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Projection of Greenhouse Gas Emission from the Agricultural Sector

Until 2017

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Data sheet

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Abstract: Projection of the emission of greenhouse gases (GHG), primarily CH_4 and N_2O and to a less extend CO_2 from Danish agriculture until 2017 has been made. The emission of greenhouse gases (GHG) from the agricultural sector in 1990 is estimated at 13.5 mio. tonnes CO_2-eqv. For 2002 the estimate is 10.5 mio. tonnes comparing to a reduction of 22%. Four different scenarios are outlined. In the basic scenario the emission in 2012 will decrease to 9.8 mio. tonnes CO_2-eqv. and in 2017 a further reduction to 9.6 mio. tonnes of CO_2-eqv. is estimated. This corresponds to a reduction of 29% from 1990 to 2017. From 2002 to 2017 the reduction is estimated to 0.9 mio. tonnes CO_2-eqv. or a 9% reduction. A further reduction may be achieved, it depends, however, very much on how the EU reform of the common agricultural policy is implemented in Denmark and how the third action plan on the aquatic environment is implemented. The other scenarios illustrate these issues.

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Contents

Preface

This report describes the expected development in greenhouse gas emission from the agricultural sector until 2017. Four scenarios for the emission until 2017 are described:

1. a basic scenario without any changes in regulations
2. implementation of the Common Agricultural Policy (CAP) reform with a decoupling of the subsidiaries from the animal production
3. implementation of the CAP reform and an unchanged pig production from 2003 and onwards
4. a scenario where certain measures related to a third action plan on the water environment (VMP III) are introduced.

The reform of the European common agricultural policy (CAP) is introduced in the beginning of 2004. The essence of the reform is a shift from subsidies based on production to subsidies with no link to whether a farmer produces or not. The EU member states are allowed to choose different models for implementing the decoupling.

The Danish Parliament is going to propose a new action plan on the aquatic environment in 2004. At the moment no political decisions have been taken to implement a new plan, so the 4th scenario is based on a proposal made by a scientific technical group. The proposal assumes a 25% reduction of leached nitrogen from agriculture compared with the leaching in 2003 and introduces measures to reach this target.

The report includes the emission from some minor sources that cannot strictly be allocated to the agricultural production – horses on riding schools and a minor proportion of the mineral fertiliser used in private gardens, golf courses and the community. The reason for the inclusion of these activities is consistency with the reporting format to UNFCCC[1] as regards definition of the agricultural sector.

All emission data given in the report is annual data unless otherwise stated.

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[1] United Nations Framework Convention on Climate Change

Summary

Greenhouse gas emission from the agricultural activities under the IPCC category “Agriculture” includes methane (CH_4), nitrous oxide (N_2O) and non-combustion carbon dioxide (CO_2).

CH_4 originates primarily from cattle production and to a less extend from pig, poultry and fur production.

Formation and emission of N_2O takes place wherever nitrogen occurs and is therefore more or less a function of the nitrogen turnover in agriculture.

CO_2 emission is caused by a breakdown of organic matter in the soil and liming.

The emission of greenhouse gases (GHG) from the agricultural sector (IPCC) in 1990 is estimated to 13.5 M tonnes CO_2- eqv. For 2002 the estimate is 10.5 M tonnes corresponding to a reduction of 22%.

From 1990 to 2002 an increase in pig production and a decrease in cattle production took place. The emission of CH_4 has been calculated to be unaltered and the reduction of emissions of GHG is primarily due to a reduction in the emission of N_2O and a reduction in emission of CO_2 from liming. The reduction in N_2O emission is mainly caused by measures in action plans targeted at the aquatic environment.

In the basic scenario the emission in 2012 will decrease to 9.8 M tonnes CO_2-eqv. and in 2017 a further reduction to 9.6 M tonnes of CO_2-eqv. is estimated (Table 1 and Figure 1). This corresponds to a reduction of 29% from 1990 to 2017. From 2002 to 2017 the reduction is estimated to 0.9 M tonnes CO_2-eqv. or a 9% reduction.

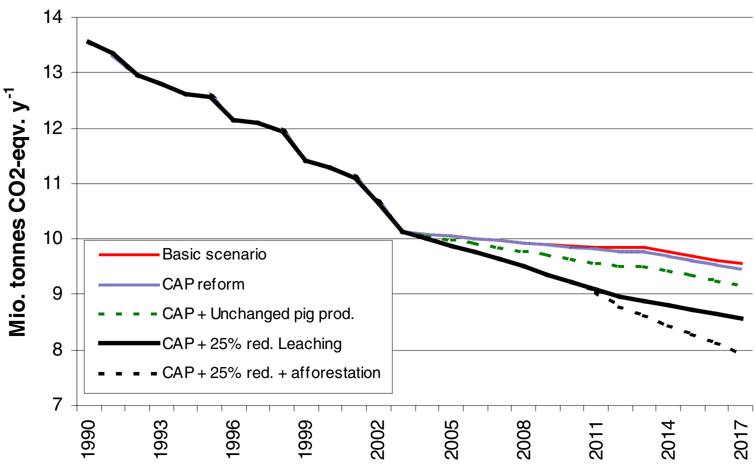


Figure 1 Emission estimates from 1990 to 2017

Table 1 GHG emission estimates from 2002 to 2017 (M tonnes CO_2-eqv. per year).

	2002	2003	2012	2017	2008-2012	2013-2017	Reduction 2002-2017	
Basic scenario	10.45	10.13	9.84	9.55	9.88	9.69	0.90	9%
CAP Reform	10.45	10.13	9.78	9.45	9.86	9.62	1.00	10%
CAP + unchanged pig prod.	10.45	10.13	9.50	9.17	9.64	9.34	1.28	12%
CAP + 25% red. in leaching	10.45	10.13	8.97	8.57	9.24	8.77	1.88	18%
CAP + 25% red. in leaching + afforestation[1]	10.45	10.13	8.78	7.95	9.15	8.37	2.50	24%

[1]Increased afforestation on agricultural soils. The CO_2 sequestration must be reported under forestry and not under agriculture.

The main part of the greenhouse gas emission is related to the livestock production. The production of cattle in 2012 is expected to decrease due to an increased milk production per cow.

The increase in the production of slaughter pigs and poultry, which was seen from 1990 to 2002, is expected to continue until 2012, however, with a lower growth rate than previous. Despite the increase in the pig production the emission of GHG is not expected to increase at the same rate. There will be improvements in the utilisation of nitrogen in the fodder and changes in manure handling, which leads to a decrease in use of mineral fertiliser. The emission will be reduced as a consequence of this development.

At the moment no decision has been made on how to implement the EU reform of the common agricultural policy (the CAP reform) in Denmark. However, the organisation Danish Agriculture has proposed a model with 75% decoupling of the prices for male premiums. Implementing this model, the CAP reform will reduce the number of suckling cows and meat production from cattle but will have no influence on the dairy production. The reform is estimated to increase the pig production by 2% from 2005. The GHG emission in 2012 is estimated at 9.8 M tonnes CO_2-eqv. and 9.5 M tonnes CO_2-eqv. in 2017. Implementation of the CAP reform will reduce the emission compared with the basic scenario by 0.03 and 0.10 M tonnes per year in 2012 and 2017 respectively or 0,5-1% lower than the basic scenario.

A third scenario has been made as a sensitivity-testing scenario. The production of slaughter pigs is kept at the 2003 level. Danish agriculture is a highly technology and export orientated industry. About 75% of the agricultural production is exported giving a high sensibility to future export markets development. The productions most sensitive to diseases and monetary changes are the pig production and the broiler production. In 2012 the number of produced pigs will be 3 M lower (23.9 M compared to 26.9 M) than in the CAP reform scenario. The consequence is a reduction of 0.38 M tonnes CO_2-eqv. in the emission of GHG compared with the scenario including the CAP reform. The GHG emission in 2012 and 2017 is estimated at 9.5 CO_2-eqv. and 9.2 CO_2-eqv., respectively.

In 2003 the Danish Parliament decided to implement a third Action Plan on the Aquatic Environment to succeed the former plan (VMP II) which expired by the end of 2003. Several technical subgroups have been working on the background documentation. The scenario group has proposed several ways to reduce the leaching. One proposal is to reduce the leaching by 25% by implementing different farming practices (Chapter 4.4). Implementation of the scenario group proposal combined with the CAP reform is estimated to reduce the GHG emission from 10.5 M tonnes CO_2-eqv. in 2002 to 9.0 M tonnes CO_2-eqv. in 2012 and 8.6 M tonnes CO_2-eqv. in 2017 corresponding to 8-10% lower emission than the CAP scenario.

In Table 1 the average emission figures for the period 2008-12 and 2013-17 is given. The table assumes a partial implementation of a new action plan until 2012. The estimated figures for 2008-12 may therefore be lower or higher depending on when the action plan is implemented in practice.

The fourth scenario includes afforestation as a measure to reduce the nitrogen leaching. In relation to the reporting obligations, consideration has been given to the sector demarcation between agriculture and forestry. This should be noticed when reading this report. In 2017 the increased afforestation rate (+1,500 ha per year from 2004 to 2013) will be responsible for a carbon sequestration of 0.62 M tonnes CO_2-eqv., which must be reported under “Forestry”. It should be noted that afforestation on agricultural soils from 1990 to 2003 and an afforestation of 2,500 ha per year from 2004 to 2013, are not taken into account in emission/sequestration calculations. The afforestation will continue to sequestrate CO_2 in the following years until a maximum carbon binding has taken place after 100-150 years.

The most likely emission of GHG from the agricultural sector in 2012 and 2017 respectively is an estimate between scenario 2 and scenario 4. The best estimate could be 9.3 M tonnes CO_2-eqv. in 2012 and a further reduction to 9.0 M tonnes CO_2-eqv. in 2017.

Sammenfatning

Emission af drivhusgasser fra landbrugssektoren under IPCC kategorien ”Agriculture” omfatter metan (CH_4), lattergas (N_2O) og kuldioxid (CO_2).

Udledningen af CH_4 stammer hovedsageligt fra dyrenes fordøjelsesproces og en mindre del fra håndtering af husdyrgødning. Størstedelen af emissionen er relateret til kvægproduktionen, mens produktionen af svin og fjerkræ er af mindre betydning.

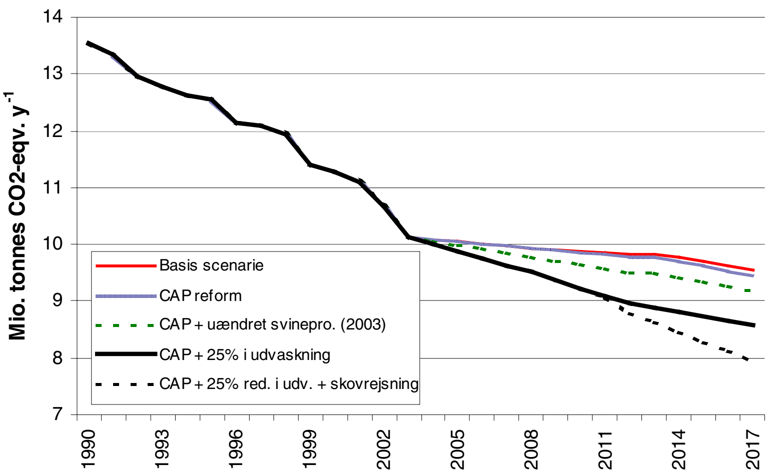
Emissionen af N_2O forekommer alle steder hvor der sker en omsætning af kvælstof, og er derfor i større eller mindre grad relateret til kvælstofbalancen.

