KLIMATMÄRKNING FÖR MAT.

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GREENHOUSE GAS EMISSIONS

IN CHICKEN PRODUCTION

DECISION SUPPORT FOR CLIMATE CERTIFICATION

Written by Ulf Sonesson, Christel Cederberg and Maria Berglund
Translated by Mary McAfee

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1 INTRODUCTION

This report forms part of the project 'Climate Labelling of Food'. This project was initiated by KRAV and the IP Sigill quality system in 2007 with the aim of 'decreasing climate impact by creating a labelling system for food through which consumers can make conscious climate choices and businesses can increase their competitive power'. The project is being run by KRAV and the IP Sigill quality system in partnership with Milko, Lantmännen, LRF, Scan and Skånemejerier. The Swedish Board of Agriculture is also participating as an associate in the project (www.klimatmarkningen.se).

In spring 2009, the project commissioned the Swedish Institute for Food and Biotechnology AB (SIK) to draw up decision support for climate certification of beef, pig meat, chicken and eggs. This task was carried out by Ulf Sonesson, and the commissioning agents from the project were Anna Richert at Svenskt Sigill and Zahrah Ekmark at KRAV. In addition, Christel Cederberg, SIK, and Maria Berglund, Halland Rural Economy & Agricultural Society, were involved in producing this report.

Within the project, reports containing proposed criteria for fruit & vegetables, fish and shellfish, cereals and pulses, transport, animal feed and milk production have also been produced. A decision support report on packaging was completed in June 2009. A criteria report on lamb may be produced later in 2009.

The aim of the present report was to identify critical points in the life cycle of chicken as regards the climate impact of this product. On the basis of this analysis, criteria for climate certification at product level are proposed. The starting point was mainly published Life Cycle Analyses (LCA) of the products, complemented with other relevant research and information.

Chapter 2 gives a detailed description of the climate impact of chicken production, which provides the starting point for the remainder of the report. Chapter 3 deals with emissions of the biogenic greenhouse gases methane and nitrous oxide and identifies important aspects and measures. Chapter 4 deals with energy consumption on the farm and Chapter 5 with feeding. Chapter 6 then presents proposed criteria.

2 CLIMATE IMPACT OF CHICKEN PRODUCTION – SUMMARY OF EXISTING KNOWLEDGE

Production of broiler chickens is carried out in a relatively similar way throughout Sweden and also in large parts of the industrialised world. The birds are delivered to the rearing farm as day-old chicks and are reared to a slaughter weight of around 1.4 kg at approx. five weeks of age, corresponding to a live weight of approx. 1.8 kg. The chicks are supplied by producers that specialise in the phase from hatching to delivery of production birds, in Sweden from one main hatchery. This hatchery imports 'grandparent' birds, the progeny of which comprise the 'parent' generation for the broiler chickens. Breeding work on broiler chickens is an activity carried out by global agencies and it is mainly these that produce the generation before grandparents. The actual rearing of broiler chickens is carried out in batches, with the house being emptied, cleaned and disinfected before the next batch is introduced. The house is heated throughout the growing period. The feed consists of grain and a protein-rich concentrate. The broiler producer either buys a ready-made feed or buys a concentrate to mix with home-grown grain. Broiler chickens require a relatively high protein content and also require the correct amino acid composition in order for growth rate to be high. The manure is managed as dry solid manure, i.e. as deep litter. Poultry manure is generally rich in nitrogen, which means that ammonia emissions from manure management can be considerable, but also that the manure can be valuable in crop production. Poultry manure is also rich in phosphorus

In organic production of broiler chickens the growing period is longer. The birds must be 10 weeks at slaughter, must be allowed outdoors and must be fed organic feed. There are currently no life cycle analysis (LCA) studies of organic production and since organic production differs significantly from conventional, at present we cannot identify climate certification regulations for organic chicken.

Consumption of chicken has been increasing for a long time. In 1990 per capita consumption was 5.9 kg and in 2005 16.6 kg. During the same period, Swedish production increased from the equivalent of 5.7 kg/capita to 11.8 kg per capita, with the additional increase in consumption being met by imported chicken, primarily from Denmark.

There are a limited number of life cycle analyses of chicken in the literature. In Sweden, Thynelius (2008) has published a study on the climate impact of Swedish chicken, which in turn is partly based on an earlier study (Anon., 2002). Both these studies are of a case study nature. A completely new study by Cederberg et al. (2009) is not a conventional LCA of a case study nature, but a 'top-down' LCA study of all Swedish production of animal-based foods, divided into different animal species. This will allow the climate impact of Swedish mean chicken to be quantified. The outcome of the study is that, similarly to other studies, it will be possible to distinguish the parts of primary production that make the greatest contribution and also the gases emitted. The study can be regarded as the most comprehensive presented to date. The study will be published in 2009 and the values presented here are the final results.

Internationally, there is a study from the UK by Williams et al. (2006), which calculated the climate impact for chicken with the help of computer simulations of type farms. Three systems were analysed: 'conventional', 'conventional free-range' and 'organic'. In addition to outdoor access the latter also had higher slaughter weight and thus a considerably longer growing period, which gives higher greenhouse gas emissions. The values reported in that study were considerably higher than the Swedish values. There are several reasons for the higher figures in the British study. Use efficiency of the nitrogen in the manure was assumed to be very low, which led to a small amount of mineral fertiliser being replaced and greater nitrogen losses causing emissions of nitrous oxide. The authors justified this assumption by considering the manure as biological waste rather than a good fertiliser, which led to high doses for spreading. In addition, the efficiency in feed production was lower, which gave a somewhat higher climate impact for the feed. Finally, fossil fuel was used for heating the houses, whereas in the Swedish studies biofuel dominated.

