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Greenhouse Gas Emissions due to Dairy Farm Operations

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About this thesis:

This thesis has been written as a part of the degree project course in the Masters program "Sustainable Business Leadership" at the School of Economics and Management, Lund University.

The course was based on the methodology of action learning and self-managed learning. The students were all assigned to an in-company project as consultants. As a part of course the students were responsible for organizing several learning events addressing relevant issues related to the in-company projects. The students continuously documented their learning in learning journals and participated in tutorials on these journals.

The assessments of the students are done partly on the written thesis, partly on the consultancy process and report to the client company, partly on performance in learning events and other parts of the course and partly on the ability to document and reflect on the student's individual learning and development.

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Executive Summary:

The term “Carbon footprint” is often used to describe the amount of greenhouse gas (GHG) emissions that are produced by a particular activity or entity, and therefore provides a means for organizations and individuals to assess their contribution to climate change. It is necessary to understand these emissions and how and where they originate if any progress is to be made towards reducing them. According to Skånemejerier executives approximately 80% of GHG emissions occur on the farm. Therefore, a comprehensive study of existing research on GHG emissions at the farm gate may help to develop valuable insight and a better understanding of the issue; which in turn, can enable Skånemejerier to set reasonable mitigation goals and to better inform their farmer-owners and customers.

Relatively early on in the study it was found that there is presently no statistical net difference in the emissions of GHG between conventional and organic dairy farms not only in Sweden, but worldwide as well. The prominent source for this finding was the research of Flysjö, A. and Cederberg, C., 2004, whom analyzed 23 organic and conventional Swedish dairy farms and suggested a range of GHG emissions from 0.76 to 1.26 kg CO2eqv/kg milk for the conventional farms and from 0.73 to 1.11 kg CO2eqv/ kg for organic farms. They went on to conclude that there was no difference in total emissions among the farm groups.

However, there are many caveats to this statement and it should not be construed as true for all farm management scenarios. One of the primary reasons for this finding is that the issue of GHG emissions in agriculture, as are all biological processes, is a very complex issue and there is no general consensus on which methodology is most appropriate to use in emission calculations. As a result, there is a large variability among the data and results within current research. However, the expert consulted for this paper, Maria Henriksson (SLU Alnarp), is of the opinion that farm management is the area that offers the most potential for reducing GHG emissions at the farm level (Henriksson, M., et al., 2011). Attached in Appendix 9.9 is a “practical guide for Cadbury’s dairy farmers” produced by Cadbury Chocolates in the UK. Although this guide is tailored for UK farmers, it serves as an example of a farm level management improvement strategy which may be of value to Skånemejerier. During one of the farm visits and interviews with a Skånemejerier farmer/owner, it was noted that there was some defensiveness towards and outright rejection of the idea of a companywide voluntary farm management improvement program to reduce greenhouse gas emissions. A guide for Swedish dairy farmers similar to the Cadbury guide would provide a non-confrontational way to inform Skånemejerier farmers of how they will benefit from implementing more sustainable management practices.

Another important point is that a study at the farm level will have very different and/or conflicting results when compared to a study that includes the entire supply chain and co-product handling between the dairy and beef industries (section 3.3). In consideration of these findings, it is the opinion of the Grigsby, Huang & Wei (GHW) Group that Skånemejerier will gain the most benefit from the improvement of management practices at the farm level and choosing supply chains which have the lowest practical carbon footprint.

Abstract:

According to Skånemejerier executives, approximately 80% of greenhouse gas emissions occur on the farm. Public concern in greenhouse gas emissions has steadily grown over the past few years prompting inquiries about the amount of greenhouse gases are emitted by Skånemejerier during its course of business. The most common question received relates to the amount of greenhouse gas emitted in the production of organic milk versus regular milk. Since there was no readily available answer for Skånemejerier to offer its customers, the Grigsby, Huang & Wei (GHW) Group accepted the opportunity to research and answer this question. It was initially thought that the answer to that question would be straightforward and intuitive; it was not. However, based on analysis of current research literature it was found that at this time there is no statistical net difference in the emissions of greenhouse gasses between conventional and organic dairy farms; thus, the greenhouse gasses, or "CO_2" in layman's terms is statistically the same for organic and regular milk. The parsing of words in that answer is indicative to the complexities of the issue and should not be construed as to hold true for all farm management scenarios and locations. The take away from this thesis study is that the area which holds the most potential for mitigation of greenhouse gas emissions at the farm gate is efficient farm management practices; consideration should also be given to the supply chain and the co-production relationship between the dairy and the beef sectors as these have the potential to offset any gains made on the dairy farm.

In addition to the research literature analysis, a simplified case study was undertaken as a means to gather further insight into the issue that may not have been apparent with a literature analysis alone. It was almost immediately apparent that there would be some serious limitations to the case study due to the limited sample size and relative size of the two farms studied. However, it did prove to add greater insight into the calculation process and the sensitivity of the results to the variations in the data. Another consequence of the case study was that it required the GHW Group to become very familiar with the topic of Dry Matter Intake (DMI) as it is not only significant in the emission of CH_4 and N_2O, it is also an important factor in animal health and optimizing milk production.

The two farms chosen by Skånemejerier executives to visit were Wanås (organic farm) and Lilla Kyrkhult (conventional farm). The data collected was determined from parameters found in existing research literature; however, no calculation process for the actual calculation of the emissions was given. Valuable guidance was given to the group by Maria Henriksson of the Swedish University of Agricultural Sciences (SLU) in Alnarp, Sweden. From our interview and subsequent email communications with her, we learned that there is a lack of consensus among current researchers and academics as to which models and emission factors are best to use in the mapping of carbon footprints. When several models have been implemented using emission factors that vary depending on what country or region is under consideration, it becomes apparent why there is a large variation among the results of existing research literature.

Keywords: milk, organic milk, carbon footprint, CO2, N2O, CH4, dairy, dairy farm, dairy cow, SLU, greenhouse gas emissions

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1 Purpose:

The purpose of this paper is to determine whether or not there are differences in GHG emissions between conventional dairy farms and organic dairy farms in Sweden. According to Skånemejerier executives approximately 80% of greenhouse gas (GHG) emissions occur before the milk leaves the farm and that this is the area in which they have the least data; therefore, most benefit can be gained by limiting study to this area. This scope was agreed upon between the Grigsby, Huang & Wei (GHW) Group and Skånemejerier executives in consideration of the time allotted for the project and the fact that they currently have sufficient data on the processing and transport phases of their production. The focus on farm-level CO_2-equivalent emissions will produce the most benefit for Skånemejerier given the firm's needs and project constraints.

2 Background:

Skånemejerier is the local food company which develops, produces and markets healthy and fresh dairy products in the Skåne region of Southern Sweden. The goal of Skånemejerier is to offer consumers dairy products which contribute to healthy and quality life. Currently, Skånemejerier is growing from a regional dairy into a modern, international food company. In doing so, they are mindful of the sustainability of their enterprise as it grows and desire to distinguish themselves from their competitors as a leader in sustainability in the dairy industry. At the same time, more and more of the general public are becoming aware and concerned about the impact of the dairy industry on the environment. Distributors and consumers have inquired about the differences of environmental impact between conventional farm and organic dairy farms. The major impact that dairy farming operations have on the environment are in the form of GHG emissions.

3 Introduction:

Initially, a Skånemejerier executive mentioned that the most frequently asked question they receive from the consumer is *"What is the difference in CO_2 emissions between a conventional farm and an organic farm?"* At first glance, this seems to be a relatively straight forward and easy to answer question; however, after preliminary study of existing literature and research on the subject, it became clear to our group that it is anything but straight-forward and easy.

The inference that "CO_2" is the primary issue concerning emissions from dairy farming operations indicates a fundamental lack of understanding on this complex issue by the general public. A more appropriate term to use is Greenhouse Gas (GHG) emissions since CO_2 is only one of three major GHG gasses emitted during dairy farming operations and it is not even the most damaging one. The three major GHGs emitted during dairy farming operations are Nitrous Oxide (N_2O), Methane (CH_4), and Carbon Dioxide (CO_2). Furthermore, these three GHGs are also referred to as Long Lasting Greenhouse Gasses (LLGHGs) because they are chemically stable and persist in the atmosphere for decades to centuries; their emission has long-term influence on the Earth's climate (IPCC, 2007; TS.2.1).

The term, "CO_2 equivalents" refers to the application of a conversion factor called the global warming potential (GWP) with which GHG emissions are converted into CO^2 equivalents (CO_2e). CO_2 equivalents standardize emissions of GHGs so that they may be compared by how efficiently each gas traps heat in the atmosphere. The GWPs used for calculating CO_2 equivalents are derived by the IPCC as a function of two values: the radiative efficiency/heat-absorbing capacity and the rate of decay of each gas, i.e. how long a given mass of the gas persists in the atmosphere until it has completely decayed (IPCC, 2001). The most recent IPCC guidelines give the conversion factors 1 kg CH_4 = 25 kg CO_2-equiv and 1 kg N_2O = 298 kg CO_2-equiv (IPCC, 2007).

As evident from **Figure 1,** (Henriksson et al., 2011); the emissions generated throughout the milk production system 'from cradle to farm gate' is a complex issue. There are many factors contributing to the carbon footprint (CF) that are not in control of the farmer. Additionally, the carbon footprint of agricultural products (e.g. milk) always includes a certain level of uncertainty; emission estimates of the GHGs Methane (CH_4) and Nitrous Oxide (N_2O) are associated with large uncertainties due to the nature of the biological processes causing these emissions in the soil, the rumen and manure (Rypdal and Winiwarter, 2001). There are also large variations between management practices from farm to farm regardless of the system employed, e.g. conventional vs. organic. Farm management is of particular interest since it represents the area where most improvement can be made to reduce the carbon footprint of milk production in Sweden (Henriksson, M. et al. 2011).

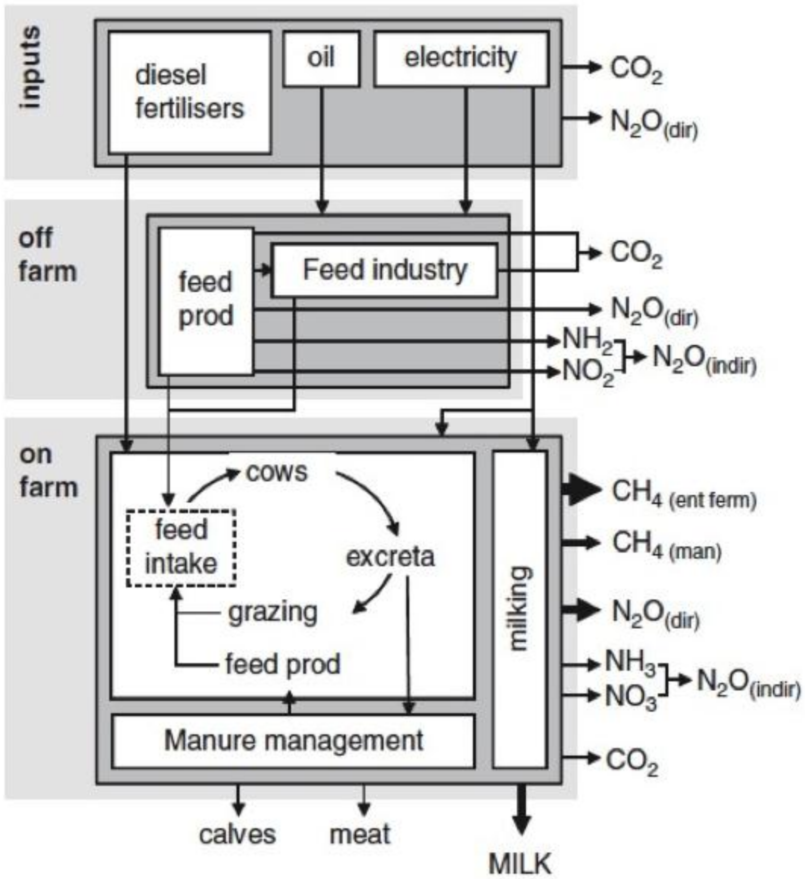


Figure 1: Schematic Overview of the Milk Production System from 'Cradle-to-Farm Gate' in Sweden

An example to illustrate the complexity of the issue may go something like this: To increase the yield per acre of land and thus, per cow, a conventional dairy farm typically uses synthetic chemical fertilizers and pesticides to grow feedstuffs which not only increases the N_2O emissions, but also increases the carbon footprint in CO_2 through the manufacture and transport of the chemical fertilizers and pesticides before they reach the farm (see **Figure 1**). But because of this, the conventional farmer typically achieves a higher yield of milk per cow which translates into a smaller CF when the total amount of GHG emissions is divided by the total milk produced. Whereas, an organic farm uses very little to no synthetic fertilizers or pesticides and as result, has lower yield per cow. Due to lower yield, more land is required to grow an adequate amount of feedstuffs. As a consequence, the cows may receive insufficient Dry Matter Intake (DMI) in order to achieve maximum milk production per cow while at the same time larger quantities of diesel and electricity are used to farm larger areas of land thereby negating the gain from not using synthetic fertilizers to begin with. This means that in the case of the organic farm, there is a greater amount of GHG emissions to be distributed over a smaller amount of produced milk resulting in the organic farm producing more GHG emissions per kilogram of milk than the conventional farm and thus, a larger CF. Therefore, contrary to what one may intuitively conclude, it has been observed that many organic farms produced larger carbon footprints than comparable conventional farms. When measured by GHG emissions per kg of milk, current research has shown that there is no statistical difference in GHG emissions between Conventional and Organic Farms. However, there are many caveats to this statement and it should not be construed as true that all conventional farms produce a smaller footprint than organic farms. However, before proceeding any further, an explanation of how organic farming is defined seems appropriate.

According to the **Organic Trade Association**, the term "organic" refers to the way agricultural products, food and fiber, are grown and processed. "Organic farming" is the process of producing food naturally. This method avoids the use of synthetic chemical fertilizers and genetically modified organisms to influence the growth of crops. The main idea behind organic farming is 'zero impact' on the environment. Furthermore, organic food production is based on a system of farming that maintains and replenishes soil fertility without the use of toxic and persistent pesticides and fertilizers and is minimally processed without artificial ingredients, preservatives, or irradiation to maintain the integrity of the food. The absence of this process constitutes "conventional farming".

3.1 System Description

3.1.1 Farm System Description

In Sweden, dairy cows graze outdoors 2.5 moths per year and heifers graze outside for 5.5 months. For the remainder of the year, the livestock are kept indoors. The feed intake from grazing constitutes less than 10% of total intake (Cederberg et al., 2009a). Typically, organic dairy farms utilize a longer grazing season than do conventional dairy farmers; organically produced milk comprised 5% of total milk deliveries in Sweden in 2005 (Cederberg et al., 2009a). The diet of dairy cows mainly consists of roughage fodder, grain and concentrates (Cederberg and Flysjö, 2004). Roughage mainly contains silage from various grass and clover grown on the dairy farms. Additionally, the majority of dairy farms grow their own grain, while protein concentrate feed, which mainly consists of rapeseed meal, soy meal and by-products from the cereal and sugar industry, is bought from the feed industry. More details of concentrate feed are shown in **Appendix 9.5**. On average, each dairy cow produced 8274 kg ECM milk for the dairy industry in 2005 with a heifer replacement rate of approximately 38% in year 2005 (Cederberg et al., 2009a).

