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Christel Cederberg
Ulf Sonesson
Maria Henriksson
Veronica Sund
Jennifer Davis

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Summary

The goal of this study was to estimate the life cycle greenhouse gas (GHG) emissions from Swedish livestock production in 1990 and 2005 with the purpose to gain increased knowledge of current GHG emissions from the production of meat, milk and eggs in Sweden and to analyse emission trends following 1990 which is the base for the Kyoto-protocol. Also, with the results as a base discuss short-term mitigation potentials for Swedish animal production.

National accounts and statistics were the primary data sources but since the statistics are not detailed enough and sometimes too aggregated or even lacking, complementary data have been inventoried from advisory services, research reports and agricultural businesses. Examples of the deficiencies in the national statistics are use of diesel that is only presented as one aggregated number for the whole agricultural sector given approximately every fifth year, and consumption of concentrate feed where the statistics only provide information on amounts sold by the feed industry but not on amounts of feed used at the farms. Therefore, the “top-down” approach used to model the investigated livestock production systems were combined with modelling the systems “bottom-up”. Feed consumption and production and nitrogen losses were analysed more in detail through this process-base model. The method of combining top-down sector input-output data with bottom-up process data is called “hybrid-LCA”.

The results were presented as life cycle GHG emissions per kg pork, poultry meat, beef, milk and egg - defined as the product´s **Carbon Footprint (CF) at the farm-gate -** and as total emissions for each production system.

In 1990, total GHG emissions from Swedish animal production were ~8.5 million tons (Mtons) carbon dioxide equivalents (CO_2e) and emissions decreased to 7.3 Mtons CO_2e in 2005, i.e. a reduction of close to 14 % (approximately 1 % per year). Production of milk and beef represented 82 % of emissions in 2005, pork 13 % and poultry products being the source of only around 5 % of total emissions. However, cattle production had by far the largest emissions cuts; in the production of milk and beef, GHG emissions were reduced by approximately 1 Mtons CO_2e between 1990 and 2005.

Pork production has become more efficient and the CF decreased from ~4 kg to 3.4 CO_2e kg per carcass weight (CW) between 1990 and 2005. The largest reduction was for fossil CO_2 of which emissions were lowered by almost 25 %. Feed production generates the largest share of emissions in pork´s life cycle; in 2005 more than 50 % of total emissions came from feed followed by manure management (32 %) and manure application (8 %). Emissions from the total Swedish pork production were reduced from ~1.16 to 0.93 Mtons CO_2e between 1990 and 2005, corresponding to an overall reduction of approximately 20 %.

In the production of chicken meat, GHG emissions decreased between 1990 and 2005 by ~22 %, from 2.5 to 1.9 kg CO_2e kg per kg CW. The largest emission cut was for fossil CO_2 where emissions were reduced by 35 %. During the studied 15 year period, there has be an on-going switch from oil to biofuels for heating of chicken stables in Sweden which is the main cause for the reduction of poultry meat´s CF. The overall production of chicken meat in Sweden has doubled (although from a very low level) over the past 15 years and therefore total emissions from the poultry meat sector has increased. However, due to the efficiency gains in production, total emissions increased by 63 % while production increased by 112 %.

The CF for egg remained unchanged during the studied time-period, corresponding to ~1.4 kg CO_2e per kg egg at the farm-gate. Feed production was the source of almost 85 % of emissions, and during the studied time period, the strategy of protein feeding changed significantly. In 1990, animal protein (meat-meal and fish meal) and also peas were the major protein components but in 2005, soymeal was the dominant protein feed ingredient. Overall Swedish egg production decreased by ~15 % between and 1990 and 2005; from this follows that total GHG emissions from the egg sector decreased.

Beef is closely linked to milk production in Sweden; in 1990 almost 85 % of beef had its origin in the milk sector and this was reduced to close to ~65 % in 2005, being an effect of the considerably lowered dairy cow population. In 1990, total emissions from milk and beef production were estimated at ~7 Mtons CO_2e, which was reduced to ~6 Mtons CO_2e in 2005. Approximately 60 % of this

reduction was due to efficiency in production and 40 % to lowered total production. CO_2 and N_2O emissions were reduced by around 20 % each between the two years while CH_4 emissions were reduced by less than 10 %. The lower emission cut of CH_4 is mainly explained by changes in the cattle population as 130 000 fewer dairy cows were held in 2005 while the suckler-cow herd increased by 100 000 head to compensate a lower by-production of beef in milk production.

In most LCA studies, the allocation of resource use and emissions between milk and meat has been done with economic or physical allocation. Here, we used a physical allocation and allocated 85 % of the milk sectors emissions to milk and 15 % to meat. With this allocation factor, the CF was 1.27 kg CO_2e per kg ECM (energy corrected milk) in 1990 which was reduced to ~ 1 kg CO_2e in 2005. The emission reduction of close to 20 % in milk production is mainly explained by a higher production of milk per dairy cow in 2005. In contrast to milk, the CF for beef increased during the 15 year period. Using the allocation factor of 85 % to milk and 15 % to beef, results in CF from the average Swedish beef production of 18 kg CO_2e per kg CW in 1990 and 19.8 kg CO_2e per kg CW at the farm-gate in 2005. This increase is explained by that in 1990 around 85 % of the Swedish beef production had its origin in milk production (culled dairy cows and surplus bull calves) while this was reduced to ~65 % in 2005 due to a lower dairy cow population and a larger suckler cow population. However, although the emissions per kg beef increased between 1990 and 2005, it must be emphasized again that there was an overall emission reduction in dairy and beef sector corresponding to 1 Mtons CO_2e.

According to the official statistics for GHG emissions in Sweden, the agriculture sector has a reduced its emission by 830 000 ton CO_2e, totalling 8.55 Mtons in 2005. In this study, we have estimated a higher emission cut for the Swedish livestock production, corresponding to 1.2 Mtons CO_2e and totalling 7.3 Mtons in 2005. However, the numbers are not comparable since system boundaries are set differently; the official statistics include only methane and nitrous oxide emitted in Sweden and assess the whole agricultural sector, i.e. also including vegetable production. In this study, we have used LCA methodology calculating GHG emissions from the whole livestock production chain, also including emissions embedded in imports (e.g. imported feed) and emissions from energy use, mainly fossil CO_2. Although there are differences in relative and absolute numbers when comparing the results presented in this study and in the official statistics, the emission trend is clear – livestock production and agriculture in Sweden have been reducing their GHG emissions over the past 15 years.

Some of the emission cuts in Swedish livestock production can be explained by a lowered production; with the exception of poultry meat (+112 %), production volumes have diminished since 1990 (milk -8 %, beef -2 %, pork -5 %, eggs -16 %). Approximately two-thirds of the total emission cut (1.2 Mtons CO_2e) were due to more efficient production (less GHG emission per produced kg meat, milk and egg) while around one third was caused by the overall reduced production in the Swedish livestock sector.

The positive emission trends in the livestock production form a sharp contrast to the trends in Swedish consumption of animal products during the studied time-period. Life cycle GHG emissions from the overall consumption of meat, dairy products and eggs increased from 8.1 to ~10 Mtons CO_2e between 1990 and 2005, corresponding to a per capita consumption of approximately 1 100 kg CO_2e in 2005. A very strong increase of meat consumption based on imports explains the almost 25 % growth of consumption-related emissions which have not been illustrated earlier in the Swedish emissions statistics.

International studies show that the actual levels of GHG mitigation are below the technical potential for the measures and that is difficult to assess the real outcome of measures in agriculture to reduce GHG emissions. Based on the findings on current level of emissions and trends during the two past decades, some measures for further emission cuts in the in the short term (2020) were suggested: further improvements of manure utilisation, reducing losses of reactive N, reducing and improving nitrogen fertiliser production and use, changing protein feed composition, biogas production and improved energy efficiency throughout the production chain.

We conclude that present method for estimating national GHG emissions give inadequate information on the size of emissions from food production and also that it fails to give information on what parts of the production chain that give rise to the largest emissions (so-called hot-spots) due to the lacking life-cycle perspective. Thereby, it is a risk that the most optimal measures for reducing GHG emissions are not prioritised when choosing between different mitigation options.

Sammanfattning

Målet med detta projekt var att estimera utsläppen av växthusgaser i ett livscykelperspektiv från produktionen av animaliska livsmedel i Sverige 1990 och 2005, projektets två frågeställningar var:

- Hur stora är utsläppen totalt respektive per producerad enhet från den svenska animalieproduktionen 1990 och 2005?
- Hur ser utsläppstrenden ut och vilka möjliga förbättringsåtgärder kan göras på kort sikt (2020)?

Nationell statistik var den primära datakällan men eftersom statistiken inte är tillräckligt detaljerad och ibland saknas, inhämtades kompletterande data från rådgivningsverksamhet, litteratur och företag inom jordbruk och livsmedel. Exempel på bristande nationell statistik är dieselförbrukning där endast ett aggregerat värde för hela jordbrukssektorn redovisas ungefär var femte år och användningen av kraftfoder där endast foderindustrins uppgifter finns tillgängliga i nationell statistik men inte direktanvändningen av foderspannmål på gårdsnivå. Vid inventeringen av data användes en ”top-down” modell av produktionssystemen och data samlades på nationell nivå men p g a bristerna i den nationella statistiken fick denna modell kombineras med en mer detaljerad process-”bottom-up” metod, särskilt i analysen av produktion och konsumtion av foder. Kombinationen av att använda ”top-down” input-output data och ”bottom-up” process data brukar kallas hybrid-livscykelanalys.

Resultaten presenteras som så kallade ”livscykel-utsläpp av växthusgaser” per kg griskött, kyckling, nötkött, mjölk och ägg – i studien definierat som produktens **Carbon Footprint (CF) vid gårdsgrinden** - samt även som totala utsläpp av växthusgaser för respektive produktionsgren.

1990 uppgick utsläppen från svensk animalieproduktion till ca 8,5 miljoner ton koldioxidekvivalenter (CO_2e) och dessa reducerades till ca 7,3 miljoner ton CO_2e 2005, d v s en utsläppsminskning om nästan 14 % (ca 1 % per år under 15-årsperioden). En del av utsläppsminskningen kan förklaras av lägre produktionen, med undantag för kyckling (+112 %) så har produktionen minskat sedan 1990; nedgången är för mjölk -8 %, nötkött -2 %, griskött -5 % och ägg -16 %. Det beräknas att ca 2/3-delar av den totala minskningen om 1,2 miljoner ton CO_2e beror på en mera effektiv produktion (d v s lägre utsläpp per kg produkt) och att ca en tredjedel förklaras av de minskade produktionsvolymerna.

Produktionen av griskött har effektiviserats och CF reducerades från ca 4 till ca 3,4 kg CO_2e per kg slaktvikt (vara med ben) mellan 1990 och 2005. Utsläpp av fossil CO_2 var den växthusgas som visade störst reduktion vilket generellt förklaras av en mera effektiv produktion av grisar och foder. De totala utsläppen från svensk grisköttsproduktion minskade med ca 20 % och uppgick 2005 till ca 0,93 miljoner ton CO_2e.

Även kyckling produceras med lägre utsläpp idag, CF reducerades från ca 2,2 till 1,9 kg CO_2e per kg slaktvikt. Även här utgjorde minskade utsläpp av fossil CO_2 den största reduktionen, vilket framförallt beror på en övergång till biobränslen för uppvärmning av stallar. Eftersom kycklingproduktion har ökat (förvisso från en låg nivå) under 15-årsperioden så har de totala utsläppen från svensk kycklingproduktion ökat men tack vare lägre utsläpp per producerad enhet 2005 ökade de totala utsläppen med drygt 60 % till 0,19 miljoner CO_2e 2005 medan produktionen ökade med 112 %.

I produktionen av ägg var CF relativt stabilt och uppgick till ca 1,4 kg CO_2e per kg ägg vid gårdsgrinden. Eftersom den totala äggproduktionen minskade mellan 1990 och 2005 så reducerades de totala utsläppen från svensk äggproduktion och uppgick till ca 0,14 miljoner ton CO_2e 2005.

Mjölk- och nötköttsproduktion är nära sammankopplat i Sverige; 1990 hade ca 85 % av nötköttet sitt ursprung i mjölkproduktionen (överskottskalvar som råvara för köttproduktion samt kött från utslagskor) vilket reducerades till knappt 65 % 2005 som en effekt av det kraftigt reducerade antalet mjölkkor i Sverige. De totala utsläppen från mjölk- och nötköttsproduktionen estimeras till 7 miljoner ton CO_2e 1990 vilket reducerades till ca 6 miljoner ton CO_2e 2005, ca 60 % av utsläppsreduktionen bedöms bero på effektiviserad produktion och ca 40 % på minskad produktion. Utsläpp av CO_2 och lustgas (N_2O) reducerades med ca 20 % medan metanutsläpp minskade med 10 % från nötkreatursproduktionen. Att utsläppsminskningen var lägre för metan beror framförallt på förändringar i den svenska nötkreaturspopulationen; antalet mjölkkor minskade med 130 000 samtidigt som köttkorna ökade med mer än 100 000 för att kompensera den minskade produktionen av överskottskalvar och kött från utslagskor i mjölksektorn.

Om utsläppen från mjölkproduktionen fördelas med 85 % till huvudprodukten mjölk och 15 % till biprodukten kött så estimeras att mjölkens CF minskade från 1,27 kg CO_2e per kg 1990 till ca 1 kg CO_2e år 2005. Utsläppsminskning om nära 20 % i mjölkproduktionen beror framförallt på den kraftigt ökade mjölkproduktionen per ko; för att erhålla samma mjölkmängd krävdes väsentlig färre mjölkkor 2005. Samtidigt ökade CF för nötkött, från 18 kg CO_2e 1990 till 19,8 kg CO_2e per kg slaktvikt (vara med ben) 2005. Ökningen under 15-årsperioden beror på att en större andel av nötköttsproduktion kom från självrekryterande köttbesättningar 2005. Det skall dock betonas att trots ökade utsläpp från nötköttsproduktionen mellan 1990 och 2005 så har det skett en utsläppsminskning från den totala mjölk- och nötköttsproduktionen, resultaten visar entydigt att intensifieringen av mjölkproduktionen har varit positiv ur klimatsynpunkt, även beaktat de förändringar detta har medfört för nötköttsproduktionen.

Enligt den nationella utsläppsstatistiken har det svenska jordbrukets utsläpp minskat med 0,83 miljoner ton CO_2e mellan 1990 och 2005 vilket motsvarar en reduktion om knappt 8 %. I denna studie har vi beräknat större utsläppsminskningar för den svenska animalieproduktionen motsvarande 1,2 miljoner CO_2e. Resultaten är dock inte jämförbara eftersom systemgränserna är satta olika, den officiella statistiken inkluderar endast metan och lustgas som släpps ut inom Sveriges gränser och räknar på hela jordbruket, inklusive vegetabilieproduktionen. I föreliggande studie har utsläppen av växthusgaser beräknats med ett livscykelperspektiv vilket innebär att även utsläppen från importvaror (mineralgödsel, kraftfoder) samt utsläpp från energianvändning ingår. Även om det är skillnader i absoluta och relativa tal när resultaten från denna studie jämförs med den nationella statistiken så är trenden entydig – jordbruket och animalieproduktionen i Sverige har minskat växthusgasutsläppen under de senaste 15 åren.

Den positiva emissionstrenden för produktionen av animalier står i bjärt kontrast till trenden för växthusgasutsläppen från konsumtionen av animaliska livsmedel i Sverige under perioden 1990 till 2005. Växthusgasutsläppen från den totala konsumtionen av kött, mjölk och ägg ökade från ca 8,1 miljoner ton CO_2e till ~10 miljoner ton CO_2e 2005. En mycket stor ökning av köttkonsumtionen som nästan uteslutande baserades på importerat kött förklarar ökningen om nära 25 %.

Det är mycket svårt att uppskatta de verkliga (praktiska) effekterna av åtgärder mot växthusgasutsläpp i jordbruket. Internationella studier visar att när det gäller åtgärder i jordbruket så ligger de reduktioner av växthusgasutsläpp som erhålls i praktiken ofta under åtgärdernas tekniska (teoretiska) potential. Med utgångspunkt från projektets estimat av nuvarande växthusgasutsläpp från svensk animalieproduktion samt kunskapen om hur utsläppen av de olika växthusgaserna har förändrats under de senaste decennierna föreslås några åtgärder på kort sikt (2020):

- Fortsatta satsningar på att förbättra stallgödselanvändningen i hela kedjan samt på att minskade förlusterna av reaktivt kväve
- Minskad och förbättrad produktion och användning av mineralgödselkväve
- Förändrad proteinfoder-sammansättning med mera närodlat protein och ökad användning av livsmedelsavfall
- Satsning på biogasproduktion av särskilt svinflytgödsel
- Satsning på åtgärder för energieffektivisering och energibesparing i hela produktionskedjan

Sammanfattningsvis menar vi att nuvarande metodik för beräkning och rapportering av nationella växthusgasutsläpp ger otillräcklig kunskap om livsmedelsproduktionens utsläpp. Bristen på ett livscykelperspektiv i metodiken kan leda till felaktig information om vilka delar av produktionskedjan som ger upphov till de största utsläppen (så kallade hot-spots) och därmed finns det en risk att de mest optimala åtgärderna inte prioriteras när insatser skall sättas in för att begränsa utsläppen av klimatgaser.

1 Introduction

Only in recent years, a common understanding has arisen of the importance of livestock production to some of the most serious environmental problems of today. The FAO-report “Livestock´s Long Shadow” was a true eye-opener for policy makers and the general public, indicating that present world livestock production is a major contributor to environmental problems at the local as well as global scale. FAO estimated that the livestock sector is responsible for around 18 % of world greenhouse gas (GHG) emissions when land use changes (predominantly deforestation) are included and around 13 % when not included (Steinfeld et al, 2006).

In the FAO-report “Livestock´s Long Shadow”, GHG emissions from the global production of meat, milk and eggs were estimated using a life cycle approach. This method is not used in individual nations´ GHG emission statistics – so-called National Inventory Reports (NIR) - that follow a reporting format according to the UNFCC[1]. The approach used in NIR is national and production-focused and it does not take into account embedded GHG emissions from imports, for example, import of concentrate feed. The NIR-method does not provide a complete picture of the emissions from a nation´s livestock production and it is not possible to make any statements of emission trends. For example, over a period of time, a country can decrease its domestic cultivation of fodder crops, which most probably will lead to lowered internal GHG-emissions, and instead increase imports of raw materials to the feed industry supplying the livestock production. This change in the overall supply chain will probably result in lowered agricultural emissions in the NIR-reporting but when studying the whole feed production using a life-cycle perspective, it is likely that they are small if even any improvements; increased feed import could actually have increased the overall emissions from the livestock production.

Moreover, only methane and nitrous oxide are reported as emissions from agriculture in the NIR reporting format. Emissions from fertiliser production are entered as industry processes and from fossil CO_2 as energy use. Consequently, if there are fossil energy savings leading to lower CO_2-emissions in agricultural production, this cannot be found in the official statistics. Today, it is not possible to obtain a complete picture of the GHG emissions of a country´s livestock sector with current methodology used in the statistics.

The purpose of this study was to gain increased knowledge of current life cycle greenhouse gas emissions from the production of meat, milk and eggs in Sweden and to analyse trends in emissions following 1990 which is the base for the Kyoto-protocol. Also, with the results as a base discuss mitigation potentials for climate gases from the Swedish animal production. The main objectives were:

- to estimate total and per product unit GHG emissions from the production of meat, milk and eggs in 1990 and 2005 and
- to analyse the trends in emissions (total and per production unit) from Swedish livestock production between 1990 and 2005.

The report is structured as follows: in section 2, methodology and studied systems are described. In Section 3, the inventory analysis of inputs to animal production is given and detailed background data are found in Appendix 1-4. In section 4, production data, consumption of feed and estimates of nitrogen flows and emissions from meat products, milk and eggs are described and detailed information and calculations are shown in Appendix 5-8.

The results, reported as total GHG emission per production sector as well as GHG emission per product unit from the Swedish production of meat, milk and eggs in 2005 and 1990, are presented in section 5 and Appendix 9 and further discussed in section 6.

In this study, we have received help when collecting data from several persons in the advisory service, livestock organisations, industries etc. We want to thank Kerstin Ahnér, Uppsala; Claes Björck, Falkenberg; Ingvar Eriksson, Linköping; Bengt Henriksson, Kristianstad; Cees Hermus, Blentarp; Per-Johan Jonsson, Skänninge; Rebecka Jönsson, Eldsberga; Ola Karlsson, Lidköping; Maria Kihlstedt, Stockamöllan; Ulla Kyhlstedt, Stockholm; Birgit Landquist, Köpenhamn; Rolf Lindholm, Eldsberga;

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[1] United Nations Framework Convention on Climate Change

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2 Methods

2.1 Goal and purpose of the study

The primary goal of this study was to estimate the life cycle greenhouse gas emissions of Swedish animal production in 2005 and 1990. The purpose of the study was to gain increased knowledge of current greenhouse gas emissions from the production of meat, milk and eggs in Sweden and to analyse trends in emissions following 1990 which is the base for the Kyoto-protocol. Also, with the results as a base, discuss mitigation potentials for climate gases from the Swedish animal production.

2.2 Scope of the study

The study included the emissions of greenhouse gases as shown in Figure 2.1 including production of materials and energy, also taking transport steps into account. This study is part of the larger research project also including consumption-related emissions and in this report, focus is on primary production of meat, milk and eggs. The system boundary is therefore at the farm-gate in this report, food industry is not included here, see further SIK-report 794 (Cederberg et al., 2009).

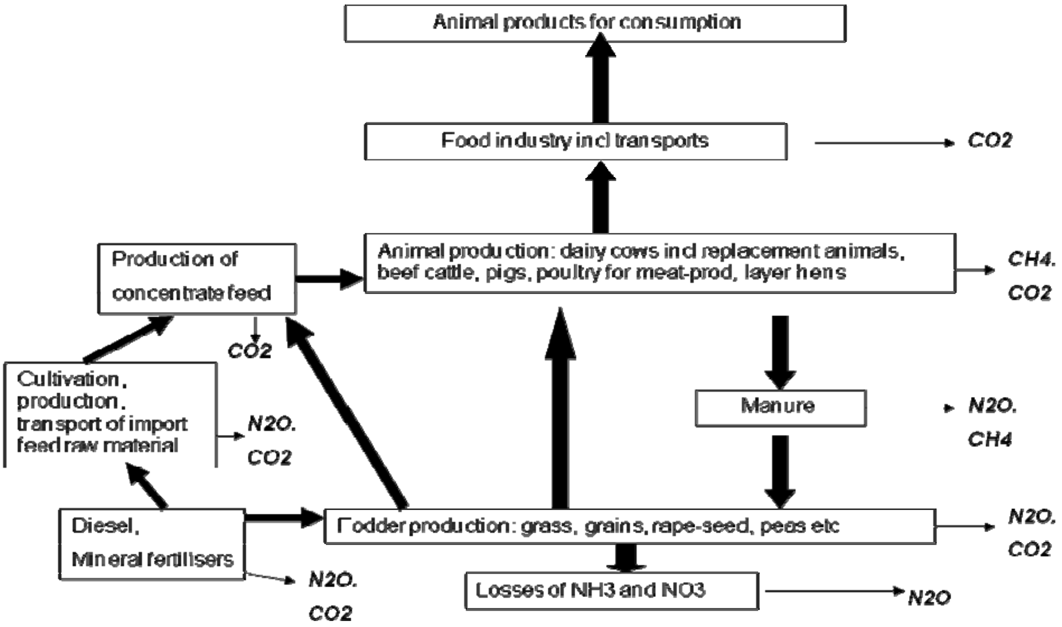

Figure 2.1 This figure shows a flow diagram of the production systems studied and greenhouse emissions considered in the analysis. N.B, the system boundary is the farm-gate in this report

2.2.1 System modelling

In the life cycle inventory of a product system, there are basically two ways of modelling the system, a bottom-up approach based on a process life cycle assessment (LCA) and a top-down approach, based on national accounts and statistics. The choice of system modelling is very much determined by the purpose of the study. In this project, focus has been on assessing the whole production systems for producing meat, milk and eggs in Sweden and to investigate emission trends between 1990 and 2005. The purpose has not been to compare different production systems within the total national production, e.g. to compare conventional and organic production, but to gain knowledge in the size of emissions from the whole Swedish animal production. Therefore, the top-down modelling approach has been used, analysing the activities and emissions linked with the total production of animal products.

National accounts and statistics have been the primary data source but since the statistics are not detailed enough, for some data too aggregated and sometimes lacking, complementary data have been inventoried from advisory services (experts judgement), research reports and agricultural business. Examples of the deficiencies in the national statistics are use of diesel that is only presented as one aggregated number for the whole sector given approximately every fifth year, and consumption of concentrate feed where the statistics only give information on the feed sold via industry and not the feed grain used directly at the farm sites. Therefore, the top-down model of the livestock production systems had to be combined with a more detailed modelling of "bottom-up" processes where especially feed consumption and production were analysed mo in detail. The method of combining top-down sectorial input-output data with bottom-up process data is called "hybrid-LCA".

2.2.2 Delimitations

Infrastructure

GHG emissions from the production of capital goods and infrastructure are not included. Frischknecht et al (2007) estimate that these emissions correspond to less than 10 % of the climate gases from agriculture plant production. Since methane and nitrous oxide are of such importance in animal production, the share should be even smaller in livestock production.

Storing of roughage fodder (hay and silage) can be done in different ways. Flysjö et al (2008) included emissions from capital goods from this storage when assessing feed production and showed that there were small differences in GHG emissions between the methods when comparing silage in plastic bales (including plastic production and waste handling), silage on the ground (cement production) and silage in towers (steel production). Production of capital goods for the storage of roughage fodder (also plastics) was also not included and this should have no relevance when comparing the results in emissions trends over the analysed fifteen-year period in this study.

Land use changes

CO_2-emissions from land use change (LUC) are not included and this can lower as well as increase the calculated GHG emissions from the Swedish livestock production. In Sweden, the arable land (mineral soils) is considered to be in balance, not being a carbon source while permanent grassland for grazing are known as carbon sinks, while peat soils are net carbon sources (Naturvårdsverket, 2009). The area of permanent grassland has increased over the studied time period and consequently, this carbon sink too. If this LUC was included, the GHG estimates would probably be lower in 2005 compared to 1990 due to the increase of this carbon sink. On the other hand, LUC emissions caused by imported feed are excluded, and since there has been an increased import of protein feed from regions with on-going deforestation between 1990 and 2005, these emissions are underestimated in 2005 compared to 1990. The reason for omitting GHG from LUC is that there is still no consensus on methodology on how to calculate for LUC in life cycle accounting of GHG emissions from land-based products. Also, inadequate data is a problem when estimating LUC.

Production of chemicals

GHG emissions from the production of pesticides and silage agents are not included in the study due to lack of data and since it is known from other studies that the emissions from this input goods are of small significance in livestock production.

2.3 Functional units

The functional unit defines the specified functions of the systems under study and is the reference base in an LCA. The functional units used in the study are summarized in Table 2.1.

Table 2.1 Functional units in the study

	Product	*Functional unit*
Meat	Pork	1 kg meat with bone (carcass weight, CW) at the farm-gate
	Chicken meat	
	Beef	
Milk	Milk	1 kg energy corrected milk (ECM) at the farm-gate
Eggs	Eggs	1 kg eggs at the farm-gate

2.4 Allocation

Milk and beef
Beef is an important by-product from milk production. The GHG emissions from milk production were allocated as 85 % to milk and 15 % to the by-product beef (surplus calves and meat from culled cows). This is based on the physical relationship on feed intake with calculations according to feed requirements to cover the dairy cow´s milk production, maintenance and pregnancy respectively.

Feed
In the production of concentrate feed, by-products from food industry are important raw materials. Economic allocation was used when dividing the environmental burden between the main products and the by-products.