Emissionen af CO_2 i denne opgørelse er ikke forbrændingsrelateret. Der indgår således kun emission af CO_2 fra nedbrydning af organisk stof i organiske jorde samt fra kalkning af landbrugsjord.

Emissionen af drivhusgasser fra landbrugssektoren er i 1990 beregnet til 13,5 mio. tons CO_2-ækvivalenter og er reduceret til 10,5 mio. tons CO_2-ækvivalenter i 2002, svarende til en reduktion på 22%.

Fra 1990 til 2002 er der sket en forøgelse af svineproduktionen og en reduktion i kvægproduktionen. Emissionen af CH_4 er uændret i perioden. Reduktionen af emissionen af drivhusgasser skyldes et fald i N_2O-emissionen og CO_2-emissionen fra kalkning. En del af reduktionen skyldes tiltag iværksat på baggrund af vandmiljøplanerne.

I basisscenariet forventes at emissionen i 2012 vil blive reduceret til 9,8 mio. tons CO_2- ækvivalenter og i 2017 forventes en yderligere reduktion til 9,6 mio. tons CO_2- ækvivalenter. Dette svarer til en reduktion på 29% i perioden 1990 til 2017. Fra 2002 til 2017 er reduktionen beregnet til at udgøre 0,9 mio. tons CO_2- ækvivalenter, hvilket svarer til en reduktion på 9%.



Figur 1 Estimeret emission af drivhusgasser fra landbruget fra 1990 til 2017 opgjort i mio. tons CO_2-ækvivalenter.

Tabel 1 Estimeret emission af drivhusgasser fra landbruget 2002 til 2017 i mio. tons CO_2- ækvivalenter.

	2002	2003	2012	2017	2008-2012	2013-2017	Reduction 2002-2017	
Basis scenarie	10.45	10.13	9.84	9.55	9.88	9.69	0.90	9%
CAP Reform	10.45	10.13	9.78	9.45	9.86	9.62	1.00	10%
CAP + svineproduktion som i 2003	10.45	10.13	9.50	9.17	9.64	9.34	1.28	12%
CAP + 25% reduktion i udvaskning	10.45	10.13	8.97	8.57	9.24	8.77	1.88	18%
CAP + 25% red. i udvaskning incl. skovrejs.[1]	10.45	10.13	8.78	7.95	9.15	8.37	2.50	24%

[1]Ekstra skovrejsning på landbrugsjord. Den ekstra CO_2-binding skal opgøres under skov og ikke under landbrug.

Langt størstedelen af emissionen er relateret til husdyrproduktionen.

Produktionen af kvæg forventes at blive reduceret frem til 2012 som følge af forøget mælkeydelse. Stigningen i svine- og fjerkræproduktionen forventes at fortsætte, men dog med en mindre vækstrate end i perioden 1990 til 2002. På trods af en stigning i husdyrproduktionen, forventes det ikke at emissionen af drivhusgasser vil stige tilsvarende. Der vil ske en forbedring af kvælstofudnyttelsen i foder og husdyrgødning, hvilket medfører et fald i anvendelsen af handelsgødning. Emissionen vil blive reduceret som følge af denne udvikling.

På nuværende tidspunkt er det ikke vedtaget hvorledes EUs landbrugsreform (CAP) skal implementeres i Danmark. Dansk Landbrug har forslået en model med delvis afkobling af landbrugsstøtten, hvor 75% af handyrpræmien bevares. Iværksættelsen af dette forslag vil medføre et fald i produktionen af ammekvæg og kødkvæg, men ikke have nogen indflydelse på antallet af malkekvæg. Reformen antages at forøge svineproduktionen med 2% fra 2005. Emissionen af drivhusgasser forventes at blive reduceret til 9,8 mio. tons CO_2- ækvivalenter i 2012 og 9,5 mio. tons CO_2- ækvivalenter i 2017. Implementering af CAP-reformen i denne form har således ikke en betydelig effekt på emissionen. Det er beregnet at emissionen vil blive reduceret med 0,03 mio. tons CO_2- ækvivalenter i 2012 og 0,10 mio. tons CO_2-ækvivalenter i 2017 eller 0,5-1% lavere end i basisscenariet i 2012.

Det tredje scenarium omfatter et følsomhedsscenarie for ændring i svineproduktionen. I scenariet fastholdes produktionen af svin svarende til niveauet i 2003. Den danske landbrugsproduktion er en højteknologisk og eksportorienteret industri. Omkring 75% af landbrugets produkter bliver eksporteret og forholdene på eksportmarkedet har derfor stor indflydelse på betingelserne for den fremtidige landbrugsproduktion. I det tredje scenarium forventes svineproduktionen i 2012 at være 3 mio. grise lavere (23,9 mio. sammenholdt med 26,9 mio.) end i basisscenariet med implementering af CAP-reformen. Konsekvensen af dette er en yderligere reduktion på 0,38 mio. tons CO_2- ækvivalenter. Det forventes at emissionen af drivhusgasser i dette scenarie vil være 9,5 mio. tons CO_2- ækvivalenter i 2012 og 9,2 mio. tons CO_2- ækvivalenter i 2017.

I 2003 har Folketinget foreslået en tredje vandmiljøplan (VMP III) til afløsning af VMP II, der udløber ved udgangen af 2003. I den forbindelse er der nedsat en række underudvalg, som skal supplere det faglige- og tekniske grundlag, herunder scenarie-gruppen, som har forslået forskellige modeller for reduktion af nitratudvaskningen. Et af disse forslag omfatter en 25% reduktion ved indførelse af forskellige nærmere definerede tiltag (kapitel 4.4). Ved implementering af dette forslag kombineret med CAP-reformen, og på baggrund af opstillede forudsætninger for hvordan implementeringen vil ske, forventes emissionen af drivhusgasser at blive reduceret til 9,0 mio. tons CO_2- ækvivalenter i 2012 og 8,6 mio. tons CO_2- ækvivalenter i 2017, svarende til en reduktion på 8-10% lavere end i basisscenariet.

I tabel 1 er den gennemsnitlige emission for perioden 2008-2012 og 2013-2017 angivet svarende til første og anden afrapporteringsperiode i Kyoto-protokollen. I emissionen er der antaget en løbende implementering af nye tiltag frem til 2012. Emissionen kan således være højere eller lavere end angivet i perioderne afhængig af hvornår tiltagene i praksis iværksættes.

I det fjerde scenarium indgår skovrejsning som et middel til at reducere udvaskningen. Ved estimering af drivhusgasudledningen i denne rapport er der delvis taget hensyn til sektorafgrænsningen mellem landbrug og skovbrug. Det er antaget at skovrejsningen øges med 1500 hektar per år i årene 2004-2013 udover den forventede skovrejsning på 2500 hektar per år på landbrugsjord. Omfanget af CO_2-binding i nyplantet skov medregnes ikke i landbrugssektoren, men indgår i sektoren for skovbrug. I fjerde scenarium er effekten af CO_2-binding derfor angivet separat. Den yderligere skovrejsning på 1500 hektar per år medfører en CO_2-binding på 0,18 mio. tons CO_2 per år i 2012, stigende til 0,62 mio. tons i 2017.

Omfanget af den tredje vandmiljøplan er ukendt og det er således kun muligt at skønne drivhusgasemissionen i 2012 og 2017. Det bedste skøn for den forventede emission vil være mellem scenario 2 med CAP reformen og scenarie 4 med en delvis implementering af en ny vandmiljøplan. Et skøn vil derfor være en emission på 9,3 mio. tons

CO_2- ækvivalenter i 2012 og en yderligere reduktion til 9,0 mio. tons CO_2- ækvivalenter i 2017.

1 Introduction

In accordance with the Kyoto Protocol Denmark is committed to reduce the total emission of greenhouse gases by 21% on average in the period 2008 to 2012 compared with the emission in the base year 1990. The National Environmental Research Institute (NERI) has the responsibility to prepare the annual emission inventories and to report to the Climate Convention (UNFCCC).

The agricultural sector without LULUCF[2] contributes in 2002 with 15 % of the total greenhouse gas emission (GHG). Next to the energy sector the agricultural sector is the largest source of GHG emission in Denmark. The different greenhouse gases can be converted into CO_2-eqv., which is a way to compare the environmental effects according to the global warming potential of the gases. The effect of methane is 21 times more powerful than CO_2 and N_2O is even more powerful corresponding to 310 times.

Given in CO_2 equivalents the emission of nitrous oxide contributes with 61% (2002) of the total GHG emission from agricultural activities. The emission of methane amounts to 36% and the remaining 3% originates from emission of carbon dioxide.

The development of GHG emission from the agricultural activities in the period 1990 to 2002 is given in figure 1. About 74% of the CH_4 emission is derived from digestive processes of livestock and the remaining part originates from manure management. The N_2O emission is closely related to the nitrogen balance where reduction and oxidation of nitrogen cause the emission. The emissions occur in stables, manure stores and in agricultural soils. In Denmark leaching is the most important sources of N_2O followed by manure handling and mineral fertiliser application.

The emission of CO_2 originates from cultivated soils with high organic content and liming of agricultural soils.

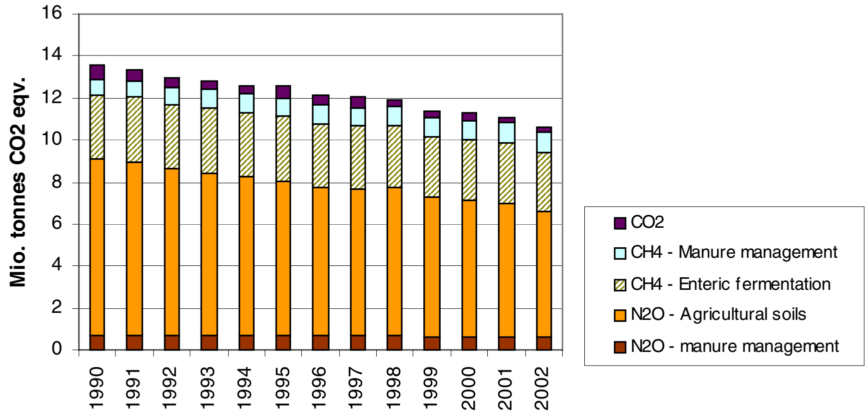


Figure 1 Greenhouse gas emission 1990 – 2002

[2] Land Use, Land Use Change and Forestry. LULUCF estimates the emission and the sequestration of CO_2 in agricultural soils and forests.

During the last decades there has been an increasing focus on the environmental impacts from the agricultural production. An optimisation of the use of nitrogen has been one of the consequences of this development, which gives the farmers both an environmental and economic profit. Due to the Action Plans on the Aquatic Environment (I and II) (VMP I, 1987; VMP II, 1998), Action Plan for Sustainable Agriculture (HBL, 1991) and The Ammonia Action Plan (AAP, 2002) a series of measures to prevent loss of nitrogen in the agricultural production has been initiated. At present no action plan is targeted to reduce the GHG emission. However, the action plans have proved to be efficient in reducing the GHG emission since the formation of nitrous oxide is closely related to the turnover of nitrogen in the agricultural production.

