KLIMATMÄRKNING FÖR MAT.

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GREENHOUSE GAS EMISSIONS

IN PIG MEAT PRODUCTION

DECISION SUPPORT FOR CLIMATE CERTIFICATION

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CONTENTS

1 INTRODUCTION

This report forms part of the project ‘Climate Labelling of Food’ 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 pig meat 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 pig meat 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 PIG MEAT PRODUCTION – SUMMARY OF EXISTING KNOWLEDGE

2.1 CONVENTIONAL PRODUCTION

Conventional pig meat is a production enterprise that is relatively uniform in Sweden. The animals are kept indoors and fed a ration consisting of grain and protein concentrate. The manure from fattening pig production is mainly managed as slurry. The two main systems in Swedish pig meat production are integrated and specialist rearing, where the specialist system means that piglets are bred by a specialist producer and delivered to the fattening pig producer, who fattens the pigs from around 20 kg live weight to slaughter at around 110 kg live weight. The integrated model means that the pigs are kept by the same producer from birth to slaughter. In addition, there is a sliding scale between these two systems, with far-reaching partnerships between producers and integrated producers who also sell piglets. Consumption of pig meat has increased somewhat since 1990. Between 1990 and 2005, consumption increased from 30.6 kg/capita to 35.9 kg/capita. During the same period, Swedish production decreased from the equivalent of 34 kg/capita to 30.5 kg/capita, with imported pig meat coming mainly from Denmark.

Pig meat is a product that has been studied relatively well within research on life cycle analysis. There are studies from a number of countries in northern and western Europe, including several from Sweden. In general, the results do not differ very much between studies, although some differences exist. These differences are partly due to choice of method and issue and partly to actual differences in production systems.

The Swedish studies that have been published are by Cederberg & Darelius (2001) and Anon (2002), both descriptive LCA studies. Within the MISTRAS research programme Mat21 a futures study was presented of three alternative pig production systems in which different sustainability objectives were prioritised (Cederberg & Flysjö, 2004; Stern et al., 2005). Strid Eriksson et al. (2005) constructed and developed a simulation model that was used to illustrate various environmental aspects of pig production. A completely new study has been produced by Cederberg et al. (2009). This study 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 pig meat 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 is still not published (August 2009), but will be in 2009 and the values presented here are the final results.

Internationally, there is a pig study from the UK that forms part of a project on the climate impact of British agricultural products (Williams et al., 2006). These analyses are based on farm and plant production modelling combined with agricultural statistics. A French study analysed the differences between efficient conventional production (GAP, Good Agricultural Practice), production according to the LR (Label Rouge) quality system and organic production in Brittany. That study was based on data from official statistics, the literature and a panel of experts consisting of researchers and advisors (Basset-Mens & van der Werf, 2003).

The results for greenhouse gas emissions and energy consumption (secondary energy) from the above studies are shown in Table 1. By secondary energy consumption is meant direct energy consumption, i.e. the amounts of diesel, electricity and oil used on the farm, as opposed to primary energy consumption, which also includes the energy required for production and transport of fuel, or for electricity the amount of fuel required to generate the electricity.

Table 1. Emissions of greenhouse gases and secondary energy consumption per kg bone-free meat in conventional pig production, summary of published studies

Study	CO_2-equiv./kg meat				MJ/kg meat
Swedish studies	Total	CH_4	N_2O	CO_2	
Cederberg & Darelius (2001)	4.8	1.0	2.4	1.4	22
Anon. (2002)	4.2	0.8	2.0	1.4	23
Cederberg & Flysjö (2004), Scenario A	4.1	1.1	2.0	1.0	16
Cederberg & Flysjö (2004), Scenario B	3.6	1.1	1.6	0.9	15
Cederberg & Flysjö (2004), Scenario C	4.4	1.1	2.1	1.2	18
Strid Eriksson et al. (2005)[a,b]	3.2-3.5				13-16
Cederberg et al. (2009)[c]	5.2	1.3	2.6	1.3	
International studies					
Williams et al., 2006	5.6-6.4				14-17
Basset Mens & van der Werf (2003)[a,b], Scenario GAP	5.3				37
Basset Mens & van der Werf (2003)[a,b], Scenario RL	8.0				42

[a] *In this study, emissions of each greenhouse gas are not presented*
[b] *Results converted from live weight to kg meat with 73% kill-out from live weight to slaughter weight and 59% recovery from slaughter weight to bone-free meat*
[c] *Results converted from slaughter weight to bone-free meat with 59% recovery.*

As the results in Table 1 show, there are variations between studies. These variations are due partly to actual differences between the production systems and partly to differences in choice of method and sources of data. In the older studies, the former weighting factors for methane and nitrous oxide have been used (these were changed in 2007). The change involved methane receiving a higher emissions factor and nitrous oxide a lower factor, so how that affects the results varies between studies, but generally the change means that later studies show somewhat higher results.

Unfortunately, the distribution between greenhouse gases is not presented in all the studies, but a common feature for the studies where this was done was that nitrous oxide made up almost half the total greenhouse gas emissions and methane and carbon dioxide equal proportions of the other half. Nitrous oxide emissions are mainly caused by feed production and the associated manufacture and use of mineral fertiliser. Methane originates from manure management, particularly storage.

Table 2 shows emissions of greenhouse gases from pig production divided between activities and together with Table 1 provides information on the activities giving rise to the different types of emissions. Against this background, the potential for improvement can be identified.

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

Study	Proportion of emissions (%)	
	Feed (crop growing, inputs)	Animal rearing (manure, energy)
Cederberg & Darelius (2001)	69	31
Strid Eriksson et al. (2005)[a]	67	33
Cederberg et al. (2009)[b]	57	43
Basset Mens & van der Werf (2003)[a], Scenario GAP	70	30
Basset Mens & van der Werf (2003)[a], Scenario RL	66	34

[a] *Results converted from live weight to kg meat with 73% kill-out from live weight to slaughter weight and 59% recovery from slaughter weight to bone-free meat*

[b] *Results converted from slaughter weight to bone-free meat with 59% recovery.*

A consistent conclusion in all studies is that the total nitrogen use efficiency is a decisive factor for the final outcome. It is influenced mainly by nitrous oxide emissions, which are the single largest item. The other consistent conclusion is that feed conversion is critical, both for feed consumption per kg live weight gain and feed consumption per kg meat, i.e. a high recovery of meat from the animal. Choice of feedstuff is important, as the feed must be produced with low emissions of greenhouse gases. The fourth conclusion given in several of the above-mentioned studies is that reproduction, i.e. the number of litters per sow, also affects the results. Having more litters weaned per sow is positive for the climate impact since the emissions caused by feed production for the sow and her manure are spread over a greater number of fattening pigs. However, this effect is lower than the first three listed.