Meat by-products
Meat production systems also generate some by-products, most hides and intestines. None of the calculated GHG emissions were allocated to these by-products, i.e. the meat products carries the whole estimated GHG emissions.

Manure
Manure handling (storing and field application) is the source of significant GHG emissions. Methane and nitrous oxide are emitted from the storages and after field application, there are direct soil emissions of nitrous oxide. Also, when manure is handled at different stages, there can be considerable ammonia losses which lead to indirect emissions of nitrous oxide. At most Swedish farms, the manure is normally used at the farm site and when conducting a bottom-up process LCA of such a system, all the emissions from manure handling are included since the manure does not leave the studied system. But manure can also be exported from an animal farm to an arable farm and then becomes an output product (a by-product). In Sweden, this is most common in poultry production, more occasional in pig production and quite seldom found in cattle production.

In the case when manure is an output product going into another production system, there is an allocation problem. There is a lack of data on what quantities of manure in Sweden is transferred from livestock production into arable production systems and also, no consensus methodology on how to deal with this allocation problem. In this study, allocation of manure being an output product of livestock production systems is avoided by distributing all the resource use and emissions from manure to the animal products under study. In return, emissions from the use and production of phosphorous and potassium mineral fertilizers were not included since animal farms have very little use of these fertilizer nutrients. For example, LCAs on milk production based on input data from more than 40 dairy farms showed an input of only a few kg per hectare of phosphorous and potassium fertilizers due to use of manure (Cederberg & Flysjö 2004; Cederberg et al., 2007). Moreover, production and use of phosphorous and potassium fertilizers (especially potassium) have significantly lower GHG emissions than nitrogen fertilizers.

In later years, there is an increase in interest and use of anaerobic digestion to produce energy (biogas) from manure. This was very rare around 1990s but started to be introduced around 2005, although still only a minority of the manure is treated in digesters. The energy production from manure in 2005 was not included in the analysis, due to lack of data on the amount and to make both years comparable.

2.5 Data inventory

Production output data are based on national accounts. Input data on use of fertilizers, energy use and feed are a combination of national statistics and bottom-up inventoried production input data. The estimated total use of these inputs was balanced against the national statistics. Biogenic emissions of methane and nitrous oxide were mostly estimated with models and emission factors according to the latest IPCC guidelines (IPCC 2006). Input data to these models were national statistics and expert judgements from advisory services.

Data for electricity production and use was the Swedish mix in 2005 and this was also used for 1990. During the studied 15 year period, Swedish electricity production has been based on hydro and nuclear power resulting in small GHG emissions. It was assumed that differences in emissions from electricity would be of little significance between 2005 and 1990.

The whole life-cycle is included in the emissions from fossil fuels. Data on GHG emissions from the production and use of energy were taken from the Ecoinvent (2003) database.

2.6 Global Warming Potentials

Global Warming Potentials is a metric making it possible to compare future climate impacts of emissions of long-lived climate gases. The emission of 1 kg of a compound is related to 1 kg of the reference gas CO_2 and expressed as kg CO_2-equivalents. The emissions of climate gases in this study were calculated according to the latest IPCC report (Forster et al. 2007), see Table 2.2.

Table 2.2 Global Warming Potentials, GWPs, used in the study

	GWPs, time horizon 100 years
Carbon dioxide, CO_2	1
Methane, CH_4	25
Nitrous oxide, N_2O	298

3 Inventory of inputs to animal production

3.1 Nitrogen fertilisers

Production and use of nitrogen (N) fertilisers in feed production are important sources of GHG emissions in animal production. In later years, statistics have improved on fertiliser rates in individual crops and the rates are also aggregated and balanced with the total amount of fertilisers sold. In 2005, 158 000 ton N as mineral fertiliser was used in Swedish agriculture in total; fertiliser rates in crops used in fodder production are summarised in Appendix 1 (SCB 2006a).

One third of the grassland area for cutting and grazing was in organic production in 2005 with no mineral fertiliser application. This is partly an effect of the growth of organic production of milk and beef and partly due to the Rural Development Program in Sweden where for example, subsidies to organic agriculture have been included. The subsidies have been used in grassland in particular; in 2005 almost one third of total grassland area used for cutting (silage and hay) did not receive any mineral fertilisers and ~40 % of the grassland used for grazing. In grains and rapeseed, only smaller areas were in organic production in 2005 with the exception of oats, where ~15 % of total areal was non-fertilised.

There are no statistics of N fertiliser use in individual crops in the early 1990s, we only have data on total fertiliser sales to agriculture. In Table 3.1, the use of N-fertilisers (based on sales statistics) during the years 1990-1992 is shown and average rates for fertilised arable was calculated (peas and fallow land excluded since no N fertilisers are applied here). In the early 1990s, there was very little organic production.

Table 3.1 Use of N-fertilisers, total amount and average rates on fertilised arable land in the early 1990s

Sales period	*Crop year*	*Area, x 1000 ha*	*Total sale, ton N*	*Average rate, kg N ha^{-1}*
June-May, 89/90	1990	2 564	224 500	88
June-May, 90/91	1991	2 416	208 600	86

Source: SCB 1991, SCB 1992

N-fertiliser rates in individual fodder crops in 1990 were estimated with the help of fertiliser recommendations from the early 1990s, expert discussions and a final balancing where the estimated fertiliser rates in each crop were multiplied with the total area of individual crops in 1990 and 1991 so that the total amount of used N could be checked against the sale statistics, see Appendix 1. The N-fertiliser rates we finally estimated to be used in fodder production in 1990 are shown in Table 3.2.

Table 3.2 Use of N-fertilisers in fodder crops 1990 and 2005 (estimate 1990 and statistics 2005)

Crop	N-fertiliser rate, kg N ha^{-1}	
	1990	2005
W-wheat	125	138
Barley	65	73
Oats	65	59
W-rapeseed	130	140
Spring rapeseed	90	108
Grassland, cut and grazing	85	79 / 17

In 1990, there were two fertiliser industries in Sweden (owned by Norsk Hydro, today Yara) where a significant amount of the fertilisers were produced, with some adding imports added. We used data on

GHG emissions from fertiliser production in 1990 as West-European average (data collected in the late 1990s) from Davis & Haglund (1999), corresponding to emissions of 7.3 kg CO_2e kg N^{-1}. In 2005, the Swedish fertiliser industry had shut down and only imported fertilisers were used, mainly from Yara. Data on emissions from fertiliser N-production in 2005 are from Jensen & Kongshaug (2003) and represent average data from the European fertiliser industry in the beginning of 2000, estimated at 6.8 kg CO_2e kg N^{-1} (as ammonium-nitrate).

Ammonia emissions from the application of N-fertiliser (mostly ammonium nitrate) were calculated at 2 % of N application (Hutchings et al, 2001).

3.2 Direct energy

The use of direct energy in animal production is in the following activities: diesel for machinery (diesel in tractors, harvesters etc), heating (heating of stables, drying of grains) and electricity (ventilation, milking equipment etc in stables). Statistics on the use of energy in Swedish agriculture are given with some irregularity and during the past 20 years, data are available for the years 1986, 1994, 2002 and 2007 (SCB 2008). Energy data are collected and presented aggregated for the whole agricultural sector and it is therefore not possible to assess the energy use in animal production with official statistics solely. Information from other sources and some assumptions have therefore been used to complete the information on energy use in Swedish animal production.

3.2.1 Diesel

There are official data on diesel use based on surveys for the years 2007, 2002, 1994 and 1986 (SCB 2008). As seen in Table 3.3, total diesel use in agriculture was reduced by ~15 % over the past 20 years. However, when diesel use is distributed over the area “arable land in production”, there are only small changes over the period and based on this, we estimate the same diesel use per hectare arable land in 1990 and 2005. Indicator values for diesel use in crops have been suggested, for example approximately 70 l ha^{-1} for grains and 50 l ha^{-1} for grassland (silage); handling and application of manure not included (Edström et al, 2005). These indicator values were lower than estimates of diesel use in earlier LCA-studies which were based on data collected on farms. We increased the indicator values suggested by Edström and colleagues by 25 % for diesel use in fodder crops, final in-data used for diesel in fodder crops are shown in Appendix 2.

Table 3.3 Total diesel use in agriculture 1986, 1994, 2002 and 2007 and diesel use per hectare of arable land in production

	1986	1994	2002	2007
Total diesel, m^3	332 772	294 500	277 060	278 762
Arable land in production, 10^6 ha	2.804	2.552	2.402	2.365
Average, l ha^{-1}	119	115	115	118

Data on diesel use in stables for feeding, manure and straw handling, livestock management etc are scarce and several sources are old. In cattle production, 26 l diesel per dairy cow*yr and for other cattle 13 l per head*yr were estimated based on surveys in the 1980s (Edström et al, 2005). These data were used for dairy cows in 1990 and all other cattle for 1990 and 2005 but for cattle with a long grazing period diesel use were assumed to be lower and reduced to 10 l per head*yr. For dairy production in 2005, new data were available based on recent surveys on modern dairy farms corresponding to a use of 0.0032 l diesel per kg milk for feeding (and some manure management) (Neumann, 2007).

There are old data (from 1980s) available for diesel use of manure handling in stables for slaughter chicken corresponding to 0.005 l per fowl*yr (Edström et al, 2005). We used these data for all slaughter chicken in 1990 and in 2005, and for layer hens in 2005. In 1990, all hens were kept in cages, manure was then mainly handled with electricity as energy source.

Handling of manure, transport to field and manure application were estimated to require 0.25 l diesel per ton manure by Edström et al, 2005, also this indicator value was found to be lower than in earlier LCA-studies (with data collected on real farms). We assumed an average use corresponding to 0.4 l diesel per ton manure.

Handling of straw (for bedding and fodder) and transport to stable were estimated to require 11 litres per hectare (Edstöm et al, 2005). Assuming a straw yield of 4.5 t ha^{-1} leaves an estimate of 2.5 l diesel per ton straw.

With all the indicator values presented above for plant production and animal production, we used these numbers to calculate the total diesel use in all agriculture. Then we ended up with a total diesel use for the cultivation of all arable land corresponding to ~65 % of gross diesel use reported in the statistics. The sum of all diesel used in animal production (feeding, manure applications etc) and this calculation ended up with a sum corresponding to around 12 % of gross diesel use.

The diesel use reported in the national statistics includes all diesel used in agricultural and of course, plant production and animal production are the major sectors. But there is also diesel used in forestry work, for entrepreneur work such as snow-ploughing, in the leisure horse-sector etc. The first check after distributing diesel use to different sectors gave us the result of 77 % of total diesel to be used in crop and animal production. We found the discrepancy to be rather high and therefore added 25 % extra diesel for the handling and spreading of manure, feeding, handling of straw etc and the final input data are presented in Appendix 2 (Table 2-4). After this, 82 % of all agricultural diesel reported in the statistics was distributed to the Swedish crop and animal production. The overshooting surplus we assumed to be used in forestry work, entrepreneur work, “leisure services”, private cars etc.

3.2.2 Electricity

In pig production, electricity is the predominant energy source used for ventilation, heating (piglets) and feed handling. We used data corresponding to an energy use of 29 kWh per fattening pig (100 % electricity) and 40 kWh per piglet (95 % electricity, 5 % biomass for heating) based on a recent survey of pig stables (Neuman, 2009). These data were in good agreement with indicator values for energy use in pig stables based on data from the 1980s (Edström et al, 2005); therefore we assumed the same use of electricity in pig stables both years.

In production of chicken meat, electricity is foremost used for ventilation in farm buildings, Edström et al (2005) give data of 1.3 kWh per head and year which is based on information from current advisory services in Denmark. We use this piece of data for both years.

Mostly electricity is used as energy source for layer hens corresponding to 1 kWh per kg egg with data from a recent LCA where energy use were inventoried on two farms (Sonesson et al, 2008). For the hatching of chickens we calculated 0.36 MJ/chicken. In the production of layer hens (0-17 weeks), electricity corresponded to 1.1 MJ per head*yr (Sonesson et al, 2008).

For cattle production, Edström et al (2005) give data on electricity use (ventilation, handling of feed and manure) at 90 kWh per head*year in farm buildings with mechanical ventilation and 38 kWh per head*year in farm buildings med “natural” ventilation. We adjusted these data for different categories in the cattle population according to the grazing period´s length.

In dairy production, electricity is used for milking, ventilation, feeding service etc and average energy use was set at 1 300 kWh per dairy cow*yr (including replacement heifer) and this was based on data from Cederberg & Flysjö (2004), Cederberg et al (2007); Neumann (2009); the same data for both years.

For electricity used in feed preparation, crushing of grains and peas at the farms we used an estimate of 8 kWh per ton. For drying of grains, peas and rapeseed, electricity use was 18 kWh per ton (Edström et al, 2005).

3.2.3 Heating

Oil is the predominant energy source when drying grain, rapeseed and peas. In later years, some farms have started to use bio-fuel, e.g. straw, for drying operations but this is still of small significance and not included here. Depending on weather conditions at harvest, use of energy for drying varies between years. Official statistics are only available for 1986, 1994, 2002 and 2007 and total use in agriculture varies between an annual use corresponding to 48 000 – 76 000 m^3 oil for these years (SCB 2008) with no clear trend of decrease or increase. Here, we assumed a water content in the grain at harvest at 19 % for winter wheat and 17 % for barley and oats. Grain was dried to 14 % water content and we calculated the need of oil at 0.15 l oil per kg dried water (Edström et al, 2005). This corresponds to a total use of around 38 000 m^3 oil for the drying of all grain in 1990 and 35 000 m^3 in 2005.

Oil for heating in stables is mostly used in slaughter chicken production and production of young hens for egg production. Edström et al. (2005) gives a of an energy use of 7.7 kWh per fowl (one year) and according to Svensk Fågel, the energy source in chicken stables is 80 % bio-fuel (mostly straw) and 20 % oil today and in 1990, 80 % was oil and 20 % bio-fuel (Waldenstedt, pers comm. 2008).

In egg production, heating is added in the rearing of young hens during the first five weeks after hatching. This was calculated at 16.2 MJ per fowl and year with 80 % biomass and 20 % oil 2005 and the opposite distribution in 1990 (Sonesson et al, 2008).

3.3 Grain

3.3.1 Use of grain in animal production

In 2005, approximately 2.7 million tons (Mtons) grains were used as feed in 2005, i.e. 50-55 % of the total Swedish grain yield is used in the production of milk, meat and eggs (SJV 2006b). When the Board of Agriculture estimates the Swedish cereal balance, grain for feed is the difference between the total national grain yield and the sum of grain used in food industry, for seed production, for technical purposes (e.g. energy) and exports (Svensson, H., pers comm. 2009). However, data on the total national grain production have major uncertainties since the methods for estimating yields are inadequate. Yield data are, due lack of financial means, no longer based on objective measurements by sampling plot yields at a larger scale. Instead, yield data are collected through telephone interviews with farmers. Since most farmers do not weigh grain that is used as feed at the farms and the dominant share of feed grain is used directly at the farms, yield estimations are uncertain. In 1990, the official statistics had programs sampling and measuring crop yields and thus, yield statistics in the early 1990s were of higher quality than today.

In the inventory of feed used in animal production in 2005 (see further section 4), our estimate is a total use of approximately 2.4 Mtons grain; i.e. approximately 10 % less than the Board of Agriculture´s cereal balance predicts. We choose not to adjust the final estimates shown in Table 3.4 due to the uncertainties in the present national cereal balance.

Table 3.4 Estimated use of grain (ton) in animal production in 2005 (see further section 4)

	Pork	Chicken	Egg	Beef	Milk	Total
Use of grain, tons	910 000	190 000	162 000	255 000	916 000	2 433 000

Around 1990/91 approximately 3.2 Mtons grains[2] were used as feed according to the balance sheet of grain resources from the Board of Agriculture (SCB 1993). This is in good agreement with the estimates made in this report on grain consumption in 1990, see Table 3.5 and further on in Section 4. In 1990, yield levels were estimated by sampling of yields in field that was carried out by the official statistical organization and data on yield and total production in grains used as feed was probably more correct then.

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[2] Grains for feed, seed and wastes were given in a lump sum, seed and waste were estimated as ~0.35Mtons

Table 3.5 Estimated use of grain (tons) in animal production in 1990 (see further section 4)

	Pork	Chicken	Egg	Beef	Milk	Total
Use of grain, tons	1 100 000	110 000	204 000	370 000	1 360 000	3 144 000

3.3.2 Input data

Input data for the cultivation of grain are summarised in Appendix 3. For triticale, we used cultivation data for wheat and for "mixed grain" data for barley was used. Yield levels were estimated from an average over five years of yield averaged for the whole of Sweden, based on the official statistics (yields in 1990 average of1988-1992 and yields in 2005 average of 2003-2007). The distribution of barley, wheat (triticale) and oats used on the farms in the different livestock products were own assumptions based on how the feed grain delivered by the feed industry is mixed and also on discussion with the advisory service. Due to uncertainties in the official cereal balance, we only balance the total grain use estimated in the study and not the separate varieties. The GHG emissions per kg feed grain, no matter of variety, are similar so we assumed that is was necessary only to balance each individual grain variety separately, only the total use.

Seed was calculated as a net flow, i.e. output yield was set at total yield subtracted by the seed rate. Transport and handling of seed were not included. Background data on direct energy (diesel, oil and electricity) and use of mineral N-fertilisers were described in previous sections. No application of phosphorous and potassium synthetic fertilisers was included as the animal production systems was modelled including all manure from the livestock (see section 2.4).

Nitrogen (N) in crop residues returned to the soil was calculated according to the IPCC guidelines (2006). We assumed that 35 % of the straw was harvested from the field and 65 % was returned to the soil based on statistics from 1997 (SCB 1997). Estimations on direct emissions of nitrous oxide (N_2O) from soils were based on total input of N in mineral fertilisers and crop residues with an emission factor (EF) of 0.01 kg N_2O-N emitted per kg N applied (IPCC 2006). Indirect N_2O emissions caused by emissions of ammonia and N leaching from soil bas were estimated with EFs 0.01 kg N_2O-N per kg emitted NH_3-N and 0.0075 kg N_2O-N per kg N leached (IPCC 2006). Two percent of applied mineral N fertilisers were assumed to be emitted as ammonia (Hutchings et al., 2001). Losses of N caused by soil leaching vary due to soil type, climate conditions and management methods and obviously it is difficult to set an average leaching for all the grain cultivation. Larsson (2004) estimates the average N-leaching in cereals in different production areas in the range 30-40 kg N/ha, based on a report by Johnsson & Mårtensson (2002). When calculating indirect N_2O emissions we assumed an average leaching of 34 kg N ha^{-1} cereals in 2005 and 35 kg N ha^{-1} in 1990.

3.4 Concentrate feed

Concentrate feed includes grain, protein feed, fibre feed (e.g. dried beet pulp), milk replacers, minerals, vitamins etc. In this section, we present statistical data on concentrate feed not including grains, the volumes used in calculations and finally we present the sources for calculating GHG emissions from the concentrate feed components.

3.4.1 Cattle

In the statistics, data are given for production of concentrate feed to milk and beef cattle aggregated and for the years 2004, 2005 and 2006, the industry feed production was 835 000, 788 000 and 927 000 tons respectively (SJV 2005a; SJV 2006a; SJV 2007a) and ~85 % of this was consumed in the dairy sector. As input data in 2005, we estimated that the consumption in the dairy sector at ~720 000 tons and in the beef sector ~130 000 tons, i.e. a total of 850 000 tons.

Concentrate feed production was 680 000, 648 000 and 598 000 tons to cattle in 1989, 1990 and 1991 of which 92-93 % was for the dairy sector (SCB 1992; Lantbruksstyrelsen 1990). As input data in 1990, we estimated that the consumption in the dairy sector was ~ 594 000 tons and in the beef sector 53 000 tons, see Figure 3.1. In Appendix 4, total concentrate feed consumption in dairy and beef are shown. NB in Appendix 4, total grain consumption is also included.

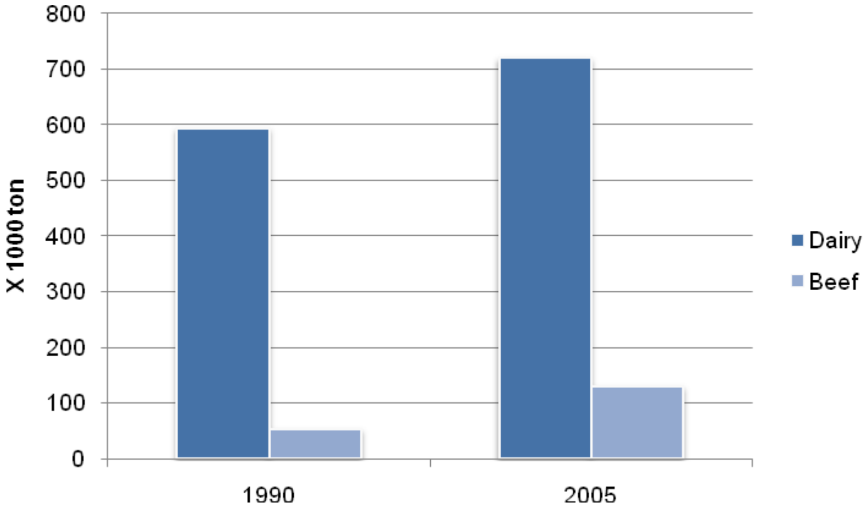

Figure 3.1 Use of concentrate feed (grain excluded) in dairy and beef production 1990 and 2005

3.4.2 Pork

Concentrate feed used in pig meat production was 198 000, 197 000 and 191 000 tons in 2004, 2005 and 2006 respectively (SJV 2005a; SJV 2006a; SJV 2007a). As input data, ~200 000 ton concentrate feed ingredients was used in 2005, see also Appendix 4.

In the early 1990s, concentrate feed use was 305 000, 297 000 and 275 000 tons in 1989, 1990 and 1991 respectively (SCB 1993). As input data, ~300 000 ton concentrate feed was used in 1990. As seen in Figure 3.2, overall use of concentrate feed ingredients in pig meat production has decreased significantly between 1990 and 2005.

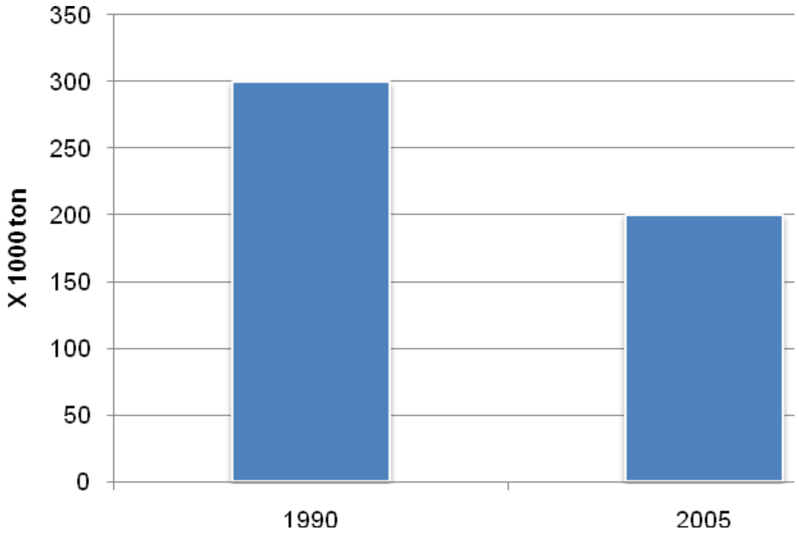

Figure 3.2 Use of concentrate feed (grain excluded) in pig meat production 1990 and 2005

3.4.3 Poultry

Concentrate feed used in all poultry production is reported aggregated in the statistics, close to 4 % of this feed is used in other production than eggs and slaughter chicken (e.g. turkey; ostrich). Total use in egg and chicken meat production was estimated at 217 000 tons, 200 000 tons and 216 000 tons in 2005, 2005 and 2006 respectively (SJV 2005a; SJV 2006a; SJV 2007a). Feeding experts assisted when dividing total volumes of the feed ingredients between egg and chicken meat production. As input data in 2005 we used a total of 210 000 ton concentrates distributed as 112 600 ton feed for slaughter chickens and 98 000 tons for egg production, Appendix 4.

Use of concentrate feed was 153 000, 148 000 and 164 000 ton feed in 1989, 1990 and 1991 respectively (SCB 1992). Input data for 1990 was 47 000 tons in chicken meat production and 106 000 tons in egg production.

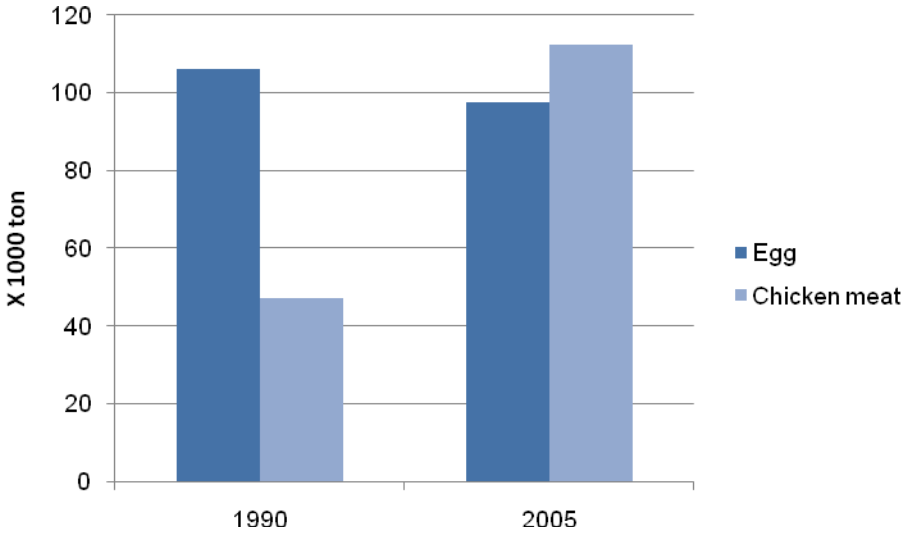

Figure 3.3 Use of concentrate feed (grains excluded) in egg and chicken meat production 1990 and 2005

Due to an increased chicken meat production, concentrate feed has more than doubled between 1990 and 2005 while concentrates used in egg production decreased by 5-10 %.

3.4.4 Ingredients in concentrate feed

The statistics on the amount of different feed ingredients are reported more accurately in 2005 compared to 1990 when some feed materials are registered as “other” feed components. We classified the feed components (grains excluded) in different classes: by-products from cereal industry, by-products from sugar industry, protein feed, fatty acids (also palmkernel expels), others and minerals (see Appendix 4).

By-products from cereal industry include middlings, bran, germ etc from extraction and grinding of grains, distiller´s dried grains and maize gluten. LCA-data for wheat bran/middlings, distiller´s dried grain and maize gluten were taken from a Swedish LCA feed database (Flysjö et al, 2008). For imported by-products, Swedish production data were used and a transport of 1200 km was assumed. All small volumes (e.g. maize germ expeller, maize, oat flakes) were aggregated to a lump sum and data for wheat bran production were used.

By-products from sugar industry include beet pulp, molasses and sugar. Data were taken from feed database (Flysjö et al., 2008). For Swedish beet pulp in 2005, natural gas is the energy source in the drying process (Landqvist B., pers comm. 2009), for imported beet pulp (Denmark/Germany) a mixture of coal and oil was assumed to be the energy source. In 1990, energy source for drying the pulp was a 50/50 mixture of oil and natural gas (Landqvist B., pers comm. 2009). Sugar beet cultivation data was the same for both years (Flysjö et al, 2008).

Protein feed ingredients include rapeseed products, soymeal, fishmeal, meat meal, grass/lucernmeal, peas/horsebeans, potatoe protein, synthetic amino acids, sources for these are shown in Table 3.6.