The life cycle of milk production process is illustrated by Maria Henriksson of SLU, Alnarp Sweden in **Appendix 9.4**. The GHG emissions outside the farm gate will not be considered in this study. **Figure 2** and **Figure 3** illustrate the proportion of the emission sources in the farm gate according to the latest study in Sweden (Flysjö et al, 2011). The two pie charts illustrates that the dominant GHG emission is from methane, which is mainly from the animals' enteric fermentation. Nitrogen oxide is the second largest emission in dairy farms, which amounts 28.8% of the total carbon footprint. The carbon dioxide emission occupies 12.9% and the main source is from diesel use.

Figure 2: The Proportion of GHG Emissions Sources

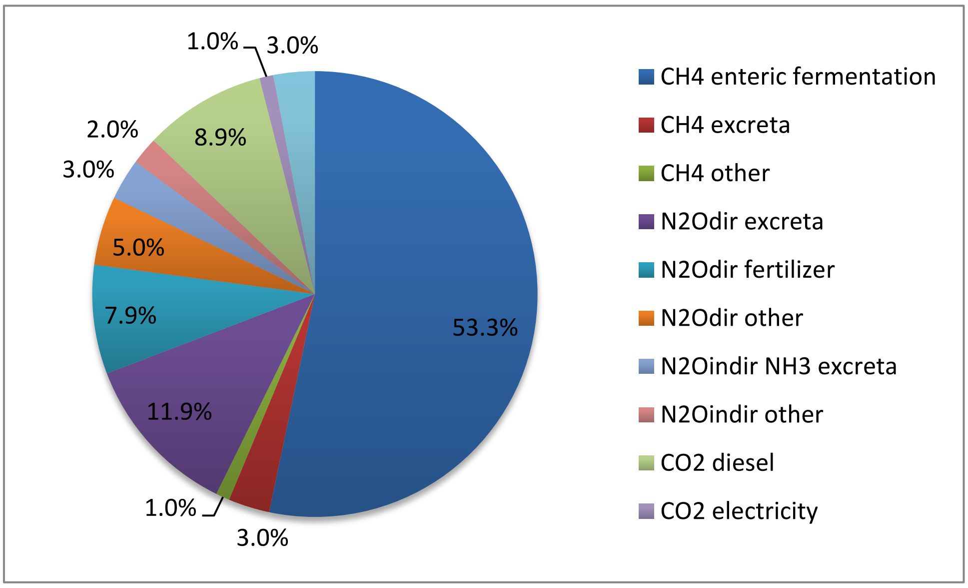
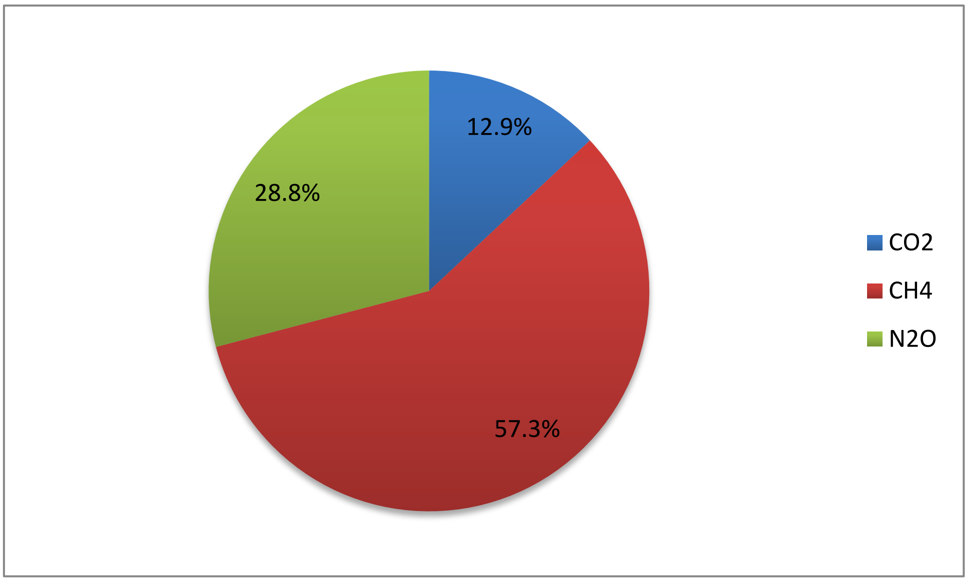


Figure 3: The Proportion of Three GHG Emissions



3.2 CO_2 and CO_2 Equivalent Emissions:

The inference that "CO_2" is the primary issue concerning emissions from dairy farming operations indicates a fundamental lack of understanding on this complex issue by the general public. A more appropriate term to use is Greenhouse Gas (GHG) emissions since CO_2 is only one of three major GHG gasses emitted during dairy farming operations and it is not even the most damaging one. The three major GHGs emitted during dairy farming operations are Nitrous Oxide (N_2O), Methane (CH_4), and Carbon Dioxide (CO_2). Furthermore, these three GHGs are also referred to as Long Lasting Greenhouse Gasses (LLGHGs) because they are chemically stable and persist in the atmosphere for decades to centuries; their emission has long-term influence on the Earth's climate (IPCC, 2007; TS.2.1).

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3.2.1 Methane (CH_4):

CH_4 emissions due to dairy farm operations are mainly the by-product of Rumen digestion/fermentation and the handling and field application of manure/slurry. Methane is 25 times more potent than CO_2 and makes up approximately 50% of the CO2-equivalent emission (Flysjö et al, 2011, p4 & IPCC, 2007). Methane emissions on the dairy farm are from two primary sources, enteric fermentation within the cows and manure storage and handling.

3.2.1.1 Enteric fermentation

Methane is a by-product of microbial breakdown of carbohydrates during the digestion process in the cow; this is known as enteric fermentation. For the average Swedish dairy cow producing 8843 kg ECM/year in 2005, the annual emissions were estimated to be 127 kg of CH_4; heifers, emitted an estimated average value of 53 kg of CH_4 per head per year (Cederberg et al., 2009).

3.2.2 Excreta on field and manure management

In Sweden, the majority of excreta from cows are stored since the cows stay inside for most of the year; the remainder is deposited directly on field while grazing. Methane resulting from the decomposition of excreta on the field will not be discussed in detail since its contribution to total emissions is negligible.

3.2.3 Nitrous Oxide (N_2O):

N_2O is generated by the transformations of Nitrates in the soil as a result of synthetic fertilizers, manure and organic matter decomposition in the soil; as a GHG, it is 298 times more potent than CO_2 and contributes approximately 25% to the Carbon Footprint (CF) of milk production at the farm gate. (Cadbury, 2009 & IPCC, 2007). N_2O emissions occur in two ways, namely:

3.2.3.1 Direct emission

Direct nitrous oxide emissions from soil are due to nitrogen (N) application through the use of synthetic fertilizers and manure. Crop residues also emit N_2O as they decompose.

3.2.3.2 Indirect emission

3.2.4 Carbon Dioxide:

CO_2 is generated by Rumen Respiration but it is mainly released in farming operations during the burning of fossil fuels in the operation of machinery and the generation of electricity. CO_2 accounts for approximately 23% of the CF of milk production at the farm gate (Cadbury 2009 & IPCC, 2007).

3.2.4.1 Diesel

Diesel is primarily used on the farm in cultivation of feed, manure application, processing and transportation of feed production, transportation of animals, etc. (Flysjö et al., 2011, p.5). Both production and use of diesel fuel has caused the release of carbon dioxide, 12% and 88% respectively as shown in **Appendix 9.6**. The values for diesel use and release of carbon dioxide in various machine operations vary greatly. In the case study, the production of diesel was not considered; however, an average value of 2.9 kg of carbon dioxide per liter of consumed diesel fuel was used (Appendix 8.4).

3.2.4.2 Electricity

Electricity is mainly used on the farm for milking and milk cooling. The GHG emission of electricity mix is shown in Table 1. In the case study, the electricity used in unit kWh in year 2010 of conventional farm and organic farm was used. Then the value of 55.9g carbon dioxide equivalent emissions per kWh was selected from **Table 1** to calculate carbon dioxide emission of two farms for comparison.

Table 1: Greenhouse Gas Emissions Associated with Different Electricity Production Mixes (Viberke, Cecilia, 2008)

		Electricity Mix (2007)					
	g CO2-equivalents/ kWh	Norwegian Hydroelectricity	Nuclear	Coal	Other fossil fuels	Other renewable fuels	Waste
Norwegian Hydro Electricity	1.99	100					
Norwegian Residual Mix	63.80	89.85	4.07	1.73	2.36	1.78	0.21
Swedish electricity	55.90	49.72	43.86	2.16	1.94	2.15	0.15
Swiss electricity	30.47	54.01	41.06	0.00	0.00	0.4	2.93
German electricity	741.71	4.33	22.08	48.86	1.42	10.2	3.2
UCTE electricity	629.75	11.28	29.10	39.44	14.86	4.7	0.62

3.3 Milk and Beef production (Co-product handling)

When considering the findings of this literature analysis and case study, one should have a basic understanding of "co-product handling". The dairy industry not only provides milk production, but also contributes significantly to the beef and leather industries. In order to produce milk, a cow must produce a calf. Male calves and other "surplus calves" not used in the production of milk as well as culled dairy cows are slaughtered for the production of beef and leather. In In 2005 approximately 65% of Sweden's beef production came from the dairy sector (Cederberg et al., 2009a,b). Therefore, it becomes evident that a certain percentage of the CF of milk production should be borne by the beef industry since it gains a significant benefit from the dairy industry's co-production of beef. The questions then becomes, how much of the dairy industry's CF should be allocated to the beef industry and what methodology should be used to achieve this? The answer to that question is "it depends". There are several methodologies such as ISO, IDF, PAS 2050, and EPD for co-product handling based on different standards and guidelines; as a consequence, results of the CF size will vary depending on the method chosen. The main point to keep in mind is, if you are comparing carbon footprints to one another, they must have been calculated using the same method (Flysjö, A., et al. 2011). Table 3 in Flysjö, A., et al. 2011, shows the variation between the different methods one can expect.

The relationship between the dairy and beef industry regarding co-production adds yet more complexity to the challenge of carbon footprint mapping by creating a paradox within the intensification of milk production. Intensification of milk production per cow is viewed as an important strategy to help reduce the CF of the dairy industry and is on the increase; however, for the intensification of milk production to be successful, the number of total cows must be reduced once they are no longer required to meet milk demand. Fewer cows would decrease the CF of the dairy farm, but this would also mean less co-production of beef from the dairy sector for the beef industry. In an analysis of the environmental improvement potentials of meat and dairy products in Europe, Weidema et al. (2008) concludes that an intensification of milk production through increased milk yield per cow would lead to reduced methane emissions per kilogram of milk (-24%), but would not lead to any significant reduction in GHG emissions (-0.27%) in total, due to an “induced additional beef production from suckler cows necessary to keep the meat output unaltered”. Also, intensification may lead to an increase in impacts for most of the other environmental categories (Weidema et al., 2008).

A study analyzing GHG emissions from animal production and consumption had been conducted from 1990 and 2005 in Sweden. In year 1990 approximate 85% of all beef came from the dairy sector, but it reduced to 65% in year 2005 due to the intensification of milk per cow (Cederberg et al., 2009a,b). Thus, we summarize, although more intensified milk production will lower GHG emissions per kilogram milk, it would at the same time, increase GHG emissions per kilogram beef due to an increase in suckler cows required to compensate for the reduced number of culled cows and surplus calves from the dairy sector. There is concern that this could offset any gains made by the intensification of milk production. However, there have been studies asserting that “reduced emissions due to intensification of the dairy sector were sufficient to compensate for the increased emissions from the beef production sector” (Cederberg et al., 2009a). In other words, there was a net reduction in GHG from milk and beef production in Sweden the period in question; but, due to the variation in available data and competing methodologies for calculating CFs, it is difficult to accurately conclude just how much of an actual reduction it was. In light of the increase of beef consumption in Sweden, intensification in milk production as well as a reduction in the demand for beef will be needed for maximum reduction in GHG emissions.

4 Case Study

4.1 Case Study Introduction

The collected data for the case study presented in this paper is based upon two farms in Skåne Sweden: Lilla Kyrkhult, a conventional farm, and Wanås, an organic farm. This study focus on the major GHG emissions associated in the life cycle of milk production at farm gate. The life cycle of milk production process is illustrated by Maria Henriksson of SLU, Alnarp Sweden in the **Appendix 9.4**.

4.2 Purpose of Case Study:

For case studies, five components of a research design are especially primary (Yin, 2003):

1. A case study's questions
2. Its propositions, if any
3. Its units of analysis
4. The logic linking the data to the proposition, and
5. The criteria for interpreting the findings

The original purpose of the case study is to compare the difference of GHG emission between the organic and conventional farms. However, due to limited time and limited sample size, the result is hard to answer the initial question. Thus, the final analysis of the case study will be drawn carefully. The average emission data of the whole industries will be the criteria to analysis to the case study.

In addition, the data collection part and calculation model help to illustrate the difficulty of carrying out an accurate carbon footprint in dairy farms. Uncertainty analysis will be given in the case study section.

4.3 Emission sources in dairy farm

The emissions generated throughout the life cycle of milk production that are considered in the case study include the following:

- Transportation in the farm (CO_2)
- Electricity use in the farm (CO_2)
- Animal production through enteric fermentation (CH_4)
- Manure storage (CH_4 and direct N_2O)
- Deposition of manure dropped in the pasture (direct N_2O)
- Fertilizer application (direct N_2O)

- Crop residues (direct N_2O)
- Nitrogen losses related to the volatilization of NH_3 in the house, manure storing and field operation (indirect N_2O)
- Leaching of NO_3 as a result of using using NH_4NO_3 fertilizer

Note: *This assessment does not consider the GHGs emitted as a result of the land use management practices chosen on a particular farm since there is no consensus on methodology in this area; the existing data is limited and unreliable.*

4.4 Function Unit

The functional unit (FU) of measurement used in is "1 kg energy-corrected milk (ECM)" at the farm gate. The ECM equation is as follows:

ECM (kg) = milk (kg) * 0.25 + fat (kg) * 12.2 + protein (kg) * 7.7

(Sjaunja et al., 1990)

4.5 Category Analysis

According to the methodology above mentioned, we divide the data into five categories. They are shown below in **Table 2**.

Table 2: Categories of Data to be collected

Information of farm	Information of cows	Feed:	Mature:	Energy use:
Arable land	Dairy cow	PURCHASE FROM OUTSIDE	Manure slurry	Electricity
Natural meadows	Young heifer	protein concentrate feed	Solid Manure	Diesel
Milk yield	Calf	mixed concentrate feed		
Milk dilivered	Lactation period	By-products from the sugar industry		
	House period	calf feed		
	Replacement rate	mineral feed		
	Live weight	Roughage fodder		
		Grains		
		Soy meal		
		Rapeseed meal		
		Beet pulp		
		Cereals		
		Fibres		
		protein ingredients		
		FROM LAND		
		Grain		
		Maize		
		Ley(grassland)		
		Roughage		
		Leguminous		

Data Collection

Data was collected by interviewing the operators/owners of the farms. The data is shown in **Table 3**. Those data would be used in the GHG emission calculation.