Furthermore the action plans included demands on improved utilisation of nitrogen in husbandry manure, ban on field application of husbandry manure during the winter, establishment of green fields during the winter, regulation of the number of animals per ha and a maximum nitrogen fertilisation rate to field crops. This means that despite an increase in the livestock production both the ammonia emission and the emission of GHG have been reduced considerably. Another result is an appreciable reduction in the use of mineral fertiliser.

2 Recalculation of the GHG emission

Since the last reported emission inventory (Illerup et al. 2003) NERI has together with Danish Institute of Agricultural Sciences (DIAS) improved the model for calculating the GHG emission (Gyldenkærne et al. 2003 - in prep). The model is an integrated model covering all aspects of agricultural inputs and it calculates the emission of both ammonia and GHG.

A result of this work is a recalculation of the emission from 1990 to 2001. The recalculated emissions are implemented in the emission inventories to be reported to EU in January 2004 and to the UNFCCC in April 2004.

The major changes are that the method for calculating the CH_4 emission has been changed from a TIER 1 approach to a TIER II, where Danish norm figures for feed consumption (Poulsen et al. 2001) as well as the actual stable type distribution is used in the calculation. The N_2O emission estimates from crop residues are using more statistically proven data, changed input data for leaching from a standard figure to model based emission calculation and a changed methodology to calculate nitrogen fixation. As a result, the revision has lowered the emission level of GHG compared with previous inventories, but the reduction of 18-19%, obtained in the period from 1990 to 2001, is the same. However, the percentage distribution between N_2O and CH_4 has changed.

Unlike previously, there is no reduction in the estimated CH_4 emission from 1990 to 2001. The emission from enteric fermentation has decreased caused by a decreased number of cattle. But, on the other hand, the emission from manure management has increased due to the change into more slurry based stable systems, which has a higher emission factor. By coincidence this decrease and this increase have a size as to balance, so the trend for CH_4 emissions from 1990 to 2002 is about zero.

The reduction of N_2O emission is nearly the same as given in the previous inventory but the absolute level is lower, primarily due to a changed calculation method for crop residues (Table 1).

The recalculation gives a first estimate of CO_2 emission from organic soils and from liming from 1990 to 2001. The emission has decreased due to less liming of agricultural soils.

Table 1 The recalculation compared with the previous emission inventory

	1990	2001	Reduction	
	M tonnes CO_2-eqv.		M tonnes CO_2-eqv.	pct.
Reported to UNFCCC (2002)				
Total GHG	14.3	11.6	2.7	19
CH_4	4.1	3.6	0.5	12
N_2O	10.3	7.9	2.4	23
CO_2	0	0	0	0
Recalculation				
Total GHG	13.5	10.8	2.7	20
CH_4	3.9	3.9	0.0	0
N_2O	9.0	6.6	2.4	27
CO_2	0.6	0.3	0.3	57

3 Basic data

In the following chapter the assumptions for the basic scenario and the four other projected scenarios are described. The basic scenario is based on the situation in 2003 including measures already implemented in the legislation. A decrease in the use of mineral fertiliser, a decline in the agricultural area and an improved nitrogen utilisation in the fodder and manure are taken into account. The basic scenario is a relatively conservative projection, which in a way can be considered as a worst case situation. The estimated emission is the expected result if no further action to reduce the GHG emission or nitrogen turnover is implemented.

The three other scenarios include implementation of the CAP reform with a decoupling of the subsidiaries from the animal production, an unaltered pig production from 2003 onwards and implementation of measures in relation to the VMP III action plan. A more detailed description of the scenarios is given in chapter 4.

The estimated emission in all scenarios is based on the same methods, which correspond the method used in the annual emission inventory. The emission is estimated until 2012 for all activities. From 2012 to 2017 only changes in the number of dairy cattle, the number of sows and a decline in the agricultural area has been included.

3.1 Livestock production

The procedure for calculation the projections follow the methods described in the IPCC Guideline (IPCC 1996) and in the Good Practice Guidance (IPCC 2000). A more detailed method description of the Danish emission inventory is given in Gyldenkærne et al. (in prep). The estimation of ammonia and GHG emission is based on input data from different Danish sources (Table 2).

Activity data and data for estimation of emission factors are collected and discussed in corporation with specialists and researchers at different institutions such as the Danish Institute of Agricultural Sciences, Statistics Denmark, the Danish Agricultural Advisory Centre, the Danish Plant Directorate and the Danish Environmental Protection Agency. It means that both the data and the methods will be evaluated continuously according to the latest knowledge and information.

Table 2 List of data and information sources

References	Input data to estimation of emission
Statistics Denmark – Agricultural Statistic (www.dst.dk)	-No. of animal -milk yield -slaughtering data -land use -crop production
Danish Institute of Agricultural Sciences (www.agrsci.dk)	-N-excretion -feeding situation -growth -N-content in N-fixed crops -N-content in crops -N-leaching/runoff -NH_3 emissions factor
The Danish Agricultural Advisory Centre (www.lr.dk)	-stable type -grassing situation -manure application time and methods
The Danish Forest and Landscape Research Institute (DFLRI) (www.fsl.dk)	-afforestation -carbon sequestration in forest
Danish Environmental Protection Agency (www.mst.dk)	-sewage sludge used as fertiliser -industrial waste used as fertiliser
The Danish Plant Directorate (www.plantedirektoratet.dk)	-organic farming -mineral fertiliser

The projection of GHG emissions closely follows the same assumptions as used in the projection for the ammonia emission 2010 (Illerup et al. 2002). However, there have been corrections according to the agricultural development from 2000 to 2003.

The expected livestock production in 2012 is based on a projection of historical data especially from the past five years. Furthermore an assessment made by the Danish Research Institute of Food Economics has been taken into account (Jacobsen et al. 2003). Some of the most essential assumptions for the projection are outlined below:

- ♦ The production of dairy cattle will decrease due to an expected growth in milk yield by 150 litre per cow per year.
- ♦ The production of slaughter pigs and poultry are expected to increase by 1.1% and 1.4% respectively from 2003 to 2012. The past decrease in nitrogen excretion is expected to continue.
- ♦ The agricultural area is reduced by 0.35% per year as a consequence of afforestation, more focus on protection of sensitive areas, growth in urban area and infrastructure.
- ♦ The use of nitrogen in mineral fertiliser decreases by 21,000 tonnes per year from 2003 up to 2012. From 2012 to 2017 a further reduction of 3,000 tonnes per year is foreseen, due to changes in total nitrogen in husbandry manure and reduction in the agricultural area.
- ♦ 40% of the slurry applied on the fields is expected to be incorporated directly into the soil, affecting the ammonia and N_2O emission.

3.1.1 Development in animal production

The emission model operates with 27 different livestock categories depending on type of livestock and weight class. Furthermore each category is separated into stable type systems. Altogether approximately 150 different classes. The emissions of NH_3, N_2O and CH_4 from each class of livestock and the corresponding manure handling are estimated. Basic information on fodder consumption, N-excretion rates, days of grassing, the distribution of the different types of manure and the emission in stables, during storage and in relation to the application of manure on the fields are based on Danish norm figures (Poulsen et al. 2001). The data are generally updated every second year.

In the estimates for 2003, updated quarterly, figures of livestock from Statistics Denmark is used to include the most recent development.

3.1.1.1 Cattle

There are approximately 593,000 dairy cattle in Denmark in 2003 (Table 3). The number has decreased for many years due to an increased milk yield per dairy cow and a fixed milk quota. In the future the number of dairy cattle will decrease further as a consequence of an increasing milk yield of 150 kg per cow per year. From 2006 the Danish milk quota will increased by 1.5% due to the agreement in Agenda 2000. The CAP reform is assumed not to have influence on the milk production in Denmark within the next 6-10 years (Jacobsen et al. 2003; K.B. Lind Pedersen, Danish Meat Board, Pers. comm). Under these conditions the number of dairy cattle is expected to be reduced to 510,000 in 2012 and 470,000 in 2017.

The number of other cattle (calves, heifer and bulls) is expected to decrease proportionally with the development of dairy cattle. In the basic scenario a slight decrease in suckling cows is assumed from 115,000 in 2003 to 110,000 in 2012.

Table 3 Development in number of cattle (Statistics Denmark, 2003 and own calculations(*)).

	2000	2001	2002	2003	2012	2017
Dairy cattle	635,500	623,400	609,600	593,000*	510,000*	470,000*
Other cattle	1,107,600	1,356,700	1,066,200	1,009,000*	956,600*	881,500*
Suckling cattle	124,800	130,100	120,300	115,000*	110,000*	110,000*
Cattle, total	1,867,900	2,110,200	1,796,100	1,717,000*	1,576,600*	1,461,500*

3.1.1.2 Pigs

The number of produced pigs has increased every year for the last 15 years. In 2002 the production was 24.2 M pigs (Table 4).

The majority of the pork meat is exported and the future production level depends very much on the world market prices and the export conditions. In the period 1995 to 2003 the production has increased significantly corresponding to 2.1% per year. However, it is expected that the production will increase at a lower rate in the next few years because of keen competition from other exporting countries such as Brazil, Canada and USA. Jacobsen et al. (2003) has estimated an annual increase of 1.1% until 2010 based on an economical supply/demand. This percentage is used in this projection until 2012.

From 2012 to 2017 an unaltered production of 26.4 M pigs per year is assumed, however, with an increased number of piglets per sow.

The improved genetic development and management in the pig production influences the number of produced piglets per sow. It is assumed that the number of piglets per litter increases by 0.3 piglets per sow per year (Illerup et al. 2002). This corresponds to 24.4 piglets per litter in 2012 and 25.9 in 2017. The number of sows in 2012 and 2017 is expected to be 1.13 M and 1.06 M respectively, as a result of this development.

Table 3 Development in number of sows and produced pigs (Statistics Denmark, 2003 and own calculations(*)).

	2000	2001	2002	2003	2012	2017
	M	M	M	M	M	M
Sows	1.08	1.12	1.13	1.13*	1.13*	1.06*
Produced pigs	22.41	23.2	24.2	24.4*	26.4*	26.4*

3.1.1.3 Poultry

The Danish production of eggs is approximately 80 M kg per year (Statistics Denmark, 2003). No changes have occurred for the last 6 years, despite rough competition from cheaper imported eggs. Denmark has been a net importer of eggs for the last six years.

The broiler production is around 200 M kg per year or equivalent to 130-135 M produced broilers in 2003. No changes have been seen for the last six years. About half of the production is exported on a very competitive market, mainly to the Middle East.

Other poultry is of minor importance for the emission estimates.

Jacobsen et al. (2003) assumes an increase of 1.7% per year until 2010 for all poultry as a whole. This rate seems to be to high considering that the production the past three years has been stagnant (Figure 2). The reason for this development has been the outbreak of New Castle disease, increasing competition from the Far East. The Danish Poultry Council expects better production conditions in the future and assess the production to increase by 2 M produced broilers per year until 2012 (Jensen, 2003). Under these circumstances the production in 2012 is estimated to be 150 M produced broilers. The same production level is assumed from 2012 to 2017.

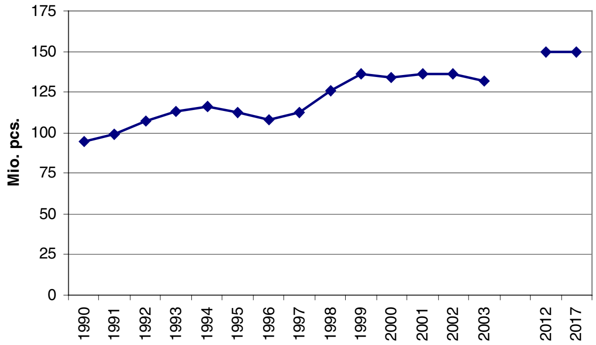


Figure 2 Number of produced broilers from 1990 to 2017.