Table 3.6 Overview of sources for LCA data on protein feeds

Protein feed ingredient	LCA data
Rape seed and rapeseed meal Sweden 2005	Flysjö et al. (2008)
Rapeseed meal, import EU, 2005	Ecoinvent (2003)
Rapeseed meal, Sweden 1990	Modified LCA data in comparison with 2005 from Flysjö et al. (2008), due to changes in yields and energy sources in extraction industry, see Appendix 3
Soymeal (Brazil)	Flysjö et al (2008), same data for both years
Fishmeal[3]	Pelletier et al (2009)
Grass/lusern meal (Sweden and import)	Flysjö et al (2008), same data for both years
Peas/horsebean	Flysjö et al (2008), same data for both years
Potatoe protein (by-product from starch industry)	No data were found. We assumed that drying is the major input (all cultivation were allocated to the starch) and used the same data for drying as for imported beet pulp.
Synthetic amino acids	Production data Binder (2003), transport 1150 km

For fatty acids, palmkernel expels and minerals such as monocalciumphospate, LCA-data from the feed database (Flysjö et al, 2008) were used for both years. Data on calciumcarbonat were taken from Davis & Haglund (1999) and salt production from Ecoinvent (2003).

In 1990, a lump sum was given in the statistics for “other” feed ingredients; for this group of unknown feedstuff, we used the average GHG estimate from all the other known ingredients in the total feed compound.

Energy in feed industry was calculated as 50 MJ per ton feed (Flysjö et al, 2008) with electricity as source. All transports from feed industry to farm were estimated at 100 km.

3.5 Rapeseed products

In 2005, 168 000 ton rapeseed products were used in concentrate feed according to the statistics, of which 26 000 tons was whole rapeseed and 142 000 tons was meal and expeller (SJV 2006b). The total harvest of rapeseed was ~200 000 tons in 2005, after deducting the whole rapeseed reported as used as feed raw material, we estimate that ~175 000 tons was used for extraction and that 58 % of the rapeseed mass goes into meal after extraction. Total potential use of the Swedish rapeseed feed is thus approximately 130 000 ton feed and we conclude that the volume of domestic rape seed products are overestimated in the feed statistics with almost 40 000 tons. As final input data, 40 000 ton rapeseed products reported as domestic in the feed statistics were substituted with imported rapeseed products.

According to the feed statistics approximately 170 -190 000 ton rapeseed products are used in the concentrate feed in the early 1990s (SCB 1992). As a five year average 1988-1992, total rapeseed yield was ~305 000 tons (9 % water content). Assuming an extraction rate of ~60 % as meal/cake in the early 1990s, we estimate that the yearly production of rapeseed products for feed was around 180 000 tons. In the early 1990s, the feed statistics gave no information on the origin of the feed ingredients but we assumed that rapeseed products used as feed in 1990 were of domestic origin. LCA-data for rapeseed were modified from the ones used in 2005, yields and fertiliser rates were

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[3] The GWP data used for fishmeal is calculated as an average fishmeal of north atlantic and south american fish species.

lower in 1990 and in the extraction industry, fossil fuels were used as opposed to 2005 when bio-fuels are the dominating energy source, used data are summarised in Appendix 3.

3.6 Peas and horse-beans

Similar to grains, some of the peas and horse-beans are sold to the feed industry and used in the concentrate feed and thus included in the national feed statistics while a considerable share is used directly at the farms, Table 3.7 shows the use of domestic legumes in concentrates in the feed industry.

Table 3.7 Use of peas and horse-beans in concentrate feed sold from feed industry in animal production (from official feed statistics)

	2005, tons	1990, tons
Milk	8 500	23 200
Beef	1 500	1 700
Pork	12 600	27 900
Chicken	10 000	
Eggs	2 500	12 000
Total	35 100	65 000

In 1990, we estimated the area of peas cultivated for feed production at ~28 000 ha (SCB 1991), the statistics give data on yields and we estimated it at a national average of 3 000 kg ha^{-1} after deduction of seed. This results in a total production of approximately 85 000 tons peas, ~65 000 tons was used in feed industry (Table 3.7) and we add 20 000 ton peas as a protein feed consumed directly at the farms, assuming it be 10 000 tons each in milk and pork production.

Total yield of peas and horse-beans was around 80 000 tons in 2005 and 100 000 tons in 2004 (SJV 2006c). Approximately 35 000 ton peas and horse-beans were used by the feed industry around 2005 and this means that a considerable amount of the total pea/horse-bean harvest was used directly at the farms, which is verified by farm advisers. There are, however, no data available on how this farm-produced protein is distributed between the different animal production systems. We did a rough assumption that in 2005, a total of 45 000 ton peas and horse-beans were used directly at farms and divided a third each of this to cattle, pigs and poultry.

Data for the cultivation of peas and horse-beans were taken from Flysjö et al (2008) and since yields have been relative stable over time, the same data were used for both years.

3.7 Silage, hay, grazing

Consumption of roughage fodder - silage, hay and pasture - is difficult to quantify since this fodder is used directly at the farms, rarely weighed by the farmers and hardly ever systematically recorded when it comes to total consumption including fodder waste. Moreover, the statistics on yields of roughage fodder are uncertain or lacking (for example pasture). In the early 1990s, yields were monitored in the official statistics but at present, yield recording of silage and hay are based on telephone interviews solely and most farmers do not systematically weigh the fodder. Due to these uncertainties in the statistics and also in how much roughage feed the cattle actually consume, we estimated the areas of grassland and pastures used in the production of milk and beef based on calculated feed consumption (see further Section 4.4-4.5), expert judgements and estimations of roughage fodder consumed by other livestock (horses and sheep). Consequently, input data were therefore not given per kg of feed but instead for the hectares of grassland used in milk- and beef production.

1990

In 1990, there was a total of 958 000 ha arable land cultivated as roughage fodder and corresponding to approximately 35 % of total Swedish arable land (SCB 1991), for its distribution see Table 3.8.

Table 3.8 Areas of roughage fodder on arable land in 1990 according to the statistics

	Grassland, cut	Grassland, pasture	Total grassland (leys)	Green fodder crops	Total roughage crops
Arable land, ha	728 000	190 000	918 000	40 000	958 000

Table 3.9 summarises the assumptions we made for how this area was distributed between different livestock consuming roughage fodder.

Table 3.9 Areas of grassland and green fodder estimated distribution between different livestock categories in 1990

Category	Grassland, cut	Grassland, pasture	Total Grassland	Green fodder
Dairy cattle	436 000	140 000	576 000	30 000
Beef cattle	125 000	75 000	200 000	10 000
Horses	90 000	20 000	110 000	
Sheep	15 000	15 000	30 000	
Total	666 000	250 000	916 000	40 000

In 1990, there were also 330 000 ha natural meadows (SCB 1991), grassland that is never ploughed and thus not included in the land category arable land. This was distributed as 200 000 ha for dairy cattle (foremost grazed by replacement heifers), 100 000 ha for beef cattle and 30 000 ha for sheep and horses.

Input data cultivation 1990

Use of mineral N fertilisers in the grassland was estimate at 85 kg N ha^{-1}, see section 3.1. In the 1990s, a large share of the grassland was harvested as hay (SCB 1991). Edström et al (2005) gives data on 5.7 – 7.7 l diesel per ton dry matter (DM) when harvesting in hay or silage in different systems. We used an average yield of 5 t DM ha^{-1}, thus consuming 35 l ha^{-1} and other operations to use approximately 27 l ha^{-1}. Total diesel use was set as 65 l ha^{-1} for cut grassland and 20 l ha^{-1} for grazed grassland. Since we have very scarce data on proportions of the roughage feed harvested in different systems (hay, plastic bags, silage tower etc), we did not include emissions from the capital goods (e.g. steel in silage tower, plastic for bales), see further 2.2.2.

For grasslands, we made an assumption of in average three years length between ploughing and renovation, we calculated an annual input of 30 kg N ha^{-1} from crop residues when calculating direct N_2O-emissions from soil (IPCC 2006). Average N-leaching in grassland was estimated at 10 kg N ha^{-1} in grassland on arable land and 5 kg N ha^{-1} in natural meadows (never ploughed), this was based on Larsson (2004). 40 000 ha green fodder was added to milk and beef production (see Table 3.9) to balance the total area of roughage fodder reported in the statistics. Inputs of mineral N and diesel on this land were assumed to be the same as cut grassland, see further Appendix 3.

2005

In 2005, overall grassland production had gone through considerable changes; one third of total grassland area is now included in the Rural Development Program for organic agriculture and thus do not receive any mineral fertilisers. Also, total grassland area has increased by 80 000 ha since the early 1990s, this also being an effect of subsidies in the program for grassland cultivation. Areas of grassland and green fodder on arable land are shown in Table 3.10.

Table 3.10 Areas of roughage fodder on arable land in 2005 according to the statistics

	Conventional	Organic	Total
Grassland, cut	545 000	259 000	804 000
Pasture	113 000	80 000	193 000
Grassland, total			997 000
Green fodder			40 000
Total			1 037 000

Based on the estimates of fodder consumption of beef and dairy (se section 4.4-4.5), discussion with the advisory service and on data collected in LCAs of milk production (Cederberg & Flysjö 2004; Cederberg et al, 2007), the areas of different types of grassland were distributed between different animal categories, see Table 3.11.

Table 3.11 Areas of grassland estimated distribution between different livestock categories in 2005

	Conventional grassland cut	Organic grassland cut	Conventional pasture	Organic pasture	Total
Dairy cattle	315 000	30 000	72 000	10 000	427 000
Beef cattle	145 000	145 000	20 000	50 000	360 000
Horses	75 000	70 000	18 000	10 000	173 000
Sheep	10 000	15 000	3 000	10 000	38 000
Total	545 000	260 000	113 000	80 000	998 000

In 2005, there was around 500 000 ha natural meadows which we distributed as 150 000 ha for dairy sector (grazed foremost by replacement heifers), 250 000 ha for beef cattle and 100 000 ha for horses and sheep.

Input data cultivation 2005

Total use of mineral N fertilisers in grasslands was significantly reduced between 1990 and 2005, the rate per hectare use were of the same magnitude both years, but a large share of grassland area are now non-fertilisers. N fertiliser rates used here (Appendix 1) were in good agreement with use inventoried on real dairy farms (Cederberg & Flysjö 2004; Cederberg et al, 2007). Diesel use was calculated as for 1990 (Appendix 2)

Apart from 1 million hectares of grassland, there were also 40 000 ha green fodder in 2005 according to the statistics. Here, we used input data as for cut grassland and distributed this land use as 30 000 ha to milk production and 10 000 ha to beef production.

Maize for silage was introduced in the early 2000s, in 2005 there was 5 800 ha (SJV 2006c). Based on feeding experts, we assume the whole area was used in milk production, data in Appendix 3.

3.8 Super pressed pulp

In 1990s, the technique of making silage from beet fibre instead of drying it was introduced and 2005, 69 000 ton dry matter super pressed pulp was used in cattle production (SJV 2006a); based on discussion with the advisory service we assumed that all was used in dairy production. Super pressed pulp is transported directly to the dairy farms (not via feed industry). We estimated an average distance to the farms of 150 km. All data on super pressed pulp are from Flysjö et al (2008).

4 Inventory of animal production

4.1 Pork

The production of pig meat as carcass weight (CW) and the number of slaughtered animals are shown in Table 4.1. In the statistics from 1990, private slaughter at the farms was reported separately and then represented 0.6 % of total slaughtered animals (included in overall production). No private slaughter was reported in the statistics of 2005, however, it is assumed to be much smaller than in 1990 because the number of farms holding pigs in 2005 is only 20 % of the pig farms in 1990.

Table 4.1 Production of pig meat, 2005 and 1990

	2005	1990	% change
Production, ton meat with bones (CW)	275 130	290 795	-5.4
Slaughtered head	3 159 930	3 622 688	-12.7
Average weight, kg per slaughtered pig	87	80.3	+ 8.5

Source: SJV 2008, SJV 2006c, SJV 1998

The total production of pig meat was reduced by more than 5 % from 1990 to 2005. The total number of pigs decreased even more, and in 2005, close to 13 % fewer pigs were slaughtered than in 1990.

4.1.1 Pig population

The pig population according to the agricultural census is shown in Table 4.2 (SJV 2006c, SCB 1991) and the number of sows has been significantly reduced by over 15 %. The number of farms holding pigs also decreased significantly, from 14 000 farms in 1990 to 2 800 farms in 2005.

Table 4.2 Head of pigs in June 1990 and 2005 according to the agricultural census

Livestock category	2005	1990
Sows for breeding >50 kg	185 415	221 092
Boars for breeding >50 kg	2 697	8 591
Other pigs >20 kg	1 085 304	1 024 820
Other pigs <20 kg *	537 800	1 009 440
Total	1 811 216	2 263 943

* up until 1993, younger pigs were divided between ´young´ and ´older than 3 months´, this is the explanation for the high number of pigs>20 kg in 1990.

It is important to have a reasonable correct number of heads in each livestock category when calculating consumption of feed and manure production for the overall pig meat production. The agricultural statistics are based on the number of pigs at one single occasion during a year and using this data solely can lead to errors in calculations of the number of pigs in production necessary to reach the real output of product. Therefore, the total number of pigs in production was calculated with the reported slaughtered pigs as the base.

In 2005, 3 159 930 pigs were slaughtered, of which 3 100 123 were fattening pigs and 59 807 were sows (mostly) and boars (SJV 2008). At the slaughterhouses, 0.29 % of pigs are rejected and from the live weight 30 kg (beginning of fattening phase) until slaughter, mortality is 1.5 % (Svenska Pig 2008)[4]. Thus, 3 217 379 pigs are needed to produce 3 100 123 slaughtered fattening pigs.

Based on discussions with the advisory service and statistics from the PIGWIN, we estimated the piglet production at 21 piglets per sow in 2005, this number includes mortality up until the piglets are

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[4] All kind of statistics on pigs are found in PIGWIN on the homepage www.svenskapig.se

delivered to the fattening phase. With this piglet production per sow, ~150 300 sows are needed for giving birth to the fattening pigs. In addition, 2 900 sows are needed to produce replacement sows. In Table 4.3, the number of pigs in different categories is summarised and these numbers are the base for the coming calculations of feed consumption, manure production etc.

In 1990, 3 622 688 pigs were slaughtered of which 3 554 865 were fattening pigs and 68 565 were sows and boars. At the slaughter-houses, 0.3 % of the pigs were rejected and from the weight 30 kg up until slaughter, mortality was estimated at 1.7 %[5]. Thus 3 696 813 pigs and piglets are needed to produce 3 554 865 slaughtered fattening pigs. Based on discussions with the pig advisory service we estimated piglet production at 18 piglets per sow in 1990, this number includes mortality until the piglets are delivered for fattening phase (Svensson, Å, pers comm. 2008). From this piglet production, we calculated the number of sows needed at ~205 400 in 1990.

Table 4.3 Estimated head of pigs needed in production in 1990 and 2005 to obtain the slaughtered number of pigs reported in the slaughter statistics

	2005	*1990*	*Change, %*
Sows	153 209	205 378	-25
Boars	2 697	8 597	
Piglets	3 217 379	3 696 813	-13
Fattening pigs	3 217 379	3 696 813	-13

4.1.2 CH_4 emissions from enteric fermentation

Methane (CH_4) emissions due to enteric fermentation are suggested at 1.5 kg CH_4 head^{-1} yr^{-1} for pigs in developed countries (Tier 1) (IPCC 2006). From the start of the fattening phase (live weight 30 kg) until slaughter, the pigs are fattened in average 97 days in 2005 (www.svenskapig.se), i.e. close to 3.2 months. We assume that the piglet emits only small amounts of CH_4 due to its low feed intake and round off the time period emitting CH_4 at four month for the fattening pig. From this we estimate the EF for one fattening pig as 4/12*1.5 = 0.5 kg CH_4 per fattening pig. In Table 4.4, the total calculated emissions are shown.

Table 4.4 Emissions of CH_4 caused by enteric fermentation from the Swedish pig population 1990 and 2005

	2005 ton CH_4	*1990 ton CH_4*
Sows and boars	234	320
Fattening pigs	1 610	1 850

4.1.3 Feed consumption

2005

There are three major feeding systems for pig in 2005 and in Table 4.5, an estimate by the largest feed industry Lantmännen (market share 65-70 %) is shown on how these feeding systems are divided between different pig categories. The most common feeding system is grain (mostly cultivated at the pig farm) combined with a concentrate delivered from the feed industry. For fattening pigs it is becoming more common that both grain and concentrate are delivered separately (or partly cultivated at the pig farm) and a premix containing amino acids, vitamins, minerals etc from feed industry is added. Finally, a complete feed is a feed that includes all components (grain, protein, minerals, amino acids etc) and this is always delivered from the feed industry (Slåtterman, M. pers. comm. 2008).

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[5] Mortality based on data from around 1995 given by PIGWIN, no earlier data available

Table 4.5 Share of feeding system in 2005 for sows, piglets and fattening pigs

Feeding system	*Share of feed for sows, %*	*Share of feed for piglets, %*	*Share of feed for fattening pigs, %*
Complete feed,	37	25	25
Grain + concentrate	46	70	40
Grain+protein+premix	17	5	35

In the official statistics from the Board of Agriculture, only feed produced in the industry is reported. To calculate the total feed consumption, it is therefore necessary to also include the feed that is consumed directly at the farms and mostly cultivated there. This is foremost grain but to some extent also peas/horsebeans.

Total feed consumption was calculated at close to 1.11 Mtons in 2005, see Table 4.6. The data on feed consumption per head include waste of feed and are based on different agricultural cost estimates for pig production and interviews with pig feed specialists at the major feed industry Lantmännen (Svensson, Å pers comm).

Table 4.6 Estimated total feed consumption for pigs in 2005

Animal category	*Head, 2005*	*Feed consumption, kg head^{-1}*	*Total feed, tons*
Sows	153 209	1 350	206 832
Piglets	3 217 379	40	128 695
Fattening pigs	3 217 379	240	772 171
Boars	2 697	800	798
Total			~1 110 000

According to Lantmännen, share of grain of the total pig feed ration is 82 - 87 % for sows, 79 - 82 % for piglets and 81 - 83 % for fattening pigs (Slåtterman, M., pers comm. 2008). We estimated the grain share at an average of 82 % in the overall pig feed, corresponding to a total of ~910 000 tons in 2005. According to the official feed statistics, 238 000 tons of cereals were used in feed products delivered by the feed industry in 2005 (SJV 2006a). We therefore estimated that roughly 670 000 ton cereals for pig feed are cultivated and used directly at the pig farms (or bought from neighbouring farms). In Appendix 4, the total feed consumption for the production of pig meat in 2005 is summarised. The distribution of the farm-produced grain between wheat, barley and oats was done in accordance with the distribution in the grain sold by the feed industry. All data for the consumption of other feed ingredients were according to the official feed statistics (SJV 2006a) with the exception of amino acids and vitamins. Amino acids were calculated to be consumed at approximately 4 700 tons based on an average blend in complete feed corresponding to 0.1 % in feed for sows, 0.5 % in feed for piglets and 0.5 % in feed for fattening pigs (Slåtterman, M. pers comm., 2008).

Of the total feed consumption of approximately 1.11 Mtons, close to 90 % is of domestic origin (see Appendix 4). It is mainly protein feed ingredients and minerals that is imported.

1990

Total feed consumption in 1990 was estimated at 1.34 Mtons. The base for this estimation was the number of pigs in different categories and data on consumed feed per pig were taken from agricultural cost estimates for pig production in early 1990´s (SLU 1996, Lantbruksnämnden 1991). Experts in advisory services have estimated the consumption rates to be reasonable.

Table 4.7 Estimated total feed consumption for pigs in 1990

Animal category	*Animals head, 1990*	*Feed consumption, kg head^{-1}*	*Total feed, tons*
Sows	205 378	1 260	258 776
Piglets	3 696 813	30	110 904
Fattening pigs	3 696 813	260	961 171
Boars	8 597	800	6 878
Total			~1 340 000

According to feed statistics, approximately 300 000 ton concentrate feed excluding grain was sold to pig farms this year (SCB 1991), see Appendix 4. This is around 22 % of total feed consumption as calculated in Table 4.7 and thereby around 78 % of the total feed consumption is grain, corresponding to roughly 1.04 million tons. 385 000 ton grain were sold from the feed industry, thus leaving 655 000 ton to be cultivated and consumed directly at the farms. It is reasonable to assume that 78 % grain is a little low and overall grain consumption was therefore rounded off from 1.04 to 1.1 Mtons in 1990. This means that overall feed consumption of pigs is finally estimated 1.4 Mtons. Amino acids (not included in the official feed statistics) were calculated at 5 600 tons in 1990, with the same blend in feed as in 2005.

4.1.4 Manure

Total production of manure was calculated with data on manure production per animal category according to a report from the Board of Agriculture which is used by the advisory service when planning new stables (SJV 2001). The share of different handling systems of manure for pig production is based on the official statistics (SCB 2006a). From Table 4.8, it is obvious that solid manure has decreased significantly since 1990 and the slurry systems now make up more than 90 % of manure system in pig production.

Table 4.8 Total production of manure in pork production 2005 and 1990

System	*% dry matter*	*2005, tons*	*1990, tons*
Solid Manure	23	57 000	324 000
Urine	1.8	105 000	535 000
Liquid/slurry	9	3 150 000	3 000 000
Deep bedding	38	107 000	178 000
Total		3 420 000	4 050 000

Emissions from manure management

Emissions of CH_4 and N_2O from manure storages were calculated according to the IPCC guidelines (2006). Calculations and used parameters are presented in Appendix 5. The emissions from pig manure were estimated at ~8 420 ton CH_4 in 2005 and ~9 500 ton CH_4 in 1990. Calculations for direct N_2O emissions are shown in Appendix 6; they total at 277.4 ton N_2O in 2005 and 353.1 ton N_2O in 1990.

Nitrogen, production and losses in manure

The amount of nitrogen excreted by the pig population (based on the number of head in Table 4.3) was calculated with Stank in Mind[6] (SiM) and it amounted to ~17 300 ton N in 2005 and close to 21 000 ton N in 1990, see Appendix 6. From the calculated value of nitrogen excreted in manure, emissions of ammonia, nitrous oxide and N-leaching caused by autumn application were estimated. The calculated N-losses are summarised in Table 4.9 (see also Appendix 6).

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[6] Stank in Mind is a software program developed by the Board of Agriculture and used in the advisory service for calculating nutrient flows and losses on farms

We calculated the total ammonia-losses from pig production in 2005 at 4 450 ton NH_3-N and this is lower than the official estimates of 5 500 ton NH_3-N (SCB 2007). There are many explanations for the different estimates. Here, we divided pig production between ages and different manure system more thoroughly and thus, have different estimations of manure production. We based the preconditions for emissions during application of pig manure on discussion with the advisory service and for example, we have estimated that more manure spreading is done with trail hoses compared with the official statistics and also, with shorter time before incorporation. In the official statistics on manure handling (SCB 2006a), use of spreading methods is aggregated for all types of manure and regions in Sweden. It was a clear expert opinion (Lindholm, R.; Henriksson, M. pers. comm. 2008), that in regions with dominating pig production (flat country of southern Sweden), more advanced techniques when handling manure are practised which is not apparent in the aggregated statistics. In 1990, we calculated the total ammonia emissions from pig production 7 400 ton NH_3-N. No official statistics for ammonia emissions are available for 1990. The earliest statistics, from 1995, estimated that all handling of pig manure resulted in emissions of approximately 7 000 ton NH_3-N (SJV 1999).

Table 4.9 Total N production in pig manure, ammonia losses and ammonium-N (available for crop) in 1990 and 2005

	2005, ton N	*1990, ton N*
N excreted in manure	17 300	21 000
Losses in stable, NH_3-N	2 600	3 000
Losses in storage, NH_3-N	900	1 600
Losses in application, NH_3-N	950	2 800
Left after ammonia losses, total-N	12 850	13 600
NH_4-N, available for crop*	6 200	4 300

*after losses in field due to denitrification and additional N-leaching from manure that was spread in the autumn

We estimated that 26 % and 35 % respectively of N excreted from the pigs was lost as ammonia-N in 2005 and 1990. Important for the reduction is the lower emissions from manure storage in 2005 since significantly less manure is stored in solid forms and urine (Table 4.8). Also, time of application is of importance and in 2005, less manure was applied in autumn compared to 1990. The estimated ammonium-N available for crops after the manure was field application was estimated as 36 % respectively 20 % of N excreted in 2005 and 1990.

Direct N_2O emissions from soil are calculated with an EF of 0.01 kg N_2O-N per kg N applied as manure.

Table 4.10 Direct N_2O emission from application of pig manure on soils, 2005 and 1990

	2005, tons	*1990, tons*
Total-N in pig manure, spread in crops	12 850	13 600
NH_3-N, lost in application	950	2 800
Direct emission from soil, N_2O	217	257.5

Indirect losses of N_2O, caused by the emissions of ammonia and nitrate leaching from manure handling are shown in Table 4.11. EFs are 0.01 kg N_2O-N per NH_3-N emitted and 0.0075 kg N_2O-N per kg N leached.

Table 4.11 Indirect N_2O emissions caused ammonia volatilisation and N leaching due to pig manure handling and spreading

	2005, tons	*1990, tons*
Total ammonia losses, NH_3-N	4 450	7 400
Indirect N_2O emissions from ammonia-losses, N_2O	70	116
N-leaching caused by application in autumn, N	1 200	1 700
Indirect N_2O emissions from leaching, N_2O	14	20

4.2 Poultry meat

The total production of poultry meat in 2005 was reported as 106 200 tons, of which 98 600 tons were chicken meat, and meat from hens, turkey and duck/goose was 4 000, 3 300 and 300 tons respectively (SJV 2006d). The official slaughter statistics reports that 96 200 ton chicken meat was produced at the slaughterhouses and that 73.458 million heads were slaughtered, i.e. an average slaughter weight (meat with bone) of 1.3 kg per chicken (SJV 2008). We choose the production data from the market survey of the Board of Agriculture of 98 600 ton chicken meat (SJV 2006d) and adjust the number of slaughtered chicken to 73.9 million heads in 2005 (1.33 kg CW per fowl), see Table 4.12.

According to the Board of Agriculture, the overall production of poultry meat was 49 100 tons in 1990 and 55 100 tosn in 1991 (SJV 2000). It has not been possible to find information on how this poultry meat was distributed among different fowls as was the case for 2005. The slaughter statistics give data on 44 000 and 49 000 ton chicken meat produced in slaughter houses in 1990 and 1991 respectively, and slaughtered head of 38.9 and 43.3 million head for these two years (SJV 2008). We assume the total poultry meat production at 50 000 tons around the year of 1990 and we assume that the proportion of chicken meat is the same as in 2005; thus estimating an overall chicken meat production of 46 400 tons in 1990. The average slaughter weight in the early 1990´s was 1.1 kg head^{-1} (www.svenskfagel.se) and thus we estimate that 43.8 million heads were slaughtered.

Table 4.12 Overall production of chicken meat and total number of slaughtered chicken, 2005 and 1990

	2005	*1990*	*Change*
Production chicken meat, ton meat with bone (CW)	98 600	46 400	+112 %
Slaughtered head, million	73.9	43.8	+69 %
Average weight, kg CW per chicken	1.3	1.1	+25 %

According to data from Svensk Fågel, the average live weight of chicken was around 1.9 kg hd^{-1} in 2005 and 1.5 kg hd^{-1} in 1990 (Waldenstedt L., pers. comm. 2008). Carcass weight is 70 % of the bird´s live weight at slaughter. The very strong production increase between 1990 and 2005 is foremost an effect of increased volumes, but to some extent also due to that heavier fowls at slaughter. However, live weight at slaughter can vary from 1.7 to 2.3 kg per fowl or even more, depending on the poultry product demanded.

