

GREENHOUSE GAS EMISSIONS IN EGG PRODUCTION

DECISION SUPPORT FOR CLIMATE CERTIFICATION

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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 eggs 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 egg 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 EGG PRODUCTION – SUMMARY OF EXISTING KNOWLEDGE

2.1 CONVENTIONAL PRODUCTION

Conventional production of eggs is carried out in two essentially different ways in Sweden, either with furnished cages or with loose hens on barn floors. Organic production is described in a later section. The production animals, laying hens, are often supplied to the egg producer at 15-17 weeks of age, when they are ready to start laying. The chicks are supplied by producers that specialise in hatching to delivering egg-producing hens. The hatcheries import 'grandparent' birds, the progeny of which comprise the 'parent' generation for the production birds. Breeding work on laying hens is an activity carried out by global agencies and it is mainly these that produce the generation before grandparents. The actual egg production phase is carried out in batches, with the house being emptied, cleaned and disinfected before the next batch is introduced. Heating may be needed if the batch change occurs during winter, when the house must be heated before the hens are introduced, but the energy input is minimal. Otherwise the heat generated by the birds is sufficient to maintain the correct

temperature. However, for the rearing stage of production birds, i.e. from hatching until the hens are ready to lay, heating is required in the house.

The feed consists of grain and a protein-rich concentrate. The egg producer either buys a ready-made feed or buys a concentrate to mix with home-grown grain. Laying hens require a relatively high protein content and also require the correct amino acid composition in order for egg production to be high. The manure is managed as hen slurry or as dry solid manure (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.

A case study LCA on eggs by Sonesson et al. (2008) analysed two farms, one with barn hens and one with furnished cages. Both farms were in Västergötland and can be regarded as relatively representative of Swedish conventional egg production. A more recent 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 eggs 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 August 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 eggs with the help of computer simulations of type farms combined with agricultural statistics. Three systems were analysed: ‘conventional, cages’ (type of cages unclear), ‘conventional, free-range’ and ‘organic, free-range’. 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 efficiency in feed production was also lower, which gave a somewhat higher climate impact for the feed.

Table 1. Emissions of greenhouse gases per kg eggs at the farm gate for conventional production, summary of published studies

Study	CO ₂ -equiv./kg eggs			
	Total	CH ₄	N ₂ O	CO ₂
Sonesson et al. (2008)	1.4 - 1.6	0.02	0.7 – 0.8	0.7 - 0.8
Cederberg et al. (2009)	1.4	0.05	0.8	0.55
Williams et al. (2006), conventional cages ^a	5.2			
Williams et al. (2006), conventional free-range ^a	6.2			

^a In this study, emissions of each greenhouse gas are not presented

Table 2. Proportion of emissions of greenhouse gases arising from different activities in conventional egg production

Study	Proportion of emissions (%)	
	Feed (crop growing, inputs)	Animal rearing (energy, production birds, manure)
Sonesson et al. (2008)	78 - 81	19
Cederberg et al. (2009)	84	16

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 Frisknecht 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 egg 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.

2.2 ORGANIC PRODUCTION

Organic egg production differs from conventional in two important ways. The first is that the hens must be allowed outdoors, and the second is that the feed must be organically produced. The latter means that synthetic amino acids may not be used. Since the hens require certain essential amino acids, this means that either a certain amount of fish meal is used or that a certain degree of overfeeding of protein occurs. For large flocks, the outdoors requirement often handled by having a permanent range yard with the hens being brought indoors overnight. The requirement for KRAV certification is 4 m² outdoor area per hen. Indoors, the houses are generally similar to those used for barn hens in conventional production.

In the literature we only found one study (Williams et al., 2006), which analysed the environmental impact of organic egg production among other things. For this reason, a study of Swedish organic egg production was carried out in a project initiated by the Climate Labelling of Food project, co-funded by the Swedish Board of Agriculture within 'A Food Strategy for all of Sweden', LISS (Carlsson et al., 2009), which studied existing production. The data may be regarded as somewhat sparse, but we consider that it is possible to propose criteria for climate certification as organic egg production shares many similarities with conventional, with the same parameters being important. Table 3 summarises the results of these two studies.

Table 3. Emissions of greenhouse gases per kg organic eggs at the farm gate

Study	CO ₂ -equiv./kg eggs			
	Total	CH ₄	N ₂ O	CO ₂
Carlsson et al. (2009)	1.2	0.05	0.70	0.45
Williams et al. (2006), 'organic' ^a	7.0			

^a In this study, emissions of each greenhouse gas are not presented.