Table 1. Emissions of greenhouse gases per kg bone-free meat at the farm gate, summary of published studies

Study	CO_2-equiv./kg meat			
	Total	CH_4	N_2O	CO_2
Thynelius, 2008 [a]	1.5			
Anon. 2002	1.4	0.1	0.85	0.55
Cederberg et al. (2009) [c]	2.5	0.1	1.2	1.2
Williams et al. (2006), conventional [b]	6.1			
Williams et al. (2006),	7.3			

free-range [b]	

[a] *In this study, emissions of each greenhouse gas are not presented*
[b] *Results converted from slaughter weight to kg meat with 77% cutting-out from slaughter weight to bone-free chicken*

In the studies listed in Table 1 different weighting factors were used, as IPCC updated theirs in 2007 when new information on the greenhouse gas potential of the different gases had emerged. In brief, the updates meant that the weighting factor for methane was increased from 21 to 25 and the factor for nitrous oxide was lowered from 310 to 298. Emissions of both compounds are important and whether the overall outcome using the updated values is higher or lower depends on the relative proportions of nitrous oxide and methane. However, this did not affect the conclusions of this report.

Table 2. Proportion of emissions of greenhouse gases arising from different activities

Study	Proportion of emissions (%)		
	Feed (crop growing, inputs)	Animal rearing (energy, chickens)	Manure
Thynelius, 2008 [a]	67	17 [b]	16
Cederberg et al. (2009) [c]	84	3	13

[a] *Read off histogram*
[b] *Of this, rearing of day-old chicks represents around 95%*
[c] *Includes rearing of day-old chicks in the respective groups (feed, animal rearing and manure).*

A factor that was not included in the studies above is emissions of greenhouse gases caused by the construction and upkeep of buildings and on-farm equipment. There is limited information on how this affects the overall results, but according to Frishknecht et al. (2007) these emissions represent less than 10% of the total emissions for feed production. There are no data on animal production in that paper. Another study of this area has been presented by Erzinger & Badertscher Fawaz (2001), who analysed the proportion of the energy inputs for milk production coming from buildings. The results showed that this proportion can be up to 50%. Since energy-related emissions constitute a small proportion of greenhouse gas emissions and since chicken production has not been studied, no far-reaching conclusions can be drawn from that study, other than that it would be good to have a more in-depth study of production under Swedish conditions.

3 WAYS TO DECREASE EMISSIONS OF METHANE AND NITROUS OXIDE

Since the greatest proportion of greenhouse gas emissions from chicken production consist of nitrous oxide emissions, partly from the manufacture of commercial fertiliser and partly from nitrogen conversion in the soil during feed growing, this is a logical area on which to concentrate. The area is relatively complicated and the level of knowledge as regards nitrous oxide formation in soil is insufficient to allow specific measures for decreasing emissions to be identified, other than to generally decrease nitrogen flows in the system. There are probably large variations in the amounts of nitrous oxide formed in arable soil, both between years and between regions or even between fields (Jungkunst et al., 2006). The method used to quantify nitrous oxide emissions in the studies presented above was the official method from IPCC (2007), which is a statistical method that calculates nitrous oxide formation as a function of the amount of total nitrogen added to the soil. This results in measures to decrease nitrous oxide emissions largely consisting of decreasing nitrogen flows in the system in general, while maintaining production levels. This is not a problem per se, as increased nitrogen use efficiency in agriculture has many advantages and is positive for many environmental targets.

As regards methane emissions from chicken production, this is mainly a question of manure management, storage in particular. However the emissions are low since the manure is handled in dry form and anaerobic conditions occur to a very small extent during storage. Since poultry manure is nitrogen-rich, manure management can also give rise to considerable ammonia emissions. Ammonia is not a greenhouse gas itself, but when the ammonia is deposited the nitrogen it contains is added to ecosystems, which means nitrous oxide emissions. This effect is called indirect nitrous oxide emissions.

Nitrogen use efficiency in feed growing is included in the proposed criteria for feed and is not considered in this report

3.1 Improving nitrogen use efficiency

In general, the nitrogen content of the feed should be as low as possible without affecting growth. Having a low nitrogen content in the feed generally gives a lower nitrogen content in the manure, which in turn means that the risks of indirect emissions of nitrous oxide and ammonia in later stages are decreased (see more below under 'Manure management'). A low nitrogen content can be achieved through better knowledge about the composition of home-grown feed, plus addition of synthetic amino acids. Frequent analyses of protein in feedstuffs, in terms of both quantity and amino acid composition, are essential for optimising nitrogen supply.

3.2 Manure management

Ammonia, (NH_3), which is very volatile, is formed during storage of manure. Emissions of ammonia mean two things: 1) The ammonia itself can contribute to nitrous oxide formation when it is oxidised and affects nitrogen turnover in the ecosystem on which it is deposited; and 2) the lower amount of nitrogen left in the manure leads to a greater requirement for supplying other nitrogen to the crop, as mineral fertiliser nitrogen, green manure or biogas digestor residues, which in turn have given rise to emissions of greenhouse gases. Covering the stored manure decreases ammonia emissions.