4.2.1 Fowl population

The population of slaughter chicken needed for the production as estimated in Table 4.12 was calculated and adjusted for mortality during rearing and rejection at slaughter, see Table 4.13. Data for rejection and mortality are according to the largest chicken meat producer in Sweden, Kronfågel (Henriksson, B., pers. comm., 2008) and both parameters have improved during the period. In 2005, the average rearing time was 36 days per chicken and in 1990 this was estimated at 37-38 days. In 2005, there were approximately seven batches of chickens per year in the stables (SJV 2005c). In 1990, there were 5.5 batches per year in the stables (Lantbruksstyrelsen, 1989).

When calculating the production of feed and manure, the number of 77.75 million slaughter chickens in production was used for 2005 and 46.47 million heads in 1990, see Table 4.13.

Table 4.13 Population of slaughter chickens for meat production in 2005 and 1990

	2005	*1990*
Slaughtered chicken, million head	73.9	43.8
Rejected at slaughter, %	1.35	1.5
Chicken to slaughter, million head	74.9	44.5
Mortality in rearing, %	3.5	4.5
Chicken into stables	77.75	46.47

Production of first and second generation chicken and hatchery of third generation is done in one large facility in southern Sweden. The number of parent and grand-parent hens and roasters needed for the production of slaughter chickens in 2005 and 1990 are shown in Table 4.14. The mode of production is very similar between 1990 and 2005 (Hermus C., pers. comm., 2008).

Table 4.14 Number of fowls for the production of slaughter chickens, 2005 and 1990

	2005	*1990*
Parent hens*	729 000	443 000
Grand-parent hens*	13 200	8 200
Imported chicken (not followed)	13 400	8 200

*also including roosters (one per eight hens)

4.2.2 Feed consumption

Feed consumption was estimated at 1.75 kg feed per kg live weight (including feed waste) in 2005 based on data from the largest chicken meat producer and feed producer (Henriksson, B.; Jonsson P. J., pers. comm., 2008). Feed composition in 2005 is mostly winter wheat completed with a concentrate feed constituting mainly by proteins (soymeal) and some wheat, from the feed industry. Total feed consumption was rounded off at 260 000 tons in 2005. We assumed that 10 000 ton peas were used directly out on the farms in 2005 (see section 3.5).

In 1990, we estimated a feed consumption of 1.8 kg feed per kg live weight in accordance with discussion with feed industry (Jonsson, P. J., pers. comm., 2008) and cost estimates (SLU 1996). This leaves a total feed consumption close to 120 000 ton in 1990.

Data for feed consumption was collected directly from the facility holding hens for the production of chickens. Total feed consumption per parent animal was estimated at 63 kg per head, being the same 2005 and 1990 (Hermus, C; pers comm., 2008). The overall consumption was estimated at 42 000 ton in 2005 and 25 000 in 1990.

Use of synthetic amino acids was calculated as ~1 350 tons in 2005 and ~600 tons in 1990.

All feed consumption in the production of slaughter chicken is summarised in Appendix 4, Table 4.

4.2.3 Manure production and emissions

Production of manure was calculated with data from SiM, used data were 1.08 and 1.09 kg manure per slaughter chicken in 1990 and 2005, respectively. As bedding material, planning shaving is mostly used, and 3 000 ton shavings were estimated for both years. More bedding material was assumed to be used in 1990´s since less heat was applied in the stables. Dry matter content in chicken manure is normally between 60 – 70 %.

Table 4.15 Total production of manure in the production of chicken 2005 and 1990

	2005, tons	*1990, tons*
Slaughter chickens	80 800	47 300
Hens for chicken production	14 600	8 700
Total	95 500	56 000

Emissions from manure management

Methane emissions from manure management were calculated with EFs according to IPCC guidelines (2006) and the manure production according to Table 4.15. The emissions were estimated at 195 ton CH_4 in 205 and 115 ton CH_4 in 1990, se Appendix 5.

Direct N_2O emissions from manure management were calculated at 5.2 ton N_2O in 2005 and 3 ton N_2O in 1990, calculations see Appendix 6.

Nitrogen, production and losses

The amount of nitrogen excreted by the fowls in the production of chicken meat (broilers and hens for chicken production) was calculated with SiM for 2005 and with data from the Board of Agriculture for 1990 (SJV 1993). $N_{excreted}$ was calculated at 3 300 ton N in 2005 and 1 800 ton N in 1990. The calculated N-losses are summarised in Table 4.16 and can be studied more thoroughly in Appendix 6.

Table 4.16 Total N production in manure from slaughter chicken production, ammonia losses and ammonium-N (available for crop) in 1990 and 2005

	2005, ton	*1990, ton*
N excreted in manure	3 300	1 900
Losses in stable and storage, NH_3-N	620	360
Losses in application, NH_3-N	350	300
Left after ammonia losses, total-N	2 330	1 240
NH_4-N, available for crop*	600	160

*after losses in field due to denitrification and additional N-leaching from manure that was spread in the autumn

The calculated ammonia emissions totalled at ~970 and 660 ton NH_3-N in 2005 and 1990. We estimated that 30 % respectively 35 % of N excreted was lost as ammonia-N in 2005 and 1990. The EFs for ammonia losses in stable and manure storage were the same for the two years, the reduced emission are explained by improved measures in application 2005; especially a much shorter time before the manure is incorporated in the soil was assumed, based on experience from the advisory service. Also, a lower share of the manure is applied during autumn in 2005 and this contributes, as well as an overall larger volume of manure in 2005, that more plant-available nitrogen from slaughter chicken is produced in 2005, Table 4.16.

Direct N_2O emissions from soil are calculated with an EF of 0.01 kg N_2O-N per kg N applied as manure. The direct losses of N_2O from agricultural soils caused by the application of slaughter chicken manure were estimated 42.1 ton N_2O in 2005 and 24.2 ton N_2O in 1990, Table 4.17.

Table 4.17 Direct N_2O emission from application of slaughter chicken manure on soils, 2005 and 1990

	2005, ton	*1990, ton*
Total-N in slaughter chicken manure, spread in crops	2 330	1 240
NH_3-N, lost in application	350	300
Direct emission from soil, N_2O	42.1	24.2

Calculated indirect losses of N_2O, caused by the emissions of ammonia and nitrate leaching from manure handling are shown in Table 4.18. EFs are 0.01 kg N_2O-N per NH_3-N emitted and 0.0075 kg N_2O-N per kg N leached (IPCC 2006).

Table 4.18 Indirect N_2O emissions caused ammonia volatilization and N leaching due to slaughter chicken manure handling and application

	2005, ton	*1990, ton*
Total ammonia losses, NH_3-N	970	660
Indirect N_2O emissions from ammonia-losses, N_2O	15.2	10.4
N-leaching caused by autumn-spreading, N	60	85
Indirect N_2O emissions from leaching, N_2O	0.7	1

4.3 Eggs

The production of eggs was 102 000 tons in 2005 which was a reduction with more than 15 % compared to 1990, see Table 4.19. The statistics for egg production are based on sales information from the largest egg warehouses and it is assumed that 27 % and 35 % of total sales were done outside these storehouses in 2005 and 1990 (SJV 2006b). The hen population shown in Table 4.19 is only hens in production. Normally the productive phase for a hen is from 5 to 18 months, corresponding to 58-60 weeks in production.

Table 4.19 Production of eggs and number of hens, 2005 and 1990

	2005	*1990*	*% change*
Production, ton eggs	102 000	122 000	-16
Layer hens in production, million head	5.1	6.4	-20
Average production, kg egg per hen	20	19.1 (18)	+ 5

Source: SJV 2006d, SCB 1991, SJV 2000

In 2005, there were 4 900 farms with layer hens and 600 farms rearing the young hens that goes into egg production (SJV 2006c). This is a substantial decrease from 1990 when the number was 12 900 and 1 900 farms, respectively, for egg production and rearing of layer hens.

Since a hen produce egg for more than one year, the total amount of hens needed for the egg production in 2005 and 1990 was the base for the calculations.

In the year around 2005, approximately 38 % of the hens were in cages, 56 % were on free range indoors and 6 % in organic (free outdoors) (www.svenskaagg.se). In an LCA of eggs with data from two farms in 2007, production was 22.6 kg eggs per hen during her lifetime production (60 week, 6.2 % mortality) on a farm with indoor free range system, and 20.2 kg eggs per hen during her lifetime production (58 weeks, 3.8 % mortality) on a farm with a cage system (Sonesson et al., 2008). From these data we estimate the average production (including mortality) at 20 kg eggs per hen for her lifetime production. Thus, to produce 102 000 ton eggs in 2005, 5.1 million hens are needed which is in good agreement with the statistics on hen population (Table 4.19).

Producing one layer hen from hatching until the young hen is delivered at the egg farm, takes about 16 weeks. Feed consumption and energy use during this period as well as transports of the young fowls between the two farm phases are included in the analysis. The breeding hen producing the eggs for hatching is not included in the analysis. We calculate a total of 5.1 million fowls being reared for layers hens in 2005.

In the early 1990s, basically all layer hens were held in cages and there was no organic production (Björck, C. pers. comm., 2009). Since no production data from real farms were available, we used the statistics of production and hen population, showing data of a layer hen population of 6.4 million head to produce 122 000 ton eggs, which correspond to an average production of 19.1 kg egg per layer hen and we calculated a total of 6.4 million young fowls reared for the production of layer hens.

4.3.1 Feed consumption

The major ingredients in feed for egg production in 2005 were grain, ~60 % (including by-products cereal production), proteins (mostly soymeal) 17 – 23 %, calcium carbonate ~10 %, fatty acids (most vegetable) ~4 %. Synthetic amino acids (mostly methionine and some lysine) are normally included at 0.2 % of total feed weight (Sonesson et al., 2008). Feed consumption was measured at 2.24 kg per kg egg in an indoor free range system and 2.06 kg feed per kg egg in a cage system (Sonesson et al., 2008). Economic calculations of egg production estimate the feed consumption at 2 kg feed per kg egg in cage systems, 2.2 kg feed per kg egg in indoor free range door systems and 2.3 kg feed per kg egg in organic outdoor free range systems (www.svenskaagg.se). With the present distribution of hens in these three production forms (see above), the average feed consumption in 2005 is calculated at 2.1 kg feed per kg egg. We estimate the overall feed consumption including waste at 2.2 kg feed/kg egg in 2005 corresponding to 225 000 ton feed.

Feed consumption for the chickens, from hatchery to the age of ~16 weeks when the young hen is delivered to the egg farm, was estimated at 5-6 kg feed per head (Bjorck, C., pers, comm., 2008). The overall consumption for production of 5.1 million layer hens (0-16 weeks) was estimated at 30 000 ton feed in 2005.

Feed statistics are aggregated for all poultry, so feed used in egg production is not reported separately from feed in slaughter chicken production. In 2005, approximately 494 000 ton feed for poultry was processed for poultry and of this, 19 000 tons was aimed for other production than chicken meat and eggs (SJV 2006a). With the help of feeding expertise, aggregated feed consumption was divided between the different fowl products and a total feed consumption of ~ 260 000 tons for egg production (productive layer hens and rearing of layer hens) in 2005 was divided at 162 000 ton grain and 98 000 ton concentrates. Also added was 5 000 ton peas produced at the farms (see Appendix 4).

After discussions with feeding expertise, we estimated that feed consumption per kg egg has been relatively stable between 1990 and 2005, and we calculated a feed consumption of 2.2 kg feed per kg egg in 1990 (Björck C., pers. comm., 2009) and of approximately 6 kg feed per young hen in production of the layer hen. In 1990, total feed consumption corresponded to 268 000 ton feed for layers hens and 38 000 ton feed for young hens, this was rounded off at a total of 310 000 ton feed (Appendix 4, Table 5).

In 1990, basically all grain was supplied by the feed industry as opposed to in 2005, when some farms used grain cultivated at the farms. Another important change during the 15 years is the protein supply (Björck C., pers. comm., 2009). In 1990, meat meal and fishmeal were important protein sources. Because of the BSE-crisis in the 1990s, restrictions in meat meal have made soymeal more frequent in the feed in 2005. Also, the use of synthetic amino acids was probably lower since feed components then had a more favorable amino acid composition, we estimated at an average of 0.15 % of total feed weight in 1990.

4.3.2 Manure production and emissions

Production of manure was calculated with SiM (SJV 2004), see Table 4.20.

Table 4.20 Total production of manure in the production of eggs 2005 and 1990

	2005, tons	*1990, tons*
Solid	64 500	213 000
Deep litter	61 300	12 000
Total	126 000	225 000

Emissions from manure management

CH_4 emissions from manure management were calculated with EFs according to the IPCC guidelines (2006) and the manure production according to Table 4.20. The emissions were estimated at 175 ton CH_4 in 2005 and 157 ton CH_4 in 1990, see Appendix 5. Direct emissions of N_2O from manure management were calculated at 4.8 ton N_2O in 2005 and 6 ton N_2O in 1990 (Appendix 6).

Nitrogen, production and losses

Nitrogen excreted by the fowls in the production of eggs was calculated with SiM (SJV 2004). A total of 0.6 kg N per layer hen (including the chicken raised to layer hen) was input data corresponding to 3 060 ton N in 2005 and 3 840 ton N in 1990. From this, emissions of ammonia, nitrous oxide and N-leaching caused by autumn application of manure, were calculated. The calculated N-losses are summarised in Table 4.21 and can be studied more thoroughly in Appendix 6.

Table 4.21 Total N production in manure from egg production, ammonia losses and ammonium-N (available for crop production) in 1990 and 2005

	2005, ton	*1990, ton*
N excreted in manure	3 060	3 840
Losses in stable and storage, NH_3-N	1 150	870
Losses during application, NH_3-N	310	840
Left after ammonia losses, total-N	1 610	2 125
NH_4-N, available for crop*	530	460

*after losses in field due to denitrification and additional N-leaching from manure that was applied in the autumn

The calculated ammonia emissions totalled at close to ~1 460 and ~1710 ton NH_3-N in 2005 and 1990, respectively. We estimated that 48 % and 44 % respectively of N excreted was lost as ammonia-N in 2005 and 1990. An increased use of deep litter-based systems in 2005 is the main explanation for higher ammonia emissions, despite lower production.

In the national emission statistics, ammonia emissions are reported aggregated for all poultry and it was reported as 1 730 ton NH_3-N in 2005 (SCB 2007). Here, we have estimated the loss from chicken meat and egg production at 2 400 ton NH_3-N, considerably higher than in the official statistics. The main explanation for this is that we have assumed a larger use of deep bedding as manure system in the poultry production which we base on discussions with the advisory service.

Direct N_2O emissions from soil are calculated with an EF of 0.01 kg N_2O-N per kg N applied as manure (IPCC 2006). The direct losses of N_2O from agricultural soils caused by the application of manure from fowls in egg production were estimated 30.1 ton N_2O in 2005 and 46.6 ton N_2O in 1990, Table 4.22.

Table 4.22 Direct N_2O emission from soils caused by manure from egg production, 2005 and 1990

	2005, ton	*1990, ton*
Total-N in hens manure, spread in crops	1 610	2 125
NH_3-N, lost in spreading	310	840
Direct emission from soil, N_2O	30.1	46.6

Calculated indirect losses of N_2O, caused by the emissions of ammonia and nitrate leaching from manure application are shown in Table 4.23. EFs are 0.01 kg N_2O-N per NH_3-N emitted and 0.0075 kg N_2O-N per kg N leached (IPCC 2006). Total indirect N_2O emissions were calculated at 23.4 ton N_2O in 2005 and 29.6 ton N_2O in 1990.

Table 4.23 Indirect N_2O emissions caused ammonia volatilization and N leaching due to hen manure handling and spreading

	2005, ton	*1990, ton*
Total ammonia losses, NH_3-N	1 455	1 710
Indirect N_2O emissions from ammonia-losses, N_2O	22.8	26.8
N-leaching caused by autumn application, N	52	237
Indirect N_2O emissions from leaching, N_2O	0.6	2.8

4.4 Beef

Data used for beef production are according to official slaughter statistics and average production data for the years 2005/06 as well as 1990/91 were used, see Table 4.24. Overall production is relatively stable and has decreased by roughly two percent over the 15 years.

Table 4.24 Yearly production of beef (ton meat with bone, carcass weight CW) 2005/06 and 1990/91

	Ton beef, adult	*Ton beef, calves*	*Total beef, tons*
2005	131 400	4 500	135 900
2006	132 900	4 500	137 400
Average 2005/06			136 700
1990	138 400	5 400	143 800
1991	132 000	3 700	135 700
Average 1990/91			139 800

Source: SJV 2008

4.4.1 Cattle population

Total cattle population (dairy sector also included) was around 1.71 million head in 1990/91 and this was reduced by around 100 000 heads in 2005/06. The most striking change during this time period is the reduction of the dairy cow population (by around 180 000 head, more than 30 %). Instead, the number of suckler cows has increased, from around 85 000 in the early 1990's up to 177 000 head 2006 (SJV 2006c, SCB 1991).

Figure 4.1 Cattle population in June, 1990 and 1991 and in 2005 and 2006, based on the yearly agriculture census

For 2005, there are robust slaughter statistics[7] (including e.g. breed, slaughter age, weights) and with the help of this statistics and the advisory service Taurus, we characterised the cattle population. Since a significant share of the cattle slaughtered in 2006, were raised and fed during 2005 and also, since there is a very small difference in the production between 2005 and 2006 (see Table 4.24), we used data for the beef production of the year of 2006, see Table 4.25, and the characterisation of beef cattle in individual categories shown in Appendix 7.

Table 4.25 Production of beef in 2006 from different cattle categories, number of slaughtered heads, slaughter age (months) and kg meat with bone (CW) per slaughtered head

Livestock category	*Slaughter age months*	*Slaughtered head*	*Total production, Ton CW*	*Kg CW, head^{-1}*
Calves	8.3	32 400	4 500	139
Adult cattle				
Bulls	16-19.5	180 900	58 800	325
Steers	26	50 100	15 400	307
Heifers	22-28	46 100	12 500	271
Cows, suckler		36 500	12 500	343
Cows, dairy		120 100	33 700	280
Cows, all		156 600	46 200	
Total, adult cattle		433 700	132 900	306
Total, all cattle		466 100	137 400	295

In 2006, the Swedish cattle population was close to 1.6 million cattle. A total of 466 000 head slaughter means that the turnover rate of the cattle herd was 0.29. Approximately 88 500 tons (64 %) of the production had its origin from the dairy sector, this “by-product” meat came from 150 000 bulls and steers, 14 000 heifers, all calves (32 000) and 120 000 culled dairy cows (see also Appendix 7).

In 2006, 12 200 of the slaughtered adult cattle were organic (certified), corresponding to close to 3 % of the total adult slaughtered cattle. Of these organic cattle, half were steers (calves coming from dairy

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[7] Statistics available at www.taurus.mu

production) and the rest were bulls and heifers from suckler cows. Only certified organic cattle are registered as organic beef in the statistics. A significant share of the suckler cows are only fed with non-fertilised fodder (mainly roughage feed) but not controlled for certification and therefore not reported as organic in the slaughter statistics (Lindahl, C., pers. comm., 2008). In practice, the production of beef closely resembling organic beef is larger than the statistics report.

The slaughter statistics from the early 1990´s are more aggregated than the one of today and in 1990/91, production was only reported as total quantity and total slaughtered heads from all adult cattle. From 1992, slaughtered head is divided for bulls, heifers and cows respectively (48 %, 10 % and 42 %) in the statistics (SJV 2008); we use these distributions from 1992 when dividing the total number of slaughtered adult cattle in 1990/91 into different categories, see Table 4.26 and Appendix 7.

In 1990/91, the cattle population was ~1.71 million heads (SCB 1991), around 551 000 heads were slaughtered per year (Table 4.26), thus the turnover rate was 0.32. In average, the cattle had lower slaughter weight age in 1990/91 and one explanation is the use of steers in beef production which have developed during the past years leading to higher slaughter age and weights. In 1990/91, around 243 000 male cattle were slaughtered (SCB 1991) to be compared with 231 000 in 2006, and more 20 % of the male slaughtered in 2005 were steers with an average slaughter age as high as 26 months. A larger share of the total cow population was slaughtered in 1990/91 compared to 2005/06 probably because larger share of the cow population was suckler cows in 2005 and these cows have longer life than dairy cows.

Table 4.26 Production of beef in 1990/91 (average two years) from different cattle categories, number of slaughtered head and kg meat with bone (CW) per slaughtered head

Livestock category	*Slaughtered head*	*Total production, ton CW*	*Kg CW head^{-1}*
Calves	45 000	4 600	103
Adult cattle			
Bulls	243 000		
Heifers	51 000		
Cows	212 000		
Total, adult cattle	506 000	135 200	267
Total, all cattle	551 000	139 800	254

* Distribution between bulls, heifers and cows assumed to be as 1992 (no data available 1990/91)

By-products from dairy production made up a very significant share of the Swedish beef production in the early 1990s; we estimated it to be around 85 %, see distribution of different livestock categories in Appendix 7.

4.4.2 CH_4 emissions from enteric fermentation

The EFs for enteric fermentation used were based on a model suggested and calculated by Lindgren (1980) and Bertilsson (2001) and further elaborated by Berglund et al (2009), see Table 4.27.

Table 4.27 Emission factors used for calculating CH_4 emission caused by enteric fermentation from beef cattle population

Livestock category	*Kg CH_4 hd^{-1} yr^{-1}*	*Comment*
Suckler cow	72 / 82	Light / heavy breed
Heifer	53	Calving ~24 month
Bull, extensive roughage fed	59	Slaughter age, 19-22 month
Bull, intense roughage fed	61	Slaughter age, 16-17 month
Bull, concentrate fed	56	Slaughter age, 14-15 month

Calculations of CH_4 from enteric fermentation are shown in Appendix 8. Methane emissions were ~35 000 ton CH_4 in 1990/91 and increased to ~46 000 ton CH_4 in 2005/06. The difference was mainly due to a bigger share of the beef cattle population coming from suckler cows in 2005/2006.

4.4.3 Feed consumption

Beef is the most difficult animal product to make estimates of total fodder consumption. A large share of total feed intake is roughage fodder and pasture, produced and consumed on the farms with no systematic weighing and monitoring. In dairy production, there is an extensive feed advisory service and rather uniform feeding strategies, in contrast to beef cattle farms where there is a much larger variety feeding practices and also less documentation. Based on the slaughter statistics from 2005/06, where data on breed and slaughter ages are important information, feeding expertise from the advisory service calculated feed consumption for the different categories in cattle population, see Appendix 7. These calculations were based on net feed intake, we added extra fodder (especially of roughage fodder) to compensate for losses, waste and over-feeding in production. In Appendix 4, estimates of concentrate (including grain) in beef production are summarised.

Feed consumption estimates were carried out in a similar way for 1990/91, however, due to lack of data these estimates are even more uncertain than the ones for 2005/06, see Appendix 7. Data on consumption of concentrate feed are summarised in Appendix 4.

4.4.4 Manure

Production of manure in stables was calculated with SiM and the distribution of manure between different indoor manure systems and grazing was made after discussions with advisory service and data from statistics (SCB 2006a). Suckler cows and heifers were estimated to have a grazing period of 6 months, and steers (a large cattle category in 2005 but not in 1990), 5.5 months. Straw-based deep bedding increased in steer and suckler cow production where it is today more common to have a free range system on deep litter.

Table 4.28 Total production of manure in the production of beef, 2005 and 1990

System	*% DM*	*2005, ton*	*1990, ton*
Solid Manure	17	97 000	436 000
Urine		78 000	392 000
Liquid/slurry	9	2 000 000	2 100 000
Deep bedding		927 000	465 000
Total		3 100 000	3 400 000

Emissions from manure management

Calculations of CH_4 emissions are shown in Appendix 5. We assumed an average production of 0.8 ton volatile solids (VS) per head and year for whole beef cattle population based upon a beef cow production of around 0.95 ton VS per head and yr and a heifer 0.3 ton VS per head and year <12 months and 0.82 ton VS per head and year between 12-24 months (Berglund et al, 2009). We calculated that CH_4 emissions from manure management increased from ~5 550 ton in 1990 to ~7 200 ton CH_4 in 2005. A larger share of manure as straw-based deep bedding is the main explanation for this increase.

Losses of nitrous oxide from manure storage were estimated at 175.1 ton N_2O in 1990 and 216.8 ton N_2O in 2005 (Appendix 6). Also here, an increased use of deep bedding is the main explanation for this increase.

Nitrogen, production and losses

Losses of ammonia in beef production were calculated with SiM, all calculations are shown in Appendix 6, and estimated losses are summarized in Table 4.29. Ammonia emissions from manure dropped during grazing were calculated with an EF of 8 % of excreted N. Assumptions on application techniques used were based on statistics (SCB 2006a) and discussion with the advisory services. We assumed that 70 % of the manure application was done in grassland and 30 % in grain crops, the same distribution for the two years.

Table 4.29 Total N production from cattle beef production, ammonia losses and ammonium-N (available for crop) in 1990 and 2005

	2005, ton N	*1990, ton*
N excreted in manure in stable, total	20 000	20 000
Losses, grazing, NH_3-N	720	460
Losses in stable and storage, NH_3-N	4 900	3 750
Losses during application, NH_3-N	2 850	3 500
Left after ammonia losses, total-N in manure (excluding manure dropped in pastures)	12 000	12 600
NH_4-N, available for crop*	3 000	3 300

*after losses in field due to denitrification and additional N-leaching from manure that was applied in the autumn

Total ammonia losses are estimated at 7 700 ton NH_3-N in 1990 and 8 500 ton NH_3-N in 2005, this is around 30 % of total $N_{excreted}$ with no change between the years. Emissions from manure application have decreased during the time-period but instead emissions from stables and storage have increased, mainly explained by the increased use of straw-based deep bedding.

Direct N_2O emissions from soils caused by manure spreading and from the manure dropped during grazing are shown in Table 4.30. Direct emissions are estimated at 516 ton N_2O in 2005 and 434 ton N_2O in 1990. More beef cattle grazed in 2005 compared with 1990 and the EF is 2 % for this activity compared to 1 % for N in manure applied mechanically.

Table 4.30 Direct N_2O emission from manure application and manure dropped in pastures, beef cattle 2005 and 1990

	2005, ton	*1990, ton*
Total-N in manure, applied in crops	12 000	12 600
NH_3-N, lost in application	2 850	3 500
Direct emission from soil, N_2O	233.1	252.8
Total-N in manure, dropped in pasture	9 000	5 700
Direct emission from pasture	283	181

Indirect losses of N_2O, caused by the emissions of ammonia and nitrate leaching from manure applied in autumn were calculated at 137.2 ton N_2O in 2005 and 129.9 ton N_2O in 1990, see Table 4.31.

Table 4.31 Indirect N_2O emissions caused by ammonia volatilization and additional N leaching caused by autumn application of beef cattle manure

	2005, ton	*1990, ton*
Total ammonia losses, NH_3-N	8 500	7 700
Indirect N_2O emissions from ammonia-losses, N_2O	133.4	120.9
N-leaching caused by autumn-spreading, N	320	765
Indirect N_2O emissions from leaching, N_2O	3.8	9

4.5 Milk

Total milk production (milk delivered at dairies) decreased by almost 300 000 tons ECM[8] (between 1990 and 2005, approximately 8 % (SJV 2008). Over these 15 years, there has been a remarkable increase in milk production, from around 6.1 to 8.2 ton ECM per dairy cow and year. This resulted in

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[8] ECM=energy corrected milk

a strong decrease of the dairy cow herd, comprising 183 000 fewer head in 2005 compared to 1990. Also a scale of specialization has taken place, in 1990 there were close to 25 000 dairy farms and 71 dairies and this was reduced to 8 600 farms and 37 dairies in 2005 (SCB 1991, SJV 2006c).