Table 3: Data Collected from Farmer Interview

	Organic farm	Conventional farm	
Information of farm			
Arable land	725	138	hectare
Natural meadows	250	12	hectare
Milk yield	3,500,000	1,442,000	kg
Milk delivered	3,200,000	1,400,000	kg
Information of cows			
Dairy cow	460	150	
Young heifer	460	110	
Calf	4	25	
Lactation period	10	13.7	month
House period	8	6	month
Replacement rate	35%	34%	
Live weight	500-650	650	kg
Feed:			
PURCHASE FROM OUTSIDE			
protein concentrate feed		110	tonnes
mixed concentrate feed			
By-products from the sugar industry			
calf feed		18	tonnes
mineral feed		5.5	tonnes
Roughage fodder			
Grains			
Soy meal			
Rapeseed meal			
Beet pulp		365	tonnes
Cereals			
Fibres			
protein ingredients			

FROM LAND			
Grain		300	tonnes
Maize		440	tonnes
Ley(grassland)		1,100	tonnes
Roughage		110	tonnes
Leguminous			
Mature:			
Manure slurry	15,000	4,000	tonnes
Solid Manure	500	300	tonnes
Energy use:			
Electricity	620	264	MWh
Diesel	80,000	14,000	L

4.6 Calculations and Results

Table 4 displays the yearly production of milk of the two farms considered in the case study. From the interviews with the farmers, the conventional farm of Lilla Kyrkhult produced 1,400,000 kg of milk per year, while the organic farm Wanås produced 3,200,000 kg milk per year. In order to calculate the amount of ECM from the two farms, the fat and protein content of the milk production from both farms was supplied by Skånemejerier. The milk from Lilla Kyrkhult farm contained 3.94% fat and 3.42% protein, while the milk from Wanås organic farm contained 4.19% fat and 3.55% protein.

4.6.1 ECM Calculation

For ECM from Wanås organic farm:

*ECM = 3,200,000 kg * 0.25 + 134,080 kg * 12.2 + 113,600 kg *7.7 = 3,310,496 kg*

For ECM from Lilla Kyrkhult farm:

*ECM = 1,400,000 kg * 0.25 + 55,160 kg * 12.2 + 47,880 kg * 7.7 = 1,391,639 kg*

4.6.2 Carbon Dioxide (CO_2) Calculation

The CO_2 emissions are primarily the result of the consumption of diesel and electricity on the farm. In order to calculate the CO_2 emissions, the diesel and electricity usage data of the two farms was multiplied by the relevant emission factors as shown below in **Table 4**.

Table 4: CO_2 Emission Factor of Diesel and Electricity

	CO_2 Emission Factor
Diesel	2.9 kg/l [a]
Electricity	55.9 kg/MWh [b]

a. **Appendix 9.6**

b. Viberke and Cecilia (2008)

Note: The details of the calculation procedure are shown in **Appendix 9.1**.

4.6.3 Methane Calculation

According to the latest research, the most important GHG in dairy farming is methane which occupies approximately 50% of the CO_2-equivalent emissions generated (Flysjö et al, 2011, p4). The amount of CH_4 released as a result of enteric fermentation by the average cow calculated in the case study is the product of the feed intake multiplied by an emission factor (EF) of 21.6 g CH_4 kg^{-1} DMI (Clark, 2001) and the dry matter intake (DMI) per cow of 6534 kg per year (Henriksson, 2011), which gives a result of approximately 141 kg cow^{-1} yr^{-1}. If the emissions from replacement heifers are included, the estimated methane emission from enteric fermentation would be approximately 178kg cow^{-1} yr^{-1} in Sweden (Flysjö et al, 2011, p4). Methane resulting from the storage of manure is given as 8.4 kg cow^{-1} yr^{-1} and 9.6 kg $heifer^{-1}$ yr^{-1} in the organic farm. For conventional farms, it is 13.6 kg cow^{-1} yr^{-1} and 9.2 kg $heifer^{-1}$ yr^{-1} at conventional high farms (more than 7500 kg ECM per hectare of arable land) and 17.4 Kg cow^{-1} yr^{-1} and 6.7 kg $heifer^{-1}$ yr^{-1} in conventional medium farms (Cederberg and Flysjö, 2004, p14).

Emission factors used in the calculation of methane emissions are presented in **Table 5**.

Table 5: CH_4 Emission Factor

	CH_4 Emission Factor	
	Organic Farm	Conventional Farm
Enteric fermentation	178 kg $cow^{-1}year^{-1}$ [a]	178 kg/ $cow^{-1}year^{-1}$ [a]
Cow's Manure Storage	8.4 kg / $cow^{-1}year^{-1}$ [b]	13.6 kg / $cow^{-1}year^{-1}$ [b]
Heifer's Manure Storage	9.6 kg/ $heifer^{-1}year^{-1}$ [b]	9.2 kg / $heifer^{-1}year^{-1}$ [b]

a. Flysjö et al. (2011)

b. Cederberg and Flysjö, (2004)

Note: The details of the calculation procedure are shown in **Appendix 9.2**.

4.6.4 N_2O emission calculation

The calculations of direct N_2O emissions in this case study are based on the following factors and information.

Direct Emissions: According to the IPCC, the default emission factor (EF) for direct emissions is 0.01 kg N_2O-N kg^{-1} N for both N application and crop residues (IPCC, 2006b). For the N-fixation, the EF is 0.0125 kg N2O-N/kg N (Cederberg and Flysjö, 2004, p20) and for the N_2O emission from excreta dropped directly in the field, the IPCC guidelines default EF is 0.02 kg N_2O-N kg^{-1} N (IPCC, 2006b). N_2O emission from manure storing is calculated based on IPCC default EF 0.005 kg N_2O-N kg^{-1} N (IPCC, 2006a). Nitrogen excretion was calculated as the total amount of N in feed intake less the amount of Nitrogen in the milk and cows. In Sweden, it is estimated as 161 kg N cow^{-1} yr^{-1} for cows and replacement heifers (Flysjö et al, 2011, p4). The Nitrogen applied to the soil as manure in the field is calculated on average 134 kg N cow^{-1} yr^{-1} and 40 kg N $heifer^{-1}$ yr^{-1} and feed waste which is 5.7 kg N cow^{-1} yr^{-1} including both cows and heifers minus Nitrogen losses as NH_3 and N_2O in the house and storing process (Henriksson et al, 2011, p4).

Indirect Emissions: In accordance with the IPCC, indirect emissions were estimated using the EF of 0.01 kg N_2O-N kg^{-1} NH_3-N and 0.0075 kg N_2O-N kg^{-1} NO_3-N (IPCC, 2006b). Volatilization of NH_3 in the house, manure storing and excreta in the field is calculated using the software SiM developed by Swedish Board of Agriculture (Linder, 2001). The average nitrogen losses is 0.043 kg NH_3-N kg^{-1} N in the house, 0.068 kg NH_3-N kg^{-1} N in manure storing, 0.219 kg NH_3-N kg^{-1} N in field application, 0.10 kg NH_3-N kg^{-1} N for the excreta directly dropped in the field and 0.02 kg NH_3-N kg^{-1} N for the NH_4NO_3 fertilizer (Cederberg et al, 2009).

The emission factors of N_2O emission sources are summarized in the following **Table 6**:

Table 6: The Emission Factor for N_2O Emission Calculation

N_2O sources	Implied Emission Factors Unit [a]
Direct emission	
Synthetic Fertilizers	0.01 kg N_2O-N/kg N
N-fixation Crops	0.0125 kg N_2O-N/kg N
Crop residue	0.01 kg N_2O-N/kg N
Animal excreta dropped in the field	0.02 kg N_2O-N/kg N
Manure storing	0.005 kg N_2O-N/kg N
Indirect emission	
NH_3 losses in the house	0.043 kg NH_3-N/kg N
Leaching of NO_3^-	0.02 kg NH_3-N/kg N
NH_3 losses in manure storing	0.068 kg NH_3-N/kg N
NH_3 losses in field application	0.219 kg NH_3-N/kg N
NH_3 losses for the excreta dropped in pasture	0.10 kg NH_3-N/kg N

a. The emission factor to convert from kg NH_3-N/kg N to N_2O-N/kg N is 0.01kg N_2O-N / kg NH_3-N; to convert N_2O-N to N_2O emission, multiply by 44/28.

The nitrogen oxide emission is calculated and all the factors used are shown in the **Table 7**.

Table 7: Factors Used in N_2O Emission Calculation

		Organic farm	Traditional farm
synthetic fertilizers	N inputs	5 kg N/ha [a]	91 kg N/ha [a]
	EF	0.01 kg N_2O-N kg^{-1} N	0.01 kg N_2O-N kg^{-1} N
N-fixation	N inputs	53 kg N/ha [a]	34 kg N/ha [a]
	EF	0.0125 kg N_2O-N kg^{-1} N	0.0125 kg N_2O-N kg^{-1} N
animal excreta in pasture	N inputs	134(heifer40) kg N cow^{-1} yr^{-1}	134(heifer40) kg N cow^{-1} yr^{-1}
	EF	0.02 kg N_2O-N kg^{-1} N	0.02 kg N_2O-N kg^{-1} N
Manure storage	N inputs	125 kg cow^{-1} yr^{-1}	125 kg cow -1 yr -1
	EF	0.01 kg N_2O-N kg^{-1} N	0.01 kg N_2O-N kg^{-1} N
NH_3 - Manure storage	$Unit_1$		
	EF	0.068 kg NH3-N/kg N	0.068 kg NH3-N/kg N
NH_3 - animal excreta in pasture	$Unit_1$		
	EF	0.10 kg NH_3-N kg^{-1} N	0.10 kg NH_3-N kg^{-1} N
$Unit_1$	convert N_2O-N to NH_3-N		0.01 kg N_2O-N kg^{-1} NH_3-N
$Unit_2$	convert N_2O to N_2O-N		(44/28) kg N_2O kg^{-1} N_2O-N

a. Cederberg and Flysjö, 2004

Note: The details of the calculation procedure are shown in **Appendix 9.3**.

4.6.5 CO_2-equivalent emission result

Recall from section 4.3; According to IPCC (IPCC, 2007), CH_4 is 25 times more potent than CO_2 and N_2O is 298 times more potent than the carbon dioxide. See **Table 8.**

Table 8: Convert the GHG emissions to the CO_2-equivalent Emission

GHG sources	Convert to CO_2-equivalent
1kg CO_2	1 kg CO_2-equivalent
1kg CH_4	25 kg CO_2-equivalent
1kg N_2O	298 kg CO_2-equivalent

The total emissions in the case study are shown in **Table 9**:

Table 9: CO_2-equivalent Emission Summary

CO_2-equivalent sources (kg)	Organic farm (Wanås)	Traditional farm (Lilla Kyrkhult)
ECM (kg)	3,310,496	1,391,639
CO_2	266,658	55,357
CH_4	2,252,000	746,050
N_2O	932,301	277,429
Total	3,450,959	1,078,836
FC/ECM	1.0424	0.7752

4.7 Case study analysis:

The final calculated emissions are shown in **Table 10.**

Table 10: Final Result of CO_2-equivalent Emission Calculation

Emission sources (kg CO_2-equiv/kg ECM)	Organic Farm	Conventional Farm
ECM	3,310,496	1,391,639
CO_2 diesel	0.0701	0.0292
CO_2 electricity	0.0105	0.0106
CO_2 total	0.0805	0.0398
CH_4 enteric fermentation	0.6177	0.4797
CH_4 manure storage	0.0625	0.0564
CH_4 total	0.6803	0.5361
N_2O synthetic fertilizers	0.0051	0.0422
N_2O N-fixation	0.0913	0.0214
N_2O excreta in pasture	0.0412	0.0318
N_2O manure storage	0.0813	0.0630
NH_3 manure storage	0.0063	0.0041
NH_3 excreta in pasture	0.0175	0.0065
Others	0.0390	0.0303
N_2O total	0.2816	0.1994
Total	1.0424	0.7752

Some minor emissions are omitted due to the complexity of the calculation and the negligible impact of the result on this case study. The results suggest that the carbon emissions from the organic farm, Wanås are approximately 1.042 kg CO_2-equiv/kg ECM while the emissions from the conventional farm, Lilla Kyrkhult are approximately 0.775 kg CO_2-equiv /kg ECM. The most critical carbon emission for both Wanås and Lilla Kyrkhult is methane; this finding is consistent with the other studies analyzed during this case study.

Figure 4: Emission Source Proportions of the Organic Farm – Wanås

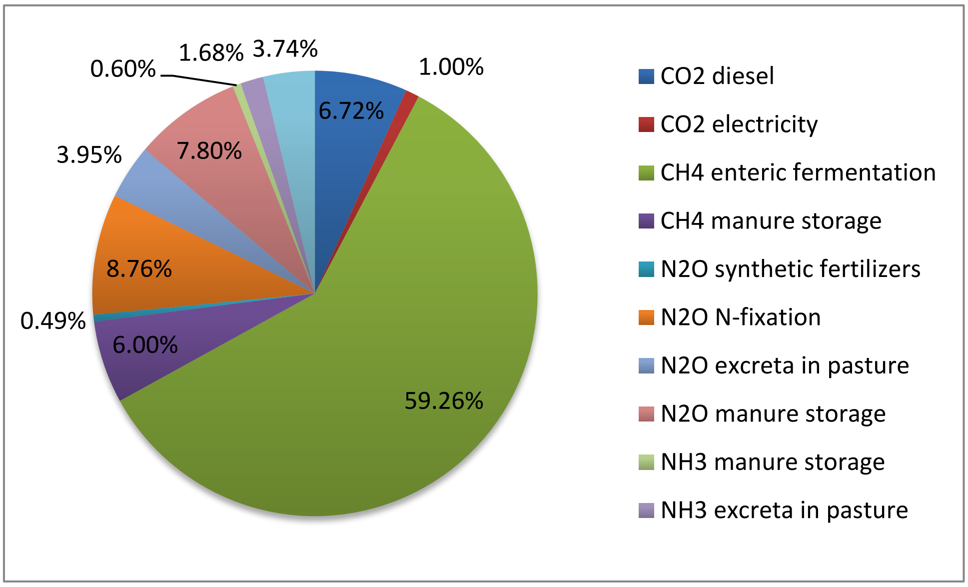
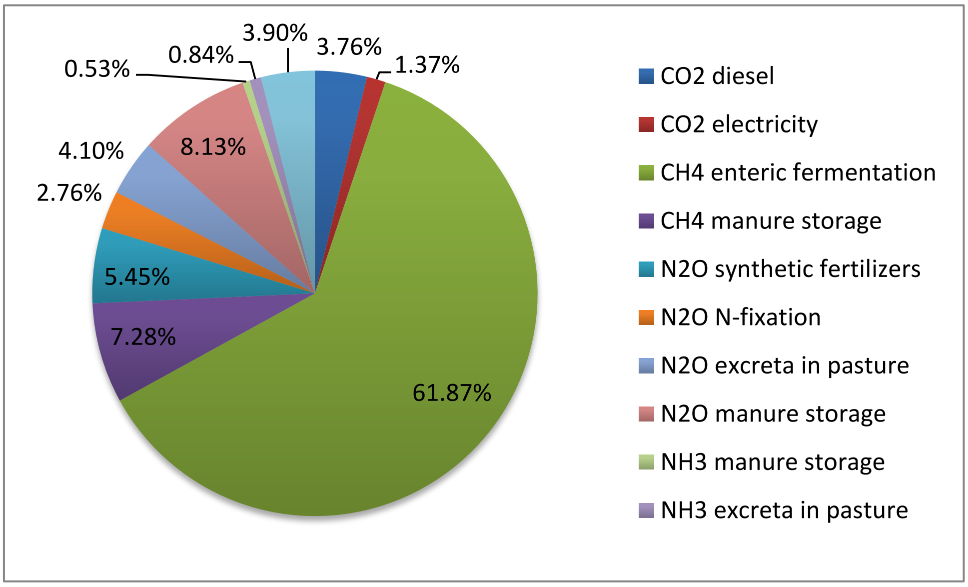


Figure 5: Emission Source Proportions of the Conventional Farm – Lilla Kyrkhult



General results are shown in **Table 11**. The conventional Lilla Kyrkhult appears to be more efficient in milk production than the organic farm, Wanås. Our outcome of the case study shows that Lilla Kyrkhult produced 2000 kg ECM/cow more than Wanås, and 5000 kg ECM / hectare more than Wanås per year.

