, fertilized or sprayed) along creeks and streams. Previously these zones were 2 meter wide. The initiative should have been implemented by the end of 2012. But in the spring of 2014, the rules were changed reducing the width of buffer zones to 9 m and do now not apply everywhere. Consequently the expected emission reductions from this measure will be smaller than assumed in Table 5.

Future reductions in soil carbon emissions may be achieved by taking more land (with annual crops) out of rotation and used for other purposes such as nature conservation, permanent grassland and perennial crops or by increased cultivation of catch crops and intercrops.

4.2. Further measures

Researchers from Aarhus University have looked at a number of actions to reduce the emission of greenhouse gases from Danish agriculture, described in "Effects of measures to reduce agricultural emissions of greenhouse gases" (DCA27, 2013), which goes beyond the projection in DCE48. DCA27 describes the combined emissions of methane and nitrous oxide, as well as changes in soil carbon content (soil-C). In addition, the report describes the potential for energy production based on agricultural products.

The report does not take into account greenhouse gas emissions connected to those excipients that Danish agriculture imports from abroad, even though e.g. the proposed conversions of land for energy crops could potentially lead to increased imports of animal feed if animal production is not reduced. The following table from the report shows the expected reductions of a number of measures (in a given magnitude) when the climatic effect of substitution of fossil fuels with biofuels is included. The figures are not in all cases an adequate description. For example, in some places (e.g. under biogas from maize), a zero is indicated under soil-C, where an emission should have been registered, but where the authors do not know the order of magnitude.

Table 6. Estimates of the reduction in greenhouse gas emissions by 2020 compared to the baseline scenario (1.000 tonnes CO2 e/year). (DCA27)

Measure	Magnitude	$CH_4 + N_2O$	Soil-C	CH_4 + N_2O+C	Bio-energy	Incl. C-storage	Excl. C-storage

Straw as fuel in CHP	100.000 ha	11	-74	-63	159	96	169
Straw for thermal gasification, returning biochar to the soil	100.000 ha	11	-59	-48	256	208	267
Biogas from manure	10 % of the liquid manure	85	-6	79	79	158	164
Biogas from manure with separation	10 % of the liquid manure	51	-5	47	64	111	116
Biogas from nature grassland	5.000 ha	-6	0	-6	35	29	29
Biogas from maise	60.000 ha	-66	0	-66	402	336	336
Biogas from organic clover/grass	20.000 ha	-12	37	25	72	97	60
Biogas from conventional festulolium	60.000 ha	-96	110	14	298	313	203
Acidification of manure in the stables	10 % of the liquid manure	102	0	102	0	102	102
Acidification of slurry in the store	5 % of the liquid manure	41	0	41	0	41	41
Covering slurry tanks	40 % of the liquid manure	82	0	82	0	82	82
Cooling of manure in pig housing	10 % of the liquid manure from pigs	6	0	6	0	6	6
Fat / altered feeding for dairy cows (without side effects)	80% of the dairy cow herd	143	0	143	0	143	143
Fat / altered feeding to other cattle (without side effects)	25 % of the herd	13	0	13	0	13	13
Nitrate feeding of dairy cows	10 % of the herd	27	0	27	0	27	27
Prolonged lactation in dairy cows	10 % of the dairy cow herd	18	0	18	0	18	18
Nitrification inhibitors to fertilizers	100% of fertilizers	335	0	335	0	335	335
Nitrification inhibitors to manure	10 % of the manure	36	0	36	0	36	36
Intensified N-utilization requirements after digestion of manure	50 % of the manure	48	0	48	0	48	48
Intensified N-utilization requirements for selected types of manure	Tightening compared to VMPIII	17	0	17	0	17	17
Reduced nitrogen standard	10 % reduction	175	0	175	0	175	175
More legumes in	200.000 ha	95	0	95	0	95	95