In the Swedish study, the feed was responsible for just over 80% of total emissions.

The large differences are mainly due to the British study having assumed a very low use efficiency for the nitrogen in the manure. This led to a double effect, increased emissions of nitrous oxide due to the large amounts of nitrogen and increased emissions in the manufacture of the mineral fertiliser needed instead of hen manure nitrogen.

3 WAYS TO DECREASE EMISSIONS OF METHANE AND NITROUS OXIDE

Since around half the emissions of greenhouse gases from egg 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. 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. However, it is difficult to quantify specific decreases in actual nitrous oxide emissions without using rather general models.

As regards methane emissions from egg production, this is mainly a question of manure management, storage in particular. 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 egg production. 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 or directly purchased feed, plus addition of synthetic amino acids. Both these measures provide the scope to avoid overfeeding of nitrogen, so it can be concluded that frequent analyses of protein in feedstuffs, in terms of both quantity and amino acid composition, are essential for optimising nitrogen supply.

According to the LCA studies that are available, the nitrogen use efficiency over the animal (ratio of the nitrogen in the eggs and cull hens to the nitrogen supplied in the feed) is 31% for conventional floor hens and 35% for cage hens (Sonesson et al., 2008). For organic production, the corresponding value is 29% (Carlsson et al., 2009). These data are derived from a few individual farms, which means that they must be used with caution, even though the farms studied can be regarded as representative of Swedish egg production.

3.2 MANURE MANAGEMENT

Ammonia, (NH_3), which is very volatile, is formed during storage of manure, both solid manure and slurry. 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 digester residues, which in turn have given rise to emissions of greenhouse gases. The most effective way to decrease methane and ammonia emissions is to store the manure in a tank, i.e. to not simply cover the store but also have walls.

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.

3.3 MANURE DRYING

Poultry manure is a valuable fertiliser with a high content of readily available nitrogen and also a high phosphorus concentration. Egg production is often carried out in large units, so large amounts of manure are generated in each unit. Overall, this means that the hen 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). 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 interesting 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 eggs, 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 egg production, there are two factors that are important, the mortality in rearing the laying hens (0 to 16-19 weeks) and the mortality during the laying period, as every bird that dies has given rise to a certain amount climate impact that must be borne by the eggs produced by the remaining hens. Thus from a systems perspective, the lower the mortality the better. The mortality in Swedish egg production is around 10% from hatching until slaughter (Schulz, 2008, cit. Sonesson et al., 2008). Mortality during the production stage has been reported to be 6.2% in a floor system and 3.8% in a cage system (Sonesson et al., 2008). However, these data originate from only one farm of each type, so the generality is limited.

The trade organisation Svenska Ägg runs an animal welfare programme comprising the following areas: Hygiene and Disease Prevention; Food Handling; and Buildings and Equipment. In addition, there is a voluntary salmonella programme. The guidelines for the programme were drawn up by a working party consisting of representatives of the industry, animal welfare, consumer organisations and researchers. The practical field work was carried out by Svenska Ägg inspectors (Svenska Ägg, 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 determine the composition of the concentrate.
- Ensure that nitrogen use efficiency is high, i.e. that the nitrogen in the feed is used to the greatest extent possible in production.
- Store manure under a roof or in a tank.
- Ensure that deep litter does not become too wet (refers to barn hens).
- Lowering mortality is an important measure and can be achieved by good stock-keeping routines and careful monitoring of production data.

- Manure must be applied on a sufficiently large area and to a crop that can utilise the nitrogen efficiently.
- Biogas production from manure.

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 CO₂ 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 CO₂-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 5). 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 4. 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

¹RME = 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.

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 CO₂-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.

Viewed over the entire life cycle of egg production, most of the energy consumption occurs in feed production (Sonesson et al., 2008). Measures within feed production are discussed in more detail in our previous report on animal feed. Within-farm energy consumption occurs mainly in the form of electricity (ibid.).