Poultry manure differs from other types of manure in that the majority of the nitrogen excreted by the animal is in the form of uric acid. The uric acid is converted to ammonium at varying rates depending on the storage conditions. In order to determine the fraction of the total nitrogen that is plant-available, not only the ammonium content but also the content of nitrogen in the uric acid must be analysed, since this is rapidly converted to plant-available ammonium on contact with the soil and can thus be regarded as directly plant-available (Salomon et al., 2006).

The manure must be spread on as large an area as possible so that the plant nutrients can be utilised efficiently in crop production and also at a time when the crop can utilise the nutrients. Using a larger area decreases the risk of ammonia emissions and nitrate leaching, which means lower indirect nitrous oxide emissions and also decreases the need for mineral fertilisers. A lower demand for mineral fertilisers leads to lower emissions of both carbon dioxide and nitrous oxide from the manufacture of such fertiliser. Due to the high content of plant-available nitrogen combined with a high dry matter content, poultry manure must be applied in low doses, which places great demands on the spraying equipment used.

Chickens are reared on straw bedding and ammonia can be formed in the bedding. Avoiding having the bedding too wet decreases the risk of ammonia emissions, but this can be difficult to achieve in practice.

3.3 Manure drying

Poultry manure is a valuable fertiliser with a high content of readily available nitrogen and also a high phosphorus concentration. Chicken production is often carried out in large units, so large amounts of manure are generated in each unit. Overall, this means that the chicken manure sometimes has to be dried before being transported away to arable farms. The positive aspect is that the manure is probably spread over a greater area, which can give better nitrogen use efficiency, with lower emissions of nitrous oxide and a lower mineral fertiliser requirement. Drying the manure also decreases the fuel requirement for transport. However, large amounts of energy are used for drying manure and if this is of fossil origin, the greenhouse gas emissions are high. An LCA of different ways to deal with poultry manure has been presented by Westgöte (2000). This study compared drying, pelleting, transport and spreading with the transport and spreading of fresh manure. The results clearly showed that drying manure is worse for the environment. In the basic scenario, emissions of greenhouse gases were almost twice as high for dried manure, despite the manure being dried using biofuel. The study also found that for a 490 km transport distance the fossil energy consumption was similar for both options, while for total energy consumption the breakpoint was 1800 km

3.4 Biogas production from manure

Poultry manure is an interesting substrate for biogas production. Biodigestion trials on hen and broiler chicken manure show similar biogas yield per ton dry matter as for cattle and pig slurry (190 m^3 per ton DM for laying hen manure (Carlsson & Uldal, 2009) and chicken manure should give a similar gas yield. The advantage with poultry manure is that it has a high dry matter content, which leads to high biogas yield per ton of manure and makes it economically justifiable to transport it longer distances than cattle or pig manure. Poultry manure also has a high plant nutrient content per ton, making it a valuable substrate in co-digestion biogas plants since it can help increase the value of the biodigestion residues as a fertiliser. However, the high nutrient content of poultry manure also makes it attractive for other purposes and it is not certain that a co-digestion plant would be the preferred outlet. There have been a few preliminary studies on dry biodigestion of poultry manure at farm level (Fjäderfäcentrum, 2007). Such biodigestion could be an interesting option, but it would require e.g. large biogas plants (for example through partnerships between businesses and/or co-digestion with other substrates) to make it financially viable and to obtain a good market for the gas. The manure would yield more biogas than the poultry producers could use internally so additional outlets would be needed. In addition, more experience of dry biodigestion is needed. There are many dry biodigestion plants in Germany in which they digest e.g. ley crops, but there are no corresponding small-scale plants in Sweden.

3.5 Animal welfare – production

In order to achieve a low climate load for the product chicken, there must be high production per unit feed and other resources used. Part of this involves the birds being healthy and thus able to produce efficiently. As regards broiler chicken production, in principle the mortality during the growing period is the most important parameter, as every bird that dies has given rise to a certain amount climate impact that must be borne by the chickens brought to slaughter, so from a systems perspective, the lower the mortality the better. The mortality in Swedish broiler chicken production is around 3.5%, based on data from Sweden's largest broiler chicken producer, Kronfågel (B. Henriksson, pers com. 2008, cit Cederberg et al., 2009). Today there is an animal welfare programme run by the sector organisation Svensk Fågel that includes a range of aspects, such as density, requirements on the technical equipment and upkeep. The animal welfare programme comprises inspections in which a total of 31 items are checked. There are also programmes to control Salmonella, Campylobacter, Coccidiosis and to improve foot health. All these programmes aim to improve animal health, and will probably also lead to lower mortality over time (Svensk Fågel, 2009; Waldenstedt, 2009).

3.6 Suggested measures for decreasing methane and nitrous oxide emissions

- Analyse home-grown feed with respect to protein content and amino acid composition and in consultation with the feed supplier devise a feed formulation for concentrate that decreases emissions in feed production while maintaining growth per kg feed.
- Store manure under a roof or in a tank
- Ensure that deep litter does not become too wet through choice of appropriate drinking water nipples, adequate amounts of litter and good upkeep of houses.
- Lowering mortality is an important measure and can be achieved by good stock-keeping routines and careful monitoring of production data. It is important here to include effects causing losses at later stages in the form of rejections at slaughter.
- Sampling of the manure and subsequent adaptation of the dose of any complementary fertilisation to take account of the nitrogen-supplying capacity of the poultry manure (considering both the ammonium and the uric acid concentration).
- Manure must be applied on a sufficiently large area to allow efficient use of the nutrients in the manure and to a crop that can utilise the nitrogen efficiently.
- Use the manure for biogas production

4 Energy consumption

Energy consumption represents a relatively small proportion of the total greenhouse gas emissions from agriculture. Based on statistics on energy consumption in the agricultural sector and standard values for the climate impact of different energy carriers, these emissions are estimated to be just over 1 million tonnes of CO_2 equivalents per year (SCB, 2008; Berglund et al., 2009). This can be compared with estimated methane and nitrous oxide emissions from the Swedish agricultural sector of 8.8 million ton CO_2-equiv per year (Naturvårdsverket, 2009). This does not include emissions from the production of input materials such as mineral fertiliser and imported feedstuffs or the effects of changes in carbon stocks in the soil.

