National carbon footprint of milk

Life cycle assessment of British and German milk

1990 at farm gate

Preface

This report presents the life cycle inventory (LCI) and life cycle impact assessment (LCIA) of milk produced in the United Kingdom and in Germany in 1990. It should be noticed the used terms, definitions and methodological framework is described in Schmidt and Dalgaard (2012). Further, this report serves as an appendix to Dalgaard and Schmidt (2012b), where parameters for calculation of Carbon Footprint (CF) of milk produced in 2005 in Denmark and Sweden are presented.

The current report focuses mainly on parameters and assumptions that are different from those utilized for calculation modelling CF of milk produced in 2005 in Denmark and Sweden (Dalgaard and Schmidt 2012b).
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List of abbreviations

B_0	Methane production potential
BR	Brazil
CF	Carbon Footprint
CH_4	Methane
DE	Germany
dLUC	direct Land Use Changes
ECM	Energy Corrected Milk
EF	Emission Factor
EU	European Union
FR	France
GE	Gross Energy intake
GHG	Greenhouse Gasses
Ha	Hectare
iLUC	indirect Land Use Changes
IDF	International Dairy Federation
IEA	International Energy Agency
IFA	International Fertilizer Industry Association
IPCC	Intergovernmental Panel for Climate Change
kWh	Kilowatt hour
M	Million
Mt	Million Tonnes
MS	Manure Management System
MY	Malaysia
N_2O	Dinitrogen monoxide
UA	Ukraine
UE	Urinary Energy
UK	United Kingdom
VS	Volatile Solid

1 Introduction

This report presents the results of the Carbon Foot-printing (CF) of milk production in the United Kingdom and in Germany in 1990.

Milk production is often related to large area of grassland. For this reason the United Kingdom and Germany are among the most important milk producers' countries in the European Union, together with Holland, Denmark, Belgium and some regions of France and Italy. In particular, Northern Ireland, Scotland and the South West of England are the regions in the United Kingdom with the highest milk production. Similarly, in Germany the milk production is concentrated in the grassland rich northern region of Schleswig-Holstein, in the North West part of Lower Saxony, in the central Thuringia and in the South Eastern Bavaria (Eurostat 2013).

The most common dairy cow in Britain is the black and white Holstein-Friesian breed that represents 90% of the British herd. Other breeds that can be seen are the Ayrshire, Jersey and Guernsey (DairyCo 2013). More than 80% of dairy cows in Germany belong to the major breeds German Holstein (both black and white and red and white), the German Fleckvieh (Simmental) and the German Braunvieh (Brown Swiss). The diversity of the cattle breeds depends on regional climate differences and fodder availability. In the North and East German Holstein are the most common breeds. In the south Simmental and Brown Swiss Cattle are dominant (German Livestock 2013).

The study focuses mostly on 1990 national data when these are available, or on national data collected in the following years when data from 1990 are not available. In case data are not available, figures relative to the CF of milk production in 1990 in Denmark are used (Dalgaard and Schmidt 2012a). In particular, the following changes are applied to Dalgaard and Schmidt (2012a):

- Milk yields and feed intake.
- Electricity mix in the United Kingdom.
- Crop yields, straw removal, type and amount of fertiliser applied to feed crops (**Section 4.1**).
- Prices (**Appendix C**).

The most important animal-related factors when analyzing the milk system are the lactation, amount of feed intake, the live weight and milk yield. Among these factors there are partial interactions. Therefore most of the effects are related to each other.

The milk yield in the United Kingdom in 1990 was 15,251 t of raw milk and 31,307 t in Germany (FAOSTAT 2013). The average live weight of animals was 572 kg and 608 kg respectively in the UK and Germany. Data concerning the composition of feed are also important. However information concerning composition of ration is not always available for 1990 or difficult to find.

2 General activities and data

This chapter documents the life cycle inventory data that surround the detailed inventoried product system. This includes inventory data for electricity, fuels, burning of fuels, fertiliser, chemicals, transport and capital goods, services, and indirect land use changes (iLUC).

2.1 Services (general)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

2.2 Capital goods (general)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

2.3 Electricity

The methodology for the inventory of electricity is described in Schmidt et al. (2011) and can be freely accessed here: http://www.lca-net.com/projects/electricity_in_lca/

The electricity generation in 1990 and 2000 in the United Kingdom and Germany is obtained from IEA (2012, p IV.323, p IV.701). **Table 2.1** and **Table 2.2** and show the electricity generation in the United Kingdom and Germany and the applied electricity mixes for the four switches. With regard to the switch for ISO14040/44, i.e. consequential modelling, the affected suppliers are identified as the proportion of the growth for each supplier in the period 1990-2000.