pasture land							
Energy willow, organic soil	10.000 ha	2	12	14	4	18	6
Energy willow, clay soil	10.000 ha	2	12	14	4	18	6
Energy willow, sandy soil	80.000 ha	20	96	116	30	145	49
Catch crops, clay soil	63.000 ha	0	46	46	0	46	0
Catch crops, sandy soil	177.000 ha	-20	130	110	0	110	-20
Middle crops, clay soil	110.000 ha	-3	81	78	0	78	-3
Middle crops, sandy soil	130.000 ha	-7	95	89	0	89	-7
Substitute cropping with grassland in highlands, clay	50.000 ha	39	92	131	15	146	54
Substitute cropping with grassland in highlands, sand	50.000 ha	43	92	135	15	135	43
Substitute cropping of organic soils with grassland, continuous drainage	35.000 ha	27	64	91	11	101	37
Substitute cropping of organic soils with grassland, termination of drainage	35.000 ha	104	366	470	11	481	115
Sustained meadows	90.000 ha	-6	66	60	0	60	-6
Afforestation, clay soil	31.000 ha	24	80	103	9	113	33
Afforestation, sandy soil	19.000 ha	16	49	64	6	70	21
Reduced tillage	200.000 ha	0	66	66	8	74	8
In total		1357	1349	2706	1476	4182	2833
In total taking into account the interaction		1148	946	2094	802	2896	1950

See also the documents “Technical measures to reduce emissions from manure and fertilizers” and “Explanatory notes to the table on measures” for our evaluation of measures to reduce agricultural emissions. It should be noted that we do not support the production of bioenergy undermining the soil carbon stock.

6. Summary of measures on climate change

The combined actions of business as usual and the additional actions described above will only lead to modest reductions in domestic emissions of only about 3 million tons of CO_2e/year, and smaller reductions in imports of fertilizers and feed, which is far from the goals we want.

We assume that it will not be possible to increase yields without increasing pressure on nature, the environment and the climate as and when land is set aside for afforestation and permanent grass and possibly bioenergy. Agricultural production will therefore be reduced. We suggest that it is the production of fodder and thus animal production, which will be reduced by when these land-use changes take place.

We assume further that it is not possible to increase the output per unit of feed in livestock without inflicting a negative impact on animal welfare and health. It would not make sense continuously to base animal production on imported soy feed with a very negative impact on both climate and environment. We therefore assume that soybean imports are reduced parallel to the Danish feed production. The overall result will be that the production of livestock will fall proportionally as agricultural land is converted to forest and various permanent grasslands.

For further reductions more radical structural measures will be needed such as reducing exports of animal products further and developing a new understanding of diet and consumption (both nationally and globally), in order to achieve that the consumption of animal products and other agricultural products with a high climate-impact is reduced.

The Green Development and Demonstration Programme (GUDP) is a support program under The Danish AgriFish Agency, who present the program as follows: "GDDP is a modern support system addressing some of the key challenges for the food sector and the whole society. The challenge is to create a greater sustainability, while solving some of the climate and environmental problems facing society – while at the same time the economy is improving, so that the food sector continuously can generate growth in Denmark and secure jobs". However, so far the Agency has been very traditional in their allocation of financial support, although there is – in our opinion – a huge need for more innovation.

7. Future measures to reduce ammonia emissions and leaching

Many of the measures that can be implemented to reduce the emission of greenhouse gases (see Chapter 5), will also have a positive effect on ammonia emissions and vice versa. Unfortunately, it has not been possible to find references that provide a quantitative assessment of how much each measure impact on ammonia emissions.

Acidification of slurry and covering of slurry tanks are the steps that will both reduce greenhouse gases and ammonia. Acidification, which is a relatively cheap solution, is described and evaluated in a separate document. Cleaning the ventilation air from livestock buildings can reduce emissions of ammonia from the stables, but it is a relatively expensive option. Cooling of manure and floors in housing will also reduce ammonia emissions. Better coverage of manure heaps is also an opportunity to reduce emissions of ammonia. Increased slurry injection could also reduce the evaporation of ammonia.

There is several pieces of evidence that suggest that biogas treatment increases the release of ammonium. Among other things, the organic substances are degraded, whereby the propensity to form floating crusts decreases. In addition, the pH increases, which increases the conversion of ammonium (NH_4) to ammonia (NH_3). Yet it is difficult to be sure whether an increased biogas production will lead to increased or decreased emissions of ammonia. For example, the digested slurry becomes more fluid, and thereby penetrates into the soil faster, when it is spread on the fields. See separate document on biogas.

In addition to legislative measures described in Section 3, there are a number of support schemes aimed directly towards reducing leaching of nitrogen, e.g.:
• support for the establishment of wetlands where fertilizing is not allowed (for a period of at least 5 years),
• supplementary support for reduced nitrogen inputs on farms that already receive subsidies for organic farming

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