Table 11: General Result of Milk Production per Year

	Organic farm	Conventional farm
ECM (kg)	3,310,496	1,391,639
Cow	460	150
Arable land (ha)	725	138
Natural meadow (ha)	250	12
Total land (ha)	975	150
ECM / Cow (kg/cow)	7,196.73	9,277.59
ECM / Arable land (kg/ha)	4,566.20	10,084.34
ECM / Total land (kg/ha)	3,395.38	9,277.59

Table 11 indicates that Wanås emits more carbon dioxide, methane and nitrogen oxide than does Lilla Kyrkhult. The reason for this counter intuitive result may be due to the fact that organic farms usually require more land than the conventional farms in order to compensate for not using nitrogen in the form of synthetic fertilizers; this will also increase the emission of CO_2 resulting from a higher use of diesel and electricity. The parameter which has the greatest affect on the calculation of methane emissions in the model was the number of dairy cows. This may also be a contributing factor as to why Wanås emits more methane per kg ECM than does Lilla Kyrkhult; there is three times the number of cows at Wanås than at Lilla Kyrkhult.

4.7.1 Comparison to the dairy industry

Due to the limited sample size of two farms, the case study should not be construed as being representative of the more than 600 farms within the Skanemejerier co-op. Thus, the conclusions of the case study can only be interpreted in a very general sense and serves as an illustration of the complexities involved in the science of GHG emissions mapping of biological and natural systems such as agriculture and dairy farming operations. Additionally, the results of the case study were adversely affected by the unreliability of some of the gathered data and information. Complete feed data from Wanås were not available due to lack of record keeping while most data received from Lilla Kyrkhult was based on the farmer's memory. This may explain why conventional farm seemed to outperform the industry average; they had underestimated the amounts of resources used on their farm.

According to the research in 2004, there was no statistical difference of GHG emission between the organic and traditional farms (Cederberg and Flysjö, 2004). More recent studies also support this conclusion. There were large variations in GHG emissions on the dairy farms studied. The types of dairy farming operations which release the greatest amounts of GHG emissions are under the direct control of dairy farm management; therefore, the differing and/or lack of consistent farm management strategies is most likely the cause of high variability in GHG emission between dairy farms.

The milk production per cow at Wanås was found to be much less than the average number in the dairy industry, which is 8274 kg ECM/cow in 2005 in Sweden (Flysjö et al, 2011, pg. 3). This larger than expected divergence from the industry average is most likely due to the lack of reliability of the data and small sample size used for the case study.

Figure 6 indicates the GHG emission variation in dairy farms (FAO, 2010, p50) while **Figure 4** separated the emission into two systems: organic and traditional farms (Kristensen et al, 2011, pg. 9):

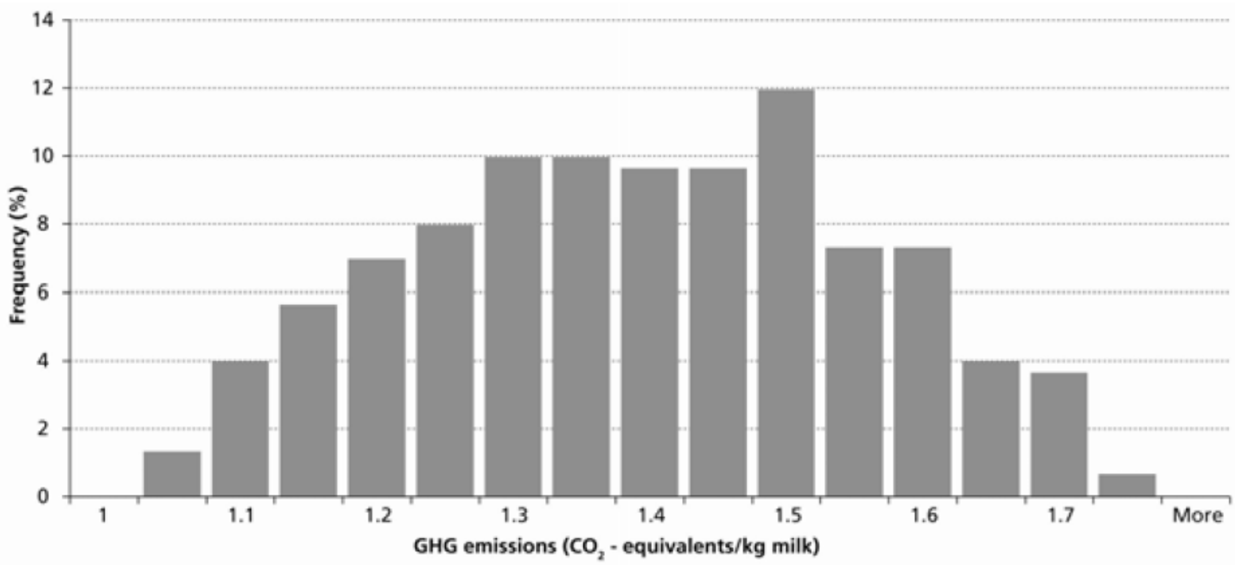


Figure 6: GHG Emissions Variation of Dairy Farms

Figure 7: GHG Emission variation of Both Organic and Traditional Farms

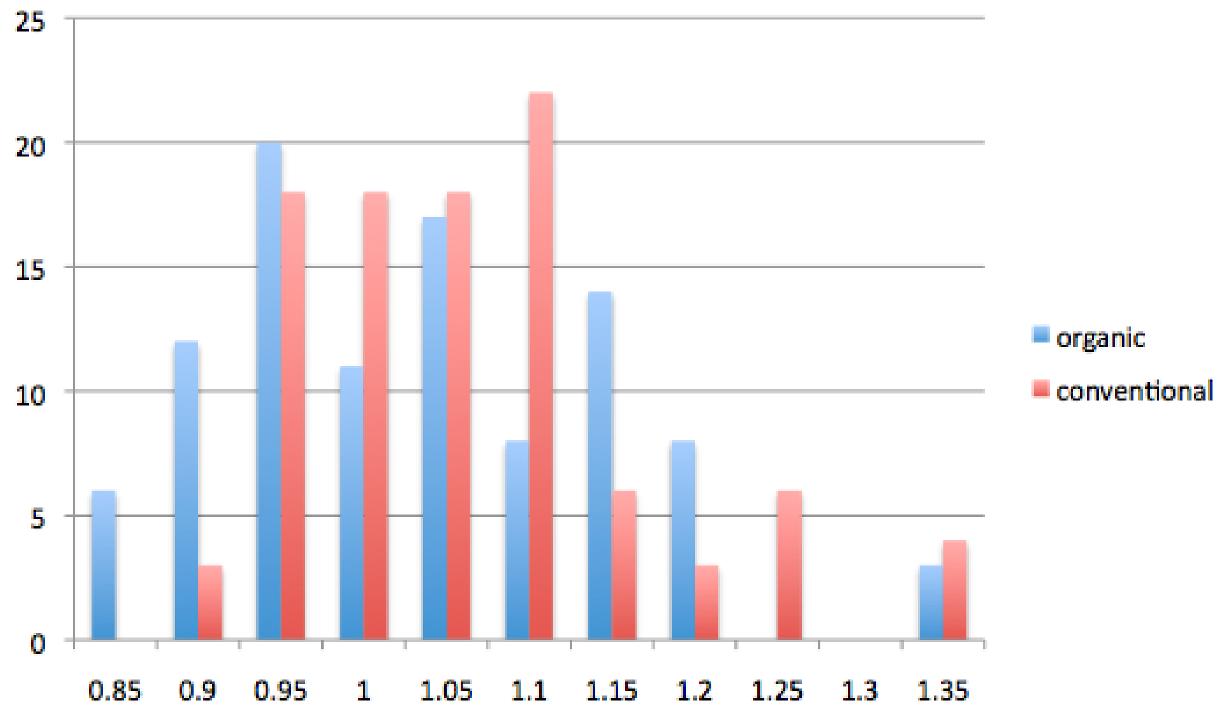


Table 12: Annual GHG Emission of Two Dairy Production Systems (Kristensen et al, 2011, pg.7)

Unit(kg CO2-equiv/kg ECM)	Organic farm			traditional farm		
	Mean	Min	Max	Mean	Min	Max
farm-level emission	1.24	0.98	1.67	1.05	0.83	1.22
CO_2	0.2	0.1	0.44	0.14	0.1	0.19
CH_4	0.69	0.61	0.85	0.62	0.53	0.73
N_2O	0.35	0.24	0.56	0.29	0.19	0.4

Although different research could carry out different result simply because they use different model to calculate the GHG emission, Monte Carlo analysis resulted in an average CF of 1.13 kg CO_2-equiv/kg ECM in Sweden and the variation is mainly from 0.94 to 1.33 kg CO_2-equiv/kg ECM. In our case, due to lack of information, the final result is much lower than average data.

Table 13 shows the CH_4 emissions in both Wanås and Lilla Kyrkhult are close to the average data in Sweden. The CO_2 emissions in Lilla Kyrkhult are much lower than the average data. A reason for this large variance of the Lilla Kyrkhult results could be the consequence of unreliable/inaccurate information offered by the farmers since they recalled the data of their diesel and electricity use from memory. We used the same model to calculate the N_2O

emissions on Wanås and Lilla Kyrkhult, however, the N_2O emission calculation in Lilla Kyrkhult seems to be unreliable comparing to the average data in **Table 13** (Flysjö et al, 2011, pg. 6). This is partly because the amount of synthetic fertilizers used at Lilla Kyrkhult was not available. Finally, there could be several reasons why the total result in Lilla Kyrkhult is so low which will be discussed in the following section.

Table 13: GHG Emissions from Milk Production in Sweden Parameters

kg CO_2e kg^{-1} ECM (%)	SE	Production parameters	Emission parameters
TOTAL CF	1.16 (100)		
CH_4 enteric fermentation	**0.54 (46.4)**	DMI	EF ent ferm
CH_4 excreta	0.03 (2.8)		
CH_4 other	0.01 (0.9)		
N_2O_{dir} excreta	**0.12 (10.5)**	N excreta	EF N_2O_{dir} Nappl, EF N_2O_{dir} graz
N_2O_{dir} fertiliser	**0.08 (6.5)**	N fertiliser used	EF N_2O_{dir} Nappl
N_2O_{dir} other	**0.05 (4.3)**	N crop res	EF N_2O_{dir} Nappl
N_2O_{indir} NH_3 excreta	0.03 (2.3)		
N_2O_{indir} NH_3 fertiliser	0.00 (0.2)		
N_2O_{indir} other	0.02 (1.6)		
N_2O fertiliser production	**0.08 (6.9)**[a]	N fertiliser used	prod of fert (N_2O/kg fert)
CO_2 diesel	**0.09 (7.6)**	Diesel used	prod + comb diesel (CO_2/l diesel)
CO_2 electricity	0.01 (0.9)		
CO_2 other energy	0.03 (2.2)		
CO_2 transport	0.02 (2.1)		
CO_2 fertiliser production	**0.04 (3.1)**	N fertiliser used	prod of fert (CO_2/kg fert)
CO_2 fertiliser application			
CO_2 other	0.02 (1.8)		

4.7.2 Uncertainty of analysis

When calculating the CF for a complex system such as a biological process, it is important to remember that the model could be over simplified. By using fixed emission factors from the Intergovernmental Panel on Climate Change (IPCC) to calculate GHG emission on dairy farms, it becomes apparent that the reliability of the model is questionable here since a single parameter could have quite a significant effect on the final CF result. Thus transparency is important to ensure a relatively accurate CF result. **Table 14** indicates the importance of changing an individual parameter in CF calculation (Flysjö et al, 2011, pg. 7). If the DMI for the dairy cows increase 10%, the total CF emission will raise 6.57%, which is a lot. Furthermore, according to FAO, when feed digestibility was set to randomly increase 10%, the conversion for enteric fermentation will increase 15%, emission factors regarding manure and N application have 50%, and the energy use for feed production 25% (FAO, 2010, pg. 49).

Table 14: Change in Total CF from Varying Individual Parameters

	SE	Increase (%)			
	kg CO_2e	Total	CH_4	N_2O	CO_2
CF result	**1.16**				
Parameters (increase%)					
DMI (+10)	**1.24**	6.57	9.81	5.12	0
N fertiliser used (+10)	**1.18**	1.63	0.02	4.04	1.76
crop res (+10)	**1.16**	0.28	0	0.87	0
EF ent ferm (+20)	**1.27**	9.27	18.51	0.00	0.00
IPCC MCF[a]	**1.19**	3.06	6.11	0	0
EF N_2O_{dir} Nappl (+100)	**1.34**	15.39	0	47.68	0
EF N_2O_{dir} graz (+100)	**1.18**	1.49	0	4.61	0
EF N_2O_{indir} f NH3 (+100)	**1.19**	2.39	0	7.39	0
NH_3 f excreta (+20)	**1.16**	0.45	0	1.40	0
Diesel (+20)	**1.18**	1.51	0.03	0.00	8.46
Electricity (+20)	**1.16**	0.21	0.02	0.02	1.06
Other energy (+20)	**1.16**	0.45	0.04	0.00	2.45
Transport (+20)	**1.16**	0.46	0.02	0.01	2.56

Additionally, the emission factors provided by the IPCC help to reduce the complexity of the CF calculation; however, the EF could be very different in other countries as a result of differing environmental factors such as rainfall and temperature. Moreover, the method offered by IPCC guidelines is based on very simplified model. For example, the nitrogen oxide calculation only takes the total amount of nitrogen applied into account. In reality, many factors could affect this biological process, such as the nitrogen from the water and soil (Hofstra and Bouwman, 2005) which resulted in very large variation in actual emissions.

5 Mitigation Suggestions

5.1 Mitigation of GHGs:

The following information and suggestions do not represent an all-inclusive summary of all possible management practices and procedures currently available to the dairy farmer. Research in this field is extensive and on-going; however, the suggestions presented in this section should serve as a good starting point toward the goal of optimum GHG mitigation.