Table 2.1: Data for power generation in the United Kingdom 1990 and 2000 and the applied electricity mixes for the four switches. Data are obtained from IEA (2010, p IV.565)

United Kingdom Source of electricity	Generation in 1990 TWh	Generation in 2000 TWh	Change in generation 1990-2000 TWh	Applied electricity mix Switch 1	Applied electricity mix Switch 2-4
Coal	206	122	-84	--	0.660
Oil	34.7	8.40	-26.3	--	0.111
Gas	5.00	148	143	0.852	0.016
Biomass	0.700	4.50	3.80	0.023	0.002
Nuclear	58.7	78.3	19.6	0.117	0.188
Hydro	7.20	7.80	0.600	0.004	0.023
Wind	0	0.900	0.900	0.005	0
Geothermal	0	0	0	0	0
Solar	0	0	0	0	0
Marine	0	0	0	0	0
Total	313	370	57.6	1.00	1.00

Table 2.2: Data for power generation in Germany 1990 and 2000 and the applied electricity mixes for the four switches. Data are obtained from IEA (2012 p IV.323)

Germany	Generation in 1990	Generation in 2000	Change in generation 1990-2000	Applied electricity mix	Applied electricity mix
Source of electricity	**TWh**	**TWh**	**TWh**	**Switch 1**	**Switch 2-4**
Coal	322	304	-17.4	--	0.585
Oil	10.4	4.80	-5.60	--	0.019
Gas	40.5	52.5	12.0	0.242	0.074
Biomass	5.20	10.0	4.80	0.097	0.009
Nuclear	152	170	17.1	0.345	0.277
Hydro	19.8	26.0	6.20	0.125	0.036
Wind	0.100	9.40	9.30	0.188	0
Geothermal	0	0	0	0.000	0
Solar	0	0.100	0.100	0.002	0
Marine	0	0	0	0	0
Total	**550**	**577**	**26.5**	**1.00**	**1.00**

The greenhouse gas emissions related to electricity in the United Kingdom and Germany are presented in **Table 2.3**.

Table 2.3: GHG-emissions related to electricity production and distribution in 1990 in the United Kingdom and Germany

Electricity GHG-emissions (kg CO_2-eq.)	Elec UK	Elec DE
Reference flow	1 kWh	1 kWh
Switch 1: ISO 14044/44		
Process data, ex infrastructure	0.435	0.203
Capital goods	0.00537	0.00863
Services	0.00195	0.00195
Switch 2: average/allocation		
Process data, ex infrastructure	0.861	0.721
Capital goods	0.0128	0.00827
Services	0.00195	0.00195
Switch 3: PAS2050		
Process data, ex infrastructure	0.861	0.721
Capital goods	n.a.	n.a.
Services	n.a.	n.a.
Switch 4: IDF		
Process data, ex infrastructure	0.861	0.721
Capital goods	0.0128	0.00827
Services	0.00195	0.00195

2.4 Fertilisers and other chemicals

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

2.5 Fuels and burning of fuels

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

2.6 Transport

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

2.7 Capital goods and services in cattle and crop farms

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

2.8 Capital goods and services in the food industry activities

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

2.9 Indirect land use changes (ILUC)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

3 The cattle system

3.1 Overview of the cattle system

Cattle turnover, stock and related parameters: United Kingdom

Figure 3.1 shows the cattle turnover and stocks in the UK milk system. As for the German flow diagram, the figure is established based on an iterative approach, where some parameters (see **Table 3.1**) have been held constant, and other adjusted in order to achieve balance while arriving as close as possible to characteristic figures for the UK milk system. In 1990 there were 2,870,000 dairy cows in the UK (FAOSTAT 2013). A 6% dairy cow mortality is estimated (Allen and McCombe 2013), resulting in an outflow of 172.000 dairy cows sent to destruction in 1990. According to Allen and McCombe (2013) in 1990 2,268,000 calves were born, with a mortality rate, both for heifers and bulls, of 5%, which means 57,000 dead born heifer and 57,000 death born bulls were sent to destruction. Further data concerning other animal categories were not available. Thus, grounded on the available date, the flow diagram was completed assuming proportionality between the UK and Danish system: British stocks and flows are hence calculated up-scaling Danish figures. The same procedure is adopted for completing the flow diagram of the German milk system.