For hens and pullets an increase at 0.8% and 0.7%, respectively, is assumed (Jensen, 2003). For other poultry no significant changes are foreseen until 2012. The total production of poultry is thus expected to increase by 1.4% per year from 2003 to 2012.

Table 4 Development in number of produced poultry (Statistics Denmark, 2003 and own calculations (*)).

	2000	2001	2002	2003	2012	2017
	M	M	M	M	M	M
Hens	3.7	3.7	3.7	3.7	4.1*	4.1*
Pullet	1.2	1.0	0.9	0.9	0.9*	0.9*
Broilers (produced)	134.0	136.6	136.4	132.0*	150.0*	150.0*

3.1.1.4 Fur animal

In accordance with the prognosis performed by Jacobsen et al. (2003) the production of mink is expected to increase by 1.5% per year. In 2012 the number of mink is estimated to 2.8 M mink.

3.1.1.5 Other animal categories

Sheep and goats are of minor importance in Denmark. It is assumed that the number of sheep and goats will increase slightly, measured in hundreds. The number of horses is assumed to increase from 152,000 in 2002 to 165,000 in 2012. From 2012 and onwards the number is maintained constant.

3.1.2 Stable type

No official statistics for the distribution of stable types exists. The allocation is based on estimates from The Danish Agricultural Advisory Centre (DAAC).

According to DAAC (Rasmussen, 2003) the distribution of cattle stables is the same as given in the projection for the ammonia emission 2010 (Illerup et al. 2002), which means that most of the dairy cattle are expected to be in stable with loose-holding systems. From 2010 the same stable type distribution is maintained, because at that time all tied-up stables are assumed to have replaced loose-holding houses with slatted floor and scrapers.

Pig stables will only change marginally until 2012 because many of the existing stables are quite new. Because of expected improved animal welfare some changes will take place from fully slatted floor into a combination of drained and partly slatted floor (Lundgaard, 2003). These changes will affect the ammonia emission marginally.

Compared with the previous projections for the ammonia emission (Illerup et al. 2002) there have been some changes in stable type for fur animals. It is expected that mink are kept in slurry based systems in 2012, but the development is going more slowly than assumed previously (Risager, 2002).

As a consequence of the EU Directive of minimum standards for protection of laying hens there will be some changes in stable type for poultry. It is expected that manure systems with manure cellar will be replaced by systems with manure houses (Jensen, 2003).

The emission of CH_4 from manure stores depends on the amount of energy in the store. Straw amendments in the different stable types are added to the stable type according to Poulsen et al. (2001).

In Table 6 the stable type distribution for dairy cattle and fattening pigs is shown for 2002 and the expected distribution in 2012. No change in stable type from 2012 to 2017 is expected.

Table 5 Stable type for dairy cattle and pigs for slaughtering

Animal category	Stable type	Distribution of stable type		
		2002	2012	2017
			percent	
Dairy cattle	Tied-up with liquid and solid manure	12	0	0
	Tied-up with slurry	23	0	0
	Loose-holding with beds, slatted floor	39	50	50
	Loose-holding with beds, slatted floor, scrabes	4	10	10
	Loose-holding with beds, solid floor	11	30	30
	Deep litter, slatted floor	7	6	6
	Deep litter, slatted floor, scrabes	1	1	1
	Deep litter, solid floor	3	3	3
Slaughter pigs	Full slatted floor	56	43	43
	Partly slatted floor	34	50	50
	Solid floor	4	1	1
	Deep litter	1	1	1
	Deep litter and slatted floor	5	5	5

3.1.3 Nitrogen excretion

The expected change in the N-excretion from 2002 to 2012 is given in Table 6. An improved nitrogen-efficiency in the fodder is expected for pigs and poultry. The N-excretion for dairy cattle is expected to increase as a result of the development in the milk yields. It is assumed that the nitrogen excretion for other animal categories is unchanged compared with 2002. From 2012 to 2017 the same nitrogen excretion rates are used in the calculations for all animals. In the basic scenario the N content in manure will decrease by 20,600 tonnes N from 2002 (Table 6) to 2017 as a consequence of the improved nitrogen utilisation in feeding stuff and changes in the animal livestock. This will affect the consumption of mineral fertiliser.

Table 6 Changes in N-excretion 2002 – 2017 in the basic scenario.

	2002	2012	2017	Change 2002-2017
	N ab animal kg N/animal/year	N ab animal kg N/animal/year	N ab animal kg N/animal/year	pct.
Animal categories				
Dairy cattle, large	129.42	135.00	135.00	+ 4%
Sows	25.95	24.20	24.20	- 7%
Piglets (7,5 – 30 kg)	0.63	0.59	0.59	- 6%
Slaughter pigs	3.08	2.91	2.91	- 6%
Hens (battery) – 100 pcs.	62.04	56.50	56.50	- 9%
Broilers – 1000 pcs.	52.77	50.50	50.50	- 4%
Total	kg N/year	kg N/year	kg N/year	pct.
N-excretion	270,700	259,500	250,100	-8%

3.1.4 Fodder consumption

The fodder consumption is used to calculate the emission of CH_4. For all animal categories the Danish norm figures (Poulsen et al. 2001) are used provided as either Danish feeding units per year or kg feed stuff per animal. The figures are converted to Mega Joule (MJ) according to Gyldenkærne et al. (in prep). No major changes are expected in the consumption of energy in feeding except for dairy cows and sows due to increased productivity. For dairy cows an increase of 0.33 feeding units per kg milk is assumed. For sows a linear increase in feeding units from 1,340 units in 2002 to 1,380 units in 2012 is assumed. From 2012 to 2017 the feeding units are assumed to be constant.

3.1.5 Energy in manure

The production of CH_4 from manure handling depends on the energy level in the manure (IPCC, 1996; 2000). The amount of energy is calculated for each stable type, due to individual straw amendments. The energy consumption is taken from the Danish norm figures (Poulsen et al. 2001) as well as the feeding efficiency rate. The amount of Volatile Substance (VS) in the faeces and the straw amendments is calculated according to the IPCC guidelines.

3.1.6 Application of manure from livestock

The ammonia emission from manure application is estimated by the method described by Hutchings et al. (2001) and Illerup et al. (2002). The emission factor depends of application technique, time of the year, the interval between application and incorporation and whether the manure is spread on bare ground or in growing crops.

The latest information about manure handling is from 2002 and is based on a questionnaire covering 1,600 farmers. The investigation was carried out by the organisation Danish Agriculture (2002) and shows that 20% of the slurry in 2002 is incorporated in the soil. It is expected that an increasing part of the slurry will be injected directly into the soil. Incorporation of slurry improves the nitrogen utilisation in the manure and reduces odour problems. In 2012 it is expected that 40% of the liquid manure will be injected (Table 7).

Table 7 Estimated handling of liquid manure 2000 to 2017

	2000	2001	2002	2003	2012	2017
	pct.	pct.	pct.	pct.	pct.	pct.
Injected/ incorporated	7	13	20	26	40	40
Trailing hoses	56	70	67	66	60	60
Broad spreading	37	17	13	8	0	0

3.2 Crops

The major source of N_2O is the nitrogen turnover in farmed areas. At average there are 8.7 tonnes of nitrogen per ha in farmed Danish soils (Heidmann et al. 2001). The average annual application is approximately 140 kg N per ha. The turnover rate depends on the nitrogen content of the soil, the crop grown, tillage, manure application and mineral fertiliser application. In the emission estimates for N_2O from agricultural fields the standard IPCC methodology (IPCC, 1996) is used with moderation’s according to national data (Gyldenkærne et al. in prep).

3.2.1 Cultivated area

A reduction in the agricultural area is expected as a consequence of afforestation, increased nature restoration and growth in the urban areas and in the infrastructure. A consequence is a reduced need for fertilisers resulting in a reduced leaching of nitrogen.

From 1990 to 2002 the cultivated areas have decreased by approximately 10,000 ha or 0.4% per year. The recent development shows a lower reduction rate than in the 1990s. In the projection a decrease in the agricultural area of 0.35% per year is assumed. The cultivated area in 2002 is 2.67 M ha. In 2012 and 2017 the area is expected to be reduced to 2.57 M ha and 2.53 M ha, respectively (Table 8).

In 1989 the Danish Parliament decided to double the forested area within the next 80-100 years. The aim is to plant 4-5,000 ha of new forest per year, of which half will be government property and the other half will be private property. A great part of the afforestation will be on farmed land. From 1990 to 2000 the forest area has increased from 445,000 ha to 486,000 ha or approximately 4,000 ha per year (Statistics Denmark, 2003). Afforestation may also take place on non-agricultural land hence it can not be concluded that all 4,000 ha per year will be raised on farmed land. A general figure is that 2,500 ha of farmed land are afforestated every year. No figures are available on the area that will be converted to urban areas and infrastructure.

Table 8 Agricultural area 1990 to 2017 (Statistics Denmark, 2003 and own calculations (*)).

	1990	2002	2003	2012	2017
			M ha		
Agricultural area	2.79	2.67	2.66*	2.57*	2.53*

3.2.2 Nitrogen fixing crops and crops residue

The calculated emission from nitrogen fixing crops and crop residues in the projection is solely influenced by a reduced agricultural area. In practice it is expected that some change in the distribution of crop types will take place. Implementation of the CAP reform is expected to favour nitrogen fixing crops and reduce the area with cereals (Jacobsen et al. 2003). On the other hand, a reduced number of dairy cattle will reduce the need for grass and clover for feeding and increase the area with cash crops. Until 2010 only small and uncertain changes can be foreseen in land use due to the CAP reform (Jacobsen et al. 2003). In 2002 the area with nitrogen fixing crops is relatively small and because the N_2O emission from crop residues from different crop types differ only slightly the crop distribution over the area in 2002 is maintained until 2017.

3.3 Mineral fertiliser

The consumption of mineral fertiliser has decreased from 400,000 tonnes of nitrogen in 1990 to 211,000 in 2002 (Table 9). The consumption of mineral fertiliser from 2002 to 2017 in the basic scenario is assumed to decrease by 24,000 tonnes of nitrogen, based on an average application rate of 140 N per ha and is due to a reduced agricultural area and improvement in utilisation of nitrogen in manure. Implementation of the CAP reform is expected to reduce the number of cattle and increase the pig production. In scenario 2 (only CAP reform) no increase in the demand for mineral fertiliser is expected. In scenario 3 (unchanged pig production from 2003), the total amount of nitrogen in manure is expected to decrease increasing the demand for mineral fertiliser at approximately 6,000 tonnes per year.

The use of mineral fertiliser includes fertiliser used in parks, golf courses and private gardens. Approximately 1-2 percent of the mineral fertiliser can be related to this use out side the agricultural area.

Table 9 The consumption of mineral fertiliser 1990 to 2017 (Statistics Denmark, 2003 and own calculations (*)).