5.1.1 Methane (CH_4):

5.1.2 Maintain Optimal Herd Health:

Healthy and "happy" cows are more productive cows; improving the health and welfare of dairy cattle enables increased milk production which reduces the amount of GHGs per kg. of milk. Additionally, healthy cows will tend to live longer, reducing culling rates which help keep replacement rates low. Productivity can be maximized by:

5.1.2.1 Improving Fertility:

- Focus on heat detection to avoid long calving intervals. Dairy cattle must calve on a regular basis if they are to maximize profit. Short calving intervals of 12 to 13 months result in more calves over the lifetime of a cow and in greater average daily milk production. Cows with long calving intervals are held at a lower level of production for a longer period and generally have longer dry periods. Many are culled each year because they are not pregnant or because they became pregnant too late. To improve the success rate of heat detection, set up a specific schedule and make one person responsible for observations. Others may be involved in the detection program, but they should report their findings on a specific form or to the individual responsible (Pennington, Jodie A. 2009).
- Ensuring nutrition and cow management at calving are appropriate to prevent milk fever and associated calving problems. Milk fever, also known as post-parturient hypocalcemia, or parturient paresis is a disease, usually of dairy cows, characterized by reduced blood calcium levels. It is most common in the first few days of lactation, when demand for calcium for milk production exceeds the body's ability to mobilize calcium reserves. "Fever" is a misnomer, as body temperature during the disease is usually below normal. Low blood calcium levels interfere with muscle function throughout the body, causing general weakness, loss of appetite, and eventually heart failure (Baillière Tindall, 1979).
- Feeding cows to minimize weight loss after calving and maintain body condition during lactation. During the lactation cycle there is essentially one opportunity to establish the lactation and ensure good health and reproduction: the transition period. The transition period refers to the time between 60 days prior to and 60 days after calving; the most critical time within this period is the 21 days before and after calving. Correct feeding and management during the transition period has a profound effect on dry matter intake

(DMI). DMI is a major factor influencing both milk yield and body weight change in early lactation. Higher DMI earlier in lactation reduces the time that cows are in negative energy balance. Minimizing the duration and extent of a negative energy balance also has a positive impact on reproduction (Schroeder, J.W, 2010).

5.1.2.2 Reducing Lameness:

Bovine lameness represents a major health problem for the dairy industry. In problem herds where incidence is high, lameness accounts for tremendous economic loss. Claw disorders associated with chronic subclinical laminitis are primary causes of lameness in most herds. These are complicated by heat stress, housing and other management considerations which are significant contributors to lameness in dairy cattle. Infectious skin disorders of the foot include *foot-rot*, *interdigital dermatitis*, and *digital dermatitis*. Regardless of cause, early detection and prompt treatment minimizes losses, improves outcome, and reduces animal suffering. Neglect not only increases losses but raises important animal welfare concerns (Shearer, J.K. et al. 2000). Measures that can help prevent lameness include:

- Providing clean spacious accommodation with comfortable lying areas to minimize standing up time, particularly after calving (Cadbury, 2009).
- Providing a diet that maintains a healthy rumen and avoids acidosis. This should include balanced minerals, trace elements and biotin (Cadbury, 2009).
- Undertaking regular foot bathing and periodic foot trimming to keep the cow's feet in good shape (Cadbury, 2009).

5.1.2.3 Reducing (S. aureus) mastitis:

Mastitis occurs when the udder becomes inflamed because leukocytes are released into the mammary gland in response to invasion of the teat canal, usually by bacteria. These bacteria multiply and produce toxins that cause injury to milk secreting tissue and various ducts throughout the mammary gland. Elevated leukocytes, or somatic cells, cause a reduction in milk production and alter milk composition. These changes in turn adversely affect quality and quantity of dairy products (Jones, G.M., et al. 2009)

- Do not milk cows and heifers with the same teat cup/claw unit used to milk mastitis-problem cows. (Petersson-Wolfe, et al. 2010)
- Segregate infected cows into one group and milk them last. Another alternative is to sort out infected cows before each milking and restrain them in an isolation pen

until all other cows have been milked. In a short period of time, these cows will become trained to sort. (Petersson-Wolfe, et al. 2010)

- If heifers or cows are purchased, segregate them until milk samples can be cultured and their mastitis pathogen status can be determined. If possible, examine the DHI SCC of cows before agreeing to make the purchase. (Petersson-Wolfe, et al. 2010)
- Cull infected cows, especially those with additional problems. Often, it is not economically feasible to cull a S. aureus-positive cow that produces 80-90 pounds of milk. However, any cow that has had clinical mastitis in the same quarter for three or more occasions, or any cow whose milk has been withheld from shipment for more than 28 days during the current lactation, should be considered for culling from the herd. (Petersson-Wolfe, et al. 2010)
- It is important to keep mastitis records, including cows and quarters treated and treatment used. (Petersson-Wolfe, et al. 2010)
- Place infected cows on a do-not-breed list. Cull them when their milk is no longer needed (e.g., to make base) or they have been in milk for 305 days. (Petersson-Wolfe, et al. 2010)
- Biting flies traumatize the teat end. Flies also carry a number of mastitis-causing organisms that can colonize these teat lesions. Elimination of fly-breeding sites is one aspect of fly control. Flies breed in decaying feed or manure that has accumulated in exercise yards, calf pens, and box stalls. Another option for control is use of back-rubbers, feed additives, and ear or tail tags with insecticide. In one trial the use of tail tags containing insecticide resulted in only one of 100 tagged heifers with a mastitis infection, compared to 18 of 100 untagged heifers. (Petersson-Wolfe, et al. 2010)
- Regular, preventive maintenance and testing of milking machine is essential for milk quality and mastitis prevention. Vacuum controllers (regulators), pulsators, and air filters need to be cleaned monthly. All rubber components must be changed according to the manufacturer’s instructions. Rubber that is cracked, flattened, or otherwise deteriorated should be replaced even if the recommended life of the product has not been reached. (Petersson-Wolfe, et al. 2010)

- Dry cow therapy (DCT) is more effective in eliminating infections than lactating treatment. When a cow is dried off, it is recommended to treat all quarters with a commercially available DCT. (Petersson-Wolfe, et al. 2010).

5.1.3 Maximize Milk Yield:

Kirchgessner et al. (1995) estimated that increasing milk production of dairy cows from 5,000 to 10,000 L of milk annually in the EU, by using high grain rations or by improving the genetic merit of the dairy cow, would increase total CH_4 production per animal per year by 23% (i.e., from 110 to 135 kg / yr). However, CH_4 production per kg of milk produced would be reduced by 40% (i.e., from 0.022 to 0.014 kg of CH_4 kg milk–1). Therefore, overall CH_4 emissions could be decreased by reducing animal numbers while maintaining milk production. Maximizing milk yield largely depends upon feed efficiency and dry matter intake; therefore, any discussion on increasing milk production would not be complete without a discussion on feed efficiency and DMI.

5.1.3.1 Maximize Feed Efficiency and cow comfort:

Calculating the Dry matter intake (DMI) is an important way to predict the amount of feed a cow actually consumes. Each cow must consume enough dry matter (DM) to maximize the milk production. The milk production will be affected by the nutritional content and the amount of DM the cow consumes. The more nutritional DM the cow ingests, the more milk she will produce. Accurately estimating the amount of DMI is important for a balanced diet as well as preventing underfeeding and overfeeding. Underfeeding of nutrients will affect both the health of the animals and the quality and quantity of the milk, while overfeeding increases the cost (BANR, 2001, P3). However, it should be kept in mind that optimizing the feed efficiency will not be achieved by simply to maximizing the DMI. In reality, there are many factors which can affect the feed efficiency including the management, environment and the cow herself (BANR, 2001). The feed efficiency value can value from 1.0 to 2.0 as the Table 11 indicates (Hutjens, 2005). In further detail, the following factors will affect the feed efficiency:

- Age and will affect the feed efficiency. Dominant cows, usually older and larger, tend to spend more time eating than others (Albright, 1993). Young cows will save nutrients to growth.
- Lactation number (the first lactation cows) can lead to lower DE values to store nutrients to late lactation. And multiparous cows will eat more than primiparous at the

early stage as the **Table 15** indicates. So cows with different lactation cows and muitiparous cows should be separated in different groups to increase the feed efficiency (Hutjens, 2005, p73).

- Pregnancy will reduce the feed efficiency as the fetus requires some nutrition from the feed and the impact is small (Hutjens, 2005, p73).
- Fresh cows may have feed efficiency value below 1.2 if cows achieve more CMI related to milk production (Hutjens, 2005, p73).
- Increasing the feed frequency can increase the milk production and is also good for health. Changing from one or two offering frequency of feed per day to four can increase the feed use by 19 percent (BANR, 2001, p9).
- Higher digestible forage will increase the feed efficiency because more nutrients will be absorbed for milk production (Hutjens, 2005, p73).
- As neutral detergent fiber ration in dry matter rises, the feed efficiency will decrease (Hutjens, 2005, p73).
- Water consumption increases when the temperature increases up to 35°C and further increases will decrease the water consumption because of low feed intake. High temperature and high humidity will both decease the feed efficiency (Coppock, 1978).

Table 15: Benchmarks for Feed Efficiency Comparisons

Group	Days in milk	FE (lb milk/lb DM)
One group, all cows	150 to 225	1.4 to 1.6
1st lactation group	< 90	1.5 to 1.6
1st lactation group,	> 200	1.2 to 1.3
2nd + lactation group	< 90	1.6 to 1.8
2nd + lactation group	> 200	1.3 to 1.4
Fresh cow group	< 21	1.1 to 1.2
Problem herds	150 to 200	< 1.3

5.1.4 Milk pricing:

Changes in milk pricing, from systems based on butterfat content to systems based on other components of milk, such as protein, has been suggested to reduce CH_4 emissions (Johnson et al. 1996). Fat content of milk accounts for about 48% of the energy content of milk and therefore reducing milk fat content will decrease the need for feed energy, which, in turn, will reduce CH_4 production. A change in milk pricing based on solid-non-fat has been estimated to reduce CH_4 emissions from US milk cows by 15% (Johnson et al. 1996).

A change in milk pricing based on solid-non-fat has been estimated to reduce CH_4 emissions from US milk cows by 15% (Johnson et al. 1996). With the demand for low fat milk increasing, pricing based on protein will encourage producers to modify feeding regimes to include the use of highly digestible protein feeds which will increase productivity and reduce CH_4 emissions. However high protein feeds are costly in dairy rations, and excessive amounts of nitrogen may be excreted in urine and feces. The impact on the environment as well as costs associated with such a strategy must be evaluated in terms of the overall benefits that can be achieved (Boadi, et al., 2004).

5.2 Nitrous Oxide (N_2O):

Within the agricultural sector, dairy production systems represent the largest source of CH_4 and N_2O emissions and may therefore have a large potential for GHG mitigation. A large number of technical and management-related measures for mitigating N2O, CH4 and CO2 emissions from agricultural systems have been suggested in the literature (Mosier et al., 1996; Smith et al., 1997; Döhler et al., 2002; Jarvis and Ledgard, 2002). The following sections contain excerpts from current research to illustrate some areas where significant mitigation of GHGs may be achieved.

5.2.1 Efficient Use of Artificial Nitrogen Fertilizers and Manure:

In the case of conventional farms, a more efficient application of animal manures mainly reduces the need for import of mineral fertilizer, thus reducing the overall farm N surplus. However, on organic farms an improved application of the manures in the field has compensating effects which need to be considered separately. Improved manure application techniques will reduce NH_3 volatilization which leads to less N_2O emissions from volatilized NH_3 which result in more nitrogen effectively being applied to soil; on the other hand, this also increases nitrate leaching and the derived N_2O emissions, but also increases the amount of nitrogen available for the crop and thus the fertilizer replacement value of the manure, which results in an increase in crop yields" (Weiske, A, et al. 2006).

Therefore, "on organic farms, there is no reduction of imported fertilizers, and the net increase in N applied to the field may increase N leaching, which in some cases leads to greater N_2O emissions and to higher total GHG emissions per kg milk produced, even if the impact on yield associated with manure use was considered. Controlling GHG emissions from manure application is particularly important because, without an improved application at the end-of-pipe of dairy production manure handling, much of the benefit of preliminary mitigation measures during animal housing and manure storage may be lost" (Weiske, A, et al. 2006).

5.2.2 Manure Handling:

On average only about one third of feed N is transformed into the protein of animal products, while the rest is excreted in urine and feces (Kirchgessner et al., 1994). About one fourth of this N may be emitted as ammonia (NH_3) directly after excretion from the animal and during manure storage. Decreasing the surface area in the cattle housing fouled by manure has a potential to reduce NH_3 emissions.

Ammonia and CH_4 emissions from cattle housing can be reduced through a more frequent removal of manure to a closed storage system, and through the regular scraping of the floor (Weiske, A, et al. 2006). However, a paradox arises regarding the scraping of the cattle-house floor in that the "daily removal of manure may reduce emissions from animal houses by 97% but simultaneously causes a large increase in emissions from manure stores" (Weiske, A, et al. 2006). In addition to the increased emissions from the manure stores, there is also a greater concentration of nutrients in the manure which will add the emissions during field application. These emissions may not reduce total GHG emissions; but, they do have benefits toward improved animal hygiene and welfare and thus better health as discussed previously.

Perhaps the best solution to the manure handling paradox is through the use of manure digesters for biogas production. Biogas production is one of the most cost-effective mitigation measures that can simultaneously reduce emissions of CH_4 and N_2O from the entire production chain while at the same time replace the use of fossil fuels (Weiske, A, et al. 2006).

5.2.3 Utilize more legume crops:

Legumes such as clover reduce the need for additional nitrogen application and consequently provide an effective way of reducing nitrous oxide emissions. Mixed cropping and the inclusion of clover in grassland mixes are encouraged (Cadbury 2008).

5.2.4 Rumen Diet Composition:

Management of dietary protein levels can influence nitrous oxide emissions. If excess protein is fed then this is excreted as urea and adds to the GHG burden of dairy production. Improving productivity with the use of high grain diets must however be evaluated in terms of its cost of production and use of fertilizers and machinery, which will increase fossil fuel use and increase N_2O emissions. The cultivation and use of high-quality forages, which are cheaper than grain and do not involve increased use of fossil fuel through tillage, has been shown to be a sustainable option for producers and an efficient way to decrease N_2O emissions and increase soil carbon stores (Johnson et al. 1996).

5.3 Carbon Dioxide (CO_2):

The carbon dioxide emissions related to milk production largely result from the use of diesel fuel, electricity, chemicals and inorganic fertilizers. Simple measures that you can take to reduce the production of CO_2 include:

5.3.1 Use of Renewable Energy Sources such as Biodiesel:

There has been much discussion on the use of digesters in the production of biogas for Skånemejerier fleet vehicles and farm use; however, the biggest obstacle to this is the need for a centralized production plant since most farms are too small to build or supply enough manure for the operation of their own digesters. It is definitely a good strategy not only for producing a cleaner fuel, but also for a significant reduction in N_2O and CH_4 emissions from the handling of manure; nevertheless, there is another alternative renewable fuel strategy that has potential benefit for Skånemejerier. That renewable fuel is biodiesel. "Biodiesel is produced from any fat or oil such as vegetable oil, through a refinery process called transesterification. This process is a reaction of the oil with an alcohol to remove the glycerin, which is a by-product of biodiesel production. Fuel-grade biodiesel must be produced to the strict industry specifications of ASTM D6751 in order to insure proper performance". (Connecticut Bio Fuels, 2011)

5.3.1.1 Economic Benefit

"Biodiesel saves money. Engines running on biodiesel have been shown to require less maintenance. Also, biodiesel use allows federal fleet managers to keep existing equipment on the road longer and still adhere to new, stricter emissions standards." (Connecticut Bio Fuels, 2011)

Biodiesel costs around 1.15 Swedish Crowns per liter to produce, which is a tremendous savings over the price of a liter of traditional gas. Considering the possible savings for fleet vehicles alone, Skånemejerier could produce bio-diesel under a separate business entity and supply its fleet vehicles and farmers-owners.