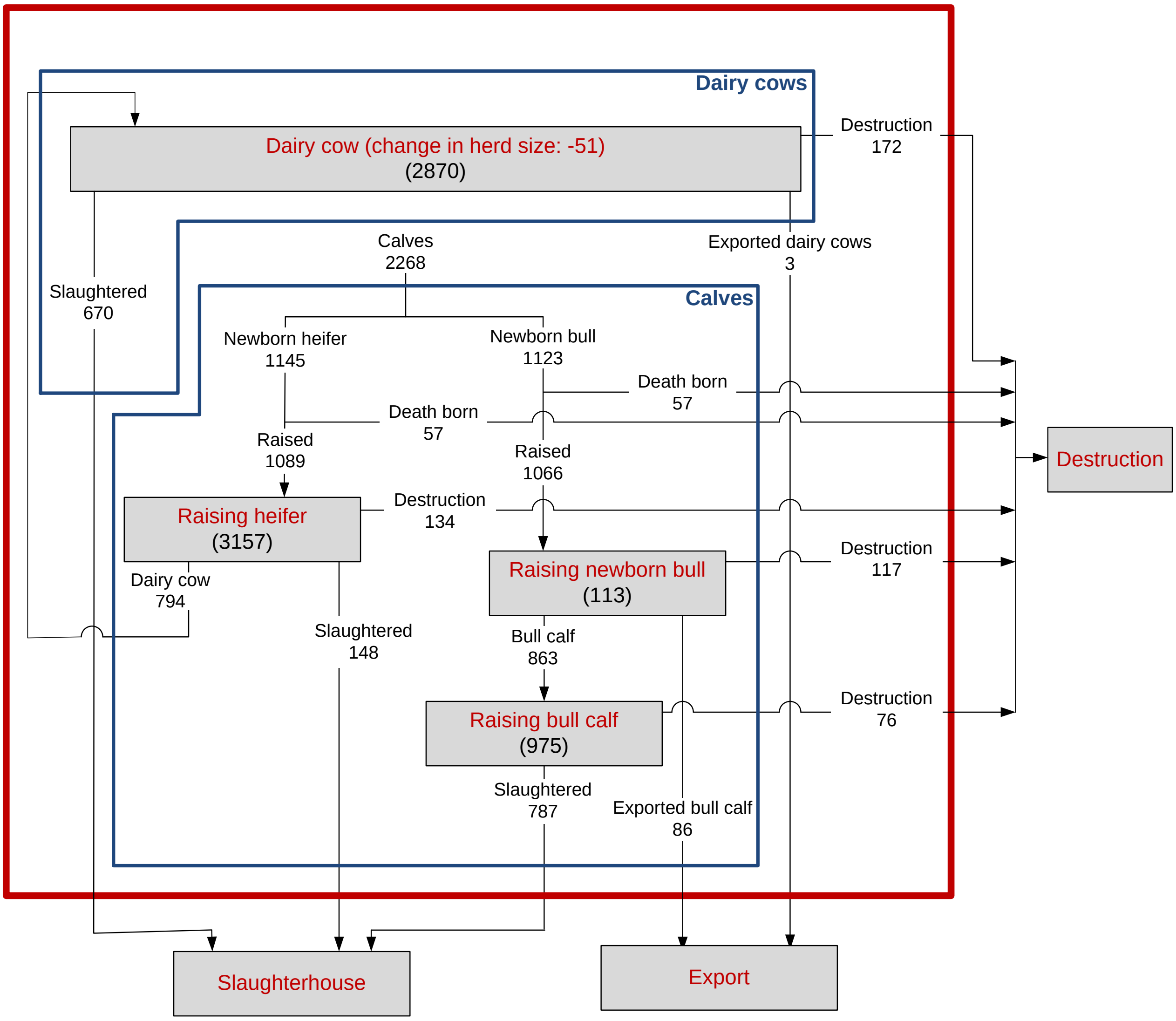

Figure 3.1: Milk system turnover in the UK 1990. Values on arrows are flows. Bracketed values are stocks. Unit: 1000 heads.

The inflow and outflows for each animal activity are presented together with further data in **Table 3.1**. All data on stock, inflow and outflows are equal to data presented in **Figure 3.2.** The average live body weight of dairy cow in 1990 was 572 kg (Webb et al. 2013, A3 p 630), 10.4% higher than weight of Danish dairy cows in 2005 (Dalgaard and Schmidt 2012b). Due to lack of data concerning other animal categories, this percentage is used to up-scale other data on weights.

Table 3.1: Parameters used for accounting for flows and stocks of animals. United Kingdom.

United Kingdom	**Unit**	**Milk system**			
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull
Stock (annual average)	Heads	2,870,170	3,157,181	113,000	975,000
Weight gain	kg day^{-1} head^{-1}	0.096	0.482	0.571	0.965
Period in activity*	Days	1,319	1,059	39	412
Inflow					
Cow or calf	Heads	794,000	1,088,500	1,066,500	863,500
Outflows					
Newborn heifers	Heads	1,145,000			
Newborn bulls	Heads	1,123,000			
Death born heifers	Heads	56,500			
Death born bulls	Heads	56,500			
Fallen heads	Heads	172,000	134,000	117,000	76,000
Slaughtered heads	Heads	670,000	148,000	0	787,000
Exported heads	Heads	3,000	12,000	86,000	0
Weights					
When entering activity	kg head^{-1}	508	42	44	66
When leaving activity	kg head^{-1}	635	552	66	464
Death born	kg head^{-1}	44			
Fallen animal	kg head^{-1}	580	113	55	121
Exported animal	kg head^{-1}	571	297	73	0
Slaughtered animal	kg head^{-1}	635	552	0	464

*Period from an animal enters an activity to it leaves for slaughter or it goes to another activity (e.g. when a heifer becomes a dairy cow).

Cattle turnover, stock and related parameters: Germany

Figure 3.2 and **Table 3.2** present cattle turnover and stocks in the German milk system. For more details on the included activities see Schmidt and Dalgaard (2012, Table 6.1).