Total energy consumption in agriculture calculated for the year 2007 amounted to 3.1 TWh for heating, lighting, etc. (excluding residences and greenhouses) and 2.9 TWh in the form of fuel for vehicles (SCB, 2008) (see Table 3). Energy consumption varies from year to year due to e.g. structural changes and variations in the weather, which affect e.g. the oil required for drying.

Table 3. Energy consumption in Swedish agriculture, 2007 (SCB, 2008)

Energy category	Volume of energy consumed	Calorific value	Energy consumption (TWh)
Heating, lighting, etc.			
Oil	$5.6*10^4$ m^3	9.95-10.58 MWh/m^3	0.57
Wood	$4.8*10^5$ m^3	1.24 MWh/m^3	0.59
Straw	$6.1*10^4$ ton	4.1 MWh/m^3	0.25
Chippings, bark, sawdust	$2.8*10^5$ m^3	0.75 MWh/m^3	0.21
Other biofuels (grain, pellets, etc.)	n.a.	n.a.	0.11
Paraffin, etc.	n.a.	n.a.	0.010
Electricity			1.4
Total			***3.1***
Use in vehicles			
Diesel	$2.8*10^5$ m^3	9.8 MWh/m^3	2.7
Petrol	$1.3*10^4$ m^3	8.7 MWh/m^3	0.11
RME[1] + ethanol (E85)	n.a.	n.a.	0.04
Total			***2.9***

[1]*RME = rape methyl ester*

Although energy consumption represents a small part of the climate impact of agriculture, the climate question is strongly linked to energy consumption in a wider societal perspective. Measures aimed at improving energy efficiency or decreasing greenhouse gas emissions from energy consumption are therefore important in all sectors, including agriculture, in order to decrease the total climate impact of society and the dependency on fossil energy. In terms of individual enterprises, high use of fossil energy can lead to high greenhouse gas emissions. This applies for chicken production if e.g. the houses are heated using fossil fuels such as oil (Widheden, 2001).

This chapter discusses the energy consumption that occurs on the farm and how the efficiency of this can be improved, i.e. by decreasing overall consumption and the proportion of fossil energy, but does not always calculate how greenhouse gas emissions are affected by these changes. The reason for this is that greenhouse gas emissions vary widely between different energy sources and thus the effects of changes in energy consumption are strongly affected by the type of energy assumed to be affected by the change. In terms of the entire life cycle of electricity, wind, hydro and nuclear electricity only produce a few grams of CO_2-equiv per kWh electricity, while greenhouse gas emissions from fossil fuel-based electricity are around a hundred times higher. The effects of increased efficiency in electricity or of new electricity production are thus very strongly influenced by the assumptions made about the origins of the electricity. This reasoning also applies to the effects of producing biofuel on the farm, since the biofuel can replace fossil fuel or other renewable fuels. In order to assess and optimise the effects of increasing energy efficiency or energy production, there is also a need for a wider societal perspective where account is taken of how the changes affect the entire energy system and where e.g. the biofuel produced can be used to best advantage

This chapter deals with the direct energy consumption that takes place on the farm, e.g. in the form of diesel for tractors, but not the indirect energy consumption that can be associated with the production of mineral fertilisers, purchased feeds and other external inputs. However, it is important to note that the same units (e.g. MJ) are used for different energy sources and energy carriers, but despite this they are not directly additive and comparable. One MJ of biofuel cannot be used for the same purposes and does not give the same benefits as 1 MJ of diesel or 1 MJ of electricity. The biofuel can admittedly be used e.g. to produce electricity, but conversion losses mean that more than 1 MJ of biofuel is needed to produce 1 MJ of electricity. One way to compare different types of energy is therefore to convert them to primary energy, which involves specifying the amounts of natural resources used in production of raw materials, production, distribution, etc. One MJ of electricity produced in a natural gas power station with a conversion efficiency of 50% would thus be equivalent to approx. 2.2 MJ of primary energy in the form of natural gas (incl. harvesting of the natural gas and distribution losses in the electricity grid). However, like other energy carriers and energy sources, electricity can be produced in many different ways with differing conversion losses and therefore different conversion factors. The primary energy concept can also be difficult to assimilate intuitively. Therefore where possible, energy consumption is divided into electricity, diesel, biofuel, etc. here, in order to make reporting as transparent as possible

4.1 Within-farm consumption of energy

In broiler chicken production, heating represents a very large proportion of within-farm energy consumption (Widheden, 2001; Hörndahl, 2007; Thynelius, 2008; Neuman, 2009). Fuel consumption for heating appears to comprise ~80-90% of secondary energy consumption on the few farms investigated in previous energy mappings and life cycle analyses. Otherwise, energy is used mainly for ventilation, lighting, manure removal and feeding. However, the heat requirement and the ventilation requirement vary greatly during the growing period. When the chicks enter the house the heating requirement is high, but it gradually decreases as the chickens grow and produce heat themselves. The ventilation requirement gradually increases to maintain good air quality and to remove humidity.