2.2 Organic production

In addition to the use of organic feed, organic pig production means that the pigs are given access to outdoor grazing and forage. The manure is handled as solid manure and deep litter is often used. Organic pig production has a slightly lower intensity, which means somewhat fewer litters weaned per sow and higher weaning age and slaughter age. In general, the nitrogen use efficiency is worse, since synthetic amino acids may not be used, which means that there is some overfeeding of protein to ensure that some essential amino acids are supplied. The buildings used are considerably simpler than in conventional production and, in addition, heating lamps are not used for piglets, both of which result in lower energy consumption.

When it comes to international studies of organic pig production, we only found one, Basset Mens & van der Werf (2003), who in addition to conventional production and production according to Label Rouge also analysed an organic scenario. One Swedish study has been published, within the research programme Mat 21. That study is based on two hypothetical farms, which are described with the help of advisors (Cederberg & Nilsson, 2004). We concluded that these two studies are not enough to base proposed criteria on because they are too old and progress has been rapid, and because the results of the two studies differed greatly.

For this reason, a study of Swedish organic pig meat production has been carried out in a sub-project initiated by the project Climate Labelling of Food, co-funded by the Swedish Board of Agriculture within 'A Food Strategy for all of Sweden' (LISS). This study examined two farms, an actual producer and a typical farm constructed in consultation with advisors within organic pig production (Carlsson et al., 2009).

The results from these three studies are presented in Table 3 and Table 4. It is difficult to definitively determine what caused the high emissions of greenhouse gases reported by Basset-Mens & van der Werf (2003), but it was probably a combination of low growth, inefficient feed production and composting of the manure, with subsequent low nitrogen use efficiency and higher ammonia emissions, leading to indirect nitrous oxide emissions. The latter led to a smaller proportion of the nitrogen being plant-available. We consider that this study is not representative of Swedish organic production, but opted to include it in this report for the sake of completeness.

Table 3. Emissions of greenhouse gases and secondary energy consumption per kg bone-free meat in organic pig production, summary of published studies

Study	CO_2-equiv./kg meat				MJ/kg meat
	Total	CH_4	N_2O	CO_2	
Carlsson et al. (2009)	4.8-4.9	0.7	2.4	1.7	21.5
Cederberg & Nilsson (2004)	4.8-4.9	0.75	2.4	1.7	22
Basset Mens & van der Werf (2003) [a, b,] Scenario OA	9.2				52

[a] In this study, emissions of each greenhouse gas are not presented
[b] Results converted from live weight to kg meat with 73% kill-out from live weight to slaughter weight and 59% recovery from slaughter weight to bone-free meat

Table 4. Proportion of emissions of greenhouse gases arising from various activities in organic pig production

Study	Proportion of emissions (%)	
	Feed (growing, inputs)	Animal rearing (manure, energy)
Carlsson et al. (2009) [a]	50	50
Basset Mens & van der Werf (2003) [b], Scenario OA	61	39

[a] Results converted with 59% kill-out from slaughter weight to bone-free meat
[b] Results converted from live weight to kg meat with 73% kill-out from live weight to slaughter weight and 59% recovery from slaughter weight to bone-free meat

Since there are fewer studies on organic pig production than on conventional, it is more difficult to draw general conclusions with the same certainty, but we consider that the two Swedish studies are of sufficiently high quality to allow areas for improvement to be identified. In addition, the pattern as regards the gases that contribute most is the same as for conventional production, approx. 50% nitrous oxide, 15-20% methane and the rest carbon dioxide. The distribution between feed-related emissions and farm-specific emissions is also similar, but for organic production a somewhat higher proportion of emissions originate from the farm. The reason is that no commercial fertiliser nitrogen is used, so all nitrogen circulates on the farm.

Compared with conventional production, organic production is characterised by higher feed consumption, which is caused by the animals moving around more and by feed losses being greater outdoors. In addition, nitrogen use efficiency in the animals is lower owing to the fact that it is difficult to get a balanced amino acid composition without the use of meat meal or synthetic amino acids. According to Carlsson et al. (2009), nitrogen use efficiency across the animal is 26% in organic production, while calculations based on data presented by Cederberg et al. (2009) show it to be approx. 33% for all Swedish pig production in 2005. Another factor that is indirectly linked to the environmental impact is that land use is considerably higher than for conventional production.

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 pig 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 gases from pig production consists of nitrous oxide emissions, partly from the manufacture of commercial fertiliser and partly from nitrogen conversion in the soil, 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 amount 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 pig production, this is generally a case of manure management, particularly storage.

Nitrogen use efficiency in feed growing is included in the proposed criteria for feed and is only referred to briefly 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 emissions of nitrous oxide and ammonia are decreased (see more below under 'Manure management'). In principle, the less nitrogen circulating in the system, the lower the risk of nitrous oxide formation. In the future scenarios that have been published (Stern et al., 2005) phase feeding and the use of synthetic amino acids were identified as ways to keep the nitrogen content in the feed low. Frequent analyses of the protein in the feedstuffs, in terms of both quantity and amino acid composition, are a prerequisite for optimising nitrogen supply.

The study by Cederberg & Flysjö reported that nitrogen use efficiency for the entire rearing period (including the sow) was between 37 and 41%, in other words that 37-41% of the nitrogen in the feed was used by the pig. Cederberg & Darelius (2001) reported a nitrogen use efficiency of 38% for the fattening pig phase. For organic production Cederberg & Nilsson (2004) reported a nitrogen use efficiency of 29 and 30% for the two farms studied, while Carlsson et al. (2009) found 26% for the entire rearing period (including the sow). Calculations of nitrogen use efficiency are complicated and sensitive to input data. There are not many studies where these have been done in such a way that comparable results are produced. Since we consider the data support to be too weak for a rule that can have a great effect on production, it is our opinion that criteria on nitrogen use efficiency cannot be introduced at present, but that this is an interesting issue for future reviews, when more information is available.