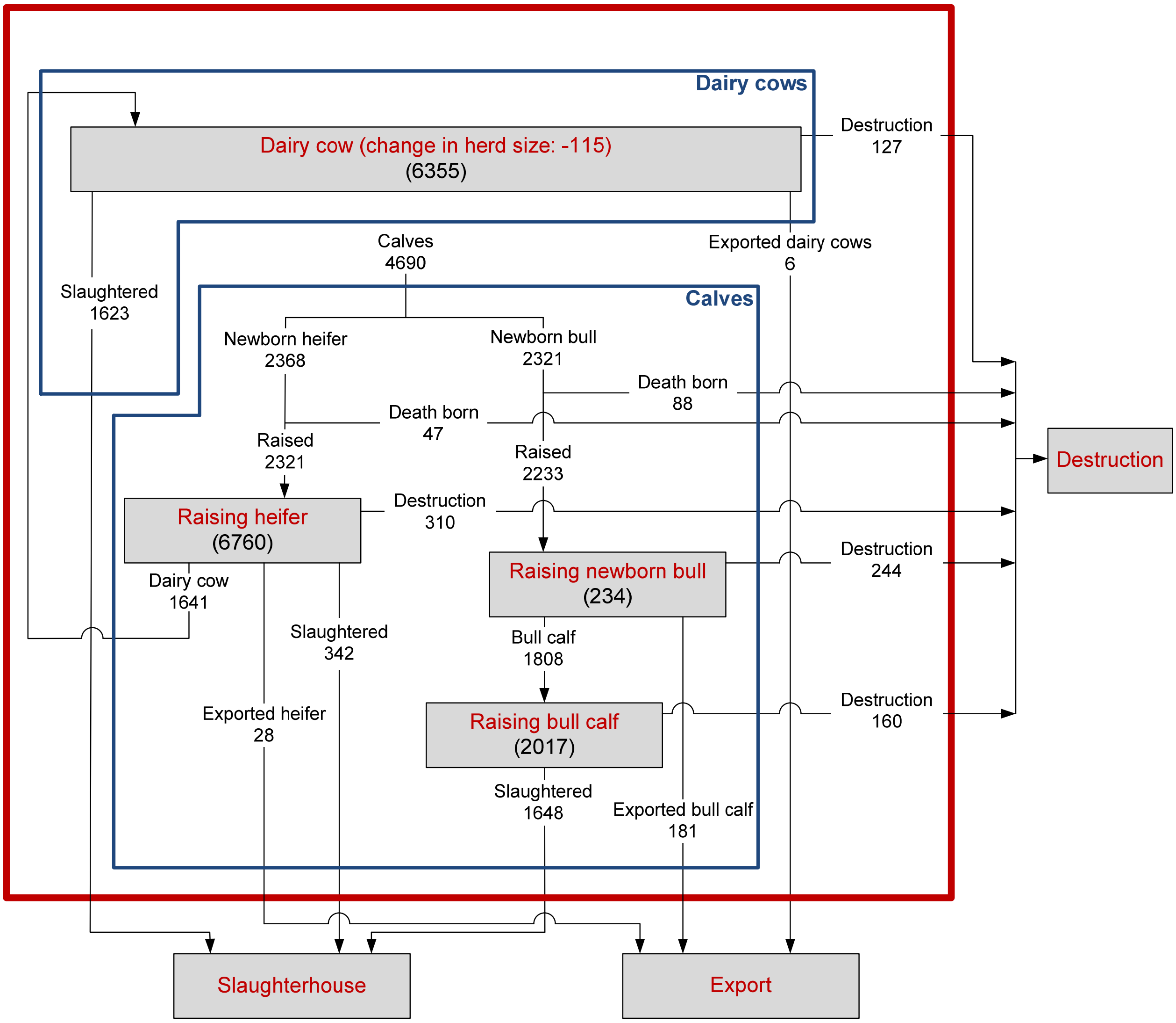

Figure 3.2: Milk system turnover in Germany 1990. Values on arrows are flows. Bracketed values are stocks. Unit: 1000 heads.

The flow is calculated through an iterative approach, where some parameters (see **Table 3.2**) have been held constant, and other adjusted in order to achieve balance. This allows a realistic representation of the German milk system in 1990. When data for the German milk system in 1990 are unavailable it is assumed that the flows and the stocks are proportional to the Danish milk system and the ratios from the 1990 Danish system are used. The starting point to establish the cattle turnover is the dairy cow stock number, dairy cow inflows and outflows. The German dairy cow stock in 1990 was 6,355,000 (FAOSTAT 2013). The number of dairy cows in Germany decreased from 1990 to 1991, causing the reduction of the dairy cow stock shown in **Figure 3.2** (change in herd size). Data on German dairy cow mortality were not available, therefore 2% mortality was assumed, based on Danish dairy cow mortality in 1990, resulting in destruction of 127,000 dead dairy cows. The inflow of new dairy cows from 'Raising heifer' per dairy cow (stock) is assumed to be proportional to the dairy cow inflow used for the Danish cattle turnover diagram. The percentage of slaughtered cows in 1990 is here assumed higher compared to the Danish system, to counterbalance the lower animal mortality and outflow to destruction. The remaining flows are calculated assuming proportionality between German and Danish system: German stocks and flows are hence calculated up-scaling Danish figures**.** When imbalances between inflows and outflows are generated due to up-scaling, the discrepancy is proportionally distributed on the outflows in order to re-obtain a balanced flow.