5.3.1.2 Recycled oil

Another advantage to making biodiesel is that it can be made out of recycled oil from restaurants. Restaurant managers most often pay for the disposal of their oil and would be very happy to "give it away". This symbiotic relationship is advantageous to all parties involved. The restaurant manager will save budget, the bio-diesel producer does not have to buy fresh vegetable oil and the farmer need not cultivate extra land for the fuel crop. Agreements could be reached with restaurant chains to supply oil for bio-diesel production; but, the oil must be pure vegetable oil and not mixed with any animal-based oil or shortenings.

5.3.1.3 Decentralized Production Advantage

One of the primary advantages is that biodiesel production can be done at each individual farm and scaled to meet the needs of the particular farmer. Bio-diesel can be used without any modification to the diesel engine. This makes biodiesel one of the easiest and cost effective alternative fuels to use and is a great option for use on farms in farm equipment.

5.3.1.4 Safety and the Environment

"Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 US Clean Air Act Amendments. Biodiesel that meets ASTM D6751 and is legally registered with the Environmental Protection Agency is a legal motor fuel for sale and distribution. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter compared to emissions from diesel fuel. In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to diesel. Additionally, a 1998 biodiesel lifecycle study, jointly sponsored by the US Department of Energy and the US Department of Agriculture, concluded biodiesel reduces net CO_2 emissions by 78 percent compared to petroleum diesel. This is due to biodiesel's closed carbon cycle. The CO_2 released into the atmosphere when biodiesel is burned is recycled by growing plants, which are later processed into fuel." (Connecticut Bio Fuels, 2011). Thus, using bio-diesel could be a triple win for Skånemejerier, the farmer-owners and the environment!

6 Conclusion:

This thesis project began with what was considered a simple frequently asked question from Skånemejerier customers; i.e. "what is the difference in CO_2 emissions between organic milk and regular milk?" Intuitively, it was expected that the organically produced milk would leave the smaller carbon footprint. However, we have found through our analysis of existing research data that this expectation is not true in the general sense. Additionally, we have discovered that the original question itself was inaccurate and misleading. While carbon dioxide (CO_2) emissions are of primary importance in the burning of fossil fuels for transportation and power generation, they actually represent the smallest part of the carbon footprint generated by dairy farming operations. In reality, Methane (CH_4) and Nitrous Oxide (N_2O) not only comprise the majority of the carbon footprint, but are far more damaging than CO_2 in terms of retaining heat in the atmosphere. The more appropriate question would be; "what is the difference in greenhouse gas emissions between organic milk and regular milk?" The short and unsatisfying answer to this question is; **there is no statistical difference in greenhouse gas emissions between the production of organic and regular milk".** It should be noted, nevertheless, that there are many caveats to this conclusion. There is a consensus among the research we have studied that the supply chain of an organic dairy farm has a smaller CF than a conventional farm, but also less yield; while a conventional dairy farm has a higher yield than the organic farm but also a larger supply chain CF. However, one does not necessarily negate the other. Additionally, there is the relationship between the dairy and beef industries of co-production which is not in the control of the farmers nor Skånemejerier executives.

Included in **Appendix 9.9** is a “practical guide for Cadbury’s dairy farmers” produced by Cadbury Chocolates in the UK. Although this guide is tailored for UK farmers, it serves as an example of a farm level management improvement strategy which may be of value to Skånemejerier. During one of the farm visits and interviews with a Skånemejerier farmer/owner, it was noted that there was some defensiveness towards and outright rejection of the proposition of a companywide voluntary farm management improvement program to reduce greenhouse gas emissions. A guide for Swedish dairy farmers similar to the Cadbury guide would provide a non-confrontational way to inform Skånemejerier farmers of how they will benefit from implementing more sustainable management practices. The “take-away” message here is that efficient farm management practices are key towards significantly reducing the CF of the dairy industry. Efficient farming practices are beneficial for both organic and conventional farming systems; however, it is not unreasonable to recognize the possibility that all farms may be required to become organic in the not so distant future for reasons other than the CF. It is therefore the opinion of the GHW Group that Skånemejerier will gain the most immediate benefit towards reducing the CF from the improvement of management practices at the farm level and by choosing supply chains which have the smallest carbon footprint practical; and as always, “drink all of your milk”!

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8 Glossary:

Acidosis: Acidosis occurs when the pH of the rumen drops below 5.8. When the rumen microbes ferment feed they produce acids. If an excess of this acid builds up as a result of too much starch and sugar being fed, or if the forage contains too much lactic acid, the rumen bacteria may be killed causing both milk production and feed intake decrease.

Dry Matter Intake (DMI): Dry matter intake is the actual amount of feed a cow consumes after the amount of water in the feed has been deducted.

Energy Corrected Milk (ECM): Fat and protein content of raw milk varies due to such factors as the time of year, diet and breed/genetics; ECM corrects for this to determine the actual energy content of milk so that equal comparisons can be made between herds and individual animals.

Footrot: Foot rot is a contagious disease of cattle characterized by the development of a necrotic lesion in the interdigital skin. The accompanying cellulitis extends into the soft tissues of the foot causing swelling and lameness (Shearer, J.K. et al. 2000).

Interdigital dermatitis: Interdigital dermatitis, also known as, “Heel Erosion”, “Slurry Heel”, “Stinky Foot” and “Stable Footrot”, is an acute or chronic inflammation of the interdigital skin, extending to the dermis (Shearer, J.K. et al. 2000).

Mastitis: Mastitis is defined as an inflammatory reaction of udder tissue which can be caused by many types of injury including infectious agents and their toxins, physical trauma or chemical irritants. In the dairy cow, mastitis is nearly always caused by microorganisms; usually bacteria, that invade the udder, multiply in the milk-producing tissues, and produce toxins that are the immediate cause of injury (Jones, G.M., et al., 2009).

Milk Fever: Milk fever, post-parturient hypocalcemia, or parturient paresis is a disease, usually of dairy cows, characterized by reduced blood calcium levels. It is most common in the first few days of lactation, when demand for calcium for milk production exceeds the body's ability to mobilize calcium reserves. "Fever" is a misnomer, as body temperature during the disease is usually below normal. Low blood calcium levels interfere with muscle function throughout the body, causing general weakness, loss of appetite, and eventually heart failure (Baillière Tindall, 1979).

N-Fixation: Nitrogen fixation is the natural process, either biological or abiotic, by which nitrogen (N_2) in the atmosphere is converted into ammonia (NH_3). Nitrogen fixation also refers to other biological conversions of nitrogen, such as its conversion to nitrogen dioxide.

Organic Farming: Organic farming is the process of producing food naturally. This method avoids the use of synthetic chemical fertilizers and genetically modified organisms to influence the growth of crops.

Papillomatous Digital Dermatitis: Digital dermatitis was first described in1974 by Drs. Cheli and Mortellaro from Italy. In the United States the condition is known by a variety of different terms including: hairy heel warts, digital warts, strawberry foot, raspberry heel, verrucous dermatitis, Mortellaro or Mortellaro's disease, and digital dermatitis (Shearer, J.K. et al. 2000).

Somatic Cell Count (SCC): Somatic cells are normal constituent of milk and only when they become excessive do they indicate a problem. Somatic cells are composed of leucocytes (75%) and epithelial cells (25%). Leucocytes (white blood cells) increase in milk in response to infection or injury while increase in epithelial cells is the result of infection or injury. The number of cells reflects the severity of mastitis.

9 Appendices:

9.1 CO_2 emission calculation:

CO_2 from Diesel Fuel

CO_2 emission of diesel consumption from Wanås farm:

*80,000 l * 2.9kg/l = 232,000 kg*

CO_2 emission of diesel consumption from Lilla Kyrkhult farm:

*14,000 l * 2.9kg/l = 40,600kg*

CO_2 from electricity generation

CO_2 emission of electricity consumption from Wanås farm:

*620 MWh * 55.9 kg / MWh = 34,658 kg*

CO_2 emission of electricity consumption from Lilla Kyrkhult farm:

*264MWh * 55.9 kg/MWh = 14,757 kg*

9.2 CH_4 emission calculation:

Methane (CH_4) emission from Wanås farm:

From enteric fermentation:

$178\ kg\ cow^{-1} year^{-1} * 460\ cow = 81{,}880\ kg$

From manure storage:

$8.4\ kg\ cow^{-1} year^{-1} * 460\ cow = 3{,}864\ kg$

$9.6\ kg\ heifer^{-1} year^{-1} * 460\ heifer = 4{,}416\ kg$

Total CH_4 emissions from Wanås farm:

81,880 kg + 3,864 kg + 4,416 kg = 90,160 kg

Methane (CH_4) emission from Lilla Kyrkhult farm:

From enteric fermentation:

$178\ kg\ cow^{-1\ 1} year^{-1} * 150\ cow = 26{,}700\ kg$

From manure storage:

$13.6\ kg\ cow^{-1} year^{-1} * 150\ cow = 2{,}040\ kg$

$9.2\ kg\ heifer^{-1}\ year^{-1} * 110\ heifer = 1{,}102\ kg$

Total CH_4 emission from Lilla Kyrkhult farm:

26,700 kg +2,040 kg + 1,102 kg = 29,842 kg

9.3 N_2O emission calculation:

Nitrogen oxide emission from Wanås farm:

From synthetic fertilizers:

5 kg N/ha $\times$ *725 ha* $\times$ *0.01 kg* N_2O*-N* kg^{-1} *N = 36.25 kg* N_2O*-N*

36.25 kg N_2O*-N = 36.25* $\times$ *(44/28) kg* N_2O *= 56.91 kg* N_2O

From N-fixation:

53 kg N/ha $\times$ *(725+250) ha* $\times$ *0.0125 kg* N_2O*-N* kg^{-1} *N = 645.94 kg* N_2O*-N*

645.94 kg N_2O*-N = 645.94* $\times$ *(44/28) kg* N_2O *= 1014.12 kg* N_2O

From the animal excreta in pasture:

168 kg N cow^{-1} $year^{-1}$ $\times$ *0.189* $\times$ *460 cow = 14605 kg N*

14605 kg N $\times$ *0.02 kg* N_2O*-N* kg^{-1} *N = 292.1 kg* N_2O*-N*

292.1 kg N_2O*-N* $\times$ *(44/28) kg* N_2O kg^{-1} N_2O*-N = 458 kg* N_2O

From manure:

125 kg N cow^{-1} $year^{-1}$ $\times$ *460cow* $\times$ *1 year* $\times$ *0.01 kg* N_2O*-N* kg^{-1} *N = 575 kg* N_2O*-N*

575 $\times$ *1.57 kg* N_2O*-N = 903 kg* N_2O

There is also some N_2O emission from the manure in stable and during storage. The energy factor is about 0.6 kg N_2O-N/cow according to Maria Henriksson, the emission is:

0.6 kg N_2O*-N/cow* $\times$ *460 cow* $\times$ *(44/28) kg* N_2O kg^{-1} N_2O*-N = 433 kg* N_2O

From NH_3 ***losses in manure storage:***

65100 kg N $\times$ *0.068 kg NH3-N/kg N = 4426.8 kg* NH_3*-N*

4426.8 kg NH_3*-N* $\times$ *0.01 kg* N_2O*-N* kg^{-1} NH_3*-N = 44.27 kg* N_2O*-N*

44.27 kg N_2O*-N* $\times$ *(44/28) kg* N_2O kg^{-1} N_2O*-N = 69.5 kg* N_2O

From the animal excreta dropped in pasture:

168 kg N cow^{-1} $year^{-1}$ $\times$ *0.189* $\times$ *150 cow = 4762.8 kg N*

4762.8 kg N $\times$ *0.02 kg* N_2O*-N* kg^{-1} *N = 95.26 kg* N_2O*-N*

95.26 kg N_2O*-N* $\times$ *(44/28) kg* N_2O kg^{-1} N_2O*-N = 149.55 kg* N_2O

Nitrogen oxide emission of manure from Lilla Kyrkhult farm:

From synthetic fertilizers:

$91\ kg\ N/ha \times 138\ ha \times 0.01\ kg\ N_2O\text{-}N\ kg^{-1}\ N = 125.58\ kg\ N_2O\text{-}N$

$125.58\ kg\ N_2O\text{-}N = 125.58 \times (44/28)\ kg\ N_2O = 197.16\ kg\ N_2O$

From N-fixation:

$34\ kg\ N/ha \times (138+12)\ ha \times 0.0125\ kg\ N_2O\text{-}N\ kg^{-1}\ N = 63.75\ kg\ N_2O\text{-}N$

$63.75\ kg\ N_2O\text{-}N = 63.75 \times (44/28)\ kg\ N_2O = 100.08\ kg\ N_2O\text{-}N$

From the animal excreta in pasture:

$168\ kg\ N\ cow^{-1}\ year^{-1} \times 0.189 \times 150\ cow = 4762.8\ kg\ N$

$4762.8\ kg\ N \times 0.02\ kg\ N_2O\text{-}N\ kg^{-1}\ N = 95.26\ kg\ N_2O\text{-}N$

$95.26\ kg\ N_2O\text{-}N \times (44/28)\ kg\ N_2O\ kg^{-1}\ N_2O\text{-}N = 148.55\ kg\ N_2O$

From manure storage:

$125\ kg\ N\ cow^{-1}\ year^{-1} \times 150\ cow \times 1\ year \times 0.01\ kg\ N_2O\text{-}N\ kg^{-1}\ N = 187.5\ kg\ N_2O\text{-}N$

$187.5 \times 1.57\ kg\ N_2O = 294.3\ kg\ N_2O$

There is also some N_2O emission from the manure in stable and during storage. The energy factor is about 0.6 kg N_2O-N/cow according to Maria Henriksson, the emission is:

$0.6\ kg\ N_2O\text{-}N/cow \times 150\ cow \times (44/28)\ kg\ N_2O\ kg^{-1}\ N_2O\text{-}N = 141.3\ kg\ N_2O$

From NH_3 losses in manure storage

$18060\ kg\ N \times 0.068\ kg\ NH3\text{-}N/kg\ N = 1228\ kg\ NH3\text{-}N$

$1228\ kg\ NH3\text{-}N \times 0.01\ kg\ N_2O\text{-}N\ kg^{-1}\ NH_3\text{-}N = 12.28\ kg\ N_2O\text{-}N$

$12.28\ kg\ N_2O\text{-}N \times (44/28)\ kg\ N_2O\ kg^{-1}\ N_2O\text{-}N = 19.28\ kg\ N_2O$

From the animal excreta dropped in pasture:

$128.8\ kg\ N\ cow^{-1}\ yr^{-1} \times 150\ cow \times 1\ yr = 19275\ kg\ N$

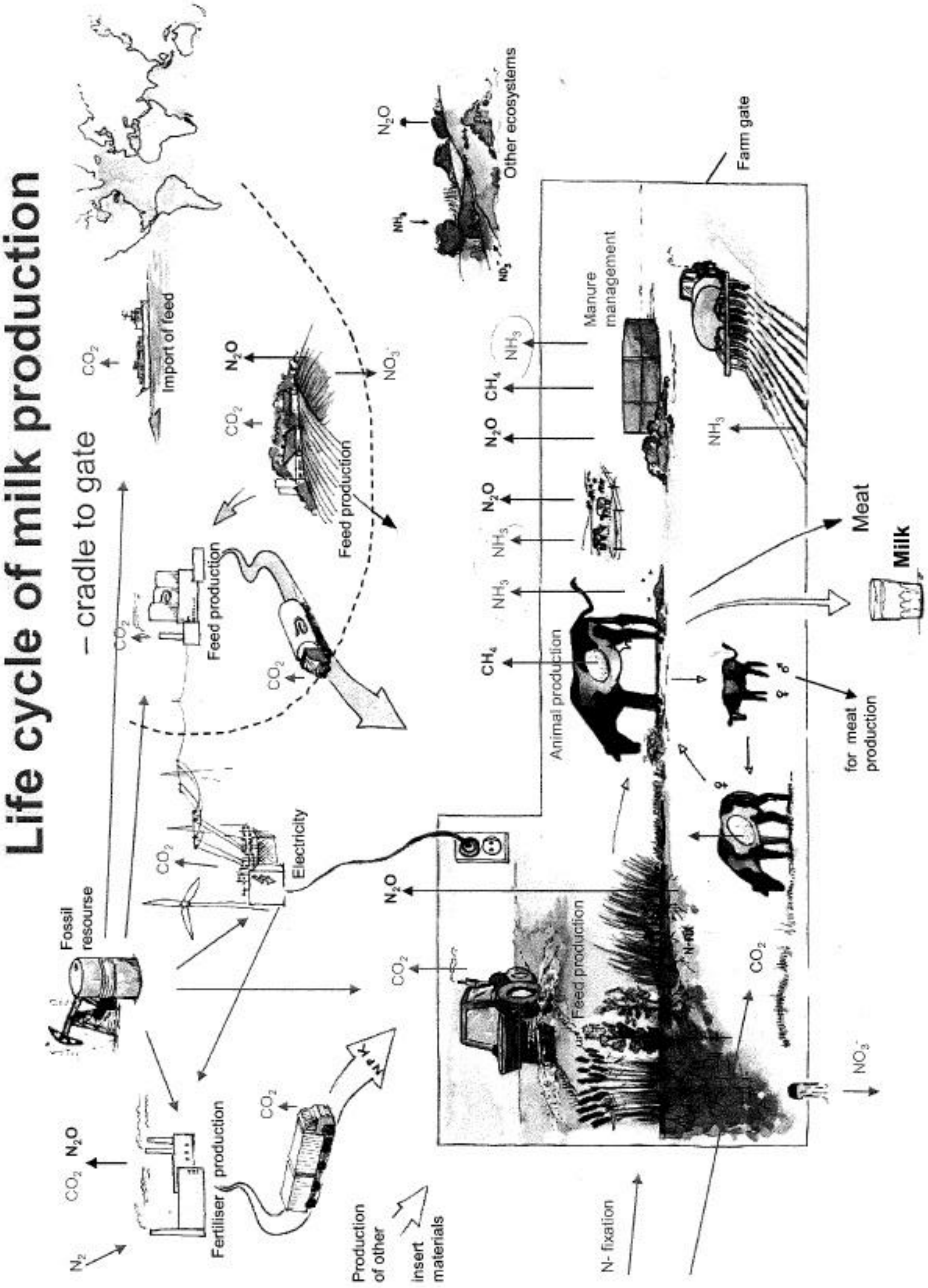
$19275\ kg\ N \times 0.10\ kg\ NH_3\text{-}N\ kg^{-1}\ N = 1927.5\ kg\ NH_3\text{-}N$

$1927.5\ kg\ NH_3\text{-}N \times 0.01\ kg\ N_2O\text{-}N\ kg^{-1}\ NH_3\text{-}N = 19.27\ kg\ N_2O\text{-}N$

$19.27\ kg\ N_2O\text{-}N \times (44/28)\ kg\ N_2O\ kg^{-1}\ N_2O\text{-}N = 30.3\ kg\ N_2O$

9. 4 Appendix: Life Cycle of Milk Production

Maria Henriksson ©



9. 5 Appendix: Feed Consumption

Table 1 Protein concentrate feed (conventional farms)

Ingredient	% (mass)	Origin
Wheat bran	3	Swe
Dried draff	5	Swe
Rapeseed meal	2	Ger
Molasses	4	Swe 40 %, Baltic 60 %
Expro®	28	Swe 40 %, Ger 60 %
Soymeal, soypass	22	Brazil
Beet-pulp	18	Swe 20 %, 80 % Baltic
Palmkernelexpels	6	Malaysia
Grass pellets	3.6	Denmark
Lime	1	
MgO	0.1	
Fats	5.6	Diff oil crops

Table 2 Mixed concentrate feed (conventional farms)

Ingredient	% (mass)	Origin
Barley	25	Swe (region)
Winter wheat	5	Swe (region)
Triticale	9	Swe (region)
Wheat/oat bran	6	Swe
Rapeseed meal	13.5	Ger
Molasses	4	Swe 40 %, Baltic 60 %
Expro®	6	Swe 40 %, Ger 60 %
Soymeal, soypass	10	Brazil
Beet-pulp	8	Swe 20 %, 80 % Baltic
Palmkernelexpels	5	Malaysia
Grass pellets	3	Denmark
Lime	1	
Salt	0.6	
Fats	3	

Expro® = heat treated rapeseed meal

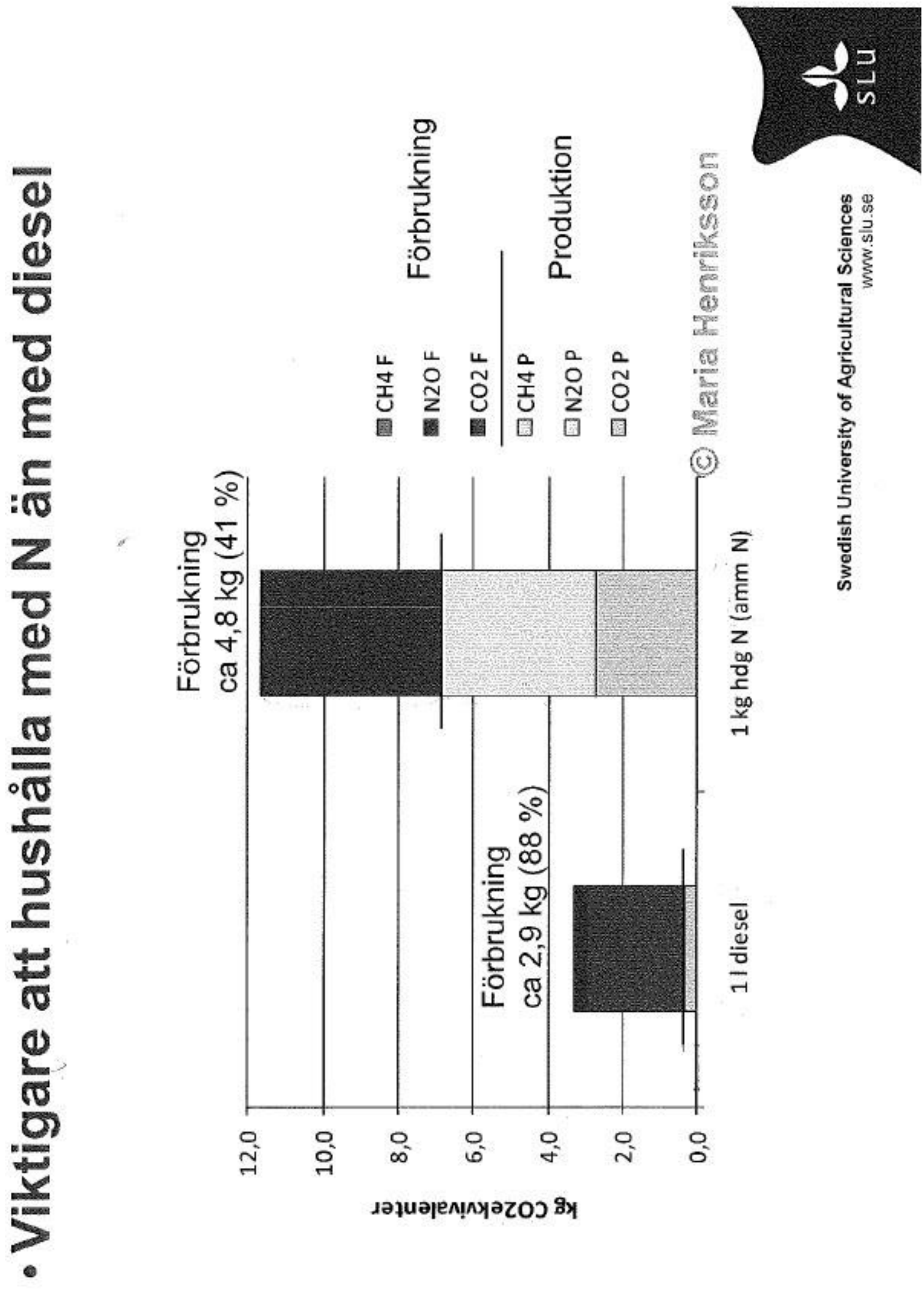
Table 3 Protein concentrate feed (organic farms)

Ingredient	% (mass)	Origin
Wheat	10	Swe-region (org)
Oats	3	Swe-region (org)
Rapeseed cake	15	Swe-region (org)
Horse-bean	20	Swe-region (org)
Soybean	15	South America (org)
Maize gluten meal	20	France (conv)
Luzern pellets	15	Swe (org)
Fats	4	(conv)
Minerals	2	
Vitamines	1	

Table 4 Mixed concentrate feed (organic farms)

Ingredient	% (mass)	Origin
Wheat	50	Swe-region (org)
Oats	7	Swe-region (org)
Rapeseed cake	7	Swe-region (org)
Horse bean	5	Swe-region (org)
Beet-pulp	2	Swe (conv)
Maize gluten meal	9	France (conv)
Luzern pellets	15	Swe (org)
Fat	2	conv
Molasses	1	conv
Minerals	2	

9. 6 Appendix： Emission Factor of Consumption Diesel



9. 7 Appendix: Manure Analysis Report

MANURE ANALYSIS REPORT

Sample Number: 7631

Date Sampled:	3/20/05
Date Received:	3/23/05
Date Mailed:	3/24/05
Description:	Heifer Barn
Statement ID:	Heifer Barn

Cornell University Dept. of Crop and Soil Sciences
Quirine Ketterings
817 Bradfield Hall
Ithaca, NY 14853

Components	As Received	lbs/ton	lbs/1000 gallons
Total Nitrogen (N)	0.42 %	9	35
Ammonium N (NH_4^+)	0.19 %	4	16
Organic N	0.23 %	5	19
Phosphorus (P)	0.08 %	2	7
Phosphate Equivalent (P_2O_5)	0.18 %	4	15
Potassium (K)	0.26 %	5	22
Potash Equivalent (K_20)	0.32 %	6	27
Total Solids	6.50 %		
Density	99 kg/l	62.07 lbs/cu.ft.	8.3 lbs/gal

9.8 Appendix: Statistics on Swedish Milk production parameters

Excerpt from **Table 2**; M. Henriksson, *et al.*, 2011

Table 2 *Basic statistics on parameters for milk production (n = 1051), N-fertiliser rate (n = 920) and diesel use (n = 46) collected from Swedish dairy farms (average values for Swedish milk production the year 2005 are shown in italics)*

Parameter	Average SE milk	Farm data						
		Mean	s.d.	CV (%)[a]	Q_1	Q_2	Minimum	Maximum
ECM produced (kg ECM/cow per year)	*8843*	9386	983	**10.5**	8794	10 000	5838	12 026
ECM delivered (kg ECM/cow per year)[b]	*8274*	8886	980	11.0	8293	9505	4724	11 785
Delivered share (%)	*93.6*	94.6	2.6	**2.8**	93.5	96.4	80.3	100.0
Protein in milk (%)	*3.38*	3.35	0.21	6.2	3.30	3.38	1.24	4.07
Feed DMI (kg DMI/cow per year)	*6559*	6534	448	6.9	6276	6822	4539	8002
Feed DMI_{ECM} (kg DMI/kg ECM produced)	*0.74*	0.70	0.054	**7.66**	0.67	0.73	0.55	1.04
Metabolisable energy (10^3 MJ/cow per year)	*77.3*	77.8	6.08	7.8	74.2	81.8	54.4	99.8
Protein in DMI (% CP)	*16.8*	17.2	0.8	4.6	16.8	17.7	13.8	20.7
N content in DMI (g N/kg DMI)	*27.0*	27.5	12.8	4.6	26.9	28.3	22.1	33.1
Roughage share (%)	*52.8*	52.5	5.5	10.4	49.1	55.0	37.0	78.0
Enteric CH_4 (kg CH_4/cow per year)[c]	*127.6*	125.4	8.1	6.5	120.7	130.8	91.1	150.9
EF CH_4 (g CH_4/kg DMI)	*19.4*	19.3	1.5	**7.7**	18.4	20.1	14.1	30.5
FCE (kg ECM/kg DMI)	*1.35*	1.44	0.10	7.0	1.37	1.50	0.96	1.82
N efficiency (kg N_{ECM}/kg N_{DMI})	*25.6*	26.7	1.96	7.3	25.6	27.9	18.3	35.1
Excreted N (kg N/cow per year)[d]	*126.7*	128.8	13.0	10.1	120.9	136.5	74.9	177.8
N-fertiliser rate (kg N/ha)	*48.8*[e] *78.5*[f]	85	33	**38.5**	64	107	0.0	252
Diesel on farm (l/ha)	NA[g]	113	35	**31.2**	88	134	62	191

9.9 Appendix: Cadbury Farm Management Guide

The following guide from Cadbury Chocolates is provided as an example of a farm management education strategy which may be useful to Skånemejerier toward reducing the carbon footprint at the farm level.

purple goes green

reducing our carbon footprint

Cadbury

A practical guide for Cadbury's dairy farmers

introduction

Cadbury is committed to tackling climate change and we have pledged to a 50 per cent reduction in our absolute carbon emissions by 2020.

We recognise that this can only be achieved by embedding sustainability into every business decision we take and by working with our partners in the supply chain to reduce our collective carbon footprint.

This booklet provides an overview of the factors that contribute to carbon emissions from dairy farming and provides practical suggestions that you can implement to reduce the carbon footprint of milk production.

By working together we can act as a united force for good, which will not only have a strong social and environmental impact, but also a positive economic impact on your farming business in the future.

what is a carbon footprint?

A carbon footprint is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced, measured in units of carbon dioxide (CO_2) equivalent per unit of output.