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 digestor residues, which in turn have given rise to emissions of greenhouse gases. Covering the slurry tank is an effective way to decrease methane and ammonia emissions (more on this below).

Manure is a more important issue in pig production than in milk production since it represents a greater proportion of greenhouse gas emissions. Against this background, it can be interesting to discuss addition of acid to the slurry tank. Adding acid to slurry and thereby lowering the pH can decrease ammonia losses considerably, but the risk of nitrogen leaching can increase slightly (Weidema et al., 2008). At lower pH values the equilibrium between ammonium and ammonia (the form that can be lost as a gas) is displaced so that the proportion of ammonium nitrogen increases. However, the net effect on greenhouse gas emissions is influenced by the way in which the effect of the nitrogen saved in the manure is evaluated and the amount of mineral fertiliser assumed to be replaced by the acid-treated manure. At low pH, a larger proportion of the nitrogen is lost as nitrous oxide through both nitrification and denitrification, and the direct nitrous oxide emissions from the stored manure are therefore higher (Sommer et al., 2001; IPCC, 2006). Research on acid treatment of cattle slurry has shown that methane emissions from the stored manure are greatly decreased (Faculty of Agricultural Sciences, 2008). The methane-producing microorganisms are sensitive to pH and their activity declines sharply at low pH values. Overall, this means that the effects on greenhouse gas emissions of lowering the pH are unclear and more information is needed on the circumstances that give rise to a net decrease.

Within weaned piglet production in particular, deep litter is often used and this is a very unsuitable manure management system from an environmental and resource perspective. Ammonia losses in the house and during storage are considerably higher than with a slurry-based system. When the deep litter manure is stored (in the house and in a clamp) there are also emissions of both methane and nitrous oxide since there are both anaerobic and aerobic zones in a deep litter layer. On the other hand, deep litter is positive from an animal welfare perspective, which is also a factor that is relevant for greenhouse gas emissions from pig production (see also section 3.4 ‘Animal welfare’). Within pig production there are some solid manure systems, which have lower methane and ammonia emissions than deep litter, but higher than slurry systems.

Ammonia emissions vary greatly and are dependent on water content, pH, bedding material, air movement around the stored manure, temperature and composition of the manure, so it is difficult to give exact figures on ammonia emissions. In the Swedish Board of Agriculture’s computer programme STANK in MIND (Jordbruksverket, undated), the following factors are used for deep litter systems: Losses in the house are 20%, while 30% of the nitrogen that ends up in storage is lost. Trials carried out by the Swedish Institute of Agricultural and Environmental Engineering (JTI) (Rogstrand et al., 2005) evaluated different ways to decrease ammonia losses from solid manure (not deep litter manure). Covering the material with a suspended rubber cover (as a simple roof) and incorporation of peat proved to be the most efficient methods, with a 28% reduction compared with normal storage in an open clamp. These measures would probably also decrease ammonia losses from deep litter, but this has not been investigated. The use of peat is debatable, since some consider it to be a fossil resource. Use of a covering can be an interesting alternative, however.

Solid manure systems have the same weaknesses as deep litter, although to a smaller extent, but ammonia emissions and nitrogen losses can be high. The emissions factor for ammonia used in STANK in MIND (Jordbruksverket, undated) is 4% in the house, while 20% of that which ends up in storage is lost as ammonia. According to measurements carried out on real farms, total nitrogen losses during the storage season amounted to between 16 and 18% of total nitrogen (Rogstrand et al., 2005). According to the same source, nitrogen losses decreased if there was efficient urine separation. These measurements were made on cattle manure, but the pattern is probably the same for pig manure.

Methane and to some extent nitrous oxide are formed during storage of slurry, since the stored slurry itself is virtually anoxic. A project at JTI has examined methane and nitrous oxide formation in cattle slurry (Rodhe et al., 2008). We did not find any corresponding investigations on pig slurry under Swedish conditions, but according to as yet unpublished results from a study at JTI, the results for pig slurry agree relatively well with the results from the cattle slurry study (Rodhe, L., pers. comm. 2009). The project on cattle slurry included both experimental manure stores and actual stores with different coverings (no cover, floating straw crust and plastic sheet). The results showed that emissions of methane were considerably lower than those reported in the literature, a finding attributed to low temperatures and shorter storage duration. Nitrous oxide emissions were generally low, apart from in some cases where a floating straw crust was used. The results are summarised in Table 5, where it is obvious that the floating straw crust did not reduce methane emissions as efficiently as the plastic sheet.

Table 5. Methane emissions from stored cattle manure with different coverings (Rodhe et al., 2008)

	kg CH_4 / kg VS
Without cover	6.4
Floating straw crust	5.9
Plastic sheet	4.3

3.3 BIOGAS PRODUCTION FROM MANURE

Biogas production from manure is dealt with in detail in the report on criteria for milk production and is summarised below.

Biogas production[1] from manure has a number of potential advantages from a climate perspective:

- Biodigestion of manure can substantially reduce methane emissions from stored manure since the biogas from the digestion chamber is collected and since there is little easily degradable organic material remaining in the biodigested manure that can be converted to methane during subsequent storage. Trials in Denmark have shown that methane losses from manure management can be halved when the manure is biodigested instead of being stored in conventional ways (Sommer et al., 2001). However, the effects on methane emissions vary greatly depending on the design and losses in the system, see discussion below.
- Biodigested manure is potentially a better fertiliser than non-biodigested manure. The proportion of directly plant-available nitrogen increases when manure is biodigested since the organic material is broken down and organically-bound nitrogen is thereby released. If this nitrogen it utilised efficiently it can decrease the need for mineral fertiliser. However, the risks of nitrogen losses from storage are greater for biodigested manure than non-biodigested, since pH values are higher, the amount of ammonium nitrogen is higher and the biodigested manure does not form a floating crust as readily (see section above on covering). The biodigested manure is more free-flowing and thus penetrates into the soil on spraying, but ammonia losses are also affected by spraying technique and weather conditions. Research indicates that nitrous oxide emissions from the soil are lower from biodigested manure, which can be explained by it containing less readily available carbon to be used by nitrous oxide producing microorganisms (Sommer et al., 2001).
- Biogas is a renewable energy source and can replace fossil fuel. Biodigestion is often the only possibility of producing energy from manure. The average amount of manure produced by a cow of 2 ton DM per year could provide around 3.6 MWh biogas per year. If account is taken of the energy required to produce the gas, the net gas yield is estimated to be just over 2 MWh per cow and year (refers to production in a central biogas plant, including transport, heat and electricity required for the biogas) (Berglund & Börjesson,