The inflow and outflows for each animal activity are presented together with further data in **Table 3.2**. All data on stock, inflow and outflows are equal to data presented in **Figure 3.2.** The cattle average live body weight is based on Rösmann et al. (2013).

Table 3.2: Parameters used for accounting for flows and stocks of animals. Germany.

Germany	**Unit**	**Milk system**			
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull
Stock (annual average)	heads	6,354,500	6,706,000	234,000	2,017,000
Weight gain	kg day^{-1} head^{-1}	0.072	0.528	0.627	0.988
Period in activity*	days	1,413	1,055	38	557
Inflow					
Cow or calf	heads	1,641,000	2,321,000	2,233,000	1,808,000
Outflows					
Newborn heifers	heads	2,368,000			
Newborn bulls	heads	2,321,000			
Death born heifers	heads	47,000			
Death born bulls	heads	88,000			
Fallen heads	heads	127,000	310,000	244,000	160,000
Slaughtered heads	heads	1,623,000	342,000	0	1,648,000
Exported heads	heads	6,000	28,000	181,000	0
Weights					
When entering activity	kg head^{-1}	557	36	36	60
When leaving activity	kg head^{-1}	659	593	60	611
Death born	kg head^{-1}	38.0			
Fallen animal	kg head^{-1}	608	315	48	335
Exported animal	kg head^{-1}	608	315	48	335
Slaughtered animal	kg head^{-1}	659	593	60	611

*Period from an animal enters an activity to it leaves for slaughter or it goes to another activity (e.g. when a heifer becomes a dairy cow).

3.2 Inventory of feed inputs to the cattle system

Determination of feed requirements: United Kingdom

Parameters used for calculation of net energy requirements are presented in **Table 3.3**.

The parameter 'FEreq' used for calculation of feed intake 'FEreq' for dairy cows is calculated from the milk yields. Three different models were available for the calculation and the results have been compared, in order to check the variability on feed energy intake as a function of milk yield.

The first is a German model (Rösmann et al. 2013), which can calculate the feed energy requirements based on parameters on milk yield, protein and fat content of milk, weight of dairy cows etc. The second is a Danish model (Østergaard 1989) and milk yield is the only parameter required. The third model is developed by the IPCC (2006) and requires same types of input parameters as the first model.

In **Figure 3.3** the feed energy as a function of milk yield is presented for the three models. The input parameters on weights and protein and fat content in milk are the same as the parameters used for modelling of carbon footprint in 1990 in Germany and are based on Rösmann et al. (2013) and ZMP (1994). The variation in feed energy requirements are rather low when the milk yields are as low as they were in 1990 in Germany (4,710 kg milk per cow per year in 1990 (ZMP, 1994)). Therefore using the model proposed by Østergaard (1989) for the Danish system does not affect the results significantly. Since this model is also used for modelling the carbon footprint of milk produced in Denmark in 1990 (Dalgaard and Schmidt 2012a) it was decided to maintain it also for the British and German CF calculations. The feed energy requirements would have been approximately 4.0% lower or 3.8% higher if the models by Rösmann et al. (2013) and IPCC (2006) respectively had been used.