	1990	1995	2002	2003	2012	2017
			M kg N			
Basic scenario	400	316	211	202*	190*	187*
Implementation of CAP reform	400	316	211	202*	190*	187*
Unchanged pig production + CAP reform	400	316	211	202*	196*	193*
25% reduction in leaching + CAP reform	400	316	211	202*	128*	125*

3.4 Nitrogen leaching

The Danish Institute of Agricultural Sciences has estimated the nitrogen leaching from 1985 to 2002 based on two different model predictions, SKEP / Daisy and N-Les2 (Børgesen og Grant, 2003). The result of these two calculations differ only marginally.

The average of these two model predictions is used to estimate the emission from 1990 to 2002. The estimated leaching in relation to the nitrogen input from mineral fertiliser, nitrogen in manure and slurry is shown in Figure 3. The average leaching percentage is decreasing from 38% to 34%. Since 1990 the use of mineral fertiliser has been reduced by more than 50% and the leaching follows closely the nitrogen input. From 2003 onwards a leaching percentage of 34% is assumed.

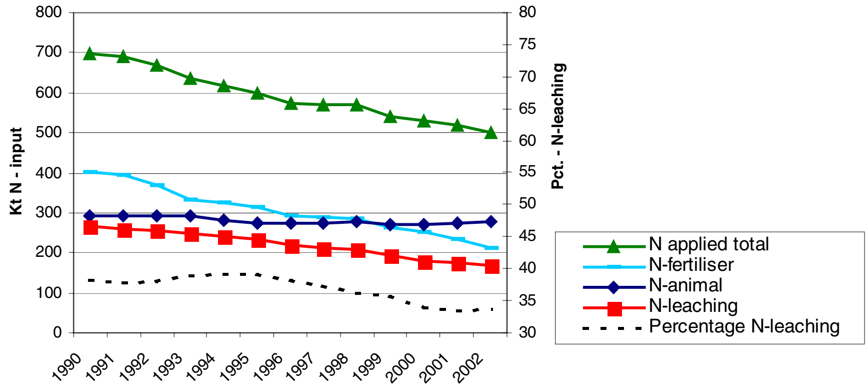


Figure 3 Nitrogen applied on agricultural soils and N-leaching from 1990 to 2000 (Source: Børgesen, 2002 and Gyldenkærne et al. – in prep).

3.5 Liming

The Danish consumption of lime for liming in agriculture has decreased from 1.3-1.6 M tonnes in the late 1980's to 0.5 M tonnes $CaCO_3$ in 2002 (Danish Agricultural Advisory Centre, 2003). The reduction is mainly due to a reduced emission of acidifying gases into the atmosphere and a reduced consumption of ammonium-containing manure and mineral fertilisers. No further decrease in lime consumption is expected unless in scenario four where slurry acidification has to be neutralised.

3.6 Biogas production

Biogas plants using animal slurry reduce the emission of CH_4 and N_2O (Sommer et al. 2001). In 2002 there were 20 common facilities and 50 individual farm facilities. At the moment (2003) 15 common facilities are under projection (http://www.biogasbranchen.dk). In 2002 about 4% of the total amount of slurry were treated in biogas plants.

Biogas plants are seen as one of the most cost-effective ways to reduce the Danish GHG emission (Danish Agriculture, 2003). Although slurry is treated in biogas plants CH_4 and N_2O emission still takes place before and after treatment. The amount depends on the origin of the slurry, the storage and the biogas facility (Sommer et al. 2001). The CH_4 emission from treated slurry is calculated as the amount of treated Volatile Substance (VS) multiplied by the IPCC emission factor and the relative emission from treated slurry (Table 10). The N_2O emission is calculated as the amount of nitrogen in the slurry multiplied by the IPCC emission factor and the relative emission from treated slurry, Table 10 (Gyldenkærne et al. in prep.).

At the moment no political decision has been taken to increase the investment in biogas plants. In the basic scenario and the scenario with the CAP reform and the unaltered pig production, the level of fermented slurry is kept at the present level. In the fourth scenario, 34% of the husbandry slurry is fermented in biogas plants.

Table 10 Relative CH_4 and N_2O emission factors for untreated slurry in relation to treated slurry in biogas plants.

					Methane (Relative to untreated)	Nitrous oxide (Relative to untreated)
	% dry matter[a]	% N[a]	% VS of dry matter	Untreated	Treated[b]	Treated[b]
Cattle Slurry	10.3	0.00538	80	1	0.70	0.36
Pig slurry	6.1	0.00541	80	1	0.50	0.40

[a] Poulsen et al., 2001
[b] Nielsen et al., 2002

3.7 Emission factors

3.7.1 Ammonia, NH_3

Emission factors used for calculation of the ammonia emission are based on Poulsen et al. (2001). The emission factor in relation to manure stores is adjusted for incomplete covering of slurry tanks (COWI, 2000). During recent years more attention has been given the obligatory surface crust layer, which will lead to less ammonia emission. In 2012 it is expected that the incomplete covered tanks will be reduced to 2% for cattle slurry and 5% for pigs slurry.

3.7.2 Methane, CH_4

The emission of CH_4 per animal is based on a calculation by the Tier 2 approach given in the IPCC guidelines (IPCC 1996; 2000) and the corresponding default emission factors. The annual emission factor per head from enteric fermentation and manure stores is calculated for every year according to changes in feeding consumption and stabling. In Table 12 the emission data for 2002 for different animal categories is listed. A more detailed description of the emission calculation is given in Gyldenkærne et al. (in prep.).

Table 11 Emission factors for calculation of CH_4 emission in 2002. The figures are not always comparable to the IPCC guidelines due to differences in grouping and weight classes.

Emission source	Emission 2002 (IPCC Tier 2)	
	Enteric fermentation kg CH_4 animal^{-1} y^{-1}	Manure management kg CH_4 animal^{-1} y^{-1}
Cattle		
Dairy cattle	120.36	17.67
Heifer calves < ½ year	3.71	0.04
Heifer ½ year to calving	33.24	1.70
Bull calves < ½ year	8.16	0.16
Bull ½ year to slaughtering	16.84	1.44
Suckling cows	66.97	1.00
Pigs		
Sows	2.53	5.05
Piglets (per produced)	0.08	0.20
Pigs, slaughter (per produced)	0.38	0.96
Other		
Poultry	-	varies
Fur farming	-	0.43
Horses	29.35	2.00
Sheep (incl. lambs)	17.17	0.11
Goats (incl. kids)	13.15	0.10

3.7.3 Nitrous oxide, N_2O

The emission factors for N_2O are based on default values in IPCC guidelines (IPCC 1996; 2000). The emission factors are listed in Table 12. The same emission factors are used for all years. Data for the ammonia emission is included in the calculation of the N_2O emission and is in accordance with the ammonia emission inventory.

Table 12 Emission factor for calculation of N_2O emission.

Emission source	Ammonia emission	N_2O emission
		kg N_2O -N/kg N
Manure Management		Liquid = 0.001 Solid = 0.02
Animal wastes applied to soils	NH_3 emission = (22-27%)	0.0125
Mineral fertiliser applied to soils	NH_3 emission = 2,2%	0.0125
Sewage sludge applied to soils		0.0125
Grassing animals	NH_3 emission = 7%	0.02
N-fixing crops		0.0125
Crop residue		0.0125
Cultivation of histosols		8 kg N_2O -N/ha
Atmospheric deposition		0.01
Leaching and runoff		0.025

3.7.4 Carbon dioxide, CO_2

The emission of CO_2 is limited to liming and the area with histosols according to the IPCC guidelines (IPCC, 1996; 2000).

The use of lime for agricultural purposes has decreased from the late 1980's until 2002 (Figure 3). The main reason for the reduction is a reduced deposition of acidifying substances and a lower consumption of ammonium fertilisers.

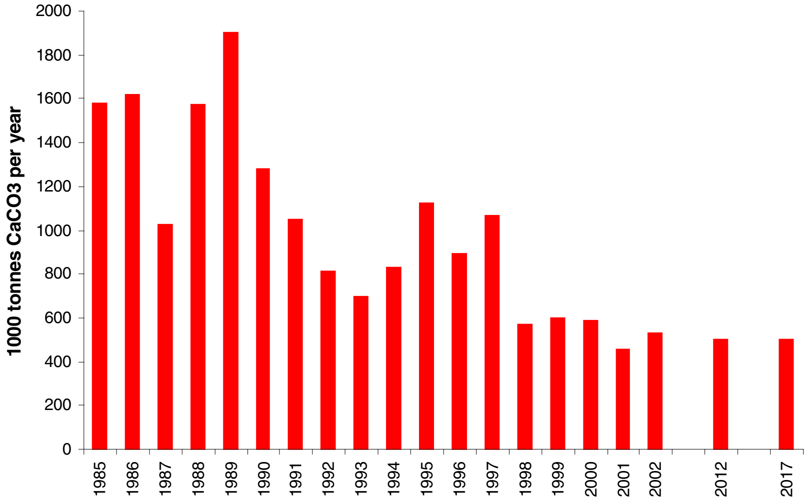


Figure 3 Lime consumption for agricultural purposes in Denmark from 1985 (Danish Agricultural Advisory Centre, 2003).

Until 2017 an unchanged need for liming is expected. The emission factor for $CaCO_3$ is the standard emission factor 0.12.

For histosols it is assumed that 10% of the organic soils are in rotation or equivalent to 18,400 ha. The emission of CO_2 from histosols is calculated with the default IPCC value of 1 tonnes C per ha and year equivalent to 3.66 tonnes CO_2 per ha. An ongoing investigation of the emission of CO_2 from agricultural soils will change the figures, but at present no knowledge about this is available.

4 Four emission scenarios from 1990 to 2017

The GHG emission from four different scenarios has been estimated:

1. a basic scenario without any further initiatives,
2. a scenario with implementation of the Common Agricultural Policy (CAP) reform with a 75% decoupling of the subsidiaries from the animal production as proposed by the Danish Agriculture organisation,
3. a sensitivity scenario where the pig production is kept at the same level as in 2003 including implementation of the CAP reform, as above
4. a scenario where a third action plan on the water environment (VMP III) is introduced. At the moment no political decisions have been made to implement a new action plan, so this scenario is based on a proposal made by a technical subgroup under VMP III preparation activities. The proposal assumes a 25% reduction of leached nitrogen from agriculture compared with the leaching in 2003 and introduces measures to reach this reduction. The scenario introduces some technical methods to reduce loss of nitrogen from agriculture mainly covering acidification of slurry and a considerable investment program in biogas plants.

All four scenarios follow the same outline on forecasting the agricultural activity, because most of the factors affecting the development in Danish agriculture are reasonably stable. This include the genetic improvements, improved feeding technology, improved milk production per dairy cow, improved number of piglets per sow, changes in stabling of the animals, changes in husbandry manure application etc. New technology is only assumed to be applied in scenario 4.

The major uncertainty can be linked to the continuity of the increase in the pig production and in the introduction of new technology in order to reduce nitrogen losses. The latter is mainly driven by political decisions.

In the following only the main figures for the different scenarios are given. Detailed data are given in Appendix A

4.1 The Basic Scenario

In the basic scenario the overall emission in 2012 is estimated to be 9.8 M tonnes CO_2-eqv. and the emission in 2017 is expected to be reduced further corresponding to 9.6 M tonnes CO_2-eqv. (Table 13). In the projection from 2012 to 2017 changes in the agricultural area and in the numbers of cattle and sows are included.

The emission of CH_4 is expected to decrease with 0.18 M tonnes CO_2-eqv. from 2003 to 2017. In the same period the N_2O emission is expected to decrease by 0.40 M tonnes CO_2-eqv. A change in emission of CO_2 from 2003 to 2017 is not foreseen.