[1] Biogas production, or biodigestion, involves microorganisms breaking down organic material, e.g. manure, in an anaerobic environment. The biogas mainly consists of methane, which is an energy-rich gas, and carbon dioxide. The gas is collected and used for energy purposes. The digested product is sometimes called biodigestate. This chapter only discusses biogas production from farm-based biogas plants and co-digestion facilities (also known as central biogas plants). Biogas production from sewage sludge is not included.

2003). If the amount of manure produced by a fattening pig is 0.13 ton organic material (volatile solids, VS) per fattening pig place and year (three batches), this could produce around 0.29 MWh biogas per year. For farm-based biogas production, it is estimated that ~25% of the biogas is needed to meet the internal heating requirement of the biogas plant. That leaves ~0.22 MWh biogas per year and fattening pig place that can be used for other energy purposes (Berglund & Börjesson, 2003).

Comparing biogas production in conjunction with pig or milk production, the benefits appear greater for a pig farm. Pig manure gives more biogas per kg volatile solids (VS) than cattle manure since much of the readily degradable material in cattle manure has already been broken down in the rumen. Today combined power and heat production is often the most interesting option for farm-based biogas production. A combined heat and power plant generally generates more heat than is required to heat the biogas plant, and there is more probability of pig producers, especially those rearing piglets, needing the excess heat. The fuel requirement for heating varies between farms, but the excess heat from farm-based heat and power production on an annual basis should be able to more than cover the heat requirement in pig production. Manure management represents a greater proportion of the total climate impact in pig production than in milk production (see e.g. Berglund et al., 2008), and collection of greenhouse gases from stored manure via biogas production thus gives a greater percentage reduction on pig farms.

Biogas production has the potential to be an efficient means of emphatically decreasing greenhouse gas emissions in a number of areas of the animal production life cycle, but there is also a risk of greenhouse gas emissions increasing if there are high losses of methane or nitrogen. We have poor knowledge of greenhouse gases emissions from farm-based biogas production. Careful covering of biodigestion residues (preferably with a tarpaulin or roof so that the gases can be collected) and collection of all biogas, by flaring if all else fails, are two important ways to minimise losses.

3.4 Animal welfare – production

To get a low climate load for the product pig meat, there must be high production per unit feed and other resources used. Part of this involves the animals being healthy and thus able to produce efficiently, both within weaned and fattening pig production.

Table 6 shows a summary of indicators that can be used to describe how production data affect the climate impact.

Table 6. Summary of indicators of animal health-related production data affecting the climate impact of pig meat

Indicator	Importance for climate-efficient pig production
Number of piglets weaned per sow and year	A greater number of litters weaned means that the climate impact of the sow (feed, manure, energy) can be divided over a larger amount of meat, which gives a lower climate impact for the system as a whole. In 2008 the number of piglets weaned was 22.8, a number that has long been increasing. Mortality from birth to weaning was 16.7% (svenskapig.se, 2009). Up to 27 piglets weaned has been reported by individual producers (svenskapig.se, 2009).
Percentage recruitment sows	Lower percentage recruitment means that every sow has more litters over its life. This leads to the same effect as above, but to a lower degree.
Percentage mortality during the fattening phase	Every pig that dies during rearing has given rise to a climate impact. This must be distributed over the meat produced in the herd, so lower mortality means lower climate impact for the system as a whole. In 2008 the mortality was 2.5%, with a slight increase from 1999 (svenskapig.se, 2009).

The Swedish Animal Health Service runs a welfare programme within pig production, both for weaned and fattening pig production. This welfare programme targets animal health and involves at least one annual visit and possible follow-up visits. The Swedish Animal Health Service also runs the voluntary programme 'Salmonella in pigs' (Swedish Djurhälsovården, 2009). By continually working on animal health and maintaining contact with experts in the area it is probable that mortality can be decreased, which is also good from a climate impact perspective.

3.5 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. The use of synthetic amino acids is an efficient way to increase nitrogen use efficiency. The objective is to increase the nitrogen use efficiency of the animals.
- Slurry tanks must be covered, a floating crust is not sufficient.
- Covering slurry tanks and solid manure clamps with a suspended tarpaulin or roof decreases ammonia losses.
- Decreasing mortality is an important measure and it can be achieved through good stock-keeping procedures and careful monitoring of production data.
- Manure must be analysed with regard to its content of plant-available and total nitrogen.
- Manure must be applied on an area that is sufficiently large to allow efficient use of the plant nutrients it contains, and on a crop that can utilise the nitrogen efficiently.
- Use the slurry for biogas production.

- Efficient production without impairing animal welfare. Increasing production without compromising animal health and welfare is beneficial as it means lower mortality and more litters weaned per sow and also faster growth of animals.
- Decreased use of deep litter can be an improvement if this can be achieved without compromising animal welfare, which is uncertain at the present time. More knowledge is required.
- It may also be positive to add acid to the slurry tank, but more knowledge is needed of the circumstances that can give a positive net effect on greenhouse gas emissions.

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 6). Energy consumption varies from year to year due to e.g. variations in the weather (which affect e.g. the oil required for drying) and structural changes.

Table 6. 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*

In the life cycle analyses and futures studies that have been made of Swedish pig production, the total energy consumption[2] has been estimated to be between 13 and 23 MJ per kg meat, which includes the energy consumption that occurs on the farm and before the factory gate, e.g. in the production of fertiliser (Table 1). Most energy consumption consists of fossil fuel, particularly diesel in feed growing. Electricity use is mainly linked to animal husbandry (Cederberg & Darelius, 2001; Cederberg & Flysjö, 2004; Strid Eriksson et al., 2005). In an LCA where data were taken from an integrated farm in Halland, total electricity consumption was estimated at 4.6 MJ electricity and 16.5 MJ fossil fuel per kg meat, which is equivalent to ~1.5 kg CO_2-equiv. per kg meat[3] (Cederberg & Darelius, 2001).