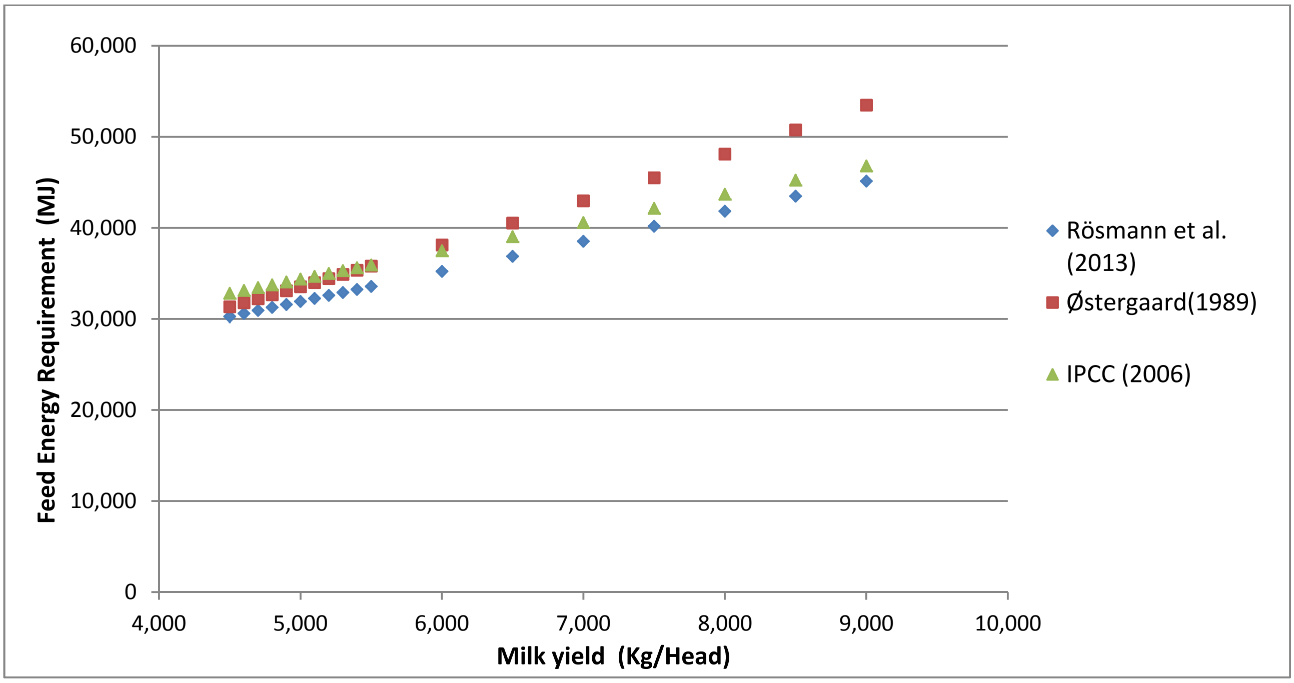

Figure 3.3: Comparison of the results obtained for three different models to calculate the feed energy requirement as a function of milk yield

According to Østergaard (1989) the feed energy intake is calculated as follow:

Equation 3.1

$$\text{FEreq} = 7.82 \cdot \left(1860 + 400 \cdot \frac{\text{ECM}}{1000} + 16.7 \cdot \left(\frac{\text{ECM}}{1000}\right)^2\right)$$

Where:

FEreq = feed energy intake, MJ net energy
ECM = energy corrected milk, kg
7.82 = Scandinavian feed unit (SFU) to net energy conversion factor, MJ net energy SFU-1. The factor is obtained from Volden (2011).

Table 3.3: Parameters used for calculating feed requirements in the United Kingdom. (*): In Schmidt and Dalgaard (2012).

United Kingdom Parameters	**Unit**	**Milk system**				**Source**
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	
NE	MJ hd^{-1} day^{-1}	100	32.1	9.92	36.7	Equation 6.1(*)
NE_m	MJ hd^{-1} day^{-1}	45.1	23.0	7.49	24.3	Equation 6.9(*)
NE_a	MJ hd^{-1} day^{-1}	3.84	1.96	0.637	2.07	Equation 6.10(*)
NE_l	MJ hd^{-1} day^{-1}	44.8	0	0	0	Equation 6.11(*)
NE_{work}	MJ hd^{-1} day^{-1}	0	0	0	0	Equation 6.12(*)
NE_p	MJ hd^{-1} day^{-1}	4.51	0	0	0	Equation 6.13(*)
NE_g	MJ hd^{-1} day^{-1}	1.99	7.12	1.79	10.3	Equation 6.15(*)
FEreq	million MJ yr^{-1}	97,051	37,011	409	13,058	Equation 6.2(*)
FEreq/hd	MJ hd^{-1} yr^{-1}	33,814	11,723	3,622	13,393	Equation 6.2(*)
FEreq/hd/day	MJ hd^{-1} day^{-1}	92.6	32.1	9.92	36.7	Equation 6.2(*)
ECM	million kg yr^{-1}	14,586	0	0	0	Allen and McCombe (2013)
ECM/head	kg hd-1 yr^{-1}	5,082	0	0	0	Allen and McCombe (2013)
C_{fi}	MJ day^{-1} kg^{-1}	0.386	0.322	0.370	0.370	IPCC (2006, Table 10.4)
Weight	Kg	572	297	55.2	265	**Table 3.1.** See text
C_a	Dim. Less	0.0850	0.0850	0.0850	0.0850	See text
Milk	kg day^{-1}	14.6	0	0	0	Allen and McCombe (2013)
Fat	%	4.01	0	0	0	Web et al. (2013, An. p. 630)
$C_{pregnancy}$	Dim. Less	0.100	0	0	0	IPCC (2006, Table 10.7)
BW	Kg	572	297	55.2	265	**Table 3.1.** See text
C	Dim. Less	0.800	0.800	1.20	1.20	IPCC (2006, p 10.17)
MW	Kg	575	575	575	575	Estimated
WG	kg day^{-1}	0.0960	0.482	0.571	0.960	**Table 3.2** See text

The total milk yield in the UK in 1990 was 15.25 million tonnes and the number of dairy cows 2.87 million (FAOSTAT 2013). This gives a yearly yield per cow of 5,314 kg milk. That is slightly higher than the milk yield presented by the UK Greenhouse Gas Inventory report (Webb et al. 2013, Annex page 630). However, it is not clear whether the figure from the UK Greenhouse Gas Inventory Webb et al. (2013) is the amount of milk coming directly from the cow or delivered to the dairy. According to Allen and McCombe (2013) the milk loss at the farm is 3%, which then results in 5,154 kg milk per cow per year delivered to dairy. The fat content is 4.01% (Web et al. 2013, Annex page 630) and the protein content 3.21% (Allen and McCombe 2013).