Table 4.32 Total volume milk delivered at dairies, fat- and protein content, number of dairy cows in production and milk yield per cow in the years around 1990 and 2005

Year	*Delivered milk, dairies, ton*	*Fat, %*	*Protein, %*	*Delivered milk, ton ECM*	*Dairy cows, head*	*Delivered kg ECM milk head^{-1}*
1990	3 432 000	4.31	3.36	3 551 000	576 409	6 160
1991	3 130 000	4.33	3.37	3 249 000	528 212	6 150
2004	3 229 000	4.25	3.38	3 322 000	403 702	8 230
2005	3 163 000	4.25	3.38	3 254 000	393 263	8 270
2006	3 130 000	4.22	3.38	3 209 000	386 204	8 310

In 2005, 155 000 tons organic milk were produced corresponding to 5 % of total milk deliveries at dairies (www.svenskmjolk.se). In 1990, only a handful of farms produced organic milk.

4.5.1 Dairy cattle population

The dairy cattle herd for milk production in 2005 and 1990 is shown in Table 4.33 based on the agricultural census (SJV 2006c). Approximately 38 % of the dairy cows are yearly culled, and replaced by a heifer. Due to increasing milk yield per cow, total number of dairy cows is reduced by approximately 2 % yearly. Thus around 140 000 heifers were needed to replace the culled cows in 2005. The heifer is in average 28 month when giving birth to her first calf. A total of ~327 000 heifers in the 0 – 28 months are needed over a year for replacement, this is rounded off to 330 000 head to compensate for some mortality.

Table 4.33 Cattle population for milk production in 2005

	2005, heads	*1990, heads*
Dairy cows	393 268	576 409
Replacement heifers	140 000	200 000
Replacement heifers, all female animal 0-28 month	330 000	470 000

In 1990, the dairy cow herd included more than 575 000 head (SCB 1991). We assume the same rate of culled cows in 1990 as today (38 %). In the early 1990´s there were a significant reduction in number of cows due to over production (e.g. 8 % less dairy cows between 1990 and 1991) so we estimate that around 200 000 heifers were needed to replace the culled cows in 1990 corresponding to around 470 000 heifers in all ages between 0 – 28 months.

4.5.2 CH_4 emissions from enteric fermentation

Models for calculating methane emissions from enteric fermentation are based on the energy intake in feed. The calculations in the IPCC methodology are based on net energy intake. In the Swedish feeding advisory system, energy intake has been calculated as metabolized energy, this is however currently being changed since a new feeding advisory system, NORFOR, is being introduced using net energy. So far, methane emissions have been calculated with a national model based on metabolized energy (Lindgren 1980; Bertilsson 2001). Until NORFOR is fully introduced which will simplify the calculations with the IPCC methodology (using net energy), the national model is used where important input parameters are feed intake and digestibility of the feed. Emission factors for dairy cows and heifers according to this model are shown in Table 4.34 and based on calculation in Berglund et al (2009). Methane emissions are calculated at a higher production level than produced (delivered) milk at the dairies. According to the milk control, the actual milk production per cow is higher than delivered milk to dairies, since some of the milk is used for feeding the calves, also when the cows are treated with medicines, the milk is not allowed to be delivered. Emission factors for the dairy cows are therefore set at the production of 7 000 kg ECM in 1990 and 9000 kg ECM in 2005 (Table 4.34).

Table 4.34 Emission factors for methane losses from enteric fermentation, dairy population

Livestock category	*Kg CH_4 hd^{-1} yr^{-1}*
Dairy cow, prod 7000 kg ECM, 1990	128
Dairy cow, prod 9000 kg ECM, 2005	135
Replacement heifer, first calf at 28 months in average	53

Calculations are shown in Appendix 8. Methane emissions from the milk production decreased from 98 700 ton in 1990 to 70 600 ton CH_4 in 2005, i.e. with 28 %. This is an effect of the strong reduction of the number of dairy cows during the 15 year period.

4.5.3 Feed consumption

Estimating feed consumption in milk production is more difficult than for non-ruminants since a large proportion of the cattle´s feed intake is pasture and silage. The consumption of roughage fodder by the cows is seldom weighed and the yields of grass are not either weighed, nor the losses. This is in sharp contrast to feed consumption of slaughter chicken and hens where a very large share of the feed is delivered from feed industry, economical transactions are done and therefore book keeping accounts provide good data for feed consumption. Not only grass (as pasture, silage and hay) is grown at the farms but also a significant share of the grain fed to the cattle. Thus, a substantial share of the dairy cattle feed ration is produced and consumed at the farm without regular measurements and this makes it difficult to make estimates of the average feed intake of dairy cattle. A further difficulty is also that statistics for concentrate feed delivered from feed industry gives aggregated information for dairy and beef cattle.

However, there is an extensive feed advisory service in the dairy sector and on a large number of dairy farms, feed consumption and economy are followed with software-programs (e.g. IndividRam) which provide reliable data on feed consumption levels. The Swedish Dairy Association recently investigated the potentials for increased use of regionally produced feed in the dairy sector and in this work a thorough survey was made of feed consumption with the help of statistics, interviews with feed industry and data and expert knowledge from the advisory service (Emanuelson et al., 2006). In this investigation, the total feed consumption of dairy cows and replacement heifers for the year 2004 was calculated and this investigation is the base for our estimation of feed consumption in 2005. When estimating the consumption of concentrates (not grain), the official feed statistics for 2004-2006 have been the basis (see section 3.4.1). The sum of concentrate estimated to be used by dairy and beef cattle equals the overall statistics, and it is the milk sector that consumes the absolute largest part, around 85 % of sold concentrates to cattle in 2005 (SJV 2006a).

Table 4.35 shows the estimated feed consumption for the dairy cattle in 2005 in total figures and average use per head. Super pressed pulp is common in the south due to shorter transporter from the sugar industry but not used at all in the north of Sweden. Concentrates include beet fibres, rape seed meal, soy meal and other ingredients. In Appendix 4, a more detailed description is given on the ingredients in the concentrate feed, based on the official feed statistics (SJV 2006a).

Table 4.35 Estimated feed consumption in milk production in 2005

	Kg per cow	*Kg per heifer*	*Total, tons*
Grass, silage, hay, pasture (DM)	3 200	1 550	1 770 000
Maize silage (DM)	100		39 000
Super pressed pulp (DM)	175		69 000
Straw	75	65	51 000
Grain	2 000	400	920 000
Concentrates	1 753	*	689 000
Minerals, salt etc	76	*	30 000
Calf feed			2 275

* included in dairy cow

The estimation of feed consumption in 1990 was based on economic cost estimates from (SLU 1989), expert estimations (Spörndly, R., pers. comm., 2009) and the official feed statistics (Lantbruksstyrelsen 1990, SCB 1991; 1992). The statistics are, however, much briefer in 1990 than in 2005 and there is no information on the origin of ingredients so we had to do some assumptions. In Table 4.36, the final estimated feed consumption is shown, concentrate feed is summarised in Appendix 4.

Table 4.36 Estimated feed consumption in the milk production in 1990

	Kg per cow	*Kg per heifer*	*Total, tons*
Grass, silage (DM)	1 600	1 110	1 440 000
Grass, hay (DM)	550		320 000
Grass, pasture (DM)	810	560	730 000
Straw	80		46 000
Grain	2 200	200	1 360 000
Concentrates	994	*	573 000
Minerals, salt etc	29	*	16 700
Calf feed			4 725

* included in dairy cow

4.5.4 Manure

Total production of manure was calculated with data on manure production according to SiM. The distribution of manure in different systems in 2005 were based on statistics (SCB 2006a) and on data from farms inventoried for LCA studies of current milk production (Cederberg & Flysjö, 2004; Cederberg et al, 2007). For 1990, manure management systems were distributed according to the NIR report of GHG emissions (Naturvårdsverket, 2009). In 2005, ~70 % of the manure was handled as slurry and 30 % as solid and some straw-based deep bedding for heifers (SCB 2006a). Average grazing period was estimated at 2.5 month for the dairy cows which was based on experts in the advisory service and data from current LCA-studies of milk based on practices on real farms. Average grazing period was 5.5 month for the replacement heifers for both years.

The distribution of manure storage in 1990 was 70 % of the manure handled as solid and 30 % as slurry. Over 80 % of the heifer manure was in solid (including minor amounts as deep bedding) in 1990. The grazing period for cows was estimated to be longer (3.5 months in average) in 1990 based on the advisory service (Persson, A-T., pers. comm., 2009).

Total manure production from dairy cattle has decreased due to a much smaller dairy cow herd, see Table 4.37. The slurry production has increased by close to 20 % while there has been a very strong decrease of solid manure and urine.

Table 4.37 Total production of manure in milk production 2005 and 1990

System	*% DM*	*2005, tons*	*1990, tons*
Solid Manure	17	1 123 000	3 302 000
Urine		1 023 000	3 010 000
Liquid/slurry	9	8 112 000	6 847 000
Deep bedding		42 700	60 900
Total		10 300 000	13 200 000

Emissions from manure management

Methane emissions from manure management were calculated according to IPCC (2006) and distributions of manure between different systems as in Table 4.34; see Appendix 5. In 2005, we calculated a production in the manure of 1.9 ton volatile solids (VS) per dairy cow and 1.8 ton VS per dairy cow in 1990. Berglund et al (2009) calculated VS in manure at 0.3 ton per heifer*yr < 1 yrs old and 0.82 ton per heifer*yr > 1 yr, we estimated an average of 0.6 per heifer and year both years.

We estimated that CH_4 emissions from manure management increased from 6 600 ton in 1990 to 8700 CH_4 ton in 2005. The larger share of manure stored as slurry in 2005 is the main explanation for this change. New Swedish research indicate that emissions calculated with the IPCC methodology probably are too high in Nordic (colder) climate conditions and that the methane conversion factor should be lowered for cattle slurry (Rodhe et al, 2009), this is further discussed in section 6.3.

Direct emissions of nitrous oxide from manure management were calculated at 355 ton N_2O in 2005 and 364 ton N_2O in 1990, calculations see Appendix 6. Less nitrogen excreted due to fewer animals is the main explanation for this reduction.

Nitrogen, production and losses

Losses of ammonia in milk production were calculated with SiM, all calculations are shown in Appendix 6 and estimated losses are summarised in Table 4.38. Ammonia emissions from manure dropped when grazing were calculated with EF 8 % of excreted N. EFs for ammonia losses in stable, storage and during manure application come from the database of SiM. Assumptions on application techniques were based on statistics (SCB 2006a) and discussion with the advisory services. We have estimated that 70 % of the manure is applied on grasslands and 30 % in grain crops, the same distribution for the two years.

Table 4.38 N production in manure from dairy cattle, ammonia losses and ammonium-N (available for crops) in 1990 and 2005

	2005, tons	*1990, tons*
N excreted in manure in stable, total	50 000	60 000
Losses, grazing, NH_3-N	935	1 480
Losses in stable and storage, NH_3-N	5 600	8 900
Losses during spreading, NH_3-N	11 000	12 300
Left after ammonia losses, total-N in manure (excluding manure dropped in pastures)	33 600	38 700
NH_4-N, available for crop	15 600	11 250

Total ammonia losses are estimated at 22 700 ton NH_3-N in 1990 and 17 500 ton NH_3-N in 2005. This is a decrease of approximately 20 % which foremost is an effect of the lower cattle herd for milk production. The estimated ammonia losses correspond to 28-29 % of total-N excreted both the years and this suggests that the reduction of ammonia emissions in milk production is an effect of fewer animals rather than increased overall efficiency in the whole chain of handling manure from stable until application.

In the national statistics, ammonia losses from all cattle are reported as 22 100 ton NH_3-N in 2005 (SCB 2007), dairy and beef sector are not reported separately. In this study, we have calculated a total of approximately 26 000 ton NH_3-N as ammonia losses in 2005 for the whole cattle population (producing beef and milk). Explanations for the discrepancy are for example that we have calculated larger use of straw-based deep bedding in beef production than the official statistics and a shorter grazing period for the dairy cows (leading to higher ammonia emissions from stable and storage).

Estimated direct N_2O emissions from soils origin from manure application and from the manure dropped during grazing are shown in Table 4.39; 1 068 ton N_2O in 2005 and 1 382 ton N_2O in 1990 which is a significant reduction. Less N production in manure because of the smaller dairy cattle herd in 2005 is the main reason for the reduction.

Table 4.39 Direct N_2O emission from manure spreading and manure dropped in pasture, dairy cattle 2005 and 1990

	2005, tons	*1990, tons*
Total-N in manure, applied in crops	33 600	38 700
NH_3-N, lost in application	11 000	12 300
Direct emission from soil, N_2O	700	800
Total-N in manure, dropped in pasture	12 000	18 500
Direct emission from pasture, N_2O	368	582

Calculated indirect losses of N_2O, caused by the emissions of ammonia and nitrate leaching from manure handling are shown in Table 4.40, calculated with EFs 0.01 kg N_2O-N per NH_3-N emitted and 0.0075 kg N_2O-N per kg N leached (IPCC 2006). Total indirect N_2O emissions from the dairy cattle were 285 ton N_2O in 2005 and 376 ton N_2O in 1990.

Table 4.40 Indirect N_2O emissions caused ammonia volatilization and N leaching due to manure handling and application of dairy cattle manure

	2005, tons	*1990, tons*
Total ammonia losses, NH_3-N	17 500	22 700
Indirect N_2O emissions from ammonia-losses, N_2O	275	356
N-leaching caused by autumn application, N	850	1 700
Indirect N_2O emissions from leaching, N_2O	10	20

5 Results

Before presenting the results, a summary of the changes in livestock production between 1990 and 2005 is shown in Table 5.1. With the exception of poultry meat, all other animal products decreased in volume between 1990 and 2005.

Table 5.1 Summary of Swedish livestock production 1990 and 2005

	1990	*2005*	*Change, %*
Pork, ton CW	290 795	275 130	-5.4
Chicken meat, ton CW	46 400	98 600	+112
Beef*, ton CW	139 800	136 700	-2.2
Milk, ton ECM	3 551 000	3 254 000	-8.4
Egg, ton	122 000	102 000	-16

* Beef production is an average for production in 1990/91 and 2005/06 respectively

In Appendix 9, the results for the products´ life cycle GHG emissions are presented in detail and divided in subsystems between feed production (grain, concentrate feed, roughage fodder and feed transports), stable (energy use), manure management (storing of manure), manure application (application of manure), indirect N_2O emissions (from ammonia emissions and nitrate leaching caused by manure application in autumn) and finally enteric fermentation.

Figure 5.1 shows the total results; in 1990, total GHG emissions from the Swedish livestock production were ~8.5 Mtons CO_2-equivalents (CO_2e) and emissions decreased to 7.3 Mtons CO_2e in 2005, i.e. a reduction of close to 14 %, or approximately 1 % per year.

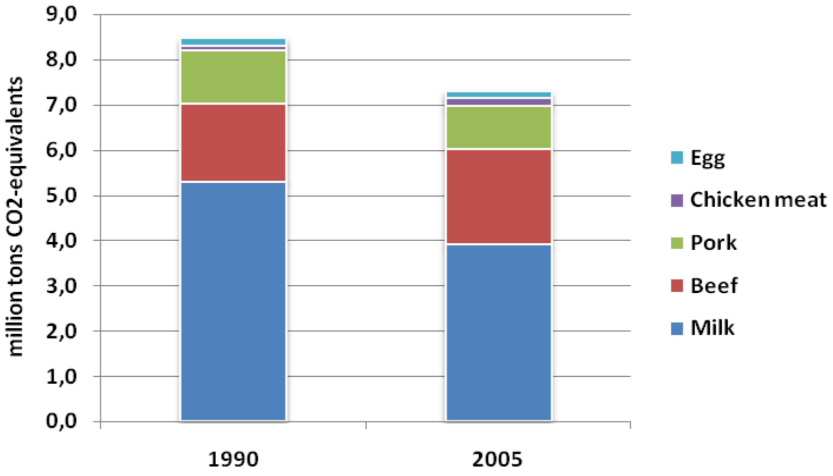

Figure 5.1 Total emissions of greenhouse gases (million tons CO_2e),from animal production in Sweden in 1990 and 2005 (NB no allocation between milk and beef)

Production of milk and beef represents 82 % of emissions in 2005, pork 13 % and poultry products being the source of only around 5 % of total emissions. However, cattle production has by far had the largest emissions cuts; in the production of milk and beef, emissions were decreased by approximately 1 Mtons CO_2e between 1990 and 2005.

5.1 Pork

Pork production became more efficient and the emissions decreased from ~4 kg to 3.4 CO_2e kg CW^{-1} between 1990 and 2005, see Figure 5.2, i.e. a reduction by 15 %. The largest reduction was for fossil

CO_2 of which emissions were almost 25 % lower in 2005 than in 1990. Production of feed generates the most emissions in pork´s life cycle; in 2005 more than 50 % of total emission is sourced in feed production followed by manure management (32 %) and manure application (8 %), see Appendix 9.

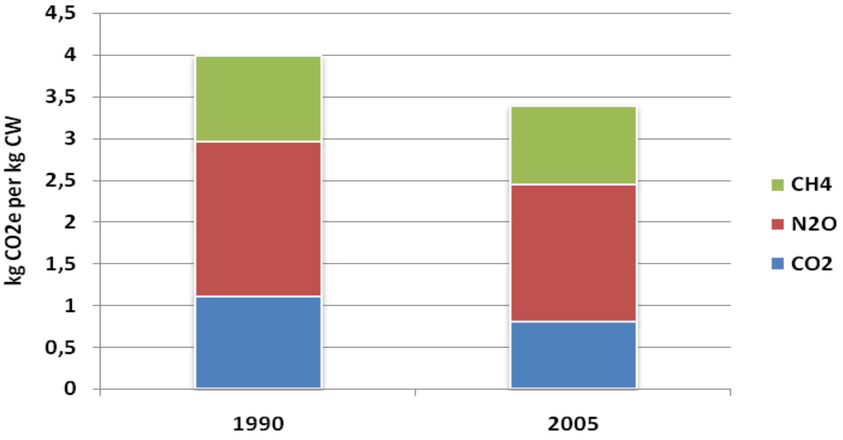

Figure 5.2 GHG emissions per kg pork meat (kg CO_2e per kg CW) in 1990 and 2005

Emissions from the total Swedish pork production were reduced from ~1.16 to ~0.93 Mtons CO_2e between 1990 and 2005, corresponding to an overall reduction of approximately 20 % (Figure 5.3). Emissions of fossil CO_2 and N_2O decreased between the two years by 97 000 and 95 000 tons CO_2e, respectively. Improved efficiency in production and consumption of feed, in manure management and also a lower production in 2005, explain most of the pork sector´s emission cut. We estimate that total emissions were lowered by approximately 175 000 ton CO_2e due to efficiencies in production (less GHGs emitted per kg pork) and that around 55 000 ton CO_2e was due to lower production volumes.

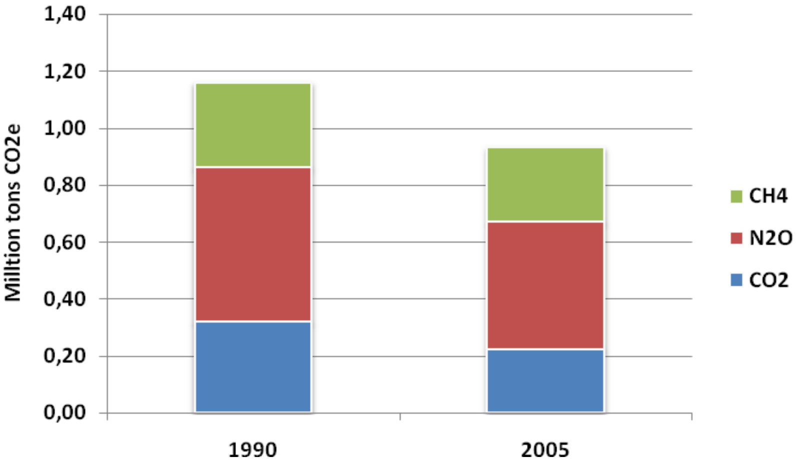

Figure 5.3 Total GHG emissions, million tons CO_2e, from Swedish pork production 1990 and 2005

5.2 Chicken meat

In the production of chicken meat, GHG emissions decreased between 1990 and 2005 by ~22 %, from 2.5 to 1.9 kg CO_2e kg CW^{-1}, see Figure 5.4. The largest emission cut was for fossil CO_2 where emissions were 35 % lower per kg CW in 2005 compared with 1990 (see also Appendix 9). During the 15 year period, there has been an on-going switch from oil to bio-fuels for heating of the chicken stables in Sweden which is the main cause for the reduction of GHGs emitted per kg meat. Efficiency gains in feed production also contributed.

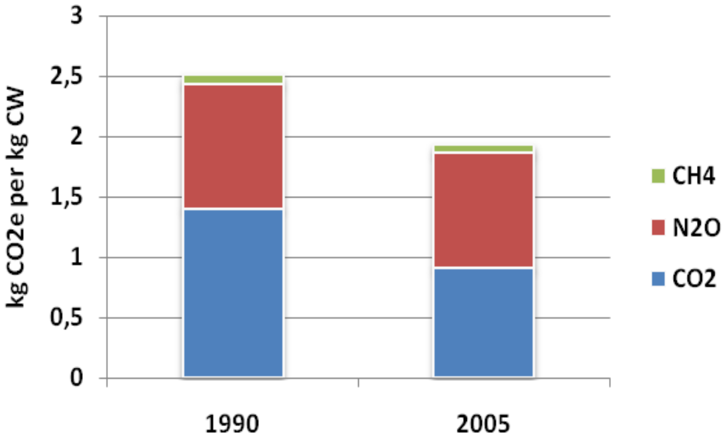

Figure 5.4 GHG emissions per kg chicken meat (kg CO_2e per kg CW) in 1990 and 2005

The overall production of chicken meat in Sweden has doubled (although from a very low level) over the past 15 years and therefore total emissions from the chicken meat sector has increased, see Figure 5.5. However, due to the efficiency measures in production, total emissions increased by 63 % (from 116 000 to 190 000 ton CO_2e) while production increased by 112 % (compare Table 4.12).

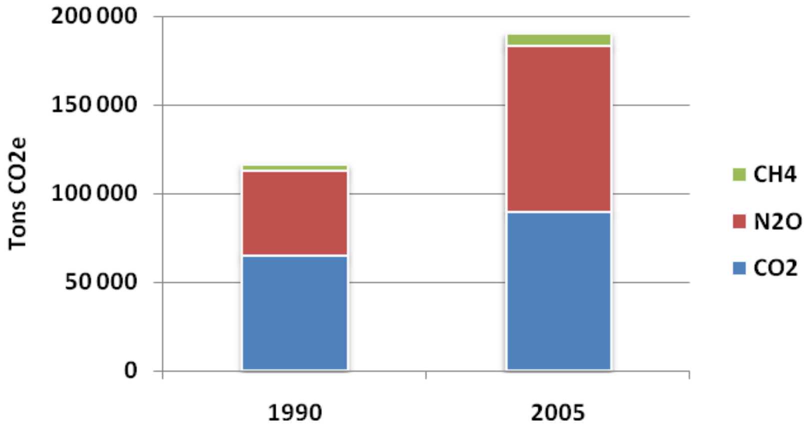

Figure 5.5 Total GHG emissions, tons CO_2e, from Swedish chicken meat production 1990 and 2005

5.3 Eggs

The emissions per kg egg were unchanged during the studied time-period, corresponding to ~1.4 kg CO_2e per kg at the farm-gate (Figure 5.6). Feed production represents almost 85 % of these emissions, and between 1990 and 2005 the strategy of protein feeding changed significantly. In 1990, animal protein (meat meal and fish meal) and also peas were the major protein components but in 2005, soymeal was the dominant protein feed ingredient. This resulted in higher emissions from protein concentrates in 2005 compared to 1990, but parallel to this, there were lower emissions from the production of the feed grain. The change in protein source resulted in higher N_2O emission per kg eggs in 2005, but in total, feed production became more efficient leading to reduced fossil CO_2 emissions (Appendix 9).

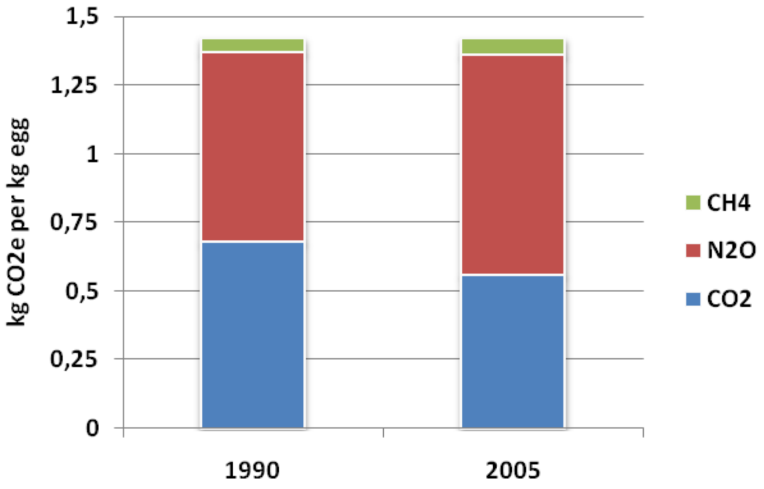

Figure 5.6 GHG emissions per kg eggs (kg CO_2e per kg eggs) in 1990 and 2005

Swedish egg production decreased by ~15 % between and 1990 and 2005 and from this follows that total GHG emissions from the egg sector decreased by ~28 000 ton CO_2e, see Figure 5.7.

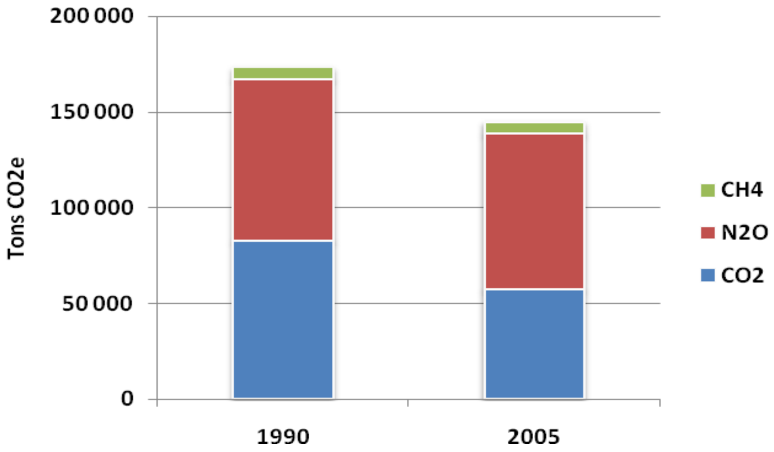

Figure 5.7 Total GHG emissions, tons CO_2e, from Swedish egg production 1990 and 2005

5.4 Milk and beef

Beef is closely linked to milk production in Sweden; in 1990 almost 85 % of beef had its origin in the milk sector and this was reduced to close to 65 % in 2005, being an effect of the considerable reduced dairy cow herd. Before presenting the results for milk and beef separately, total emissions from milk and beef production are shown in Figure 5.8. In 1990, total emissions from milk and beef production were estimated at ~7 Mtons CO_2e, which was reduced to ~6Mtons CO_2e in 2005. We estimate that around 60 % of this reduction is due to efficiency in production and 40 % is due to decreased production.

CO_2 and N_2O emissions were reduced by around 20 % each between the two years while CH_4 emissions were reduced by less than 10 % from milk and beef sector together. The lower emission cut of CH_4 is explained by changes in the cattle population as 130 000 fewer dairy cows were held in 2005 while in the same time, the suckler cow herd increased by 100 000 head to compensate a lower by-production of beef in milk production. In contrast to methane, emissions of CO_2 and N_2O were substantially reduced in the cattle sector, mainly due to that the overall feed intake and production is done with less GHG emissions in 2005.