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 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

[2] Energy consumption is given as *secondary energy*, i.e. in the form that the energy is used in the processes. This can be e.g. number of MJ electricity or MJ diesel used on the farm.

[3] Based on the assumption that energy consumption gives rise to 85 g CO2-equiv./MJ fossil fuel (corresponds to the emissions from a diesel-powered lorry, including emissions from production and end use of the fuel) and 15 g CO2-equiv/MJ electricity (corresponding to the mean electricity mix used in Sweden, account taken of emissions from production of the electricity and distribution losses).

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.

In this report energy production is only included in those cases where it has direct links to pig production, which applies e.g. to biogas and heat recovery. Production of bioenergy, energy crops, wind power, etc. falls outside the scope of this report.

4.1 Within-farm consumption of energy

To date, there are relatively few measurements of energy consumption on individual pig farms, but there appears to be very great variation between farms. Official economic calculations are based on electricity use of 595 kWh per sow and year (including piglets) and 50 kWh per fattening pig place and year (Hushållningssällskapet, 2008). In a review by the Department of Building Technology at SLU, the total electricity use in a modern, well-insulated pig house with a heat exchange system was estimated at 44-53 kWh per pig produced (during both weaned and fattening pig production) (Botermans & Jeppsson, 2007). In energy mapping carried out by LRF Konsult for 17 weaned pig production enterprises with between 60 and 600 sows, within-farm energy consumption was estimated to be on average 42 kWh electricity and other fuel per weaned pig produced, but with wide variations between the farms investigated. On average, electricity represented ~85% of total energy consumption. Electricity use varied between 15-60 kWh per weaned pig produced. Most farms in principle used only electricity as the energy carrier, but there were some farms that used oil or biofuel for heat production. On these farms, fuel-based heat production could constitute the majority of energy consumption. The energy mapping also included 14 units for fattening pig production with between 450 and 8000 fattening pigs per year. Energy consumption, almost exclusively electricity, amounted on average to 29 kWh per fattening pig, with a range of between 12 and 53 kWh per fattening pig, and there was no clear difference between large and small herds (Neuman, 2009).

4.1.1 Heating

In weaned pig production, heating represents a large proportion of total energy consumption (Botermans & Jeppsson, 2007; Hörndahl, 2007; Neuman, 2009). Heat is also needed in fattening pig production, e.g. after cleaning and before moving the pigs into the house. Heating can also give rise to considerable greenhouse gas emissions if it is based on fossil fuel. At present heating is mainly based on electricity, e.g. heating lamps or water-carried underfloor heating connected to an electric cartridge or heat exchange pump.

Heat exchange pump and underfloor heating are a good combination since the outgoing temperature from the heat exchange pump is relatively low, which is suitable for underfloor heating, and the heat output per unit kWh electricity input is high. The heat factor for soil or rock heat exchange pumps is usually assumed to be around three, i.e. every kWh electricity used gives three kWh heat. The heat exchange pump can e.g. use heat from slurry if collector pipes are installed in the slurry channel. This lowers the temperature of the slurry and thus the ammonia emissions in the house, which improves the environment in the house and can also decrease the ventilation requirement.

Heating lamps are commonly used and can represent a considerable proportion of electricity consumption in weaned pig production. The energy mapping carried out to date shows that heating lamps represent around 20% of total electricity consumption in production, but with very great variation between farms (Hörndahl, 2007; Neuman, 2009). There are several possible ways of decreasing electricity use by heating lamps. It may be possible to change to lower wattage light bulbs, e.g. from 250 to 150 W, if this has not already been done. There are also heating lamps with energy-saving switches through which the wattage of the lamp can be halved as the piglets grow and the heating lamps are mainly used to attract the piglets away from the sow in order to decrease the risk of crush damage to the piglets. The investment costs for replacing an old heating lamp with a new fitting with an energy-saving switch can be recovered once the lamp is run at half power for around 3 000 hours[4]. According to data, the energy use for heating lamps during the piglet period can be halved if energy-saving switches are used (Botermans & Jeppsson, 2007). Electricity use can also be decreased through individual control of heating lamps so that they are only used in crates that need the extra heat.

There are several different system solutions for fuel-based heating, for which the investment and fuel costs vary greatly. Oil boilers are relatively cheap, simple to manage and available in all sizes, but the oil is becoming more expensive and gives a high climate impact. The low investment costs in an oil boiler mean that it can still be an economically interesting option to other, more expensive boilers. Straw is generally a cheap fuel, but incineration requires manual labour and the investment costs are high, which means that they are mainly of interest in systems with a high heat requirement. Pellet, grain or woodchip incineration has many similarities to oil combustion and can be an interesting alternative for small herds (Botermans & Jeppsson, 2007). Greenhouse gas emissions from combustion of biofuel are very low, even when account is taken of the emissions that arise in conjunction with production and possibly growing of the biofuel. The emissions from production are higher when high inputs are required to produce the biofuel, e.g. growing energy forest, than when the fuel is a by-product (e.g. straw), where the main environmental impact is distributed over the main product. Diesel consumption in the harvest and transport of straw gives rise to e.g. ~ 2 g CO_2-equiv. per MJ straw, while the greenhouse gas emissions from growing oats (including production of inputs and emissions in the field) amount to over 30 g CO_2-equiv. per MJ grain. In small-scale combustion of biofuel for wheat production, greenhouse gas emissions amount to 2-8 g CO_2-equiv. per MJ fuel, mainly in the form of uncombusted hydrocarbons. Combustion of oil gives ~85 g CO_2-equiv. per MJ oil, including emissions from production, distribution and end-use (Berglund et al., 2009). When different fuels are being compared, account must be taken of differences in efficiency between different heating systems and thus the fact that different amounts of fuel may be needed to meet a certain heat requirement.