Table 13 Basic scenario; emission of greenhouse gases from 1990 to 2002 and the expected emission from 2003 to 2017 (M tonnes CO_2-eqv.).

Emission	1990	1995	2002	2003*	2012	2017	Reduction 2003-2017	
	M tonnes CO_2-eqv.							pct.
Methane - CH_4**	3.85	3.94	3.79	3.71	3.66	3.53	0.18	5%
Nitrous oxide - N_2O	8.98	7.90	6.36	6.13	5.89	5.73	0.40	6%
Carbon dioxide - CO_2	0.63	0.56	0.30	0.29	0.29	0.29	0.00	0%
Total GHG emission	13.46	12.40	10.45	10.13	9.84	9.55	0.58	6%

*Preliminary estimate
** Incl. emission from fur farming

4.1.1 Methane, CH_4

The CH_4 emission mostly originates from the digestion process of livestock and cattle is the most important methane-producing animal. A minor part of the emission comes from manure management.

The emission in 2002 is estimated to be 180.5 kg tonnes CH_4 (Table 14). Despite a reduction in the number of cattle from 1990 there is no reduction in the total CH_4 emission from 1990 to 2002. The reduced emission from enteric fermentation is compensated by an increase in emission from manure management. This is due to changes in stable systems, where older tied-up systems are replaced by slurry based stable systems. The emission factor for liquid manure is ten times the emission factor for solid manure.

The CH_4 emission in 2017 is estimated to be 168.1 kg tonnes $CH_{4,}$ which corresponds to 7% reduction from 2002 to 2017. This reduction is due to the decline in the number of cattle as a consequence of increasing milk yield and a fixed milk quota. Slurry based stable systems have become more dominant in the past ten years and the stable type is not expected to change considerably in the future compared with previous years. Thus, the emission from manure management in 2017 will be at the same level as in 2012.

Table 14 Emission of methane from 1990 to 2017.

CH_4 emission*	1990	1995	2002	2003	2012	2017
			1000 tonnes CH_4			
Enteric fermentation	147.6	146.3	133.2	129.5	123.3	118.1
Manure management	35.8	41.4	47.1	47.4	50.9	50.0
- reduction due to biogas plants	0.1	0.4	0.8	0.9	0.9	0.9
Total, Kilo tonnes CH_4	183.4	187.6	180.3	176.8	174.1	168.1
			M tonnes CO_2-eqv.			
Total, M tonnes CO_2-eqv.	3.85	3.94	3.79	3.71	3.66	3.53

** incl. emission from fur farming

4.1.2 Nitrous oxide, N_2O

The N_2O emission is closely related to the nitrogen turnover. The main sources are leached nitrogen, mineral fertiliser application and manure applied to the soil.

In the period from 1990 to 2002 the N_2O emission has been reduced by 29%, which is mainly due to a reduction in the use of mineral fertiliser and a decrease in the emission from nitrogen leaching. The proactive environmental policy has reduced the leaching and the overall nitrogen input, so despite an increase in the livestock production a decreased nitrogen excretion has taken place.

From 2003 to 2017 it is expected that the N_2O emission will be further reduced. In 2017 the emission is estimated to 19.01 kg tonnes N_2O corresponding to a reduction of 10% from 2002 to 2017. The reduction is primarily related to a decline in the agricultural area, a lower nitrogen excretion and a decrease in the cattle herd.

The emission from cultivated histosols is estimated to be 0.23 kg tonnes N_2O. An ongoing revision of the emissions from Danish agricultural soils may change this figure slightly, however, 0.23 kg tonnes is kept constant until a better estimate has been confirmed.

Table 15 Emission of nitrous oxide from 1990 to 2017.

N_2O Emission	1990	1995	2002	2003*	2012	2017
			1000 tonnes N_2O			
Manure management	2.21	2.09	1.95	1.86	1.79	1.73
Grassing	1.01	1.04	0.96	0.94	0.86	0.81
Mineral fertiliser	7.69	6.06	4.05	3.87	3.65	3.59
Manure applied on soil	3.51	3.41	3.58	3.45	3.44	3.31
Sewage sludge	0.09	0.18	0.22	0.20	0.23	0.23
Atmospheric deposition	1.72	1.45	1.27	1.23	1.15	1.12
Nitrogen leaching	10.50	9.23	6.59	6.31	6.04	5.87
Nitrogen fixing crops	0.88	0.73	0.66	0.66	0.64	0.63
Crop residue	1.13	1.08	1.03	1.03	1.00	0.98
Cultivated histosols	0.23	0.23	0.23	0.23	0.23	0.23
Burning of straw	0.00	0.00	0.00	0.00	0.00	0.00
- Effect of biogas plants	0.00	0.01	0.02	0.02	0.02	0.02
Total, Kilo tonnes N_2O	28.98	25.49	20.53	19.77	19.01	18.48
Total, M tonnes CO_2-eqv.	8.98	7.90	6.36	6.13	5.89	5.73

* Preliminary estimates

4.1.3 Carbon dioxide, CO_2

The emission of CO_2 from liming contributes with less than 3% of the total GHG emission. The need for liming of agricultural soils have been reduced in recent years due to a reduced deposition of acidifying substances and a lower consumption of ammonium fertilisers. No changes are assumed in the future.

Table 16 CO_2 emission from liming and histosols from 1990 to 2017 in the basic scenario

CO_2 emission	1990	1995	2002	2003*	2012	2017
			M tonnes CO_2-eqv.			
Total, M tonnes CO_2-eqv.	0.63	0.56	0.30	0.29	0.29	0.29

* Preliminary estimates

4.2 Basic Scenario and the CAP Reform

On September 29, 2003, the Agricultural Council formally adopted the legal texts of the June 2003 CAP reform agreement (EU, 2003). Reforms are to be introduced starting in 2004, though Member States have the option to delay implementing some of the decoupling measures until 2008. The essence of the reform is a shift from subsidies based on production to subsidies that have no link to whether a farmer produces or not. Fully decoupled payments could see a large part of EU farm payments shifting from the WTO Blue box (trade distorting, allowed within limits) to the Green box (non-trade distorting).

The individual countries are allowed to choose different models of implemention of the CAP reform. Danish Agriculture has recommended the Danish Government to implement the CAP reform in 2005 as a partly decoupled model where 75% of the subsidiaries for bull premiums are maintained. The Danish Meat Board has calculated the effect on the meat production in Denmark (Lind Petersen, 2003). The meat production will decline by 13% primarily due to a reduction in the number of suckling cows. A surplus of bull calves, which cannot be raised for Danish meat production, is expected to be exported. The effect of the number of calves and meat is shown in Table 17.

Table 17 The effect of the CAP reform on the meat production. It is assumed that the CAP reform will remain unchanged until 2012 and no further changes are expected from 2012 to 2017.

	2002	From 2005	2005	2005
		75 % decoupling 1000 pieces	Difference 1000 pieces	Difference, %
Cows	692	661	-31	-4
- Dairy cows	577	576		
- Suckling cows	115	85	-30	-26
Surplus of bull calves	30	75	+45	+150
	Tonnes per year	Tonnes per year		
Meat production	141	122	-19	-13
- from dairy cows	110	99	-11	-10
- from suckling cows	31	23	-8	-26

Source: Danish Meat Board, K.B. Lind Petersen (personal comm.).

From Table 17 it can be seen that the Danish meat production from cattle is reduced from 140.7 tonnes before the reform to 122 tonnes per year after implementation of the reform. The figures are based on an estimated production level in 2005. In the scenario the emission of GHG is based on a reduction of the meat production by 18.7 tonnes per year compared with the 2005 figure.

It is expected that the milk production will continue at the same level as now and not be affected by the CAP reform within a short time span because the efficacy level in Denmark is quite high (Lind Petersen, 2003; Jacobsen et al. 2003). As in the basic scenario an increase at 150 kg milk per year per dairy cow is expected. The number of suckling cows is expected to be maintained at 85,000 until 2017. In 2017 the meat production from bull calves is kept at the same level as in 2012, decreasing the “surplus of calves”.

The pig production is expected to increase by 2% above the stipulated production in 2010 due to cheaper feeding (Jacobsen et al. 2003). Therefore from 2005 and onwards the annual increase in the pig production will be 1.1% + 0.4% = 1.5% p.a. (2% / 5 years = 0.4% p.a.).

Implementation of the CAP reform is not expected to affect the set-a-side area (Arne Munk, 2003).

As mentioned in Chapter 3.2 only small changes in land use is expected due to the CAP reform. These changes are not incorporated in the scenario.

The decrease in the cattle production due to the CAP reform and the increase in the pig production have no effect on the total nitrogen content in husbandry manure as a whole taking into account the different demands for utilisation of nitrogen in the manure. Therefore no changes in the demand for mineral fertiliser are foreseen, maintaining the leaching potential from nitrogen at the same level.

4.2.1 Emission estimates

Implementation of the CAP reform has only little effect on the GHG emission. Compared with the basic scenario a reduction of 0.03 M tonnes in 2012 and 0.10 M tonnes in 2017 is expected. In 2012 a GHG emission of 9.78 M tonnes CO_2-eqv. is expected and in 2017 9.45 M tonnes is expected.

Table 18 The estimated development in the emission of GHG from 2003 to 2017 with implementation of the CAP reform (M tonnes CO_2-eqv.).

	2003	2012	2017	Reduction 2003-2017	
Methane - CH_4	3.71	3.59	3.46	0.25	7%
Nitrous oxide - N_2O	6.13	5.90	5.70	0.43	7%
Carbon dioxide - CO_2	0.29	0.29	0.29	0	0%
Total GHG emission	10.13	9.78	9.45	0.75	7%

4.3 Basic Scenario, The CAP reform and no increase in the pig production

In this scenario the cattle production is kept as in the basic scenario with implementation of the CAP reform. The pig production is kept at the same level as in 2003, but a continuous decrease in the number of sows is expected due to the increased genetic and management improvements.

All other factors described in section 4.1 and 4.2 are kept constant, except for an increased demand for mineral fertiliser due a lower nitrogen content in husbandry manure following the decreased number of dairy and suckling cows, heifers and bull calves as well as sows (Table 9).

4.3.1 Emission estimates

Table 19 shows the estimates for 2012 and 2017 with an unaltered pig production in the basic scenario plus the CAP reform. In 2012 and 2017 an emission of 9.50 and 9.17 M tonnes CO_2-eqv. is expected, respectively. One result of the stop in pig production is a further reduction from the scenario 2 (CAP reform) by 0.28 M tonnes CO_2-eqv. in 2012 and 2017.

Table 19 The estimated development in the emission of GHG from 2003 to 2017 with implementation of the CAP reform keeping the pig production at the same level as in 2003 (M tonnes CO_2-eqv.).

	2003	2012	2017	Reduction 2003-2017	
Methane - CH_4	3,71	3,47	3,34	0,37	10%
Nitrous oxide - N_2O	6,13	5,75	5,55	0,58	9%
Carbon dioxide - CO_2	0,29	0,29	0,29	0,00	0%
Total GHG emission	10,13	9,50	9,17	0,96	9%

4.4 Basic Scenario, the CAP reform and 25% reduction in leaching

A comprehensive technical work has been laid down in the third action plan on the aquatic water environment. No political decision has yet been taken on the new action plan. The scenario subgroup (Scenariegruppen, 2003) for preparation of the action plan has proposed four different scenarios. The scenarios are mainly defined with the aim of reducing the leaching of nitrogen. The four scenarios include reduction at 5, 10, 25 and 50% of the leaching of nitrogen to be reached by different reduction methods. The methods include, among others, increased set-a-side areas in river valleys, acidification of slurry, reduced nitrogen norms, increased utilisation of nitrogen in husbandry manure and investment in biogas plants.