4.1 WITHIN-FARM CONSUMPTION OF ENERGY

In the few energy mappings carried out on egg production, total within-farm energy consumption and its subdivision seem to vary greatly between different flocks. In an energy mapping of two farms with egg production, energy consumption was estimated to be 156 kWh per ton eggs on a farm with laying hens in furnished cages and 251 kWh per ton eggs on a farm with barn hens. On both farms, most electricity was used for lighting and ventilation. Both production units were relatively newly built (Hörndahl, 2007). In an energy mapping by LRF Konsult of three egg producers with barn hens, electricity consumption was calculated to be between 175 and 450 kWh per ton eggs, while one producer also used a considerable amount of oil for heating. Here too, lighting and ventilation were responsible for most of the electricity consumption (Neuman, 2009). In a Swedish LCA of eggs, within-farm electricity consumption was estimated to be 260 kWh per ton eggs in a house with barn hens and 316 kWh per ton eggs in conventional production with furnished cages (Sonesson et al., 2008).

The purpose of ventilation is to supply the birds with fresh air and to maintain the required temperature and air quality as regards e.g. humidity, carbon dioxide and ammonia in the house. In egg production, mechanical ventilation is used. 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). In egg production, it is also important that air is drawn in by a method that does not increase ammonia emissions from the manure, e.g. through strong currents of air over the surface of the manure, and does not cause the ammonia concentration in the house to increase. In winter, additional heating may be needed to maintain a sufficient degree of ventilation and compensate for heat losses. It is important that control and regulation equipment is operating properly and is set correctly. If the ventilation is trying to maintain a lower air humidity than intended, this increases the energy requirement for ventilation. 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).

Lighting constitutes a relatively large proportion of electricity consumption in egg production (Hörndahl, 2007; Neuman, 2009). The hens need light in order to produce eggs and day length is controlled by a lighting programme that takes account of the age of the hens. It must be possible to dim the lighting and the light should not flicker, since this stresses the hens. Incandescent light bulbs are tried and tested and are widely used. These light bulbs can be dimmed, give non-flickering light, are available in a range of sizes and are simple and cheap to replace, but the light returns are low, contributing to high energy consumption. In the long-term other options will be needed, since conventional light bulbs will gradually be phased out. There is already a ban on importing opaque light bulbs and clear 100 watt bulbs (Energimyndigheten, 2009). Low energy light bulbs are much more energy-efficient than conventional light bulbs. An 11 W low energy bulb gives the same energy returns as a 60 W conventional light bulb. The disadvantage with low energy bulbs is that they flicker and that ordinary low energy bulbs cannot be dimmed. There are flicker-free and dimmable low energy bulbs but they are very expensive and cannot be dimmed by more than 10%, which can be too little to be suitable for every system (Hjalmarsson, 2008). It is becoming increasingly common to install LED systems (LED stands for light emitting diode), which are very energy-efficient, can be dimmed and have a long life (ibid.). Another option can be fluorescent tube fittings with a high frequency control unit (HF ballast). Fluorescent tube fittings are much more energy-efficient than light bulbs. The HF ballast replaces the conventional glow starter in the fluorescent tube and is more energy-efficient. The HF ballast also gives flicker-free light and can therefore be used in egg production. There are fluorescent tube fittings with HF ballasts that can be dimmed down to only a few percent of full effect. It is also possible to choose fluorescent tube fittings designed for T5 tubes instead of the conventional T8 tubes. The T5 tubes give higher light returns than T8 tubes and require HF ballasts.

4.2 USE OF 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 CO₂-

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 CO₂-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

It is difficult to identify specific measures in egg production that should be included as criteria in climate certification of eggs. The situation and the requirements differ between farms and thus also the scope for, and effects of, different measures. We suggest two overarching measures (Improvements at investment and Energy mapping, see below) to be adapted to the situation on the farm. 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 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.

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:

- Lighting: Plan for energy-efficient lighting with e.g. LED rope lights or fluorescent tube fittings with HF ballasts.
- Ventilation: Revolution count or frequency regulation of mechanical ventilation.

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:

- Training, e.g. in ecodriving, reduced tillage or precision cropping.
- 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.

- 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 control equipment, ventilation, etc.
- Drying of manure should 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.

5 FEEDING

Feeding is an important aspect in achieving high feed efficiency, both during production and in use of the feed. For egg production this is partly a question of decreasing feed spillages in production 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 eggs are produced from the same inputs of feed. This leads to lower emissions per kg eggs. A high level of production per kg feed is desirable if it is compatible with good animal welfare. If feed conversion efficiency is improved with the aid of e.g. a higher protein content or other sources of protein, this must be balanced against the climate impact of feed production. At present there are no studies in which this has been analysed, but the issue should be investigated in future research. According to Cederberg et al. (2009), in 2005 around 2 kg feed per kg eggs were used in cage systems, 2.2 kg feed/kg eggs in barn systems and 2.3 kg feed per kg eggs in organic production. Sonesson et al. (2008) reported 2.0 kg feed/kg eggs for cage systems and 2.25 for conventional barn systems. For organic production Carlsson et al. (2009) reported 2.4 kg feed/kg eggs.