It is also important to decrease heat losses in order to minimise the energy and heating requirement. Heat losses can be minimised through good insulation of floors, walls and ceilings. A warm and draught-free environment can be created for piglets and growing pigs with the help of shelters (Botermans & Jeppsson, 2007). It is also important to adjust and control the ventilation according to the actual ventilation requirement. Unnecessarily high ventilation means that more electricity is needed to power the fans, but in heated houses it also means that more energy is needed to compensate for heat losses.

4.1.2 Ventilation

The purpose of ventilation is to supply animals with fresh air and to maintain the required temperature and air quality in the house. Ventilation represents a large proportion of the electricity consumption in fattening pig but also weaned pig production (Hörndahl, 2007; Neuman, 2009). In pig production, mechanical ventilation is the most common system, although systems based on natural ventilation are used for dry sows. The reason is that systems with uninsulated houses or natural ventilation are more difficult to control and have

[4] Based on the fitting costing SEK 160, electricity costs SEK 0.70/kWh and the power being halved from 150 W to 75 W. Not including installation costs.

poorer production results due to higher feed consumption and lower growth (Botermans & Jeppsson, 2007).

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 electricity consumption. Annual cleaning of the ventilation system can save up to 10% of energy (Eliasson et al., undated). It is also important that control and regulation equipment is operating properly and is set correctly, so that the ventilation and heating systems do not counteract each other. If the ventilation is trying to maintain a lower air humidity than intended, this increases the energy requirement for ventilation but also that for heating if extra heat is supplied. In a sample calculation in Hadders (undated), the energy requirement in a heated house for weaned pigs was twice as high when the ventilation was working to maintain 68% air humidity instead of 75% air humidity.

There are different 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).

4.1.3 Feeding

Feeding comprises a relatively large proportion of energy consumption in pig production, but depending on the design of the feeding system it can vary greatly between farms (Hörndahl, 2007; Neuman, 2009). Older hammer mills that suck the grain into the mill are relatively energy-demanding. Newer hammer mills that auger the grain in or disc crushers are more energy-efficient (Eliasson et al., undated). If feed is supplied via a pressurised air system, it is important that the system is air-tight in order to minimise the energy consumption.

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).

General measures to decrease diesel consumption in tractor work include regular machine maintenance, avoiding engine idling or excessive wheel slip (10-20% wheel slip gives the best efficiency) and driving at the right rev count and with a high power output. Correct setting of tyre pressure decreases diesel consumption slightly. A somewhat lower tyre pressure in field work gives better grip and less wheel slip, while a higher pressure decreases surface resistance in road transport.

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

It is difficult to identify specific measures in pig production that should be included as criteria in climate certification of pig meat. 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, or through heat recovery. 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). An unnecessarily large compressor will be largely underused and will use electricity without producing any benefit. If a smaller compressor is chosen instead, it will work to its capacity for a longer period, but total electricity consumption will be lower since idling losses will be greatly decreased.

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: Here there are measures that can be implemented in existing operations and new builds. Is it possible to install heat recovery from the manure? What scope is there to decrease electricity consumption by heating lamps (energy-saving switches, lower wattage light bulbs, control of lighting, shelters for piglets). Heating should not be based on fossil fuel.
- Ventilation: Revolution count or frequency regulation of mechanical ventilation.
- Feeding: Choose a system with low energy consumption.

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 animal 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 by 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, e.g. at Odling i Balans, the Rural Economy & Agricultural Societies and LRF Konsult.

Measures identified in energy mapping can include:

- Major overall changes, e.g. in the form of investment in more energy-efficient technology or conversion to reduced tillage where that is considered a possible solution.
- 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 (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 control features, driers, etc. or locating and repairing leaks in the pressurised system.

5 FEEDING

Feeding is an important aspect in achieving high feed efficiency, both during production and in use of the feed. For pig meat production this is partly a question of decreasing feed waste 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 meat products are produced from the same inputs of feed. This leads to lower emissions per kg meat.

Increased growth per kg feed is desirable, if this is compatible with animal welfare. If feed conversion efficiency is improved with the aid of e.g. a higher protein content, this must be balanced against the climate impact of feed production.

5.2 USING FEEDSTUFFS WITH LOWER EMISSIONS

Since the feed is such an important part of the climate impact of pig meat, it is naturally an important improvement measure to use 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.

In choice of feedstuffs it is critical to take account of feed conversion efficiency, since as discussed previously, it is important for growth to be optimal. Simply considering the climate impact of individual feedstuffs is not sufficient – a complete diet perspective must be employed so that feed conversion efficiency is not decreased so much that the benefits of more climate-efficient feed raw materials are eaten up. The effect of different diets has been studied by Cederberg & Flysjö (2004) and Strid Eriksson (2005). In both these studies, an assessment was made by animal nutritionists that the alternative diets should give similar growth to the conventional diets. The study by Cederberg & Flysjö compared three production systems where the diets differed but where other aspects also differed. The system that had the lowest emissions of greenhouse gases per kg meat produced were characterised by high nitrogen use efficiency and a high proportion of locally grown protein feed. The significance of nitrogen use efficiency has been discussed earlier, while the positive effects of locally grown feed need little explanation. In the study, locally grown feeds (rapeseed meal and peas) were used as the base for protein supply and were complemented with synthetic amino acids, which meant that a high nitrogen use efficiency could be achieved. The increased proportion of locally grown feed resulted in more climate-efficient crop growing as a whole, while better pre-crop effects gave higher yields and a lower energy requirement for soil tillage. In another system locally grown feeds were also used but without synthetic amino acids, which meant that the amount of protein in the diet had to be increased to obtain the same amount of certain essential amino acids. This in turn led to higher greenhouse gas emissions per kg meat for that system. The diet that gave the lowest climate impact per kg meat was estimated to give the same high growth as the more conventional soyabean-based diet, which acted as a reference.

The study by Strid Eriksson et al. (2005) analysed the environmental consequences of three diets for the period between 29 kg live weight and slaughter at 115 kg live weight. The three diets were a conventional diet based on soyabean, one based on peas and rapeseed and one based on peas, rapeseed and synthetic amino acids. The conclusions coincided relatively well with those of the Cederberg & Flysjö (2004) study, i.e. that increasing the use of rapeseed and peas at the expense of soyabean leads to a decrease in the climate impact per kg meat.