The consequence on the emission of GHG by implementing the 25% reduction in leaching of nitrogen into the water environment has been estimated. In this scenario the leaching is reduced from 180,000 tonnes N per year to 135,000 tonnes. The different measures are shown in Table 20 (Scenariegruppen, 2003).

Some of the measures in Table 20 have already been included in the basic scenario. These measures are improved feeding, parts of the afforestation and increase in slurry injection. These are therefore excluded in the emission calculation to avoid double counting.

The 10% increase in the utilisation demand of nitrogen in husbandry manure and the 10% reduction in the nitrogen norm is included successively until 2012 by a reduction in the need for mineral fertiliser.

The reduction of the nitrogen norm means that the highest allowable nitrogen application is 20% below the economical optimum.

An increased area with grass after cereals as catch crops for nitrogen will reduce the leaching. It is assumed that the increased area does not affect the demand for mineral fertilisers.

The reduced nitrogen application in sensitive areas and an increased area with organic farming is incorporated in the scenario.

Acidification of slurry will reduce the NH_3-content with 60-70% in treated slurry and increase the nitrogen content in the manure. The increased leaching potential is partially outweighed by the 10% increased demand for utilisation of nitrogen in husbandry manure and the reduced nitrogen norm. In the scenario 40% of all slurry from cattle and pigs is assumed to be acidified. A linear implementation of acidification from 2004 until 2012 is assumed.

In the scenario a 30%-point increase in the amount of slurry treated in biogas plants is expected. Today only 4% is treated. The large investment in biogas plants may be difficult to achieve within the time limit until 2012. It is therefore assumed that the 50% increase will take place before 2012 and the remaining 50% from 2012 to 2017.

For the last 6-8 years 2,500 ha of forest has been raised on agricultural land. In the calculation it is assumed that the afforestation of 40,000 ha results in an increase from 2,500 ha to 4,000 ha per year from 2004 to 2013 compared with the basic scenario. The agricultural area will therefore decrease further than the 0.35% reduction per year by another 1,500 ha per year compared with the basic scenario from 2004 to 2013. The afforestation includes a binding of CO_2 in the trunks and roots. The CO_2 sequestration from afforestation is calculated with a model from the Danish Forest and Landscape Research Institute assuming two third of the area as deciduous forest and the remaining as coniferous forest (Lars Vesterdal, DFLRI, 2003). The afforestation of the remaining 2,500 ha per year, which is assumed to take place anyway is not included in the calculation of the GHG emission from agriculture.

The set-a-side in river valleys has a high leaching reduction potential because it is assumed that the valleys are able to remove nitrogen from drainage water in the newly established wetlands. Petersen (2003) concluded that wetlands do not increase the N_2O emission and that the emission factor after the nitrogen has left the ground water magazine are at the same level as the emission factor in water sheds and estuaries (0,75% and 0.25%). In the GHG emission calculation no effect on the emission is assumed due to the reduced leaching in the 90,000 ha with wetlands. It is assumed that the 90,000 ha are unfertilised and that there is a further increase in the area with set-a-side compared with the present EU determined set-a-side.

Acidification of slurry is at an average done by applying approximately 5 kg H_2SO_4 (93%) per tonnes slurry. Neutralisation of one mole H_2SO_4 needs one mole of $CaCO_3$. The mole weights for H_2SO_4 and $CaCO_3$ are 98.06 and 100.09, respectively. 40% of all cattle and pig slurry in 2012 is approximately 13 M tonnes and the need for H_2SO_4

for acidification is 65,000 tonnes p.a. Acidification will therefore increase the need for liming with 66,300 tonnes per year.

In 2017 a 4.5% lower agricultural area is expected due to the general reduction by 15,000 extra ha of forest and a further set-a-side of 90,000 ha in river valleys. In total the agricultural area is reduced from 2.66 M ha in 2003 to 2.56 M ha in 2012 and 2.51 M ha in 2017.

Based on these assumptions the effect on the emission on GHG has been calculated.

Table 20 Proposal for how a further reduction in leaching of 25% from the root zone can be achieved (Scenariegruppen, 2003 and Blicher-Mathisen and Grant 2003).

	Area Ha	Approx. Reduced leaching from the root zone, tonnes N[a]	Approx. reduction in mineral fertiliser consumption, tonnes N[b]	Approx. Reduced ammonia emission tonnes N
Improved feeding		1,200	-	?
10 % (pct.-point) increase in utilisation of nitrogen in husbandry manure.		6,900	19,200	500
Targeting of existing 6% grass crops as catch crops after cereals to areas which receive manure (reduced leaching 12 kg N/ha)	185,000	2,220	-	?
Further establishment of grass crops as catch crops after cereals targeted to areas which receive manure (reduced leaching 37 kg N/ha)	185,000	6,845	-	?
Set-a-side/wetlands in river valleys (reduced leaching 100 kg N/ha)	90,000	9,000 (no effect on the GHG emission)	12,060	?
Afforestation on agricultural soils (reduced leaching 50 kg N/ha)	40,000	2,000	5,360	268
Reduction of the nitrogen norm to all crops with 10%		12,400	32,700	900
Reduced nitrogen application in sensitive agricultural areas (SFL) (reduced leaching 30 kg N/ha)	40,000	1,200	1,500	?
Organic farming (reduced leaching 28 kg N/ha)	30,000	840	2,610	150
Acidification of slurry in 40% of the stables with cattle and pig slurry.			-	11,000
30% increased treatment of slurry in biogas plants		2,000	-	
30% increase in slurry injection in the field			-	2,250
Total reduction		44,605	73,430	15,218

[a]Scenariegruppen 2003

[b] Blicher-Mathisen and Grant, 2003

4.4.1 Emission estimates

Implementation of this scenario will decrease the GHG emission from 10.13 M tonnes CO_2-eqv. in 2003 to 9.0 M tonnes in 2012 and 8.6 M tonnes in 2017 (Table 22).

Acidification of slurry has only a limited effect on the GHG emission because according to the IPCC guidelines ammonia emission has to be included in the nitrogen input in the agricultural system. The N_2O emission factor from emitted ammonia is 1%. The reduced ammonia emission caused by acidification increases the nitrogen content in the manure stored and manure applied to the field. The consequence is that “saved” ammonia will be applied with an emission factor of 1.25% or slightly higher. Acidification will only decrease the GHG emission estimate if the increased nitrogen content in the manure is recognised in the nitrogen budget by increasing the nitrogen value of the manure.

The effect of the increased fermentation of slurry in biogas plants is responsible for a reduction of 0.18 M tonnes CO_2-eqv. per year in 2017. In this figure only the reduced emission from the slurry is taken into account but not the following displacement of mineral fuel for electricity and heating.

The increased afforestation is responsible for an increased carbon sequestration. In 2012 a sequestration of 0.18 M tonnes CO_2-eqv. per year is expected and in 2017 0.62 M tonnes CO_2-eqv. per year is expected. It can be argued that this sequestration should not be included in the emission estimate from agriculture. The sequestration figure does not include the sequestration from the annual 2,500 ha of forest raised on agricultural soils.

Table 21 The estimated development in the emission of GHG from 2003 to 2017 with implementation of the CAP and a 25% reduction in leaching (M tonnes CO_2-eqv.).

	2003	2012	2017	Reduction 2003-2017	
Methane - CH_4	3.71	3.53	3.35	0.37	10%
Nitrous oxide - N_2O	6.13	5.12	4.90	1.23	20%
Carbon dioxide - CO_2	0.29	0.32	0.32	-0.03	-10%
Emission from agriculture	10.13	8.97	8.57	1.56	15%
Increased afforestation		-0.18	-0.62		
Net emission	10.13	8.78	7.95	2.18	22%

5 Results

Four different scenarios are described estimating the GHG in 2012 and 2017. The overall results are given in Figure 4.

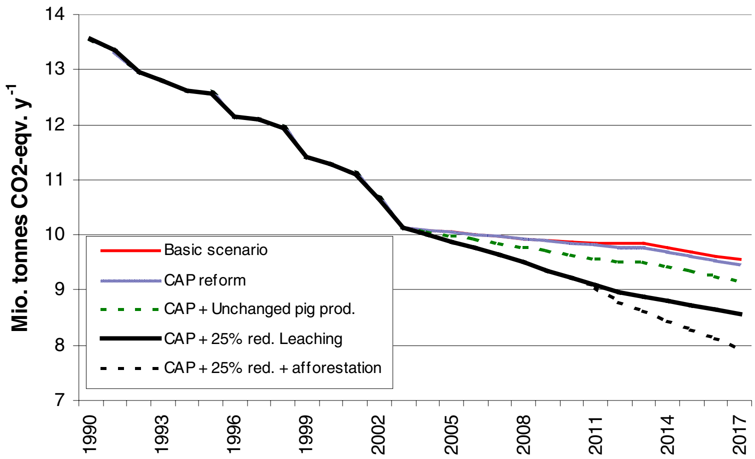


Figure 4 The development in the emission in the four scenarios from 1990 to 2017.

Despite an increasing pig production all four scenarios show a decreased GHG emission. This is mainly due to a reduced agricultural area and a decline in the cattle herd. The figures for 2003, 2012, 2017 and the average of the first and second reporting period (2008-2012 and 2013-2017) are given in Table 22.

The first scenario is the basic scenario, which is most likely to occur without any changes in the agricultural policy. From 2003 to 2012 a decrease in the GHG emission from 10.1 to 9.8 M tonnes CO_2-eqv. is expected. From 2012 to 2017 a further decrease to 9.6 M tonnes CO_2 is foreseen.

The second scenario includes implementation of the CAP reform. It assumes a further reduction of the emission of GHG with 0.03 M tonnes CO_2-eqv. compared to the basic scenario in 2012 and 0.10 M tonnes in 2017. This is mainly due to a reduced emission of CH_4 resulting from a reduced number of cattle. On the other hand the CAP reform is expected to increase the pig production by 2% beyond the 1.1% p.a. increase in the basic scenario.

The third scenario is a complete stop in the increase in the number of produced slaughter pigs. The production level is kept as in 2003. This scenario decrease the GHG emission further compared with the CAP scenario. This scenario may furthermore be seen as a sensitivity test concerning the pig production. Altering the pig production has only a limited effect on the overall emission of GHG. This is explained by the low enteric production of CH_4 from pigs and the high utilisation demand for nitrogen in the pig manure, which is almost eliminated by the change in the demand for mineral fertiliser. The difference in the pig production between scenario 2 and 3 is 3 M produced pigs per year in 2012. These pigs are responsible for an emission of 0.22 M tonnes CO_2-eqv. or 2% of the total emission.

The fourth scenario introduces some technical methods and an overall reduced leaching of 25%. This scenario estimates a GHG emission of 9.0 M tonnes CO_2-eqv. in 2012 and 8.6 M tonnes CO_2-eqv. in 2017.

If this scenario is implemented as described in chapter 4.4, the increased treatment of slurry in biogas plants is responsible for reducing the GHG emission by 0.18 M tonnes CO_2-eqv. in 2017.