Importantly, to derive the carbon footprint for the primary production of milk, a life cycle assessment must be undertaken from 'cradle to grave', looking at all inputs and outputs, traced back to primary source. This must include every activity that relates to the rearing, feeding and management of cows right up to the point that milk is sold off the farm.

The major greenhouse gas emissions are:

	Sources	Importance
Carbon dioxide (CO_2)	• Burning fossil fuels • Respiration	Absorbs infrared radiation, affects stratospheric ozone
Methane (CH_4)	• Rumen fermentation • Land fill and wetlands • Slurry	25 times more potent than CO_2 in terms of global warming
Nitrous oxide (N_2O)	• Burning biomass / fuel • Nitrogenous Fertiliser • Excretions from cattle	298 times more potent than CO_2 in terms of global warming

Methane and nitrous oxide are the main polluting greenhouse gases from livestock and milk production. Farm based modelling by Kite Consulting has established that the average conventional dairy farm will produce around 900g CO_2 equivalent per litre of milk produced (range 700g – 1500g per litre). Approximately 25 per cent of this comes from nitrous oxide, with 23 per cent coming from carbon dioxide and the remaining 52 per cent coming from methane production..

why does this matter?

Over the last few years, there is a growing consensus that the world has to act now or face devastating social and economic consequences due to climate change. It is estimated that if no action is taken by governments or business there is more than a 75% chance of global temperatures rising between 2-3°C over the next 50 years. This would lead to increased floods, crop yields declining, rising sea levels and up to 40% of species facing extinction. In the midst of discussions linked to climate change, emissions from agriculture, including dairy emissions, are in the spotlight.

In the 19th Century, the Cadbury brothers built our company on the principle that business should be "a force for good" in the world and were early advocates of environmental responsibilities. Since this time our understanding of climate change has evolved along with the science. Our environmental management programme has been in place for 15 years, covering a range of areas from energy use to groundwater. We've been reporting our emissions to the Carbon Disclosure Project since 2003 and in 2006 we went a step further and set sustainability goals in our Corporate and Social Responsibility report.

In July 2007, we launched our Purple Goes Green programme, our 'absolute' commitment to taking action on climate change. We intend to shrink our environmental footprint by cutting energy use as well as reducing packaging and water usage. In line with Purple Goes Green, we want to work with our partners in the supply chain to create a culture of environmental consciousness – to minimise the use of energy and the production of greenhouse gases.

purple goes green

so, what can be done to improve your dairy farm's carbon efficiency?

There are a number of simple actions that you can take to significantly reduce the carbon footprint of your dairy herd. Most of these are linked with improving efficiency and output levels, and reducing waste. We estimate that in nearly all cases these actions will directly benefit you from a financial point of view through improved business efficiency – as technically efficient farms are also carbon friendly farms.

methane

As previously highlighted, around 52 per cent of milk's carbon footprint is contributed by methane. Practical steps that you can take to reduce methane production include:

1) Herd Health Planning

Improving the health and welfare of dairy cows enables more milk to be produced which reduces production per litre (see below). In addition, healthy cows will tend to live longer, reducing culling rates and helping keep replacement rates low. Productivity can be maximised by:

Improving fertility:

- Focussing on heat detection to avoid lengthening the calving interval;
- Ensuring nutrition and cow management at calving are appropriate to prevent milk fever and associated calving problems;
- Feeding cows to minimise weight loss after calving and maintain body condition during lactation.

Reducing lameness:

- Providing clean spacious accommodation with comfortable lying areas to minimise standing up time, particularly after calving;
- Providing a diet that maintains a healthy rumen and avoids acidosis. This should include balanced minerals, trace elements and biotin;
- Undertaking regular foot bathing and periodic foot trimming to keep cows' feet in good shape.

Reducing mastitis – follow the mastitis management action plan:

- Hygienic teat management; including teat preparation, teat disinfection and management of the cow environment (at pasture and at housing);
- Prompt identification and treatment of clinical cases; to include routine hygienic fore-milking, use of conductivity equipment, milk sampling for bacteriological analysis and targeted treatment;
- Dry cow management & therapy; to include management of the dry cow environment, fly control, abrupt drying off and routine use of dry cow therapy;
- Accurate record keeping; to include records of date, cow ID, quarter affected, treatment used and causal pathogen;
- Removing chronically infected cows; cows with three cases in one quarter or five cases in total in a lactation should be removed from the herd;
- Regular milking machine maintenance and testing; including daily checks by the operator and regular testing in accordance with BS ISO standards.

2) Optimising milk yields

The main source of methane in agriculture is from intestinal fermentation in ruminants, specifically as a by-product from the digestion of dietary fibre. On average, dairy cows each produce around 100 kg methane/year and this figure is not greatly affected by yield (see table below).

Methane production and CO_2 equivalent per cow per year - Kirchgessner et al (1991)

Milk yield in litres	Methane kg/cow/year	CO_2 equivalent kg/cow/year	Kg CO_2 per 1000 litres/yr
9000	125	2623	291
7000	114	2397	342
5000	103	2171	434
3500	95	2001	571

As the table shows, if yield per cow is increased and cow numbers reduced correspondingly then the carbon footprint per litre can be significantly reduced. So more milk per cow = less methane per litre. And, if stable production is required, higher yields per cow mean that fewer cows are needed.

To increase yields, attention should be given to:

- Heifer rearing – growing heifers at the rate of 0.8kg/head/day to calve them down as fully grown by 24-26 months of age;
- The production of quality forages - forages that are dry, well fermented and palatable;
- The correct diet specification for milking cows that maximises dry matter intake and provides a balanced nutritional profile. Dairy cow rationing is a complex area and diet specification will depend upon the forages you have available. It is recommended that you consult an experienced ruminant nutritionist to help you prepare rations that are nutritionally balanced;
- Finally, nutrition in late pregnancy and early lactation is key to increasing milk yields, and to manipulating methane production. As methane is a by-product of fibre digestion, reducing the fibre level in the diet and increasing the starch level will reduce the methane production of the rumen and encourage increased milk yields. Increased feeding of starch, through increased use of forage maize or whole crop silage, or through feeding more cereal, will drive milk production. Care should be taken to keep the diet balanced, however, to protect milk butterfats and to avoid the risk of acidosis.*

** Acidosis occurs when the pH of the rumen drops below 5.8. When the rumen microbes ferment feed they produce acids. If this acid builds up too much because too much starch and sugar has been fed, or if the forage contains too much lactic acid, the rumen bacteria can be killed and both milk production and feed intake fall.*

3) Focus on maximising feed intake and cow comfort

Feed intake is maximised when cows have ready access to quality mixed forages, such as forage maize and whole crop silage in addition to grass silage. Cows should be permitted good access to feed at all times via clean troughs, with at least 610mm (24 inches) of space per cow, and attention should be given to cow comfort. By maximising cubicle comfort and minimising the time spent standing on concrete you can lift rumination and total dry matter intake.

In summer months heat stress can affect milk production. When temperatures rise above 28°C dry matter intake is depressed and there is an increased risk of acidosis. Management and feeding systems to avoid heat stress include providing shade in hot weather; bringing cows in to feed during the hottest part of the day; improving building ventilation and water supply; and installing fans and misting systems, particularly in the parlour and collecting yard areas.

Providing easy access to clean drinking water, especially after milking, can help to maximise dry matter intake.

4) Feed by products

By-products such as brewers grains, sugar beet pulp and bread waste have a low carbon impact when used as part of the dairy cow ration as the carbon burden associated with their production has already been borne by the human food chain. In addition, by utilising these feeds on farm it reduces the amount of waste by-product that end up in landfill – an area that contributes significantly to global warming as the biodegradable material turns to methane. What's more, in the future, the increased production of bio fuels is likely to result in wider availability of suitable by-products for feeding to dairy cows, providing greater choice of carbon friendly feeds for your cows.

5) Reduce heifer rearing period to 22-24 months

Rearing a heifer to thirty months old on a conventional silage and cake system creates a carbon footprint of 4766 kg of CO_2 . By reducing culling rates and calving heifers earlier, fewer young stock are required and the carbon footprint associated with the rearing period is significantly reduced.

The table below shows the impact of reducing heifer calving age and improving culling rates. As an example, moving from 30 month calving and a replacement rate of 24% to 22 month calving and a replacement rate of 20% would save 26 animals per year and would reduce the carbon footprint by more than 120 tonnes/ year for a 100-cow herd.

Replacement heifers needed to maintain a herd of 100 cows

Cull rate	Age of calving (in months)							
	22	24	26	28	30	32	34	36
16%	32	36	39	41	44	45	50	53
20%	40	44	48	51	54	56	62	66
24%	48	53	57	62	66	70	76	79
28%	56	62	67	72	77	82	87	92

nitrous oxide

Approximately 25 per cent of milk's carbon footprint is derived from nitrous oxide. Agricultural land is a major source of nitrous oxide (N_2O), which is generated from the transformations of nitrate in soil from fertilisers, manures and the mineralisation of soil organic matter.

There is a great deal of debate in the scientific community about how much nitrous oxide is produced and the best way to estimate these emissions. It is likely that this debate will continue but nevertheless there remain key steps that you can undertake to reduce nitrous oxide production, including:

1) Prudent use of artificial nitrogen and making better use of slurry and manure

Whilst artificial fertiliser will be required to ensure adequate forage is available to achieve high yields, fertiliser should be used prudently. Applications should be appropriate to crop demand and should be timed to minimise wastage. In general, this can be best achieved by multiple low rate fertiliser application with a precision applicator and by considering the contribution of manures to the nitrogen requirements of a crop to avoid excess use of inorganic fertilisers. If you are unsure of the correct application rates an agronomist or FACTS qualified adviser should be consulted or you can use a recognised fertiliser recommendation system, e.g. Defra's 'Fertiliser recommendations for agricultural and horticultural crops (RB209)', which is available on line at **www.defra.gov.uk.**

When applying inorganic nitrogen fertilisers and organic manure to land you should:

- Ensure that the correct application rate is used;
- Apply in as accurate a manner as is practically possible;
- Test all spreading equipment regularly for spreading accuracy and correct calibration for the application rate.

Avoid applying fertiliser:

- To uncropped areas, hedges and ditches;
- If the soil is waterlogged, flooded, or covered with snow;
- If the land has been frozen for 12 hours or longer in the preceding 24 hours.

Of most significance is the need to utilise slurry and manure efficiently. Ideally, slurry should be injected with a shallow injection system to ensure the optimum placement of nitrogen for the plants and care should be taken to ensure that the volume of slurry applied matches plant requirements.

Nitrous oxide production is thought to increase if land is left bare / fallow and the use of winter cover crops (such as kale, rape, forage brassicas, stubble turnips or winter cereals) and mixed cropping to avoid such circumstances is encouraged.

Nitrous oxide emissions also occur from manure and slurry storage systems but this area is especially difficult to quantify and hard to resolve without significant capital expenditure.

2) Make more use of legume crops

Legumes such as clover reduce the need for additional nitrogen application and consequently provide an effective way of reducing nitrous oxide emissions. Mixed cropping and the inclusion of clover in grassland mixes are encouraged.

3) Changing diet composition

Management of dietary protein levels can influence nitrous oxide emissions. If excess protein is fed then this is excreted as urea and adds to the greenhouse gas burden of dairy production. High yielders can perform very well on diets with around 17-18% protein; but because overall protein level in the diet is dependent upon the mixture of feeds used it is recommended that you consult an experienced ruminant nutritionist to help you prepare a balanced diet specification for your cows. you prepare a balanced diet specification for your cows.

carbon dioxide

A further 23 per cent of the carbon emissions related to milk production come from carbon dioxide. This natural component of the atmosphere is cycled through vegetation and soil by photosynthesis, respiration and decomposition. CO_2 has become a pollutant through the release of previously sequestered carbon, largely as a result of the burning of fossil fuels.

Crops and livestock are largely 'carbon neutral' in respect of CO_2 and agriculture has the potential to sequester some additional carbon in the soil sink by increasing the amount of good quality permanent grassland or through the increased growing of energy crops.

The carbon dioxide emissions linked to milk production are largely related to the use of diesel, electricity, chemicals and inorganic fertilisers. Simple measures that you can take to reduce the production of CO_2 include:

1) Reduce energy consumption

- Reducing energy consumption will save you energy costs – good for the environment and for your farm business. Typical energy saving measures include:
- Checking all equipment is switched off properly and not left on stand-by when not in use;
- Considering the use of timers to ensure equipment is only running when needed;
- Choosing new equipment based on its energy efficiency;
- Ensuring thermostats are set at the most appropriate level;
- Use passive infrared sensors to turn on lights, etc.;
- Recover heat from milk cooling systems.

Many organisations will now undertake energy surveys to help you identify how you can become more energy efficient, including the Carbon Trust who run the Energy Efficiency Accreditation Scheme, the UK's leading independent emission reduction award scheme.

Consideration should also be given to the fuel efficiency of farm vehicles. Factors for consideration include:

- Reducing vehicle use by being more efficient with journey planning;
- Turning off engines when not in use;
- Servicing equipment regularly to ensure engines are running to maximum efficiency;
- Checking tyre pressures on farm vehicles, tractors and machinery to minimise fuel usage;
- Ensuring tractors are properly weighted to minimise tyre slippage;
- Considering new low-carbon fuels for farm machinery (e.g. biodiesel).

2) Use of renewable energy sources

You can reduce your CO_2 output by utilising renewable energy sources. Probably the easiest way to achieve this is by selecting a renewable energy tariff from your energy supplier, however, there are often more cost effective alternatives available.

On-farm energy production methods, such as wind or water turbines or the utilisation of bio fuels or biomass instead of diesel, can provide not only reduction in carbon emissions but also significant ongoing cost savings. These methods are not suited to every farm situation, although there are a range of applications to suit most sizes of farm business, and often they require some degree of upfront investment. But, on-farm energy production can provide a real cost benefit in many cases whilst also bringing considerable advantages in respect of carbon footprint.

There is also growing enthusiasm for the use of anaerobic digestion plants at a farm level. These systems convert farm waste into biogas, which can be used for heating and electricity generation, and produce digestate, which can be used as a natural fertiliser, reducing the need for inorganic fertilisers and helping to reduce nitrous oxide production. Due to their many advantages anaerobic digestion plants have been seen by many as an answer to dairy greenhouse gas emissions. In practice they require significant capital investment to establish and require specialist knowledge to design and install. A careful economic evaluation needs to be undertaken before embarking on a project to install one of these plants. At the start of 2008 the UK government announced changes to legislation and the introduction of double Renewable Obligation Certificates (certificates awarded for each Mega Watt of renewable energy generation that can be sold to generate cash) for anaerobic digestion plants in an effort to encourage their uptake and this could make many previously marginal cases viable. In addition where a project is not viable for a single farm due to the scale of operation it may become more attractive when viewed as a co-operative project between neighbouring farms.

3) Prudent use of chemicals and fertilisers

Ensuring that fertiliser and chemical use is tailored to crop requirements to minimise overall consumption (see section above).

summary

Efficient farming reduces the carbon footprint of milk production and provides better returns for your business – a ‘win-win’ situation where the environment benefits and you see improved economic returns. By changing management practices to target efficiency and reduce waste you can benefit from improved productivity and enhanced environmental performance. And, by working together in this way, Cadbury and our dairy farmers can be a united force for good, taking real action on climate change.

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