Cederberg & Flysjö (2004) used less than 5% soyabean for the fattening pig phase and no soyabean for sows. In the soyabean-based diet, the inclusion rate of soyabean was between 11 and 15% for lactating sows and fattening pigs and 4% for dry sows. In the diets for fattening pigs analysed by Strid Eriksson (2005), the inclusion rate of soyabean meal was 11.9% for the conventional diet, while no soyabean was used in the alternative diets.

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.

The studies above did not include emissions of greenhouse gases from deforestation caused by expanding soybean growing in South America, which means that the assumptions behind the climate impact of soyabean meal can be said to be conservative. Despite the difficulty in clearly linking the use of soyabean to deforestation and quantifying this from a climate perspective, there is reason to believe that decreased use would lower the pressure for further deforestation. At the same time, work is underway on certification of 'sustainable soyabean', which can be one way to decrease the pressure for deforestation from the soyabean used, but this is something for the future.

A potentially important measure is to use by-products from the food industry to the greatest extent possible and, in the future, other waste products such as source-separated restaurant, catering and commercial waste. The use of these other waste products is not possible at present due to legislation concerning the risk of spreading diseases, but from a climate perspective it would be interesting to see whether safe pig meat production can be combined with the use of by-products. Through the re-use of waste products, materials with minimal value are converted to high value meat, which decreases emissions of greenhouse gases.

A study by Elferink et al. (2008) presented data on the amount of pig meat that could be produced in the Netherlands using only by-products from the food industry. The results showed that the equivalent of 81 g pig meat per capita and day could be produced using by-products from the sugar, potato and vegetable oil processing industries. In comparison, it can be noted that Swedish consumption of pig meat is approx. 36 kg per capita and year (Jordbruksverket, 2009), which is equivalent to 98 g per capita and day. These calculations were relatively simplified, for example they were based solely on the energy content and no account was taken of e.g. the protein content. There is no corresponding study for Swedish conditions, and it must be borne in mind that Holland processes large amounts of vegetables that are not consumed within the country, so the comparison is somewhat lacking. However, the study still gives a certain idea of the amount of meat that can be produced from by-products.

The use of waste products can make it more difficult to achieve an optimal amino acid composition, which must be borne in mind in the formulation of criteria.

5.3 Increasing the proportion of locally grown feed

If a large proportion of the feed is grown near the pig producers, transport of feed decreases. Here the concept ‘near’ refers to feed growing on the actual pig farm or feed growing in partnership with a neighbouring arable farm that produces e.g. grain and legumes for direct delivery to the pig farm 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 climate-declared feed.
- Choose feed that is ‘locally grown’ if this means that the manure can be spread on a larger area over the years.
- Choose locally or regionally grown protein feedstuffs if this means that crop rotations can be improved (e.g. in areas there the crop rotation is dominated by cereals).
- Decrease the use of soyabean, 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 waste products from the food industry. However, more information is needed on the volumes available before the potential of this can be determined.
- Feed according to the actual requirements of the animals. This can be achieved by e.g. phase feeding, possible in combination with accurate analyses of feedstuffs (for home-grown feeds).

6 PROPOSED CRITERIA FOR PIG MEAT 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.
- Analyses must be made of the nutrient content in feedstuffs, including home-grown feeds.
- 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.
- The nitrogen balance across the animals (nitrogen in the feed/nitrogen in the animals produced) must be quantified and reviewed annually.
- Phase feeding to avoid overfeeding of protein or suboptimal growth.
- In diets for fattening pigs, the inclusion rate of soyabean meal (or other soyabean products) must be less than 8%, as a mean value from weaning to slaughter.
- The feed for lactating sows should contain a maximum of 5% soyabean meal (or other soyabean product).
- The feed for dry sows should not contain soyabean.

Consequence analysis:

Increasing feed efficiency is one of the most effective measures. The feed represents between half and 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. Increasing nitrogen use efficiency is an efficient way to decrease greenhouse gas emissions, particularly of nitrous oxide. However the underlying data for the suggested levels are uncertain, so they are set relatively low. More knowledge is needed in order to raise these requirements.

Decreasing the use of soyabean gives a direct decrease in emissions of greenhouse gases, since soyabean has higher emissions per kg than peas and rapeseed. In addition, decreasing the use of soyabean should in principle lead to a decrease in the pressure for more land on which to grow soyabean in South America. This is difficult to quantify but is considered to be an important credibility factor in a climate certification system. At the same time, it is important that decreased use of soyabean does not lead to poorer feed conversion efficiency, a matter that requires further study.

6.2 Manure management

Proposed criteria:

- The plant nutrient content of the manure must be determined.
- Slurry tanks must be covered with a suspended tarpaulin or roof, a floating crust alone is not permissible.
- Solid and deep litter manure must be covered with a suspended tarpaulin or roof.
- Pig slurry may not be applied to winter cereals in the autumn.

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:

- Fossil fuel may not be used for heating pig houses.
- 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 a minor fraction of the energy consumption in weaned piglet production and the use of fossil fuel for this purpose is already low. However, this is an unequivocal and relatively simple measure. 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.

6.4 Animal welfare

Proposed criteria:

- Production must be included in the Swedish Animal Health Service’s welfare programme for pig production.
- The number of piglets weaned per sow and year must be at least 23.
- The mortality between birth and weaning must be lower than 15% at herd level.
- The mortality between weaning and slaughter must be lower than 2% at herd level.

Consequence analysis:

Mortality is obviously negative for emissions of greenhouse gases per kg meat produced and is thus an important criterion. The number of piglets weaned determines the sow’s share of total emissions of greenhouse gases and is also an important criterion.

7 References

Anon. 2002. Maten och Miljön – Livscykelanalys av sju livsmedel. LRF, Stockholm

Basset-Mens, C. & van der Werf, H. 2003. Scenario-based environmental assessment of farming systems – the case of pig production in France. Agriculture, Ecosystems and Environment 1005, 127-144

Berglund, M & Börjesson, P. 2003. Energianalys av biogassystem. Rapport 44. Miljö- och energisystem, Lunds tekniska högskola.