4.1.1 Heating

In the past, heating was mainly provided by oil, but today biofuel dominates (Widheden, 2001; Tynelius, 2008; Cederberg et al., 2009). During the 1990s, oil comprised around 80% of the energy used for heating, but today 80% of the heating is provided by biofuel, mainly incineration of straw and wood chippings, and the proportion of biofuel is still increasing (ibid.). Previous life cycle analyses show that heating is very significant for the total climate impact of chicken meat. In an LCA from 2001, greenhouse gas emissions from the broiler growing period (including production of feed and emissions occurring on the farm) were estimated to be ~1.3 kg CO_2-equiv. per kg fresh, bone-free chicken meat when heating was based on straw, but ~2 kg CO_2-equiv per kg fresh, bone-free chicken meat when heating was based on oil (Widheden, 2001).

In terms of heating it is necessary to consider both the boiler output requirement of the building (e.g. kW) and the energy requirement (e.g. kWh heat per year). The boiler output requirement varies greatly depending on external temperature, the amount of heat produced by the birds and the amount of heat lost through ventilation. In designing the heating system, it is necessary to start with the highest output requirement needed to supply the heating needs on the coldest days, but not necessarily assume that one heating system will meet the entire output required. In the case of e.g. soil or rock heat exchange pumps, it is often assumed that the base option in the system will meet 60-70% of the highest output required and that this is complemented with e.g. electricity or an existing oil boiler to meet the peak demand. It would be unnecessarily expensive to design the equipment according to the highest output required, and a base option that provides 60-70% of the highest output requirement will still almost cover the entire heat requirement on an annual basis. When comparing different heating systems it is also important to take account of any difference in power conversion efficiency, since this can vary depending on fuel, age of equipment, manufacturer, etc. The total fuel requirement can therefore differ between different heating options for a farm.

As mentioned previously, the heat requirement is very high when the chicks first enter the house but then decreases sharply. This places particular demands on the heating system since it has to cope with large variations in output requirement and requires a relatively large boiler to meet the peak requirement. Oil has been a good option in the past since oil boilers can be accurately controlled and have low investment costs per kW power output. The investment costs per kW are higher for biofuel heating boilers and therefore it can be financially preferable to have biofuel as the base option but retain the oil boiler so as to top up with oil-based heating when the demand for output is high. Such solutions can decrease oil consumption considerably, since most of the heating can be taken as the base load. The high investment costs for biofuel are balanced out by the fact that biofuels such as straw and wood chips are considerably cheaper than oil. The cost of harvesting and compressing straw is around 12-15 öre/kWh straw (including the value of the straw in crop growing) and the cost of forest chips for a power plant is currently 17 öre/kWh (Energimyndigheten, 2009).

There are heating systems with or without accumulator tanks. Oil or wood chip combustion is often based on systems without accumulator tanks, while straw combustion can either be carried out in batches in a batch incinerator with an accumulator tank or in a continuous process. The advantage of having an accumulator tank is that the boiler can be run at full effect where it has the highest power conversion efficiency instead of being regulated to meet the actual heat requirement. However, a system with an accumulator tank requires a larger boiler, which affects the investment costs, since the boiler has to heat the accumulator tank and meet the heat requirement of the farm. Today the best wood chip boilers can be regulated down to 10% of full effect, but they operate best at full effect.

It can be interesting to use heat exchange pumps to meet the heat requirement. A rock or soil heat exchange pump produces an estimated 3-4 kWh heat per kWh electricity supplied. Heat exchange pumps work well with underfloor heating since the outgoing temperature from the heat exchange pump is relatively low, which is suitable for underfloor heating. The heat exchange pump system is usually not designed to meet the highest output required but can be complemented with an electric cartridge or the heat from an existing oil boiler. The greenhouse gas emissions from a heat exchange pump system are still very low since Swedish electricity production gives only a small climate impact and the heat exchange pump can meet almost the entire heat requirement during the year.

It is also important to examine buildings and the ventilation system and to minimise heat losses. This can include blocking draughts, providing additional insulation in walls and ceilings or improving the microclimate around the house by planting windbreaks (Eliasson et al., undated).

4.1.2 Ventilation

The purpose of ventilation is to remove moisture released by the birds, supply the birds with fresh air and maintain the required temperature and air quality in the house. Mechanical ventilation is used in chicken production. There are a number of ways to decrease electricity consumption for mechanical ventilation. Maintenance and cleaning of fans, ventilation ducts and air inlets are very important in keeping down the electricity requirement. Annual cleaning of the ventilation system can save up to 10% energy (Eliasson et al., undated). It is important that control and regulation equipment is operating properly and is set correctly, so that e.g. the ventilation and heating controls are not counteracting each other. If the ventilation is trying to maintain a lower air humidity than intended, this increases the energy requirement for ventilation but also for heating when supplementary heating is used. For example, in a sample calculation in Hadders (undated), the energy requirement in a heated house for piglets was estimated to be twice as high when the ventilation was working to maintain 68% air humidity instead of 75% air humidity.