Determination of feed requirements: Germany

Parameters used for calculation of net energy requirements are presented in **Table 3.4**. The feed intake is calculated from the milk yield by use of the same model as presented in **Equation 3.1**.

Table 3.4: Parameters used for calculating feed requirements in Germany. (*): In Schmidt and Dalgaard (2012).

Germany Parameters	Unit	Milk	system			Source
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	
NE	MJ hd^{-1} day^{-1}	99.4	34.3	9.11	44.1	Equation 6.1(*)
NE$_m$	MJ hd^{-1} day^{-1}	47.3	24.0	6.75	29.0	Equation 6.9(*)
NE$_a$	MJ hd^{-1} day^{-1}	4.02	2.04	0.574	2.46	Equation 6.10(*)
NE$_l$	MJ hd^{-1} day^{-1}	41.9	0	0	0	Equation 6.11(*)
NE$_{work}$	MJ hd^{-1} day^{-1}	0	0	0	0	Equation 6.12(*)
NE$_p$	MJ hd^{-1} day^{-1}	4.73	0	0	0	Equation 6.13(*)
NE$_g$	MJ hd^{-1} day^{-1}	1.51	8.22	1.79	12.7	Equation 6.15(*)
FEreq	million MJ yr^{-1}	205,002	83,986	778	32,481	Equation 6.2(*)
FEreq/hd	MJ hd^{-1} yr^{-1}	32,261	12,524	3,325	16,103	Equation 6.2(*)
FEreq/hd/day	MJ hd^{-1} day^{-1}	88.4	34.3	9.11	44.1	Equation 6.2(*)
ECM	million kg yr^{-1}	30,055	0	0	0	Zehetmeier (2013)
ECM/head	kg hd-1 yr^{-1}	4,730	0	0	0	Zehetmeier (2013)
C$_{fi}$	MJ day^{-1} kg^{-1}	0.386	0.322	0.370	0.370	IPCC (2006, Table 10.4)
Weight	Kg	608	315	48.0	335	**Table 3.2** See text
C$_a$	Dim. Less	0.0850	0.0850	0.0850	0.0850	See text
Milk	kg day^{-1}	13.5	0	0	0	Zehetmeier (2013)
Fat	%	4.09	0	0	0	Zehetmeier (2013)
C$_{pregnancy}$	Dim. Less	0.100	0	0	0	IPCC (2006, Table 10.7)
BW	Kg	608	315	48.0	335	**Table 3.2** See text
C	Dim. Less	0.800	0.800	1.20	1.20	IPCC (2006, p 10.17)
MW	Kg	575	575	575	575	Estimated
WG	kg day^{-1}	0.072	0.528	0.627	0.988	**Table 3.2** See text

The total German milk yield in 1990 was 31.3 million tonnes and the number of dairy cows 6.35 million (FAOSTAT 2013). The yearly milk yield leaving the farm was 4,710 kg ECM milk per head (Zehetmeier 2013), that is equal to 29.9 Mt of milk totally produced from farms, with a milk loss of 4.4%.

Distribution of total feed on different feedstuffs: United Kingdom

The feed requirement and intake are presented in **Table 3.5.** Exact data on cattle feedstuff in United Kingdom in 1990 could not be obtained. However, according to Webb et al. (2013, p. 350) the ingredients of the concentrate feed in United Kingdom are barley grain, sugar beet pulp (molasses), wheat feed, wheat grain, rapeseed meal, soybean meal and sunflower meal, whereas the forage components are fresh grass (grazed), grass silage and maize silage. This indicates that there are many similarities between the Danish and British feeding regime, and data are therefore to a large extent based on the feedstuffs consumed in 1990 in Denmark (Dalgaard and Schmidt 2012a). Ensilage in Denmark in 1990 was mainly based on whole seed and pea and not maize ensilage as in 2005, and this is also assumed to be valid for the United Kingdom. The shares of feed net energy deriving from respectively feed concentrate and permanent grass are assumed to be the same as for the Danish milking cow systems in Denmark 2005 (Dalgaard and Schmidt 2012b) and 1990 (Dalgaard and Schmidt 2012a). Feed concentrate contributes with 48% of the feed net energy, whereas the contribution from permanent grass is rather low. Feed concentrate content is based on Allen and McCombe (2013), who roughly estimate the ingredients in cattle feed concentrate in 1990 in United Kingdom were the following: wheat/barley (35%), maize gluten (30%), soybean meal (10%), rapeseed meal (10%), and sunflower meal (10%).