Berglund, M., Cederberg, C., Clason, C., Henriksson, M. & Törner, L. 2009. Jordbrukets klimatpåverkan - underlag för att beräkna växthusgasutsläpp - en nulägesanalyser av exempelgårdar. Delrapport 1 i Jokerprojektet, Hushållningssällskapet Halland. Halmstad

Botermans, J. & Jeppsson, K-H. 2007. Effektiv energianvändning i grisstallar. Dokumentation från Alnarps grisdag 11 januari 2007: 17-31.

Carlsson, B., Sund, V. & Cederberg, C. 2009. GWP-Analys av ekologisk produktion av ägg och griskött. Manuskript till SIK-Rapport.

Cederberg, C. & Darelius, K. 2001. Livscykelanalys (LCA) av griskött. Naturresursforum Halland, Länsstyrelsen Halland, Halmstad.

Cederberg, C. & Flysjö, A. 2004. Environmental assessment of future pig farming systems – quantification of three scenarios from the FOOD 21 synthesis work. SIK Report 723, SIK – The Swedish Institute for Food and Biotechnology, Göteborg, ISBN91-7290-236-1

Cederberg, C. & Nilsson, B, 2004, Miljösystemanalys av ekologiskt griskött, SIK-Rapport 717, SIK – Institutet för Livsmedel och Bioteknik, Göteborg, ISBN 91-7290-230-2

Cederberg, C., Sonesson, U., Davis, J. & Sund, V. 2009. Greenhouse gas emissions from production of meat, milk and eggs in Sweden 1990 and 2005. SIK-Rapport 793, SIK – Institutet för Livsmedel och Bioteknik, Göteborg, ISBN 978-91-7290-284-8.

Elferink, E.V., Nonhebel, S. & Moll, H.C. 2008. Feeding livestock food residue and the consequences for the environmental impact of meat. Journal of Cleaner Production 16, 1227-1233.

Eliasson, K., Gustafsson, I., Karlsson, B. & Alsén, I. Undated. Hushålla med krafterna – Fakta. Hushållningssällskapet.

Energimyndigheten. 2008. Transportsektorns energianvändning 2007. ES 2008:01, Energimyndigheten.

Ericsson, K. 2004. Miljöeffekter av reducerad jordbearbetning – i jämförelse med traditionell plöjning. N kunskapssammanställning av HIR Malmöhus.

Erzinger, S. & Badertscher Fawaz, R. 2001. Life Cycle Assessment of Animal Housing Systems as part of an Overall Assessment. Proceedings from the 5:th International Conference on LCA in Foods, 26-27 April, Göteborg, Sweden. SIK-Dokument 143, SIK – Institutet för Livsmedel och Bioteknik, Göteborg

Fogelberg, F., Baky, A., Salomon, E. & Westlin, H. 2007. Energibesparing i lantbruket år 2020 – Ett projekt utfört på uppdrag av Statens naturvårdsverk. JTI Uppdragsrapport.

Frishknecht, R., Althaus, H-J., Bauer, C., Doka, G., Heck, T., Jungbluth, N., Kellenberger, D. & Nemecek, T. 2007. The environmental relevance of capital goods in life cycle assessments of products and services. Int. J. of LCA. DOI:http://dx.doi.org/10.1065/lca2007.02308

Hadders, G. Undated. Minska elanvändningen! SLA, Skogs- och lantarbetsgivareförbundet.

Hushållningssällskapet. 2008. Produktionsgrenskalkyler för husdjur i södra Sverige - Efterkalkyler för år 2008. Hushållningssällskapen i Karlmar-Kronoberg-Blekinge, Kristianstad, Malmöhus och Växa Halland.

Hörndahl, T. 2007. Energiförbrukning i jordbrukets driftsbyggnader – en kartläggning av 16 gårdar med olika driftsinriktning. JBT Rapport 145, Inst. för jordbrukets biosystem och teknologi, Sveriges Lantbruksuniversitet. Alnarp.

IPCC, 2007. Climate Change 2007. IPCC Fourth Assessment Report. The Physical Science Basis. http://www.ipcc.ch/ipccreports/ar4-wg1.htm

Jordbruksverket. 2009. konsumtionsstatistik, www.sjv.se

Jungkunst, H.F. et al. 2006. Nitrous oxide emissions from agricultural land use in Germany – a synthesis of available annual field data. Journal of Plant Nutrition and Soil Science 169 (3): 341-351.

Naturvårdsverket. 2009. National inventory report 2009 Sweden - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Naturvårdsverket, Stockholm.

Neuman, L. 2009. Kartläggning av energianvändning på lantbruk 2008. Manuskript. Borås: LRF konsult.

Regeringen. 2009. Uppdrag att främja sparsam körning. Pressmeddelande 11 juni 2009, Näringsdepartementet och jordbruksdepartementet. http://www.regeringen.se/sb/d/11999/a/128125

SCB. 2008. Energianvändningen inom jordbruket 2007. Statistiska centralbyrån.

Sommer, S.G., Møller, H.B. & Petersen, S.O. 2001. Reduktion af drivhusgasemission fra gylle og organisk affald ved biogasbehandling. DJF rapport nr 31 Husdyrbrug. Danmarks JordbrugsForskning, Tjele.

Stern, S., Sonesson, U., Gunnarsson, S., Öborn, I., Kumm, K-I. & Nybrant, T. 2005. Sustainable development of food production – A case study on scenarios for pig production, Ambio 34 (4-5) 402-407

Strid Eriksson, I., Elmquist, H., Stern, S. & Nybrant, T. 2005. Environmental systems analysis of pig production – The impact of feed choice, Int. J. of LCA 10 (2) 143-154.

Svenska Djurhälsovården. 2009. Website, information accessed 2009-06-15: http://www.svdhv.org/nyhemsida/Gris/grisindex.html

www.svenskapig.se. 2009. Information accessed 2009-06-09.

Weidema, B., Wesnæs, M., Hermansen, J., Kristensen, T., Halberg, N., Eder, P. (ed), & Delgado, L. (ed). 2008. Environmental Improvement Potentials of Meat and Dairy Products. EU Commission, Joint Research Team and Institute for Prospective Technological Studies. ISBN 978-92-79-09716-4

Williams, A.G., Audsley, E. & Sandars, D.L., 2006, Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main

Report, Defra Research Project IS0205, Bedford, Cranfield University and Defra, available at www.silsoe.cranfield.ac.uk and **www.defra.gov.uk**

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