There are various systems for controlling ventilation, with varying energy efficiency. A first step can be to introduce stepless connection of the fans instead of running all fans simultaneously regardless of ventilation requirement, if this has not already been done. Other energy efficiency solutions are revolution count and frequency regulators, possibly in combination with stepless connection of fans (Hadders, undated).

4.2 Energy for transport

Road transport by tractor is a more energy-demanding option than transport by lorry. Diesel consumption in transport by tractor lies within the range 0.035-0.08 litres per ton*km (load weight ~8-20 ton). The corresponding figures for lorries are 0.03-0.04 l/ton*km for a medium-weight lorry (load capacity approx. 15 ton) and 0.012-0.02 l/ton*km for a heavy lorry with trailer (load capacity 40 ton). With hay and straw, for example, load size can be limited by volume instead of weight, and diesel consumption per ton*km is then higher (Fogelberg et al., 2007).

Ecodriving decreases energy consumption, greenhouse gas emissions and diesel costs and thus provides a direct financial benefit for the farmer. Ecodriving involves e.g. choosing the best gear and engine load for the task in hand, minimising idling and avoiding unnecessary work. Incorporation of ecodriving into tractor work has been shown to give fuel savings of around 20% (Fogelberg et al., 2007). In occasional demonstration events considerably greater savings have been recorded, while the time requirement is also decreased when driving is planned more carefully

There are cases where tractors can be fuelled fully or partly with biofuels such as FAME (fatty acid methyl esters), including e.g. rape methyl ester (RME), biogas or ethanol. The most realistic alternative today is considered to be a low inclusion of biofuel, e.g. RME, in the diesel. This measure gives only a small decrease in greenhouse gas emissions from individual vehicles, but since it does not require any major alterations to the vehicle fleet and can be implemented on a very large scale, it is a simple way to increase the proportion of biofuel. Nearly all the FAME usage in the transport sector currently consists of low inclusion in diesel, and in 2007 two-thirds of the diesel used contained 2-5% FAME (Energimyndigheten, 2008). Total greenhouse gas emissions from a tractor are estimated to be 3.25 kg CO_2-equivalents per litre of diesel (without inclusion of biofuel, but including emissions from production, distribution and end-use). With low inclusion of 5% RME, emissions would be 3.20 kg CO_2-equivalents per litre of fuel (including emissions from growing the rape, production, distribution and end-use). More refined biofuel alternatives may require greater adaptations and adjustments, e.g. addition of an ignition improver so that ethanol can be used in diesel engines or fitting of pressurised tanks for biogas. The use of biogas as a vehicle fuel is also regulated by far-reaching legislation, and current legislation on approval of tractor types only covers liquid fuels. Those wishing to use farm-produced biogas as a tractor fuel also need to consider that biogas production is relatively constant during the year, whereas the fuel requirement of tractors follows the crop growing season and thus varies greatly. Long-term storage of biogas is not an option due to the high costs, so other solutions are needed to find an outlet for the gas. There is a need for deeper systems analyses in order to assess how and where biofuels can best be used in society, and this may be in contexts other than as a fuel for agricultural machinery.

4.3 Suggested improvement measures

Here we suggest two general measures for improving energy use efficiency in chicken production, namely improvements at investment and energy mapping. These measures need to be adapted to the situation in farms. These measures are relevant regardless of farm enterprise and should therefore be coordinated with the general regulations for climate certification and applied to all types of farms in a climate certification system.

The overall aim of these measures is to improve the efficiency of energy consumption on the farm, partly through decreasing total energy consumption, and partly through increasing the proportion of renewable energy. This can also cover utilising resources on the farm for energy generation, e.g. from straw or manure. However, more information and further systems analyses that include all of society are needed in order to determine how the renewable energy produced can best be used from a societal perspective. For example, how can harvested straw best be used for energy purposes: on the farm of origin for heat production in the business, with excess heat sold on to other properties (e.g. residential), or by selling the straw to a power or district heating plant. However, this type of analysis did not form part of the climate certification project.

Here a specific criterion for heating is also proposed since heating can constitute a very large proportion of the climate impact of chicken production if it is based on fossil fuel.

4.3.1 Improvements at investment

In order to decrease energy consumption by farm businesses, it is important that the right choices are made when investments are being planned, e.g. new builds, renovations or replacement of old equipment. Energy-efficient equipment and system solutions should be prioritised to lower energy consumption and costs. One way to identify good solutions is to calculate and compare the Life Cycle Costs (LCC) of different options. When LCC are calculated, account is taken of the investment costs and the operating costs (including energy costs and maintenance) during a certain number of years (e.g. the predicted lifetime of the product). Operating costs and energy consumption often represent a considerable proportion of the total life cycle costs for energy-demanding equipment. It is also important to design installations according to the actual requirements and have control and regulation options (e.g. rev count regulation of fans).

The following are some examples of energy-demanding processes for which the life cycle costs should be considered at investment, with possible options to be weighed up:

- Heating: Plan for energy-efficient heating with biofuel or heat exchange pump.
- Building and weatherproofing (i.e. external envelope of the building, walls, floor and roof): If possible take account of energy consumption when deciding the exact location of the building, e.g. to minimise the wind exposure. Good insulation of walls and ceilings.
- Ventilation: Revolution count or frequency regulation of mechanical ventilation. Stepless connection of fans.