Table 22 The estimated development in the emission of GHG from 2000 to 2017 in the four scenarios (M tonnes CO_2-eqv. y^{-1}).

	2003	2012	2017	2008-2012	2013-2017
Basic scenario	10.13	9.84	9.55	9.88	9.69
CAP Reform	10.13	9.78	9.45	9.86	9.62
CAP + unchanged pig prod.	10.13	9.50	9.17	9.64	9.34
CAP + 25% leaching	10.13	8.97	8.57	9.24	8.77
CAP + 25% leaching + afforestation[1]	10.13	8.78	7.95	9.15	8.37

[1]Increased afforestation on agricultural soils. The CO_2 sequestration must be reported under forestry and not under agriculture.

The emission estimates for 2012 and 2017 and the average figures for the first and second reporting period depend on whether and when the third action plan may come into force. If no actions at all are taken and no further technologies are introduced scenario 2 (CAP reform) will be the most likely option to occur. The emission of GHG may be lower because of the present interest in biogas plants although no public financial support for the investment has been granted at the moment.

Slurry acidification has only little effect on the emission of GHG because acidification will only change the nitrogen input to the agricultural system marginally. The reduced emission and its influence on the GHG calculation is counterweighted by an equivalent reduced atmospheric deposition leaving the nitrogen input into the soil system more or less unaltered. Furthermore acidification increases the need for liming resulting in an increased emission of CO_2.

It should be noted that afforestation on agricultural soils from 1990 and ahead is not taken into account in the emission calculations. In scenario 4 an increased afforestation is included (1,500 ha per year) accounting for sequestration at 0.18 M tonnes CO_2 pr year in 2012 increasing to 0.62 M tonnes CO_2 pr year in 2017. The afforestation will continue to sequestrate CO_2 in the following years until a maximum carbon binding has taken place after 100-150 years. This sequestration has to be reported under “Forestry” although it is a consequence of the applied agricultural policy.

The most likely emission of GHG in 2012 and 2017, respectively, is somewhere between scenario 2 and 4. A fairly good estimate could be a 9.3 M tonnes CO_2-eqv. in 2012 and a further reduction to 9.0 M tonnes CO_2-eqv.

6 Appendix

Detailed emission estimates from 2003 to 2017 and the average for the first (2008-12) and second (2013-17) reporting period in the Kyoto Protocol.

6.1 The Basic scenario

Table A1 The basic scenario

		1990	2003	2012	2017	2008-2012	2013-2017
CH_4	Enteric fermentation	147.61	129.48	123.27	118.12	123.80	120.70
	Manure management	35.79	47.36	50.86	50.02	50.42	50.44
	Burning of straw	0.00	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.11	0.93	0.93	0.93	0.93	0.93
	CH_4, total (1000 t)	183.40	176.84	174.14	168.14	174.21	171.14
	Total CO_2-eqv. M tonnes	3.85	3.71	3.66	3.53	3.66	3.59
N_2O	Manure management	2.21	1.86	1.79	1.73	1.78	1.76
	Grassing	1.01	0.94	0.86	0.81	0.87	0.83
	Mineral fertiliser	7.69	3.87	3.65	3.59	3.71	3.62
	Manure applied on soil	3.51	3.45	3.44	3.31	3.42	3.37
	Sewage sludge	0.09	0.20	0.23	0.23	0.22	0.23
	Atmospheric deposition	1.72	1.23	1.15	1.12	1.16	1.13
	Nitrogen leaching	10.50	6.31	6.04	5.87	6.10	5.96
	Nitrogen fixing crops	0.88	0.66	0.64	0.63	0.65	0.64
	Crop residue	1.13	1.03	1.00	0.98	1.01	0.99
	Cultivated histosols	0.23	0.23	0.23	0.23	0.23	0.23
	Burning of straw	0.00	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.00	0.02	0.02	0.02	0.02	0.02
	N_2O, total (1000 t)	28.98	19.77	19.01	18.48	19.15	18.75
	N_2O, total (CO_2-eqv. M tonnes)	8.98	6.13	5.89	5.73	5.94	5.81
CO_2	Liming	0.56	0.22	0.22	0.22	0.22	0.22
	Cultivated histosols	0.07	0.07	0.07	0.07	0.07	0.07
	CO_2, total (CO_2-eqv. M tonnes)	0.63	0.29	0.29	0.29	0.29	0.29

		1990	2003	2012	2017	2008-2012	2013-2017
Total	CH_4	3.85	3.71	3.66	3.53	3.66	3.59
	N_2O	8.98	6.13	5.89	5.73	5.94	5.81
	CO_2	0.63	0.29	0.29	0.29	0.29	0.29
Total	GHG, total (CO_2-eqv. M tonnes)	13.46	10.13	9.84	9.55	9.88	9.69

6.2 The basic scenario and implementation of the CAP reform

Table A2 The basic scenario and implementation of the CAP reform

		2003	2012	2017	2008-2012	2013-2017
CH_4	Enteric fermentation	129.48	119.48	114.32	121.58	116.90
	Manure management	47.36	51.50	50.65	50.18	51.07
	Burning of straw	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.93	0.93	0.93	0.93	0.93
	CH_4, total (1000 t)	176.84	170.98	164.97	171.75	167.97
	Total CO_2-eqv. M tonnes	3.71	3.59	3.46	3.61	3.53
N_2O	Manure management	1.86	1.72	1.65	1.74	1.68
	Grassing	0.94	0.82	0.77	0.88	0.79
	Mineral fertiliser	3.87	3.65	3.59	3.71	3.62
	Manure applied on soil	3.45	3.41	3.28	3.43	3.35
	Sewage sludge	0.20	0.23	0.23	0.23	0.23
	Atmospheric deposition	1.23	1.15	1.12	1.16	1.13
	Nitrogen leaching	6.31	6.10	5.92	6.14	6.01
	Nitrogen fixing crops	0.66	0.64	0.53	0.65	0.59
	Crop residue	1.03	1.00	0.98	1.01	0.99
	Cultivated histosols	0.23	0.23	0.23	0.23	0.23
	Burning of straw	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.02	0.02	0.02	0.02	0.02
	N_2O, total (1000 t)	19.77	19.04	18.38	19.23	18.71
	N_2O, total (CO_2-eqv. M tonnes)	6.13	5.90	5.70	5.96	5.80
CO_2	Liming	0.22	0.22	0.22	0.22	0.22
	Cultivated histosols	0.07	0.07	0.07	0.07	0.07
	CO_2, total (CO_2-eqv.)	0.29	0.29	0.29	0.29	0.29

		2003	2012	2017	2008-2012	2013-2017
Total	CH_4	3.71	3.59	3.46	3.61	3.53
	N_2O	6.13	5.90	5.70	5.96	5.80
	CO_2	0.29	0.29	0.29	0.29	0.29
Total	GHG, total (CO_2-eqv. M tonnes)	10.13	9.78	9.45	9.86	9.62

6.3 Basic Scenario, The CAP reform and no increase in the pig production

Table A3 Basic Scenario, The CAP reform and no increase in the pig production

		2003	2012	2017	2008-2012	2013-2017
CH_4	Enteric fermentation	129.48	117.76	112.62	120.25	115.19
	Manure management	47.36	47.36	46.54	46.97	46.95
	Burning of straw	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.93	0.93	0.93	0.93	0.93
	CH_4, total (1000 t)	176.84	165.12	159.16	167.22	162.14
	Total CO_2-eqv. M tonnes	3.71	3.47	3.34	3.51	3.40
N_2O	Manure management	1.86	1.66	1.59	1.69	1.62
	Grassing	0.94	0.82	0.77	0.88	0.79
	Mineral fertiliser	3.87	3.77	3.69	3.78	3.73
	Manure applied on soil	3.45	3.21	3.09	3.28	3.15
	Sewage sludge	0.20	0.23	0.23	0.23	0.23
	Atmospheric deposition	1.23	1.10	1.06	1.12	1.08
	Nitrogen leaching	6.31	5.91	5.74	6.00	5.82
	Nitrogen fixing crops	0.66	0.64	0.53	0.65	0.59
	Crop residue	1.03	1.00	0.98	1.01	0.99
	Cultivated histosols	0.23	0.23	0.23	0.23	0.23
	Burning of straw	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.02	0.02	0.02	0.02	0.02
	N_2O, total (1000 t)	19.77	18.55	17.89	18.84	18.22
	N_2O, total (CO_2-eqv. M tonnes)	6.13	5.75	5.55	5.84	5.65
CO_2	Liming	0.22	0.22	0.22	0.22	0.22
	Cultivated histosols	0.07	0.07	0.07	0.07	0.07
	CO_2, total (CO_2-eqv.)	0.29	0.29	0.29	0.29	0.29

		2003	2012	2017	2008-2012	2013-2017
Total	CH_4	3.71	3.47	3.34	3.51	3.40
	N_2O	6.13	5.75	5.55	5.84	5.65
	CO_2	0.29	0.29	0.29	0.29	0.29
Total	GHG, total (CO_2-eqv. M tonnes)	10.13	9.50	9.17	9.64	9.34

6.4 Basic Scenario, the CAP reform and 25% reduction in leaching

		2003	2012	2017	2008-2012	2013-2017
CH_4	Enteric fermentation	129.48	119.48	114.32	121.58	116.90
	Manure management	47.36	48.70	45.05	48.07	46.87
	Burning of straw	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.93	3.73	6.54	2.33	5.13
	CH_4, total (1000 t)	176.84	168.18	159.36	169.65	163.77
	Total CO_2-eqv. M tonnes	3.71	3.53	3.35	3.56	3.44
N_2O	Manure management	1.86	1.72	1.65	1.74	1.68
	Grassing	0.94	0.82	0.77	0.88	0.79
	Mineral fertiliser	3.87	2.46	2.41	2.77	2.44
	Manure applied on soil	3.45	3.41	3.28	3.43	3.35
	Sewage sludge	0.20	0.23	0.23	0.23	0.23
	Atmospheric deposition	1.23	0.89	0.86	1.02	0.87
	Nitrogen leaching	6.31	5.19	5.03	5.43	5.11
	Nitrogen fixing crops	0.66	0.64	0.53	0.65	0.59
	Crop residue	1.03	1.00	0.98	1.01	0.99
	Cultivated histosols	0.23	0.23	0.23	0.23	0.23
	Burning of straw	0.00	0.00	0.00	0.00	0.00
	- effect of biogas plants	0.02	0.09	0.15	0.07	0.12
	N_2O, total (1000 t)	19.77	16.51	15.82	17.32	16.16
	N_2O, total (CO_2-eqv. M tonnes)	6.13	5.12	4.90	5.37	5.01
CO_2	Liming	0.22	0.25	0.25	0.24	0.25
	Cultivated histosols	0.07	0.07	0.07	0.07	0.07
	CO_2, total (CO_2-eqv.)	0.29	0.32	0.32	0.31	0.32

		2003	2012	2017	2008-2012	2013-2017
Total	CH_4	3.71	3.53	3.35	3.56	3.44
	N_2O	6.13	5.12	4.90	5.37	5.01
	CO_2	0.29	0.32	0.32	0.31	0.32
Total	Agriculture (CO_2-eqv. M tonnes)	10.42	9.20	8.80	9.49	9.00
	Surplus afforestation	0.00	-0.18	-0.62	-0.09	-0.40
Total	GHG, total (CO_2-eqv. M tonnes)	10.13	8.78	7.95	9.15	8.37

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