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 eggs is a delicate balancing act. A case in point is the use of soyabean. A criterion intended to lower feed consumption per kg eggs 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. In order to decrease the proportion of soyabean in the feed without compromising growth or being forced to overfeed protein, synthetic amino acids must be added. 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.

Sonesson et al. (2008) present data on soyabean inclusion in the feed during the production period, using data obtained from Svenska Foder. In the four feeds used, the soyabean inclusion varied between 17.3 and 23.6%. Taking account of the amounts used in the different feed types during the rearing period, a weighted average of 20.2% is obtained. On the basis of this, 20% can be regarded as acceptable for feed conversion efficiency. Within organic production, soyabean (roasted whole beans) comprises 2% of the feed (Carlsson et al., 2009).

5.2 USING FEEDSTUFFS WITH LOWER EMISSIONS

Since the feed is such an important part of the climate impact of eggs, there is naturally the option of using feedstuffs that cause lower emissions of greenhouse gases. As regards the climate impact from individual feedstuffs, see our separate report on climate certification criteria for animal feed. A special case is fish meal, which is used in organic feed, but little has been published on this to date. However, there is a scientific paper in preparation in which data on many different feed fish will be presented (Pelletier et al., in prep.), and this shows that the variations in energy consumption and thus in greenhouse gas emissions between fish species and catch methods are large. Using those data, it will probably be possible to select the best fish meal from a climate perspective.

5.3 INCREASING THE PROPORTION OF LOCALLY GROWN FEED

If a large proportion of the feed is grown near the egg producers, transport of feed decreases. Here the concept 'near' refers to feed growing on the actual egg-producing farm or feed growing in partnership with a neighbouring arable farm that produces e.g. grain and legumes for direct delivery to the egg producer and that 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 with low emissions of greenhouse gases.
- Work to achieve a high egg 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.
- Use biofuel for heating houses for rearing production birds, i.e. from hatching to transfer to egg production.
- Replace fish meal with a high climate impact with other protein feeds that contain the correct amino acids, or use other fish meal that has lower greenhouse gas emissions per kg.

6 PROPOSED CRITERIA FOR EGG 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.
- Feed consumption may not exceed 2 kg feed/kg eggs in cage systems, 2.2 kg feed/kg eggs in barn system or 2.3 kg feed/kg eggs in systems with free range hens allowed outdoors.

Alternatively:

- Monitoring of feeding to avoid overfeeding, in consultation with a nutrition advisor.
- 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.
- The nitrogen balance across the birds (nitrogen in the feed/nitrogen in the eggs produced and cull hens) must be quantified and reviewed annually.
- Analyses must be made of nitrogen flows on the entire farm, 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 to reduce emissions of greenhouse gases from egg production. The feed represents around 80% of total greenhouse gas emissions, and a decrease in feed consumption per kg eggs produced gives a directly corresponding decrease in the climate impact. In addition, there are no conflicts with other environmental targets. Having a high nitrogen use efficiency decreases the total nitrogen flows in the system, which is the most efficient way to decrease greenhouse gas emissions from egg production. Overall, this is the most important area for criteria. The levels proposed for nitrogen use efficiency are relatively conservative due to the limited data support, but can be altered as more information is produced. 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).
- Stored manure must be covered.
- Slurry may not be applied to winter cereals in the autumn.

Consequence analysis:

The second greatest contributor to emissions of greenhouse gases from egg production is manure management, so criteria to decrease emissions of both ammonia and nitrous oxide are relatively important. By analysing the total amount of plant-available nitrogen, complementary nitrogen fertilisation can be optimised, which is an important measure.

6.3 ENERGY ON THE FARM

Proposed criteria:

- 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.
- Drying of manure is not permitted.

Consequence analysis:

Energy consumption represents a minor proportion of total greenhouse gas emissions, but the criteria for increasing energy efficiency, RME inclusion and environmentally labelled electricity are simple and lead unequivocally to decreased emissions. Drying of manure is unequivocally negative, even if the consequences are not very great.

6.4 ANIMAL WELFARE

Proposed criteria:

- 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 eggs and does not affect other parts of the system. In order to have a quantified criterion on maximum mortality, more data are required.

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