4.3.2 Energy mapping

Energy mapping on the farm provides information about where the energy is actually used and the potential for improvement that exists. In general, farms keep a good check on the cost of total consumption of electricity, diesel, etc., but are less aware of the proportion of that electricity and diesel that goes to different processes. Analysis and documentation are necessary to give a good understanding of the situation on the farm and to establish a good foundation for monitoring farm energy consumption. Energy mapping should include a review of current energy consumption on the farm, subdivided into different types of energy and how total energy consumption is distributed between sub-processes, and the calculation of key data (e.g. kWh electricity per bird place and year, or litres of diesel per hectare). The mapping should also include suggestions for efficiency-improving measures that substantially affect energy consumption on the farm and that are practically and financially feasible to introduce. It is important for the mapping and introduction of measures to be monitored regularly. The key data can be used for comparisons in subsequent monitoring and updating of the energy mapping. At present, there are few general key data that can be used to determine the status of the farm in comparison with other businesses. However, work is being done in various projects and by farming and advisory organisations to produce such key data

Energy mapping can be carried out either in consultation with an energy advisor or by the farmer himself. The advantage of employing a specialist energy advisor is that they have good knowledge of possible solutions and the options available on the market. Energy is used in many different areas and in different ways on the farm, and there are a number of possible technical and system solutions. It can therefore be difficult for the individual farmer to keep abreast of all that is happening within the area of energy area of relevance for farm operations. It can also be good to have a fresh external eye that can uncover areas of potential improvement and systematically analyse energy consumption on the farm. A number of advisory organisations offer various types of energy advisory services at present, including the Rural Economy & Agricultural Societies and LRF Konsult. There are also courses available in ecodriving at e.g. the local authorities. In addition, at the beginning of June 2009, the government tasked the Swedish Roads Administration, the Swedish Board of Agriculture and the Swedish Forest Agency with drawing up an action plan for promoting ecodriving of large diesel-powered machinery within e.g. road work and forestry (Regeringen, 2009). However, if a requirement is set that energy mapping must be carried out with an energy advisor before entry into climate certification, there is a risk of lack of capacity since there are relatively few agricultural energy advisors. The alternative, where the farmer carries out the energy mapping, demands the availability of a full range of good data. Today there are e.g. simple and general equations that can be used to estimate how electricity consumption is divided between different processes on the farm (Hadders, undated), but as far as we are aware there are no complete or enterprise-specific data that are intended for use directly by farmers. However, work is underway to develop various tools

Measures identified in energy mapping can include:

- **Major overall changes**, e.g. in the form of investment in more energy-efficient technology, changing from oil to biofuel or heat exchange pump, or conversion to reduced tillage where that is considered to be a possible solution.
- **Training, e.g. in ecodriving**.
- **Purchasing procedures**, e.g. how life cycle costs should be taken into account in purchasing energy-demanding equipment, or the demands that should be set when signing electricity contracts or purchasing fuel and oil (e.g. low inclusion of RME in diesel).
- **Maintenance procedures**. The energy requirement can be decreased through good maintenance. This includes keeping e.g. ventilation ducts, fittings, etc. free from dust and dirt and drawing up a schedule for regular checks of boiler, control equipment,, ventilation, etc.

- Drying of manure should preferably be avoided, but if it is required to allow transport of the manure to an adequate acreage for application, biofuel must be used for manure drying.

4.3.3 Heating with low greenhouse gas emissions

In chicken production, heating can give rise to a considerable fraction of the greenhouse gas emissions if it is based on fossil fuel. A previous life cycle analysis indicates that greenhouse gas emissions during the entire life cycle would be 28% higher if the heating is based on oil instead of straw (Tynelius, 2008). Today most of the heating supplied in chicken production is produced from biofuel, but it is important to continue phasing out oil as the base load in heating. Heating with fossil fuel supplying the base load cannot be regarded as a sustainable and acceptable system from a climate perspective.

5 Feeding

Feeding is an important aspect in achieving high feed efficiency, both during production and in use of the feed. For chicken production this is partly a question of having high production per unit feed supplied and partly of choosing the right feedstuffs

5.1 Improving efficiency

Decreasing waste in the feeding system lowers the climate impact from a systems perspective, since more meat is produced from the same inputs of feed. This leads to lower emissions per kg meat. Waste can be decreased through a range of technical measures that are partly specific for each producer depending on how the feeding system is designed. Another important aspect is management, i.e. keeping a good check on feed flows in production.

Increased growth per kg feed is desirable, if this is compatible with good animal welfare. If feed conversion efficiency is increased with the aid of e.g. a higher protein content, this must be balanced against the climate impact of feed production. At the present time there are no studies in which this has been analysed, but it is desirable that the issue be investigated in future research.

According to Cederberg et al. (2009), in 2005 1.75 kg feed was used per kg chicken leaving the house (live weight).

A critical point as regards feed conversion efficiency is that it must be weighed against the climate impact of the individual feedstuffs. Decreasing the amount of feed at the expense of increasing the climate impact per kg meat is a delicate balancing act. A case in point is the use of soyabean. A criterion intended to lower feed consumption per kg meat could lead to increased use of soyabean. Soyabean itself has a higher climate impact than many comparable feedstuffs, around twice as high as rapeseed meal (Flysjö et al., 2008). There is also the aspect of increased deforestation in South America, which is partly being driven by increasing global demand for soyabean. Decreasing the use of soyabean is probably a good climate measure although it is extremely difficult, if not impossible, to directly link the emissions from deforestation to a ton of soyabean. This could be regarded as an application of the precautionary principle. At the same time, work is underway on certification of 'sustainable soyabean', which can be one way to decrease the deforestation pressure from the use of soyabean, but this is something for the future. Tynelius (2008) cite data from Lantmännen on soyabean inclusion in the feed for broiler chickens in the range 20-30%, so these levels can be regarded as functional for feed conversion efficiency.