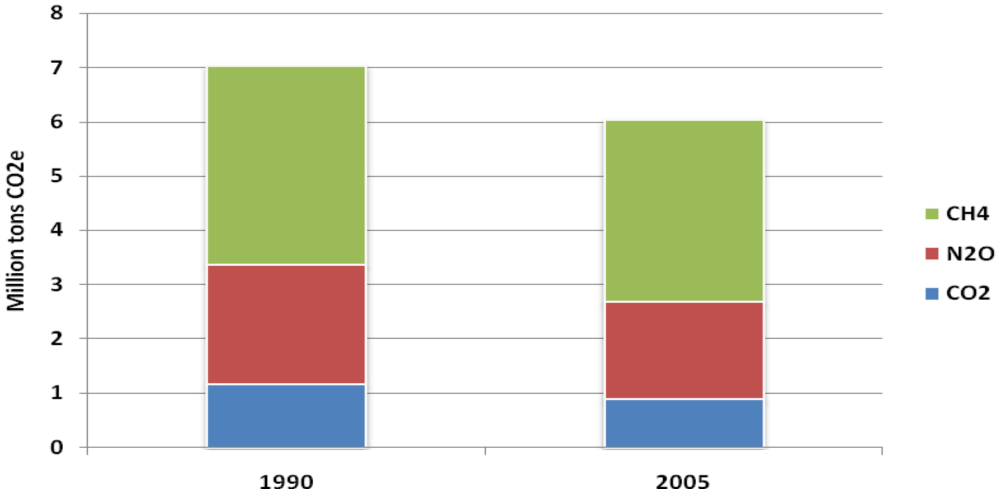

Figure 5.8 Total GHG emissions, million tons CO_2e, from production of milk and beef 1990 and 2005

In most LCA studies, the allocation of resources and emissions between milk and meat in milk production systems has been done with economic allocation or a physical allocation. Using economic allocation leads to that that around 90 % of the emissions are allocated to milk and 10 % to beef. A physical allocation usually distributes around 85 % to the milk.

Here we used 85 % allocation for both years, and the results for per kg milk is shown in Figure 5.9. With this allocation factor, GHG-emissions correspond to 1.27 kg CO_2e per kg ECM in 1990 which is reduced to 1.02 in 2005; see also Appendix 9 where all results are presented without any allocations between milk and beef. The emission cut of close to 20 % in milk production is mainly explained by a higher production of milk per dairy cow in 2005.

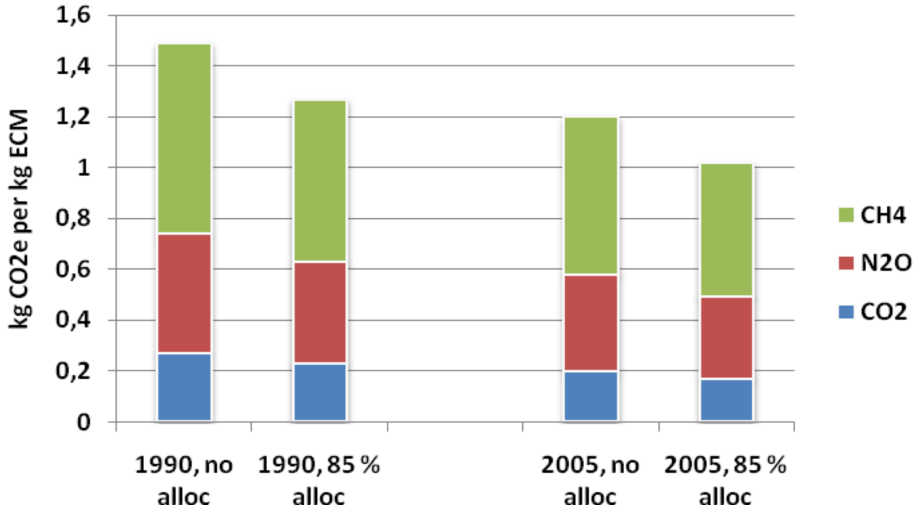

Figure 5.9 GHG emissions per kg milk (kg CO_2e per kg ECM) in 1990 and 2005. The results are presented with no allocation between milk and meat and with 85 % allocation to milk.

While the milk production significantly decreased its GHG emissions, beef production increased the emissions, between the two years, see Figure 5.10. Also here, the results are presented both with no allocation between milk and beef and when 15 % of emissions in the dairy sector are allocated to beef to account for the beef by-products (culled cows and surplus calves) from milk production. When the allocation factor in milk production of 85 % to milk and 15 % to beef is applied, this results in GHG emissions from the Swedish beef production corresponding to 18 kg CO_2e CW^{-1} in 1990 and 19.8 kg

CO_2e CW^{-1} in 2005, see Figure 5.10. This increase is due to that in 1990 around 85 % of the Swedish beef production had its origin in milk production (culled dairy cows and surplus bull calves) while this was reduced to ~65 % in 2005 due to a lower dairy cow population.

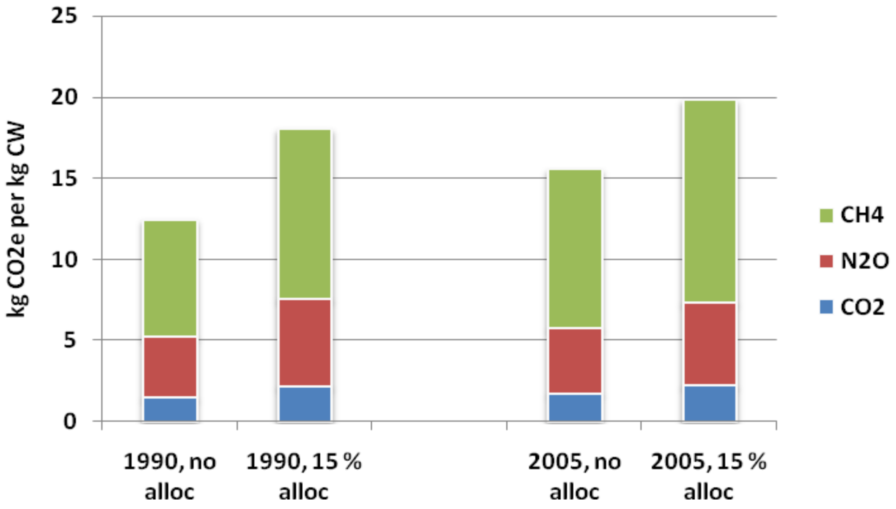

Figure 5.10 GHG emissions per kg beef (kg CO_2e per kg CW) in 1990 and 2005. The results presented with no allocation and with 15 % allocation to beef from milk production

Although the emissions per kg beef has increased between 1990 and 2015, it must be emphasized again that there was an overall emission reduction in the dairy and beef sector corresponding to 1 Mton CO_2-equivalents, shown in Figure 5.8.

6 Discussion

6.1 Emission trends

According to the official statistics on GHG emissions (NIR), the agriculture sector has reduced its emission by 830 000 ton CO_2e, totalling 8.55 Mtons in 2005 (Naturvårdsverket, 2009). In this study, we have estimated a larger emission reduction for the livestock production in Sweden, corresponding to 1.2 Mton CO_2e and totalling 7.3 Mtons in 2005 (see Figure 5.1). However, the numbers are not comparable since system boundaries are set differently; NIR includes only methane and nitrous oxide emitted in Sweden and assess the whole agricultural sector (also vegetable production). Here, we have used LCA methodology calculating GHG emissions from the whole livestock production chain, also including emissions embedded in imports (e.g. imported feed) and emissions from energy use, mainly fossil CO_2. Although there are differences in relative and absolute numbers when comparing the results presented in this study and in NIR, the emission trend is clear – livestock production and agriculture in Sweden have reduced their GHG emissions over the past 15 years. Here, we estimate an emission cut of around 14 % between 1990 and 2005 in the production of meat, milk and eggs and in 2005, life cycle GHG emissions from the livestock production corresponded to slightly more than 800 kg CO_2e per capita in Sweden. As a comparison, NIR this year reported a total GHG-emission (excluding LULUCF[9] sector) of 7.1 t CO_2e per capita in Sweden (Naturvårdsverket, 2009).

The positive emission trends in the livestock production form a sharp contrast to the trends in Swedish consumption of animal products during the studied time-period. Life cycle GHG emissions from the overall consumption of meat, dairy products and eggs increased from 8.1 to ~10 Mton CO_2e between 1990 and 2005, corresponding to a per capita emission of approximately 1 100 kg CO_2e in 2005. A very strong increase of meat consumption based on imports explains the almost 25 % growth of consumption-related emissions during the 15 year period; this is further discussed in a separate report by Cederberg et al (2009).

Some of the emission cuts in Swedish livestock production between 1990 and 2005 can be explained by a lowered production; with the exception of poultry meat (+112 %), production has diminished since 1990 (milk -8 %, beef -2 %, pork -5 %, eggs -16 %). If we assume that the production loss between 1990 and 2005 would have been produced with the same GHG emissions per unit as the average production in 2005, we can divide the emission reduction into two categories: *i*) lowered GHG emission per unit (i.e. a more "climate-efficient production"), and *ii*) changed volumes (lowered production). Approximately twothirds of the total emission reduction (1.2 Mton CO_2e) can be explained by a more efficient production (less GHG emission per produced kg meat, milk and egg) while around one third can be explained by the overall reduced animal production in Sweden.

Emissions from cattle production are by far most important, more than 80 % of the Swedish livestock production´s emissions emanated from beef and milk in 2005. But it is also in these sectors that the biggest emission cut has been carried out, we calculate it at around 1 Mton CO_2e between 1990 and 2005, of which around 60 % is due to more efficient production and 40 % due to lower production volumes. The efficiency gain is predominantly done in dairy production, annual milk production increased from 6.1 to 8.2 ton milk per dairy cow between 1990 and 2005, which is remarkable 33 % productivity increase over only 15 years.

The result presented here indicates a clear benefit of intensification in the milk sector for reducing the overall global warming potential from cattle production. This result contrasts a study of environmental improvement potentials in European meat and dairy production made by Weidema et al (2008) suggesting that further specialisation in dairy farming would have small or non impact on global warming potential since additional beef production from suckler cows would be necessary to keep meat output unchanged (given a constant meat consumption). However, this is exactly what has taken place in Sweden during the studied time period; milk production per dairy cow has increased significantly, dairy cow herds have been reduced by more than 30 % while suckler cow herds have more than doubled to compensate the lost meat production in the dairy sector. The results presented in

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[9] Land Use, Land Use Change and Forestry

this analysis are clear; the intensification of milk production has contributed to reduced GHG emissions from the whole cattle sector despite producing more beef from suckler-cow systems.

Weidema et al (2008) base their conclusions on limited benefits from intensification on model calculations based on data from different cattle production systems in Europe. Here, we have analysed the actual course of event in the Swedish cattle sector between 1990 and 2005, as far as possible based on official statistics on outputs, resource use and emissions. One possible explanation for the relative positive outcome of milk production intensification that was found in this study is that there has been a development leading to extensified roughage fodder production due to a Rural Development Program promoting organic agriculture. Especially grassland areas have been included in this program, leading to a significantly lowered use of mineral fertilisers in grass production. In 2005, slightly more than 45 000 ton N was used in grassland production (SCB 2006a) and we estimate this to be around 70 – 80 000 ton N in 1990. Consequently, the use of roughage fodder and pasture with low or no input of fertilisers has increased in beef production over the past 15 years, an effect of governmental subsidies as well as a growing demand for organic products.

6.2 Distribution of greenhouse gases

The relative share of methane, nitrous oxide and carbon dioxide to the total emission of the products (so-called product´s Carbon Footprint[10], CF-farmgate) varies and a major difference is seen between products from ruminants vs non-ruminants (Table 6.1). Methane makes up more than half of the CF-farmgate for milk and beef but is of remarkable low importance to poultry products. Nitrous oxide is important for all livestock products´ CF representing around half of total emissions from pork, poultry meat and eggs. Fossil CO_2 from energy use and fertiliser production is of varying relevance, being of relatively high significance to the CF-farmgate of poultry meat; chiefly because this is the only livestock production where heating of the stables is included in the production chain. The switch from fossil fuels to biofuels for this heating is the main explanation for the reduced chicken meat CF of more than 20 % during the 15 year period.

Table 6.1 Distribution (%) of different greenhouse gases to animal products´ total carbon footprint (at farm-gate) in 2005 in Sweden

	Methane, CH_4	*Nitrous oxide, N_2O*	*Carbon dioxide, CO_2*
Pork	28	48	24
Poultry meat	4	49	47
Egg	4	56	39
Beef	63	26	11
Milk	52	32	17

6.3 Methane

Methane (CH_4) from livestock´s enteric fermentation represents approximately one third of the emissions from the Swedish agriculture according to NIR (Naturvårdsverket, 2009). Despite some smaller differences in use of emission factors and methodology used, methane losses from the cattle population estimated in this report are very similar to the one reported in the official statistics (NIR), see Figure 6.1. Total emissions from enteric fermentation have decreased by slightly more than 10 % during the 15-year period.

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[10] Carbon Footprint, CF, is a term used (e.g. by British Standard and in ISO working documents) to describe the amount of GHG emissions of a process or a product system to indicate their contribution to climate change

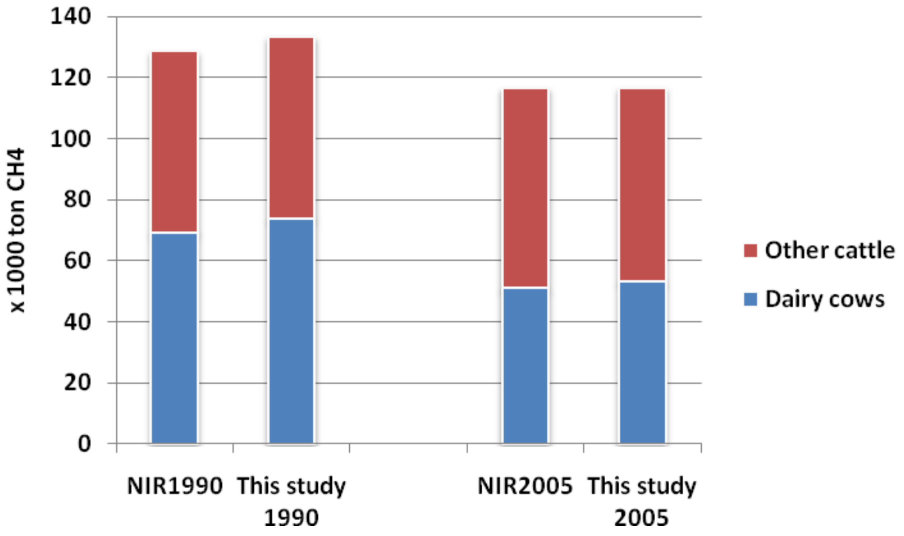

Figure 6.1 Estimates of methane (CH_4) emission from enteric fermentation in beef and milk production 1990 and 2005. NIR=official statistics

Per kg produced milk, CH_4 emissions from enteric fermentation have decreased by more than 20 % (see Appendix 9) and in 2005, 45 % of milk´s total GHG emissions came from the dairy cattle´s enteric fermentation. The results are very clear, producing milk with fewer animals means less methane emissions per kg milk produced. Per kg beef, CH_4 emissions from enteric fermentation increased by around 35 % (Appendix 9) and in 2005, almost 55 % of total GHG emissions in beef production were caused by enteric fermentation. The reason for this increase has been discussed earlier and is once more illustrated in Figure 6.1; beef cattle make up a larger share of total cattle population in 2005 and significantly more meat is produced in “pure beef” (cow-calf systems) than in 1990. Since methane from enteric fermentation makes up such a large share of the milk and beef product´s total farmgate-CF, it will be difficult to achieve any major emission cuts (>25 %) in the life cycle of these products without reductions made in this source.

When comparing the estimates of CH_4 emissions from manure management presented in this study and in the official statistics, there are some discrepancies – most important for pig production which we have estimated to have higher emissions than in NIR, see Figure 6.2. There are several explanations but one important is that emission factors and parameters in the calculations models suggested by the IPCC have changed over time. Here, we have used the latest IPCC guidelines throughout the study and we have probably also assumed that a larger share of the pig manure is handled in a straw-based system (deep bedding) which is a method resulting in fairly high emission due to a high methane conversion factor in calculation models.

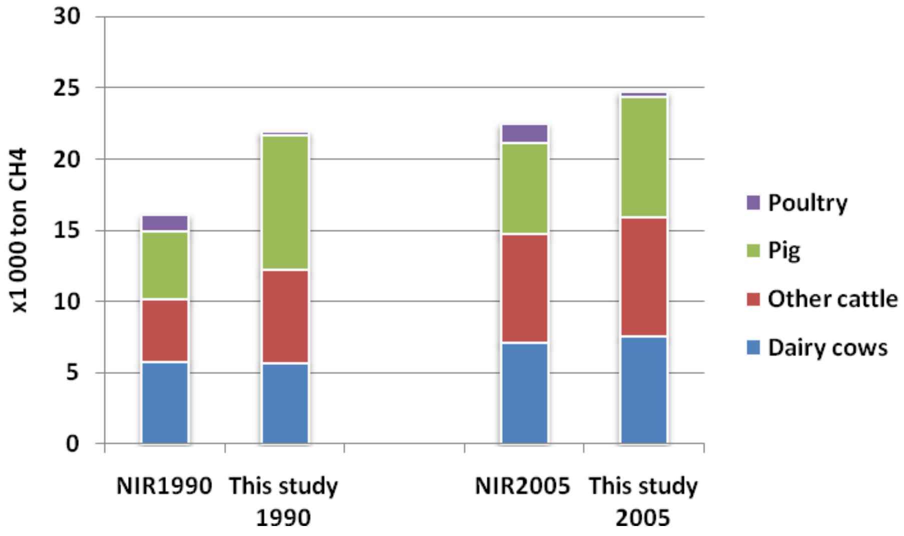

Figure 6.2 Estimates of methane (CH_4) emission from manure management in livestock production 1990 and 2005. NIR=official statistics

Methane formation in manure is highly dependent of temperature. According to the IPCC guidelines, the methane conversion factor is 10 % in cool temperatures (average 10°C) and this parameter was used when estimating emissions from slurry. We calculated that close to 6 % of milk´s farm-gate CF was methane from manure storage in 2005 (see Appendix 9). However, recent experiments in Sweden show considerable lower methane conversion in dairy cow slurry explained by lower average temperatures than the one used in the models in the IPCC guidelines. In recent Swedish experiments, the annual mean methane conversion factor was measured at 2.7 % for uncovered slurry, 2.5 % for straw-covered and 1.8 % for straw-covered slurry (Rodhe et al, 2008). We re-calculated the CH_4 emissions from storage of dairy cattle slurry with a MCF of 2.5 % and the emissions from manure management was then lowered from 8 700 to around 3 000 ton CH_4 in 2005, corresponding to an overall lower emission from milk production of around 140 000 ton CO_2e. Also methane from storing of manure in beef production is likely overrated using the MCF of 10 % according to IPPC guidelines (2006).

The experiments by Rodhe et al (2008) were only carried out in cattle slurry but it is reasonable to assume that methane emissions have been overestimated also for pig slurry due to the an average lower temperature in the Nordic climate.

6.4 Nitrous oxide

It is not possible to compare the estimates of N_2O emissions presented here with the national emission statistics since NIR includes all agriculture and the emissions are aggregated for animal and arable farming. Also, the emission factors for estimating N_2O emissions suggested by the IPCC have changed over time between 1990 and 2005 and the Swedish EPA has developed national emission factors for some activities. In this study, emission factors according to the latest IPCC guidelines are used throughout.

Nitrous oxide is a very important climate gas of the CF of animal products and it is mainly two activities that are the source of emissions; feed production and manure handling, see Table 6.2. N_2O emissions from feed production are foremost explained by emissions from N-fertiliser production and direct soil emissions when fertilising the fodder crops with nitrogen. Losses of N_2O from manure handling include direct soil emissions from manure application, emissions from storing manure and indirect emission caused by ammonia emissions from manure handling (stables, storage, application) and manure dropped in pastures.

Table 6.2 Share of N_2O emissions from feed production and manure management respectively, to Swedish animal products´ total carbon footprint (CF) in 2005

	2005 N_2O emissions from feed production, share of product´s total CF	*2005 N_2O emissions from manure handling, share of product´s total CF*
Pork	0.30	0.19
Poultry meat	0.39	0.10
Egg	0.44	0.12
Beef	0.13	0.13
Milk	0.18	0.12

N_2O emissions from pork production were with reduced more than 10 % between 1990 and 2005 (Appendix 9), the most important emission cuts sourced from manure management and indirect N_2O emissions. This is foremost an effect of the turnover to handling more manure as slurry in 2005, N_2O emissions are low from this storage method, also enabling reductions in ammonia emissions. In poultry meat, N_2O emissions were cut by 8 % equally shared between different activities suggesting it was an effect of an overall efficiency gain in feed consumption and production. In egg production, N_2O emissions increased during the studied time period due to a larger share of vegetable protein feed in 2005 compared with 1990 when fishmeal and meat meal made up a significant share of protein supply in egg production. These protein feed components have low N_2O emissions since no N-fertilisation (production and use) occurs in their product life cycle.

In the ruminant production, emissions of N_2O decreased by around 400 000 ton CO_2e, or close to 19 % between 1990 and 2005. We estimate that around 250 000 ton of this emission cut (>60 %) is due to decreased emissions in production (i.e. not lowered production) and this is predominantly done in feed production, a combination of more fodder being produced with lower GHG emission per kg feed and also improved feed efficiency, especially in the milk sector. In beef production, significantly more non-fertilised roughage fodder was used in 2005 compared with 1990. This was the fact also in milk production, and here also the grain had a lower use of N-fertiliser per kg grain in 2005.

6.5 Carbon dioxide

It is fossil CO_2 that shows the biggest reduction of the climate gases, in total it was lowered by ~24 % and ~30 % in the cattle and pork sector, respectively, between 1990 and 2005. Since only methane and nitrous oxide emissions are reported as emissions from the agricultural sector in the statistics, this emission reduction has not been made obvious earlier and it is not possible to compare the results reported in this study with the national statistics.

In the milk and beef production, we estimate life cycle CO_2-emissions to have been reduced by around 275 000 ton CO_2 of which ~60 % is caused by lowered emissions per produced unit, most importantly due to the efficiency gains in the milk sector. In 2005, 80-85 % of total fossil CO_2 emissions from the cattle sector origined from fodder production and here mineral N fertilisers and use of diesel are the major contributors. Similar to the discussion above on the reduction of fertiliser-N in the grassland production is one important explanation to the decrease of fossil CO_2 from the sector between 1990 and 2005.

In pork production, fossil CO_2 emissions decreased by close to 100 000 ton CO_2 during the 15 year period and we estimate that approximately 75 % of this is due to more efficient production. Feed production is responsible for almost all CO_2 in pork production and a more efficient production as well improved feed conversion (for example, higher piglet production per sow) explains the improvements found for this product.

There are small net changes in overall CO_2 emissions from poultry sector; emissions increased from chicken meat production due to increased production while there was a decrease from egg production due to lowered production as well as reduced CO_2 emissions per unit egg during the 15 year period.

6.6 Mitigation potentials

The results indicate that the overall life-cycle GHG emissions from Swedish livestock production have decreased by ~14 %, corresponding to a reduction of ~1.2 Mtons CO_2e, between 1990 and 2005 and of this, approximately 0.8 Mtons CO_2e is the results of reduced emissions per product unit. Although there are large uncertainties in estimates of GHG emissions from agriculture, it is fair to conclude that there is clear trend towards decreasing emissions from the Swedish livestock production. A more efficient production, here defined as less GHG emissions per product unit, is a result of several measures taken in the production chain of which some are greater significance; foremost the strong milk yield increase per dairy cow, the reduced use of mineral N fertilisers in grasslands especially utilised in beef production, reduced losses of ammonia most apparent in pork production and a switch to bio-fuels for heating in chicken farm buildings. It is also noteworthy that these emission cuts have occurred without any specified climate policies have been put into action in agriculture. The reduction is partly an effect of on-going improved practices in agriculture including genetic, nutrition, reproduction and health improvement and partly of non-climate policies, e.g. governmental subsidies to organic grassland, taxes on mineral-N fertilisers.

Recent research shows that the actual outcome of GHG mitigation in agriculture very often is below the technical potential of the mitigation measures. The gap between technical and realised GHG mitigation occurs due to barriers to implementation and cost considerations. According to Smith et al (2007), the challenge for successful GHG mitigation will be to remove these barriers by implementing creative policies. Based on the findings on current level of emissions and emission trends during the past 15 years in Swedish animal production, the following mitigation potentials for the short-term (2020) are suggested:

Improving manure utilisation and reducing N emissions

Direct and indirect nitrous oxide emissions from manure are significant contributors to animal production´s global warming potential. The ongoing work in Sweden to reduce ammonia emissions from manure, being a major path for N losses from livestock production, is important to continue. Here, we have estimated that approximately 20-30 % of N excreted in the manure is lost as ammonia, with variation between different livestock. A range of measures is available to reduce these emissions, starting with optimised protein feeding in order to lower the N excreted in the manure and to be followed by different actions in the manure management chain until the manure has been applied in the soil. There are a range of measures, both technical and biological, to put in action and it is important to increase the understanding of the N cycle and losses of reactive N to farmers. Reducing losses of reactive N from manure management and application is of major importance to several environmental impacts: climate change, eutrophication and acidification.

Reducing and improving N fertiliser use

Reduced ammonia emissions from manure must be followed by cutting down mineral-N fertiliser rates, this giving double effects in reducing climate gases both in the production of the fertilisers (emissions of N_2O and CO_2 in industry) and in the use of fertilisers (direct N_2O emissions from soil). Using more leguminous crops, such as peas, horse-beans and clover in the grassland, is yet another way of reducing the overall use of mineral N fertilisers. By applying cleaning technique in the fertiliser industry and improving its energy efficiency, emissions from production can be substantially decreased.

Protein feed composition

Since soymeal is a protein feed with relatively high GHG emissions, some of this feed can be exchanged into domestically cultivated peas and rapeseed. It is important that the benefits of this measure are not solely the use of a feed with a lower product CF but would also add positive changes within the cropping systems. The Swedish feed production to non-ruminants is today very much based upon domestically cultivated grain and imported soymeal and from this follows rather monotonous cereal crop rotation decreasing potential grain yields. A more diversified crop rotation including protein crops such as peas/horsebeans and and also rape seed would have a potential to increase grain harvests and reduce the requirement of fertiliser N per ton of feed due to positive crop rotation effects.

Increasing the use of by-products from food industry (foremost meat meal) could reduce the use of imported protein feed.

Biogas production

GHG emissions from manure handling are an important source in pork production and to some extent in cattle and poultry production. Storing slurry at high temperatures results in high methane emissions. However, recent results on GHG emissions from cattle slurry storing in Sweden indicate that the emissions are lower than previously estimated with models and emission factors according to IPCC-guidelines. The results points at relatively low methane conversion from slurry in colder winter climate as in Sweden (Rodhe et al, 2008). Also, the net energy production is lower from cattle slurry than pig slurry, and therefore the benefits of biogas production from cattle slurry in Sweden might be lower than previously anticipated due to the considerably lower methane emissions monitored in recent trials.

Given that the models suggested by IPCC (2006) for estimating methane losses from pig slurry are correct, this climate gas makes up a significant part of GHG emissions in the pork production. Here, anaerobic digestion could be an important mitigation option. Dalgaard (2008) evaluated different slurry technologies in Danish pork production showing that anaerobic digestion of slurry led to a reduction of GHG emissions per kg pork of ~15 %, when also including the energy production from the biogas.

Energy savings

Our analysis shows that between 1990 and 2005, fossil CO_2 emissions have decreased in livestock production, being an effect of more efficient energy use (e.g. in fertiliser industry), switch of fossil fuels into biofuels (e.g. in some feed industry operations) and change of techniques (e.g. more organic grassland production). There are significant potentials for this development to continue, for example improving fuel efficiency in agriculture machinery and farm buildings and also to switch for more biofuels, e.g. the use of straw instead of oil when drying grains and in longer perspective replacing fossil fuel use in machinery into renewables.