In order to decrease the proportion of soyabean in the feed without compromising growth or being forced to overfeed protein, it is often necessary to add synthetic amino acids. According to the LCA data available on the manufacture of these, it is climate-efficient to replace soyabean with synthetic amino acids. However the data available are limited and more information on manufacture would be desirable.

5.2 Using feedstuffs with lower emissions

Since the feed is such an important part of the climate impact of chicken production, there is naturally the option of using feedstuffs that cause lower emissions of greenhouse gases. See our separate report on climate certification criteria for animal feed regarding this.

5.3 Increasing the proportion of locally grown feed

If a large proportion of the feed is grown near the broiler chicken producers, transport of feed decreases. Here the concept 'near' refers to feed growing on the actual chicken farm or feed growing in partnership with a neighbouring arable farm that produces e.g. grain and legumes for direct delivery to the chicken producer and then takes back the manure. The greatest environmental impact with such a feed growing arrangement is probably not decreased transport but the manure being applied on a larger area and to different crops, which should provide the conditions for better nitrogen use efficiency

5.4 Suggested improvement measures

- Choose feeds produced with low emissions of greenhouse gases.
- Promote production systems that give a high meat yield per kg feed.
- Decrease the use of soyabean in the feed, provided that feed conversion is not affected. Here more information is needed on the function of alternative diets.
- Use soyabean certified according to Round Table on Sustainable Soy regulations (not yet available).
- Decrease waste in houses and storage
    - By technical solutions
    - By good monitoring and checks (management)

6 Proposed criteria for chicken production

The criteria we have identified are presented below. These are based on the suggested improvement measures described earlier in this report. The difference is that the criteria have to be monitorable and have to give unequivocal improvements. This means that some suggested improvement measures currently cannot form the basis for criteria, but the situation may change as more information is generated on production systems.

6.1 Feeding

Proposed criteria:

- Feed produced on the farm must be climate-certified.
- Purchased feed must be climate-declared.

- Max. 1.8 kg feed/kg chicken delivered to slaughter (live weight) may be used.
- Soyabean inclusion in feeds for production birds must be lower than 20%, considered over the entire production period.
- Analyses must be made of the nutrient content in feedstuffs, including home-grown feeds.
- Nitrogen flows on the entire farm must be analysed, e.g. a plant nutrient balance according to Greppa Näringen ('Focus on Nutrients') must be drawn up and reviewed annually.

Consequence analysis:

Increasing feed efficiency is one of the most effective measures. The feed represents more than two-thirds of total greenhouse gas emissions, and a decrease in feed consumption per kg meat produced gives a directly corresponding decrease in the climate impact. In addition, there are no conflicts with other environmental targets. Combining criteria on maximal feed consumption and soyabean inclusion ensures that soyabean inclusion is not increased as a way to decrease total feed consumption. With increased knowledge of how feed formulations with less soyabean affect egg production, the requirement on the proportion of soyabean can be decreased in the future.

6.2 MANURE MANAGEMENT

Proposed criteria:

- Analyses of the plant nutrient content of the manure, adapted for poultry manure (both ammonium and uric acid) must be carried out.
- Stored manure must be covered.
- Slurry may not be applied to winter cereals in the autumn.
- Manure must not be dried.

Consequence analysis:

By analysing the total amount of plant-available nitrogen, complementary nitrogen fertilisation can be optimised, which is an important measure. Ammonia emissions from manure comprise a minor fraction of total greenhouse gas emissions, but are relatively easy to control. Winter slurry spreading leads to poor nitrogen use efficiency and is a more important measure in achieving more climate-efficient production.

6.3 ENERGY ON THE FARM

Proposed criteria:

- Heating must be supplied mainly using renewable fuel such as straw, wood chips or wood, or using a heat exchange pump. It is permissible to use electricity (storage heater or direct electric heating) to meet peak loads, but to a maximum of 20% of the estimated energy requirement for heating during one year.
- Environmentally labelled electricity must be used.
- Energy mapping must be carried out on entry into climate certification. This mapping must include a review of energy consumption on the farm, the calculation of key data

and creation of an action plan. The action plan must be monitored and the mapping revised every 5 years.

- In conjunction with new investment or re-investment, new builds or renovations, the energy efficiency of energy-demanding processes, e.g. ventilation, feeding, lighting, must be taken into account and consideration given to the energy-related life cycle costs of different options.
- Low inclusion of RME in the diesel used on the farm.

Consequence analysis:

Heating of houses represents an important fraction of the energy consumption in chicken production and it is very important to avoid using fossil fuel for this purpose. In general, energy consumption is important, so energy mapping and the resulting energy savings is an important criterion. The use of environmentally labelled electricity is a less important measure but is easy to introduce, as is low inclusion of RME in diesel. Avoiding manure drying is also of minor significance but unequivocally positive.

6.4 Animal welfare

Proposed criteria:

- Mortality in production (between entry of the chicks into the house and delivery to the abattoir) must not exceed 2.5%.
- Production must be included in Svenska Ägg's animal welfare programme.

Consequence analysis:

Low mortality is an important criterion, since it directly gives a lower climate impact per kg meat and does not affect other parts of the system.

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7.1 PERSONAL COMUNICATIONS

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