6.7 Concluding remarks

Assessments of GHG emissions from food production must be read and interpreted with the knowledge that there are large uncertainties in the estimates and also that it is difficult to assess the effectiveness of GHG mitigation options. Despite the uncertainties, the estimates of emission trends reported here, mostly based on agricultural statistics, provide a clear cut answer when it comes to pointing out a promising trend of decreasing emissions from Swedish animal production. Noteworthy and encouraging is that the reduction of emissions has taken place without any deliberate climate policy actions being put into practice in agriculture during the studied time period.

In a global perspective, agriculture GHG emission trends are less encouraging. The US-EPA estimated that world agriculture GHG emissions increased by 14 % between 1990 and 2005, and forecasts accelerated emission growth between 2005 and 2020. Actually, Western Europe is the only region in the world where GHG emissions are projected to decrease until 2020; this is due to a number of climate-specific and other environmental policies in the EU as well as economic constraints in agriculture (Smith et al, 2007).

The present method used for estimating agriculture GHG emissions in the national inventory reports has a national production perspective and it does not take into account embedded emissions from imports. Moreover, only biogenic emissions (methane and nitrous oxide) are reported as agriculture emissions while fossil CO_2 emissions are reported under other sectors. We conclude that this method gives inadequate information on the size of the GHG emissions in food production and also that it fails to give information on what parts of the production chain that gives rise to the largest emissions (so-called hot-spots) due to the lacking life-cycle perspective. Thereby, there is a risk that the most optimal measures for reducing GHG emissions are not prioritised when choosing between different mitigation options.

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Appendix

1) Mineral N fertilisers
2) Use of direct energy
3) Input data in fodder production
4) Concentrate feed
5) CH_4 emissions from manure management
6) N losses
7) Estimated feed consumption beef cattle
8) Enteric fermentation
9) Results

APPENDIX 1) Mineral N-fertilisers

Table 1) Use of N mineral fertilisers in fodder crops 2005 according to statistics

Crop	Area x 1000 hectare	N-fertiliser total, ton	Average kg N/ha	Area in organic production x 1000 ha
Winter wheat	295.3	40 730	138	12.5
Triticale	50.2	4 160	83	4.1
Barley	373.2	27 260	73	19.6
Oats	200.1	11 730	59	30.5
Winter rapeseed	34.9	4 890	140	1.6
Spring rapeseed	38.5	4 170	108	0.7
Grassland, cut - conventional	545	42 860	79	
Grassland, cut - organic	259	0	0	
Grassland, grazed - conventional	134	2 320	17	
Grassland, grazed - organic	89	0	0	

Source: SCB 2006a, SCB 2006b

Table 2) Estimated N-fertiliser rates in individual crops in the early 1990s

Crop	1990			1991		
	Area x 1000 ha	Kg N/ha	Ton N	Area x 1000 ha	Kg N/ha	Ton N
Winter wheat	320	125	40 000	225	125	28 125
Spring wheat	30	120	3 600	33	120	3 960
Rye	73	70	5 110	43	70	3 010
Feed grain (barley, oats, triticale)	912	65	59 280	896	65	58 240
Peas, horsebeans	33	0	0	23	0	0
Winter rapeseeds	94	130	12 220	84	130	10 920
Spring rapeseeds	74	90	6 660	67	90	6 030
Grassland (ley) & greenfodder	958	85	81 430	970	85	82 450
Leys for seed production	11	100	1 100	11	100	1 100
Potatoes	36	110	3 960	37	110	4 070
Sugar beets	50	110	5 500	38	110	4 180
Other crops (e.g. vegetables)	31	70	2 170	38	70	2 660
Total area / total N	*2622*		*221 030*	*2465*		*204 745*

Source: SCB 1992, SCB 1991, Lantbruksstyrelsen 1990 b

Appendix 2) Use of direct energy

Table 1) Use of diesel in cultivation of fodder

Crop	litre/ha
Winter wheat	89
Barley	82
Oats	82
Winter rapeseed	86
Spring rapeseed	83
Peas/horsebeans	78
Grassland, silage 2005	65
Grassland, grazing 2005	20
Maize, silage 2005	100
Grassland, 1990*	54
Natural meadows	15

*The statistics did not divide grassland for cutting and for grazing in 1990, the use of diesel is an estimate based on that approximately 20 % of the area was grazed in 1990

Table 2) Use of diesel in stables

	1990, m^3	2005, m^3
Dairy	25 000	18125
Beef	8 125	11 250
Sl chicken	38	75
Egg	0	30

Table 3) Use of diesel for handling, transporting, spreading manure

	1990, m^3	2005, m^3
Dairy	6 600	5 150
Beef	1 700	1 550
Pig	2 000	1 700
Sl chicken	30	50
Egg	115	65

Table 4) Use of diesel for pressing, transport straw for bedding and fodder

	1990, m^3	2005, m^3
Dairy	760	535
Beef	425	750
Pig	800	455
Sl chicken	9	10
Egg	1	3

Appendix 3) Input data in fodder production

Table 1) Input data in grain for feed production in 2005 and 1990

	2005			1990		
	Winter wheat	**Barley**	**Oats**	**Winter wheat**	**Barley**	**Oats**
Yield, kg/ha	6100	4200	3900	6000	3700	3400
Seed, kg/ha	220	180	180	220	180	180
Diesel, l/ha	89	82	82	89	82	82
Oil for drying, l/ha	56	23	21	55	20	18
Electricity for drying, kWh/ha	113	79	73	113	70	64
Fertilisers, mineral-N, kg N/ha	135	75	70	120	65	65
N i crop residues, kg N/ha	48	36	33	48	33	31
Direct N2O-emission, kg N2O-N/ha	1,83	1,11	1,03	1,68	1	1
Indirect N2O-emission, kg N2O-N/ha	0,28	0,27	0,27	0,29	0,28	0,28

Table 2) Input data in rape seed production 1990

	1990	
	Winter rapeseed	**Spring rapeseed**
Yield, kg/ha	2250	1550
Seed, kg/ha		
Diesel, l/ha	86	83
Oil for drying, l/ha	14	14
Electricity for drying, kWh/ha	40	28
Fertilisers, mineral-N, kg N/ha	120	90
N i crop residues, kg N/ha	38	28
Direct N2O-emission, kg N2O-N/ha	1,6	1,2
Indirect N2O-emission, kg N2O-N/ha	0,32	0,32

Total yield: 60 % from winter rapeseed; 40 % from spring rapeseed

Data on rapeseed extraction and transports in 1990s according to Cederberg 1998

Data on rapeseed feed products in 2005 according Flysjö et al (2008)

Appendix 3) Input data in fodder production

Table 3) Input data for cultivation of grassland and natural meadows in 1990

	Arable land Grassland Silage/hay, grazing per ha	Natural meadows Non-fertilised Grazing per ha
Diesel, l/ha	54	15
Fertilisers, mineral-N, kg N/ha	85	0
N i crop residues, kg N/ha	30	0
Direct N2O-emission, kg N2O-N/ha	1,15	
Indirect N2O, Kg N2O-N	0,092	0,0375

Table 5) Input data for cultivation of maize, 2005

	Maize for silage per ha
Diesel, l/ha	100
Fertilisers, kg N/ha	70
N i crop residues, kg N/ha	30
Direct N2O, kg N2O-N	1
Indirect N2O, Kg N2O-N	0,389

Table 4) Input data on cultivation of grassland and natural meadows in 2005

Type of grassland, system	Arable land Conv grassland Silage/hay per ha	Arable land Env cert grassland Silage/hay (org) per ha	Arable land Conv grassland Grazing per ha	Arable land Env cert grassland Grazing (org) per ha	Natural meadows Non-fertilised Grazing per ha
Diesel, l/ha	65	60	20	20	15
Fertilisers, mineral-N, kg N/ha	80	0	21	0	0
N i crop residues, kg N/ha	30	50	25	40	0
Direct N2O-emissions, kg N2O-N	1,1	0,5	0,46	0,4	
Indirect N2O, Kg N2O-N	0,091	0,075	0,0792	0,075	0,0375

Appendix 4 Concentrate feed

Table 1) Milk production

		Input data milk prod 2005			**Input data milk prod 1990**
		Domestic	**Import**	**Total**	**Total**
	Ingredient	**ton**	**ton**	**ton**	**ton**
Grain, via feed ind	Wheat	66 600	2 600	69 200	39 000
	Triticale, rye	59 300		59 300	32 000
	Barley	87 000	1900	88 900	76 000
	Oats	29 600		29 600	76 000
Grain, direct farms	Wheat				137 000
	Barley	340 000			500 000
	Oats	333 000			500 000
Total		*915 500*	*4 500*	*920 000*	*1 360 000*
By-prod, cereal ind	Grain middlings	11 000	1 750	12 750	
	Grain bran	54 400	14 450	68 850	70 000
	Maize gluten	0	4 250	4 250	
	Distiller´s dried gr	33 150		33 150	
	Bakery/pasta prod	2 550	0	2 550	
Total		*101 100*	*20 450*	*121 550*	*70 000*
By-prod, sugar ind	Beet pulp	59 500	63 750	123 250	167 400
	Molasses	15 300	11 900	27 200	
	Beet sugar	1 700		1 700	
Total		*76 500*	*75 650*	*152 150*	*167 400*
Protein	Rapeseed,whole	5 100		5 100	
	Rapeseed, meal	93 000	88 850	181 850	107 000
	Soymeal		106 250	106 250	79 000
	Potatoe protein	50	300	350	
	Kokoa				16 000
	Lucernemeal	425	950	1 375	
	Grassmeal	0	5 950	5 950	
	Fish/meatmeal				900
	Peas/horsebean	8 500	0	8 500	23 200
Total		*107 075*	*202 300*	*309 375*	*226 100*
Palmkernel	Palmkernel exp		80 750	80 750	
Fats	Fatty acids	20 600	4 900	25 500	15 000
Other					94 500
	Milk powder			2 250	4 725
Total		*20 600*	*85 650*	*108 500*	*114 225*

Appendix 4 Concentrate feed

Table 1) Milk production, continued

		Input data milk prod 2005			Input data milk prod 1990
		Domestic	Import	Total	Total
	Ingredient	ton	ton	ton	ton
Minerals	CaCO3	15 300	0	15 300	8 500
	Salt	4 675	4 675	9 350	5 000
	Div minerals	2550	2550	5 100	3 200
Total		*22 525*	*7 225*	*29 750*	*16 700*
Total all		*1 243 300*	*395 775*	*1 641 325*	*1 954 425*

Table 2) Beef production

		Input data beef prod 2005			Input data beef prod 1990
		Domestic	Import	Total	Total
	Ingredient	ton	ton	ton	ton
Grain, via feed ind	Wheat	12 600		12 600	4 400
	Triticale, rye	10 800		10 800	3 500
	Barley	16 200		16 200	8 500
	Oats	5 400		5 400	8 400
Grain, direct farms	Wheat			0	35 200
	Barley	107 500		107 500	160 000
	Oats	102 500		102 500	150 000
Total		*255 000*		*255 000*	*370 000*
By-prod, cereal ind	Grain middlings	1 950	250	2 200	
	Grain bran	9 600	2 150	11 750	5 500
	Maize gluten		650	650	
	Distiller´s dried gr	6 000		6 000	
	Bakery/pasta prod	500		500	
Total		*18 050*	*3 050*	*21 100*	*5 500*
By-prod, sugar ind	Beet pulp	10 500	11 250	21 800	12 500
	Molasses	2 700	2 100	4 800	
	Beet sugar	300		300	
Total		*13 500*	*13 350*	*26 900*	*12 500*

Appendix 4) Concentrate feed

Table 2) Beef production, continued

		Input data beef prod 2005			**Input data beef prod 1990**
		Domestic	**Import**	**Total**	**Total**
	Ingredient	**ton**	**ton**	**ton**	**ton**
Protein	Rapeseed,whole	1 000		1 000	
	Rapeseed, meal	10 000	22 000	32 000	8 000
	Soymeal		18 800	18 800	6 000
	Potatoe protein		50	50	
	Kokos				1 200
	Lucernemeal	100	150	250	
	Grassmeal	0	1 000	1 000	
	Kött/fiskmjöl				50
	Peas/horsebean	1 500		1 500	1 700
Total		*12 600*	*42 000*	*54 600*	*16 950*
Palmkernel	Palmkernel exp		14 250	14 250	
Fats	Fatty acids	3 600	900	4 500	1 100
	Other				7 100
	Milk powder			4 150	8 775
Total		*3 600*	*15 150*	*22 900*	*16 975*
Minerals	CaCO3	2 700		2 700	650
	Salt	825	825	1 650	400
	Div minerals	450	450	900	150
	Natriumbikarbonat				
Total		*3 975*	*1 275*	*5 250*	*1 200*
Total all		*306 725*	*74 825*	*385 750*	*423 125*

APPENDIX 4) Concentrate feed

Table 3) Pork production

		Input data, pig meat prod 2005			Input data, pig meat prod 1990
		Domestic	Imp	Total	Total
	Ingredient	ton	ton	ton	ton
Grain, via feed ind	Wheat	131 902		131 902	112 100
	Triticale, rye	14 850		14 850	34 800
	Barley	77 246		77 246	204 900
	Oats	14 405		14 405	33 200
Grain, direct farms	Wheat	417 500		417 500	271 100
	Barley	214 008		214 008	378 100
	Oats	40 300		40 300	65 800
Total		*910 211*		*910 211*	*1 100 000*
By-prod, cereal ind	Grain middlings	16 300	2 600	18 900	
	Grain bran	16 260	4 760	21 020	83 100
	Maize gluten	265	90	355	400
	Distiller´s dried gr	2 420		2 420	
	Bakery/pasta prod	5 690		5 690	
Total		*40 935*	*7 450*	*48 385*	*83 500*
By-prod, sugar ind	Beet pulp	1 017	547	1 564	2 100
	Molasses	956	200	1 156	2 100
	Beet sugar	121		121	
Total		*2 094*	*747*	*2 841*	*4 200*
Protein	Rapeseed,whole	2 565	824	3 389	
	Rapeseed, meal	6772	37800	44572	49 300
	Soymeal		51625	51625	25 600
	Potatoe protein	40	1689	1 729	
	Lucernemeal	1	91	92	
	Grassmeal	6	484	490	600
	Meat meal				26 500
	Fish meal	2390	991	3 381	19 300
	Peas/horsebean	12588		12588	27 900
	Synt amino acids		4700	4700	5 600
Total		*24 362*	*98 204*	*122 566*	*154 800*
Palmkernel	Palmkernel exp		239	239	
Fats	Fatty acids	1 388		1 388	
	Animal fat	1 083		1 083	6 300
Total		*2471*	*239*	*2710*	*6 300*

APPENDIX 4) Concentrate feed

Table 3) Pork production, continued

		Input data, pig meat prod 2005			**Input data, pig meat prod 1990**
		Domestic	**Imp**	**Total**	**Total**
	Ingredient	**ton**	**ton**	**ton**	**ton**
Others	Veg oil	28	197	225	
	Skummjölkspulv	25		25	
	Whey, lactos powd	179	2315	2494	
	Others	952	773	1 725	38 400
Total		*1 184*	*3 285*	*4 469*	*38 400*
Minerals	CaCO3	4 107	7 855	11 962	
	Salt	975	682	1 657	
	Div minerals	1041	4900	5941	15 200
	Natriumbikarbonat	208	485	693	
Total		*6 331*	*13 922*	*20 253*	*15 200*
Total all		*986 404*	*123 847*	*1 111 435*	*1 402 400*

Appendix 4) Concentrate feed

Table 4) Chicken meat production

		Input data poultry meat 2005			Input data poultry meat 1990
		Domestic	Import	Total	Total
	Ingredient	**ton**	**ton**	**ton**	**ton**
Grain, via feed ind	Wheat	132 600		132 600	78 000
	Triticale, rye	2 600		2 600	
	Barley	5 100		5 100	25 000
	Oats	5 100		5 100	7 500
Grain, direct farms	Wheat	45 000		45 000	
	Barley				
	Oats				
Total		*190 400*		*190 400*	*110 500*
By-prod, cereal ind	Grain middlings	2 550	0	2 550	
	Grain bran	10 100	2 900	13 000	2 000
	Maize gluten		1 300	1 300	1 000
	Distiller´s dried gr				
	Bakery/pasta prod				
Total		*12 650*	*4 200*	*16 850*	*3 000*
By-prod, sugar ind	Beet pulp				
	Molasses				
	Beet sugar	100		100	
Total		*0*	*0*	*100*	*0*
Protein	Rapeseed,whole	2 500		2 500	
	Rapeseed, meal	0	6 700	6 700	9 000
	Soymeal		55 000	55 000	11 000
	Potatoe protein		700	700	
	Lucernemeal			0	
	Grassmeal			0	750
	Meat meal			0	2 250
	Fish meal	750	700	1 450	12 000
	Peas/horsebean	10 000		10 000	
	Synth amino acids			0	
Total		*13 250*	*63 100*	*76 350*	*35 000*
Palmkernel	Palmkernel exp				
Fats	Fatty acids	2 750	2 000	4 750	
	Animal fat	1 500	1 500	3 000	4 500
Total		*4 250*	*3 500*	*7 750*	*4 500*

Appendix 4) Concentrate feed

Table 4) Chicken meat production, continued

		Input data poultry meat 2005			Input data poultry meat 1990
		Domestic	Import	Total	Total
	Ingredient	ton	ton	ton	ton
Others	Veg oil		1 000	1 000	
	Synth amino acids				
	Others				2 250
Total		*0*	*1 000*	*1 000*	*2 250*
Minerals	CaCO3	3 000	2 500	5 500	2 000
	Salt	50	150	200	
	Div minerals		3750	3 750	250
	Natriumbikarbonat	250	700	950	
Total		*3 300*	*7 100*	*10 400*	*2 250*
Total all		*223 850*	*78 900*	*302 850*	*157 500*

Table 5) Egg production

		Input data egg prod 2005			Input data egg prod 1990
		Domestic	Import	Total	Total
	Ingredient	ton	ton	ton	ton
Grain, via feed ind	Wheat	103 200		103 200	84 000
	Triticale, rye	8 400		8 400	12 000
	Barley	16 800		16 800	87 000
	Oats	16 800		16 800	21 000
Grain, direct farms	Wheat	13 000		13 000	
	Barley	2 500		2 500	
	Oats	1 000		1 000	
Total		*161 700*		*161 700*	*204 000*
By-prod, cereal ind	Grain middlings				
	Grain bran	6 100	3 400	9 500	24 000
	Maize gluten				
	Distiller´s dried gr				
	Bakery/pasta prod				
Total		*6 100*	*3 400*	*9 500*	*24 000*
By-prod, sugar ind	Beet pulp				
	Molasses				
	Beet sugar	50		50	
Total		*50*		*50*	*0*

Appendix 4) Concentrate feed

Table 5) Egg production, continued

		Input data egg prod 2005			Input data egg prod 1990
		Domestic	Import	Total	Total
	Ingredient	ton	ton	ton	ton
Protein	Rapeseed,whole	15 000		15 000	
	Rapeseed, meal	1 500	11 200	12 700	1 500
	Soymeal		25 000	25 000	6 500
	Potatoe protein			0	
	Lucernemeal	100	350	450	
	Grassmeal	3 050	750	3 800	7 500
	Meat meal			0	7 500
	Fish meal	250	200	450	14 000
	Peas/horsebean	2 500		2 500	12 000
	Synt amino acids		510	510	
Total		*22 400*	*38 010*	*60 410*	*49 000*
Palmkernel	Palmkernel exp				
Fats	Fatty acids	2 500	750	3 250	3 000
	Animal fat				
Total		*2 500*	*750*	*3 250*	*3 000*
Others	Veg oil				
	Synt amino acids		510	510	
	Others				10 500
Total		*0*	*510*	*510*	*10 500*
Minerals	CaCO3	11 000	12 000	23 000	18 500
	Salt	125	325	450	
	Div minerals	0	1400	1400	1 000
Total		*11 125*	*13 725*	*24 850*	*19 500*
Total all		*203 875*	*56 395*	*260 270*	*310 000*

Appendix 5) CH4 emissions from manure management

Table 1a) CH4 from management of pig manure, 2005

Manure System	Emission ton CH4	Amount manure, ton	% dry matter	% VS Volatile solids	Bo m^3 CH4/kg VS	Factor kg CH4/ m^3	MCF
Slurry	6 686	3 150 000	0,088	0,8	0,45	0,67	0,1
Urine	0	105 000	0,018	0,8	0,45	0,67	0
Solid manure	63	57000	0,23	0,8	0,45	0,67	0,02
Deep bedding	1 667	107 000	0,38	0,8	0,45	0,67	0,17
Total	*8 417*	*3 419 000*					

Table 1b) CH4 from management of pig manure, 1990

Manure System	Emission ton CH4	Amount manure, ton	% dry matter	% VS Volatile solids	Bo m^3 CH4/kg VS	Factor kg CH4/ m^3	MCF
Slurry	6368	3 000 000	0,088	0,8	0,45	0,67	0,1
Urine	0	535 000	0,018	0,8	0,45	0,67	0
Solid manure	359	324 000	0,23	0,8	0,45	0,67	0,02
Deep bedding	2774	178 000	0,38	0,8	0,45	0,67	0,17
Total	*9501*	*4 037 000*					

Table 2) CH4 from management of poultry manure (chicken meat), 2005 and 1990

Manure System	Emission ton CH4	Amount manure, ton	% dry matter	% VS Volatile solids	Bo m3 CH4/kg VS	Factor kg CH4/m3	MCF
Poultry manure, 2005	195	95 500	0,65	0,87	0,36	0,67	0,015
Poultry manure, 1990	115	56 000	0,65	0,87	0,36	0,67	0,015

Table 3a) CH4 from management of hens manure (eggs), 2005

Manure System	Emission ton CH4	Amount manure, ton	% dry matter	% VS Volatile solids	Bo m3 CH4/kg VS	Factor kg CH4/m3	MCF
Solid manure	40	64 500	0,18	0,87	0,39	0,67	0,015
Deep litter	136	61 300	0,65	0,87	0,39	0,67	0,015
Total	*175*	*125 800*					

Table 3b) CH4 from manure management hens (eggs), 1990

Manure System	Emission ton CH4	Amount manure, ton	% dry matter	% VS Volatile solids	Bo m^3 CH4/kg VS	Factor kg CH4/ m^3	MCF
Solid manure	131	213 000	0,18	0,87	0,39	0,67	0,015
Deep litter	27	12 000	0,65	0,87	0,39	0,67	0,015
Total	*157*						

Manure production calculated with SiM, Stank in Mind

Data DM and VS in different types of manure according to Baky & Olsson (2007)

Appendix 5) CH4 emissions from manure managment

Table 4a) CH4 from manure management dairy cattle, 2005

Manure system	Emission ton CH4	Share of manure	Ton VS	Bo m3 CH4/kg VS	Factor kg CH4/m3	MCF
Dairy cows						
Slurry	6 728	0,56	418 437	0,24	0,67	0,1
Solid	577	0,24	179 330	0,24	0,67	0,02
Grazing	240	0,20	149 442	0,24	0,67	0,01
Total, cows	*7 545*	*1,00*	*747 209*			
Replacement heifers						
Slurry	836	0,35	69 300	0,18	0,67	0,1
Solid	76	0,16	31 680	0,18	0,67	0,02
Deep litter	122	0,03	5 940	0,18	0,67	0,17
Grazing	110	0,46	91 080	0,18	0,67	0,01
Total, replacement	*1 144*	*1*	*198 000*			
Total, all dairy	*8 689*					

Grazing period 2,5 month dairy cows in 2005, 5,5 month for replacement

Table 4b) CH4 from manure management dairy cattle, 1990

Manure system	Emission ton CH4	Share of manure	Ton VS	Bo m3 CH4/kg VS	Factor kg CH4/m3	MCF
Dairy cows						
Slurry	3 504	0,21	217 883	0,24	0,67	0,1
Solid	1 635	0,49	508 393	0,24	0,67	0,02
Grazing	501	0,30	311 261	0,24	0,67	0,01
Total, cows	*5 639*	*1,00*	*1 037 536*			
Replacement heifers						
Slurry	510	0,15	42 300	0,18	0,67	0,1
Solid	258	0,38	107 160	0,18	0,67	0,02
Deep litter	58	0,01	2 820	0,18	0,67	0,17
Grazing	156	0,46	129 720	0,18	0,67	0,01
Total, replacement	*983*	*1*	*282 000*			
Total, all dairy	*6 622*					

Grazing period 3,5 month dairy cows in 1990, 5,5 month replacement heifers

Table 5a) CH4 from manure management beef cattle, 2005

Manure system	Emission ton CH4	Share of manure	Ton VS	Bo m3 CH4/kg VS	Factor kg CH4/m3	MCF
Slurry	2 566	0,33	212 784	0,18	0,67	0,1
Solid	62	0,04	25 792	0,18	0,67	0,02
Deep litter	4 362	0,33	212 784	0,18	0,67	0,17
Grazing	233	0,3	193 440	0,18	0,67	0,01
Total	*7 224*	*1*	*644 800*			

Appendix 5) CH4 emissions from manure managment

Table 5b) CH4 from manure management beef cattle, 1990

Manure system	**Emission** **ton CH4**	**Share of** **manure**	**Ton VS**	**Bo** **m3 CH4/kg VS**	**Factor** **kg CH4/m3**	**MCF**
Slurry	2 902	0,47	240 640	0,18	0,67	0,1
Solid	99	0,08	40 960	0,18	0,67	0,02
Deep litter	2 414	0,23	117 760	0,18	0,67	0,17
Grazing	136	0,22	112 640	0,18	0,67	0,01
Total	*5 551*	*1*	*512 000*			

Appendix 6) N-losses from pig manure, 2005

Table 1) Calculated losses of ammonia from manure and N-leaching caused by autumn application

	Solid ton N/yr	**urine ton N/yr**	**deep beeding ton N/yr**	**slurry ton N/yr**	**Total ton N/yr**
N excreted					
total	*418*	*215*	*1 405*	*15 259*	*17 296*
NH3-losses, stable and storing					
stable	42	22	351	2 136	2 551
storing	71	10	316	495	892
total	*113*	*31*	*667*	*2 631*	*3 442*
Left after stable and storage losses	*304*	*184*	*738*	*12 629*	*13 854*
NH3-losses, spreading					
early spring				168	
spring	28	36	24	376	
early summer				25	
early autumn	7	11	6	230	
late autumn				27	
total	*35*	*47*	*31*	*825*	*938*
Left to soil					
total	*270*	*136*	*707*	*11 803*	*12 916*
which of NH4-N	49	118	43	8 014	8 224
Losses due to autumn spreading					
Leaching	4	9	4	1130	1 147
denitrification	3	7	3	885	
total	*8*	*15*	*7*	*2015*	*2 045*
All losses					*6 425*

Table 2) Calculated losses of nitrous oxide from manure management

	solid ton N/yr	**urine ton N/yr**	**deep bedding ton N/yr**	**slurry ton N/yr**	**Total ton N/yr**
N excreted	418	215	1 405	15 259	17 296
Default EF	0,005	0	0,07	0,005	
kg N20-N per yr	2 088		98 322	76 297	**Ton N2O/yr**
Kg N2O per yr	3 277		154 366	119 786	**277,4**

Appendix 6) N-losses from pig manure, 1990

Table 3) Calculated losses of ammonia from manure and N-leaching caused by autumn application

	Solid ton N/yr	urine ton N/yr	deep beeding ton N/yr	slurry ton N/yr	Total ton N/yr
N excreted					
total	*2 749*	*1 338*	*1 962*	*14 771*	*20 821*
NH3-losses, stable and storing					
stable	275	134	490	2 068	2 967
storing	445	60	441	642	1 588
total	*720*	*194*	*931*	*2 710*	*4 555*
Left after stable and storage losses	*2 029*	*1 144*	*1 030*	*12 062*	*16 266*
NH3-losses, spreading					
early spring					
spring	91	124	15	718	
early summer					
early autumn	134	139	23	1 288	
late autumn	46		8	211	
total	*271*	*263*	*46*	*2 216*	*2 796*
Left to soil					
total	*1 758*	*882*	*984*	*9 846*	*13 470*
which of NH4-N	338	767	57	6227	7 389
Losses due to autumn spreading					
Leaching	115	128	20	1470	1 733
denitrification	88	98	15	1124	
total	*203*	*225*	*34*	*2595*	*3 058*
All losses					*10 408*

Table 4) Calculated losses of nitrous oxide from manure management

	solid ton N/yr	urine ton N/yr	deep bedding ton N/yr	slurry ton N/yr	Total ton N/yr
N excreted	2 749	1 338	1 962	14 771	20 821
Default EF	0,005	0	0,07	0,005	
kg N20-N per yr	13 747		137 305	73 857	**Ton N2O/yr**
Kg N2O per yr	21 583		215 569	115 955	**353,1**

Appendix 6) N-losses from slaughter chicken manure, 2005 and 1990

Table 5) Calculated losses of ammonia from manure and N-leaching caused by autumn application

	2005 deep litter ton N/yr	1990 deep litter ton N/yr
N excreted		
total	*3 300*	*1 900*
NH3-losses, stable and storing		
stable and storage	616	359
Left after stable and storage losses	*2 642*	*1 532*
NH3-losses, spreading		
early spring		
spring	275	123
early autumn	74	166
late autumn		12
total	*348*	*300*
Left to soil		
total	*2 291*	*1 232*
of which plant-available NH4-N	707	313
Losses due to autumn spreading		
Leaching	58	84
denitrification	46	65
total	*104*	*150*

Table 6) Calculated losses of nitrous oxide from manure management, sl chicken

	2005	1990
N excreted, ton	3 300	1 900
Default EF	0,001	0,001
Kg N20-N/yr	3300	1900
Kg N2O/yr	5181	2983

Appendix 6) N losses from manure from egg production, 2005

Table 7) Calculated losses of ammonia from manure and N-leaching caused by autumn spread, 2005

	Solid ton N/yr	Deep litter ton N/yr	Total ton N/yr
N excreted			
total	*1 019*	*2 043*	*3 062*
NH3-losses, stables and stores			
stable	102	660	762
storage	110	277	387
total	*212*	*937*	*1 149*
Left after stable and storage losses	*807*	*1 106*	*1 913*
NH3-losses, spreading			
early spring			
spring	126	115	
early autumn	34	13	
total	*160*	*146*	*306*
Left to soil			
total	*647*	*960*	*1 607*
which of NH4-N	325	297	622
Losses due to autumn spreading			
leaching	27	25	52
denitrification	21	19	
total	*48*	*44*	*92*
Total losses			*1 546*

Table 8) Calculated losses of nitrous oxide from manure management, egg production 2005

	Solid ton N/yr	Deep litter ton N/yr	Total ton N/yr
N excreted, ton	1 019	2 043	3 062
Default EF	0,001	0,001	
kg N20-N per year	1 019	2 043	**Ton N2O/yr**
Total kg N2O per year	1 600	3 208	**4,81**

Appendix 6) N-losses from manure from egg production, 1990

Table 9) Calculated losses of ammonia from manure and N-leaching caused by autumn spread, 1990

	Solid ton N/yr	Deep litter ton N/yr	Total ton N/yr
N excreted			
total	*3 366*	*473*	*3 838*
NH3-losses, stable and storing			
stable	337	95	431
storage	364	76	439
total	*700*	*170*	*870*
Left after stable and storage losses	*2 666*	*302*	*2 968*
NH3-losses, spreading			
early spring			
spring	320	24	
early autumn	432	33	
late autumn	32	2	
total	*784*	*59*	*843*
Left to soil			
total	*1 882*	*243*	*2 125*
which of NH4-N	816	62	877
Losses due to autumn spreading			
soil leaching	220	17	237
denitrification	170	13	
total	*390*	*30*	*420*
Total losses			*2 133*

Table 10) Calculated losses of nitrous oxide from manure management, egg production 1990

	Solid ton N/yr	Deep litter ton N/yr	Total ton N/yr
N excreted	3 366	473	3 838
Default EF	0,001	0,001	
kg N20-N/år	3 366	473	Ton N2O/yr
Total N2O/år	5 284	742	6,0

Appendix 6) N-losses from beef production, 2005

Table 11) Calculated losses of ammonia from manure and N-leaching caused by autumn application, 2005

	Solid ton N/yr	Urine ton N/yr	Deep bedding ton N/yr	Slurry ton N/yr	Total ton N/yr
N excreted					
stable	520	326	8 298	10 485	19 629
total	*994*	*625*	*14 823*	*12 192*	*28 634*
NH3-losses, stable and storage					
stable	21	13	1 660	734	2 427
storage	100	21	1 991	350	2 462
total	*121*	*34*	*3 651*	*1 084*	*4 890*
Left after stable and storage losses	*399*	*292*	*4 647*	*9 401*	*14 739*
NH3-losses, manure application					
Early spring				73	
Spring	34	37	177	553	
Early summer		32		1 224	
Early autumn	18		121	333	
Late autumn	3	26		206	
total	*55*	*95*	*297*	*2 389*	*2 836*
Left to crops					
total	*344*	*197*	*4 349*	*7 012*	*11 903*
plant-available, NH4-N	44	84	167	3 262	3 558
Losses due to autumn application					
leaching	5	10	17	290	322
denitrification	4	8	13	219	
total	*9*	*18*	*29*	*509*	*565*
Total losses					*8 291*

Table 12) Calculated losses of nitrous oxide from manure management, 2005

	solid ton N/yr	urine ton N/yr	deep beeding ton N/yr	slurry ton N/yr	Total
N excreted	520	326	8 298	10 485	19 629
Default EF	0,005	0	0,01	0,005	
ton N20-N/yr	2,600		82,98	52,425	**Ton N2O/yr**
ton N2O/yr	4,086		130,397	82,307	**216,8**

Table 13) Calculated losses of N2O from manure dropped during grazing, 2005

	Grazing, ton N excreted	Default EF	Ton N2O-N	Ton N2O
Grazing	9 005	0,02	180,1	283,0

Appendix 6) N-losses from beef production, 1990

Table 14) Calculated losses of ammonia from manure and N-leaching caused by autumn spread, 1990

	Solid ton N/yr	Urine ton N/yr	Deep bedding ton N/yr	Slurry ton N/yr	Total ton N/yr
N excreted					
stable	2 714	1 683	4 127	11 321	19 845
total	*3 682*	*2 300*	*7 891*	*11 728*	*25 601*
NH3-losses, stable and storage					
Stable	109	67	825	744	1 745
Storage	521	109	991	380	2 001
total	*630*	*176*	*1 816*	*1 124*	*3 745*
Left after stable and storage losses	*2 084*	*1 507*	*2 311*	*10 197*	*16 099*
NH3-losses, manure application					
early spring				135	
spring	136	190	60	722	
Early summer		163		630	
Early autumn	172	136	76	453	
Late autumn	16	68	7	560	
total	*323*	*557*	*143*	*2 500*	*3 523*
Left to crops					
total	*1 761*	*951*	*2 168*	*7 697*	*12 577*
plant-available, NH4-N	198	434	88	3 888	4 608
Losses due to autumn application					
leaching	43	69	19	635	765
denitrification	32	52	14	478	
total	*75*	*121*	*33*	*1113*	*1 341*
Total losses					*8 610*

Table 15) Calculated losses of nitrous oxide from manure management, 1990

	solid ton N/yr	urine ton N/yr	deep beeding ton N/yr	slurry ton N/yr	Total
N excreted	2 714	1 683	4 127	11 321	**19 845**
Default EF	0,005	0	0,01	0,005	
ton N20-N/yr	13,57		41,27	56,61	**Ton N2O/yr**
ton N2O/yr	21,32		64,85	88,95	**175,1**

Table 16) Calculated losses of N2O from manure dropped during grazing, 1990

	Grazing, ton N excreted	Default EF	Ton N2O-N	Ton N2O
Grazing	5 756	0,02	115,12	180,9

Appendix 6) N-losses from milk production, 2005

Table 17) Calculated losses of ammonia from manure and N-leaching caused by autumn application, 2005

	Solid ton N/yr	Urine ton N/yr	Deep bedding ton N/yr	Slurry ton N/yr	Total ton N/yr
N excreted					
stable	8 424	5 367	376	36 035	50 203
total	*11 328*	*7 207*	*695*	*42 670*	*61 899*
NH3-losses, stable and store					
stable	337	215	75	1 523	2 150
storing	1 617	348	90	1 380	3 436
total	*1 954*	*563*	*166*	*2 903*	*5 586*
Left after stable and storage losses	*6 470*	*4 804*	*211*	*33 132*	*44 617*
NH3-losses, manure application					
early spring				258	
spring	558	605	8	1 948	
early summer		519		4 314	
early autumn	283		6	1 173	
late atumn	49	432		865	
total	*890*	*1 556*	*14*	*8 558*	*11 017*
Left to crops					
total	*5 580*	*3 248*	*197*	*24 574*	*33 600*
plant-avilable, NH4-N	1059	1168	13	14867	17 107
Losses due to autumn application					
leaching	55	113	1	687	856
denitrification	40	81	0	490	
total	*95*	*195*	*1*	*1 177*	*1 467*
Total losses					*18 070*

Table 18) Calculated losses of nitrous oxide from manure management, 2005

	solid ton N/yr	urine ton N/yr	deep beeding ton N/yr	slurry ton N/yr	Total
N excreted	8 424	5 367	376	36 035	**50 202**
Default EF	0,005	0	0,01	0,005	
ton N20-N/yr	42,12		3,76	180,18	**Ton N2O/yr**
ton N2O/yr	66,19		5,91	283,1	**355,2**

Table 19 Calculated losses of N2O from manure dropped during grazing, 2005

	Grazing, ton N excreted	Default EF	Ton N2O-N	Ton N2O
Grazing	11 697	0,02	233,94	367,6

Appendix 6) N-losses from milk production, 1990

Table 20) Calculated losses of ammonia from manure and N-leaching caused by autumn application, 1990

	Solid **ton N/yr**	**Urine** **ton N/yr**	**Deep bedding** **ton N/yr**	**Slurry** **ton N/yr**	**Total** **ton N/yr**
N excreted					
stable	22 256	14 175	537	22 983	59 952
total	*32 998*	*10 498*	*992*	*33 984*	*78 473*
NH3-losses, stable, store					
stable	890	567	108	1 264	2 829
storing	4 273	918	129	780	6 100
total	*5 163*	*1 485*	*237*	*2 044*	*8 929*
Left after stable and storage losses	*17 093*	*12 690*	*301*	*20 939*	*51 023*
NH3-losses, application					
Early spring				178	
Spring	1 111	1 599	8	1 389	
Early summer		1 370		1 823	
Early autumn	1 410		10	981	
Late autumn	128	1 142	1	1 166	
total	*2 649*	*4 111*	*19*	*5 537*	*12 316*
Left to crops					
total	*14 443*	*8 579*	*282*	*15 402*	*38 707*
plant-available NH4-N	1 624	3 655	11	9 430	14 720
Losses due to autumn application					
Leaching	278	465	2	961	1 706
denitrification	204	340	1	704	
total	*482*	*805*	*3*	*1665*	*2 956*
Total losses					*24 201*

Table 21) Calculated losses of nitrous oxide from manure management, 1990

	solid **ton N/yr**	**urine** **ton N/yr**	**deep beeding** **ton N/yr**	**slurry** **ton N/yr**	**Total**
N excreted	22 256	14 175	537	22 983	59 951
Default EF	0,005	0	0,01	0,005	
ton N20-N/yr	111,28		5,37	114,92	**Ton N2O/yr**
ton N2O/yr	174,87		8,44	180,58	**363,9**

Table 22) Calculated losses of N2O from manure dropped during grazing, 1990

	Grazing, ton N excreted	Default EF	Ton N2O-N	Ton N2O
Grazing	18 522	0,02	370,44	582,1

Appendix 7) Estimated feed consumption beef cattle

Table 1) Characterisation of beef cattle herd and estimated feed consumption 2005/2006

	Slaughter age	Number	Roughage fodder (DM)		Pasture (DM)		Straw		Grain		Concentrate	
Category	**month**	**(3)**	**kg/hd**	**total, ton**	**kg/hd**	**total, ton**	**kg/hd**	**total, ton**	**kg/hd**	**total, ton**	**kg/hd**	**total, ton**
Suckler cows (1)	~90	177 000	1 370	242 490	1 900	336 300	365	64 605	20	3 540	30	5 310
Repl heifers (2)		37 000	1 980	73 260	1 270	46 990			93	3 441	20	740
Calf (fr dairy)	8,3	32 400	263	8 521					325	10 530	372	12 053
Bull (fr dairy), intense	15	10 037	1 050	10 539					1 192	11 964	1 075	10 790
Bull (fr dairy) average	18,9	65 243	1 780	116 133					1 450	94 602	203	13 244
Bull (fr dairy) extensive	21	25 094	1 860	46 675					1 570	39 398	165	4 141
Steer (fr dairy)	26	44 000	2 258	99 352	2 612	114 928			152	6 688	46	2 024
Bull, lighter beef	17,5	23 543	1 325	31 194	303	7 134			648	15 256	605	14 244
Bull, heavier beef	16	54 382	834	45 355	309	16 804			778	42 309	745	40 515
Heifers, lighter beef	24	8 160	1 977	16 132	1 270	10 363			63	514	20	163
Heifer, heavier beef	22	20 307	1 644	33 385	1 486	30 176			73	1 482	23	467
Heifers, dairy	28	14 132	1 880	26 568	2 273	32 122			379	5 356	45	636
Org Steer (fr dairy)	26	6 100	1 912	11 663	2 612	15 933			86	525		
Org Bull, lighter beef	18	2 600	1 324	3 442	1 182	3 073			464	1 206	36	94
Org Heifer, beef	24	3 500	1 970	6 895								
Total, net intake				771 604		613 823		64 605		236 812		104 419
Added extra feed for feed waste, over-feeding (4)				~270 000				12 000		19 000		4 000
Total, gross fodder use				1 050 000				76 605		255 812		108 419

1) Feed consumption calculated for the whole suckler-cow population, **consumption data are per year**. 36 453 cows were slaughtered 2006 (~20 % of population)

2) **Lifetime feed consumption** for 37 000 replacement heifers

3) Number of slaughtered cattle in all categories except suckler cows and replacement heifers. Feed consumption for all young livestock are **lifetime consumption**

4) Estimated feed losses after discussions with expert advisory. Feeding system for suckler-cows and heifer often ad-libitum roughage fodder in loose-drift or free-range outside. Over-feeding of females assumed to be more common in 2005 since there are generally surplus of grassland on the beef farms.

Appendix 7) Estimated feed consumption beef cattle

Table 2) Characterisation of beef cattle herd and estimated feed consumption 1990/1991

	Slaughter		Roughage fodder (DM)		Pasture		Straw		Grain		Concentrate	
Category	age, month	Number (3)	kg/hd	total, ton	kg/hd	total, ton	kg/hd	total, ton	kg/hd	total, ton	kg/hd	total, ton
Suckler cows (1)	~90	86 000	1 370	117 820	1 875	161 250	365	31 390	20	1 720	30	2 580
Repl heifers (2)		17 000	1 980	33 660	1 270	21 590		0	28	476	62	1 054
Calf (fr dairy)	2,5	15 750	20	315								
Calf (fr dairy)	6,5	29 250	90	2 633					433	12 665	117	3 422
Bull, grain-fed (fr dairy)	13	30 000	310	9 300					1 317	39 510	210	6 300
Bull, general (fr dairy)	18	175 000	1 590	278 250					1 360	238 000	100	17 500
Bull, lighter beef	17	11 400	1 170	13 338	315	3 591			1 000	11 400	70	798
Bull, heavier beef	14,5	26 600	570	15 162	365	9 709			1 200	31 920	200	5 320
Heifers, lighter beef	24	6 000	1 980	11 880	1 560	9 360			64	384	18	108
Heifer, heavier beef	14	14 000	1 650	23 100	1 775	24 850			75	1 050	21	294
Heifers, dairy	24	31 000	1 100	34 100	2 100	65 100			236	7 316	40	1 240
Total, net intake				539 558		295 450		31 390		344 441		38 616
Added extra feed for feed waste, over-feeding (4)				160 000				18 000		25 000		1 400
Total, gross fodder use				700 000				50 000		370 000		40 000

1) Feed consumption calculated for the whole suckler-cow population, **consumption data are per year**. Stastitics gave no data on the distribution of slaughtered cows in dairy and suckler. We assumed the same replacement (20 %) in 1990/91 as 2005/06 and thus estimated a slaughter of 17 000 suckler cows

2) **Lifetime feed consumption** for 17 000 replacement heifers

3) Number of slaughtered cattle in all categories except suckler cows and replacement heifers. Feed consumption for all young livestock are **lifetime consumption**

4) Estimated losses after discussion with advisory service

Appendix 8) Enteric fermentation

Table 1)2005/06 Methane emissions from the beef cattle population

Livestock categories	**Slaughter age month**	**Slaughter head 2006**	**EF, kg CH4 per lifetime**	**EF, kg CH4 per year**	**Ton CH4**
Calf (fr dairy)	8,3	32 400	28		907
Bull (fr dairy), intense	15	10 037	76	61	763
Bull (fr dairy) average	19	65 243	93	59	6 068
Bull (fr dairy) extensive	21	25 094	103	59	2 585
Steer (from dairy)	26	50 100	128	59	6 413
Bull, lighter beef	17,5	26 143	82	56	2 144
Bull, heavier beef	16	54 382	81	61	4 405
Heifers, lighter beef	24	9 910	106	53	1 050
Heifer, heavier beef	22	22 057	97	53	2 140
Heifers, dairy	28	14 132	124	53	1 752
Beef cow, slaughter		36 453			
Total slaughtered cattle		*345 951*			
Beef cow, total population		177 000		78	13 806
Replacement heifer (20 %)		37 000	106	53	3 922
Total CH4 emissions					*45 954*

Table 2) 2005 Methane emissions from dairy cattle population

Livestock categories	**Production kg ECM**	**Number**	**EF, kg CH4 per lifetime**	**EF, kg CH4 per year**	**Ton CH4**
Dairy cows	9000	393 300		135	53 096
Replacement heifers		330 000		53	17 490
Total CH4 emissions					*70 586*

Appendix 8) Enteric fermentation

Table 3) 1990/91 Methane emissions from the beef cattle population

Livestock categories	Slaughter age month	Slaughter head 2006	EF, kg CH4 per lifetime	EF, kg CH4 per year	Ton CH4
Calf (fr dairy)	2,5	15 750			0
Calf (fr dairy)	6,5	29 250	15		439
Bull, grain-fed (fr dairy)	13	30 000	66	61	1 980
Bull, general (fr dairy)	18	175 000	89	59	15 575
Bull, lighter beef	17	11 400	84	59	958
Bull, heavier beef	14,5	26 600	74	61	1 968
Heifers, lighter beef	24	6 000	106	53	636
Heifer, heavier beef	14	14 000	71	61	994
Heifers, dairy	26	31 000	115	53	3 565
Beef cows, slaughter		17 000			
Total slaughtered cattle		*356 000*			
Beef cow, total population		86 000		78	6 708
Replacement heifer (20 %)		17 000	106	53	1 802
Total CH4 emissions					*34 625*

Table 4) 1990 Methane emissions from milk cattle population

Livestock categories	Production kg ECM	Number	EF, kg CH4 per lifetime	EF, kg CH4 per year	Ton CH4
Dairy cows	7000	576 400		128	73 779
Replacement heifers		470 000		53	24 910
Total CH4 emissions					*98 689*

Appendix 9) Results

*Table 1a)GHG emissions from **pork production 2005**, kg CO2e/kg CW at farm-gate*

	Grain	Concentrate feed	Trp feed	Roughage fodder	Stable	Manure management	Manure application	Indirect N2O emissions	Enteric Fermentation	Total
Carbon dioxide, CO2	0,43	0,24	0,07	0,00	0,04	0,00	0,02	0,00	0,00	0,81
Nitrous oxide, N2O	0,88	0,13	0,00	0,00	0,00	0,30	0,24	0,09	0,00	1,63
Methane, CH4	0,01	0,00	0,00	0,00	0,00	0,77	0,00	0,00	0,17	0,95
Total, GHG	*1,32*	*0,37*	*0,08*	*0,00*	*0,04*	*1,07*	*0,26*	*0,09*	*0,17*	*3,39*

*Table 1b) GHG emissions from **pork production 1990**, kg CO2e/kg CW at farm-gate*

	Grain	Concentrate feed	Trp feed	Roughage fodder	Stable	Manure management	Manure application	Indirect N2O emissions	Enteric Fermentation	Total
Carbon dioxide, CO2	0,59	0,36	0,08	0,00	0,05	0,00	0,02	0,00	0,00	1,10
Nitrous oxide, N2O	0,97	0,13	0,00	0,00	0,00	0,36	0,26	0,14	0,00	1,86
Methane, CH4	0,01	0,01	0,00	0,00	0,00	0,82	0,00	0,00	0,19	1,03
Total, GHG	*1,57*	*0,49*	*0,08*	*0,00*	*0,05*	*1,18*	*0,29*	*0,14*	*0,19*	*3,99*

*Table 2a) GHG emissions from **chicken meat production 2005**, kg CO2e/kg CW at farm-gate*

	Grain	Concentrate feed	Trp feed	Roughage fodder	Stable	Manure management	Manure application	Indirect N2O emissions	Enteric Fermentation	Total
Carbon dioxide, CO2	0,25	0,41	0,19	0,00	0,07	0,00	0,00	0,00	0,00	0,91
Nitrous oxide, N2O	0,53	0,22	0,00	0,00	0,00	0,02	0,13	0,05	0,00	0,95
Methane, CH4	0,01	0,01	0,00	0,00	0,00	0,05	0,00	0,00	0,00	0,07
Total, GHG	*0,78*	*0,64*	*0,19*	*0,00*	*0,07*	*0,07*	*0,13*	*0,05*	*0,00*	*1,93*

Appendix 9) Results

Table 2b) GHG emissions from ***chicken meat production 1990****, kg CO2e/kg CW at farm-gate*

	Grain	Concentrate feed	Trp feed	Roughage fodder	Stable	Manure management	Manure application	Indirect N2O emissions	Enteric Fermentation	Total
Carbondioxide, CO2	0,31	0,62	0,12	0,00	0,36	0,00	0,00	0,00	0,00	1,40
Nitrous oxide, N2O	0,64	0,14	0,00	0,00	0,00	0,02	0,16	0,07	0,00	1,03
Methane, CH4	0,01	0,01	0,00	0,00	0,01	0,06	0,00	0,00	0,00	0,08
Total, GHG	*0,95*	*0,76*	*0,12*	*0,00*	*0,37*	*0,08*	*0,16*	*0,07*	*0,00*	*2,51*

Table 3a) GHG emissions from ***egg production 2005****, kg CO2e/kg egg at farm-gate*

	Grain	Concentrate feed	Trp feed	Roughage fodder	Stable	Manure management	Manure application	Indirect N2O emissions	Enteric Fermentation	Total
Carbon dioxide, CO2	0,20	0,23	0,11	0,00	0,01	0,00	0,00	0,00	0,00	0,56
Nitrous oxide, N2O	0,43	0,20	0,00	0,00	0,00	0,01	0,09	0,07	0,00	0,80
Methane, CH4	0,00	0,01	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,06
Total, GHG	*0,64*	*0,44*	*0,11*	*0,00*	*0,01*	*0,06*	*0,09*	*0,07*	*0,00*	*1,42*

Table 3b) GHG emissions from ***egg production 1990****, kg CO2e/kg egg at farm-gate*

	Grain	Concentrate feed	Trp feed	Roughage fodder	Stable	Manure management	Manure application	Indirect N2O emissions	Enteric Fermentation	Total
Carbon dioxide, CO2	0,26	0,34	0,05	0,00	0,02	0,00	0,00	0,00	0,00	0,68
Nitrous oxide, N2O	0,43	0,06	0,00	0,00	0,00	0,01	0,11	0,07	0,00	0,69
Methane, CH4	0,01	0,01	0,00	0,00	0,00	0,03	0,00	0,00	0,00	0,05
Total, GHG	*0,70*	*0,41*	*0,05*	*0,00*	*0,02*	*0,05*	*0,12*	*0,07*	*0,00*	*1,42*

Appendix 9) Results

*Table 4a) GHG emissions from **milk production 2005**, kg CO2e/kg ECM at farm-gate. NB not allocated!*

	Grain	**Concentrate feed**	**Trp feed**	**Roughage fodder**	**Stable**	**Manure management**	**Manure application**	**Indirect N2O emissions**	**Enteric Fermentation**	**Total**
Carbon dioxide, CO2	0,04	0,05	0,03	0,05	0,03	0,00	0,01	0,00	0,00	0,20
Nitrous oxide, N2O	0,07	0,04	0,00	0,11	0,00	0,03	0,10	0,03	0,00	0,38
Methane, CH4	0,00	0,01	0,00	0,00	0,00	0,07	0,00	0,00	0,54	0,62
Total, GHG	*0,11*	*0,10*	*0,03*	*0,17*	*0,03*	*0,10*	*0,10*	*0,03*	*0,54*	*1,20*

*Table 4b) GHG emissions from **milk production 1990**, kg CO2e/kg ECM at farm-gate. NB not allocated!*

	Grain	**Concentrate feed**	**Trp feed**	**Roughage fodder**	**Stable**	**Manure management**	**Manure application**	**Indirect N2O emissions**	**Enteric Fermentation**	**Total**
Carbon dioxide, CO2	0,10	0,04	0,02	0,08	0,03	0,00	0,01	0,00	0,00	0,27
Nitrous oxide, N2O	0,10	0,03	0,00	0,16	0,00	0,03	0,12	0,03	0,00	0,47
Methane, CH4	0,00	0,00	0,00	0,00	0,00	0,05	0,00	0,00	0,69	0,75
Total, GHG	*0,20*	*0,07*	*0,02*	*0,24*	*0,04*	*0,08*	*0,12*	*0,03*	*0,69*	*1,49*

*Table 5a) GHG emissions from **beef production 2005**, kg CO2e/kg CW at farm-gate. NB, not allocated!*

	Grain	**Concentrate feed**	**Trp feed**	**Roughage fodder**	**Stable**	**Manure managament**	**Manure application**	**Indirect N2O emissions**	**Enteric Fermentation**	**Total**
Carbon dioxide, CO2	0,25	0,25	0,10	0,80	0,31	0,00	0,04	0,00	0,00	1,74
Nitrous oxide, N2O	0,47	0,17	0,00	1,46	0,00	0,47	1,13	0,30	0,00	4,00
Methane, CH4	0,01	0,03	0,00	0,01	0,00	1,32	0,00	0,00	8,41	9,79
Total, GHG	*0,72*	*0,45*	*0,10*	*2,27*	*0,31*	*1,79*	*1,16*	*0,30*	*8,41*	*15,53*

Appendix 9) Results

*Table 5b) GHG emissions from **beef production 1990**, kg CO2e/kg CW at farm-gate. NB, not allocated!*

	Grain	**Concentrate feed**	**Trp feed**	**Roughage fodder**	**Stable**	**Manure managament**	**Manure application**	**Indirect N2O emissions**	**Enteric Fermentation**	**Total**
Carbon dioxide, CO2	0,36	0,13	0,04	0,70	0,22	0,00	0,04	0,00	0,00	1,48
Nitrous oxide, N2O	0,66	0,05	0,00	1,44	0,00	0,37	0,92	0,28	0,00	3,73
Methane, CH4	0,01	0,01	0,00	0,01	0,00	0,99	0,00	0,00	6,19	7,22
Total, GHG	*1,03*	*0,18*	*0,04*	*2,15*	*0,22*	*1,37*	*0,97*	*0,28*	*6,19*	*12,42*