The amount of ensilage and rotation grass is calculated from the net energy requirement and the feed intake of the other feed components as described by Schmidt and Dalgaard (2012). Data on feed properties of the applied ensilage are presented in **Appendix B**.

Table 3.5: Feed requirement and intake. United Kingdom

United Kingdom Feed requirement/intake	**Milk system** TJ net energy	1000 tons protein
Feed requirement		
FEreq	147,530	
FPreq		3,204,659
Feed intake		
Barley	17,646	219,550
Corn	19,235	233,780
Soybean meal	13,077	639,024
Rape seed/cake	11,306	425,228
Sunflower meal	10,177	507,199
Feed urea	0	60,030
Permanent grass	2,987	88,818
Ensilage	63,089	724,255
Rotation grass	10,013	306,775
Total feed intake	**147,530**	**3,204,659**

Distribution of total feed on different feedstuffs: Germany

The feed requirement and intake are presented in **Table 3.6.** Apparently, it was not possible to obtain data on cattle feeding in Germany in 1990 and it was therefore decided to use the distribution of total feed (excluding ensilage and rotation grass) on different feedstuffs from Denmark 2005 (Dalgaard and Schmidt 2012b). Fodder beets were rarely used in Germany in 1990 (Zehetmeier 2013) and that is the reason for using data for Denmark 2005 instead of data for Denmark 1990, where fodder beets are part of the feed regime. The ensilage used for the modelling is based on whole seed and pea, which is similar to the data used for modeling CF of milk in Denmark and Sweden 1990 (Dalgaard and Schmidt 2012a) and the United Kingdom 1990.

Table 3.6: Feed requirement and intake. Germany

Germany Feed requirement/intake	Milk system	
	TJ net energy	1000 tons protein
Feed requirement		
FEreq	322,247	
FPreq		6,988,929
Feed intake		
Barley	62,445	776,948
Corn	3,548	35,705
Soybean meal	29,104	1,422,243
Rape seed/cake	26,703	1,004,317
Sunflower meal	18,853	939,569
Beet pulp, dried	6,555	80,467
Molasses	1,762	29,887
Palm oil	5,290	0
Wheat bran	1,787	46,994
Feed urea	59	135,651
Permanent grass	5,389	160,255
Ensilage	134,147	1,539,990
Rotation grass	26,664	816,905
Total feed intake	**322,306**	**6,988,929**

The amount of ensilage and rotation grass is calculated from the net energy requirement and the feed intake of the other feed components as described by Schmidt and Dalgaard (2012). Data on feed properties of the applied ensilage are presented in **Appendix B.**

3.3 Inventory of other inputs to the cattle system

Data on electricity consumption per cow in the United Kingdom are provided by Allen and McCombe (2013). Due to the lack of specific data concerning diesel consumption (per head) in Germany and in the United Kingdom for feed management, it is assumed data are equal to the values used in Dalgaard and Schmidt (2012a). The data regarding diesel and transportation in the British and German cattle systems are presented in the summary of LCI in **Section 3.5**.

Manure treatment

Manure treatment in the United Kingdom and Germany is to a large extent assumed to be equal to the manure treatment in Denmark and Sweden in 1990 (Dalgaard and Schmidt 2012a). The manure treatment in Denmark and Sweden in 1990 is again based on Denmark and Sweden 2005 (Dalgaard and Schmidt 2012b), but with the modifications described further below. It should be noticed that the contribution from the manure treatment processes to carbon footprint of milk is of minor importance (Schmidt and Dalgaard 2012b).

The following three aspects are considered to be the most important and are therefore integrated in the 1990-data for the United Kingdom and Germany:

- The housing systems are different and the distribution between the different types of manure is modelled and presented in **section 3.4**.

- 95% of the nitrogen in manure was applied to the fields by broad casting in 1990 (Grant et al. 2002). According to Sommer et al. (1997) the ammonia loss from pig slurry applied by broad casting is 1.7 times higher compared to slurry applied by trial hose. To include this in the model, the ammonia emission coefficients for 'liquid + slurry' and 'solid and deep litter' are multiplied by 1.67 (= (0.05 + (0.95*1.7)). Thereby it is assumed the increased ammonia loss published by Sommer et al. (1997) also is valid for cattle slurry, solid and deep litter.
- The amount of the by-product N fertiliser (named 'Market for N-fertiliser') produced per kg N expresses the expected plant available N per kg manure N. This value is also called utilisation degree in chapter 4, where it is assumed to be 33% in 1990 and 70% in 2005. For further explanation see **section 4.1**. To ensure coherency with the modelling of emissions from the plant cultivation system, it is assumed the amount of the by-product N fertiliser is 53% lower =(1-(0.33/0.7)) than for the 2005-data.

The manure treatment processes are presented in **Table 3.7**. The amount of the by-product N fertiliser (named 'Market for N-fertiliser') produced per kg N is lower compared to 2005-data and the emissions are higher. This reflects the use of manure in 1990 was less efficient and more was lost to the environment.

Table 3.7: Manure treatment processes. Reference product is 1 kg N in manure

Treatment process		**Manure deposited outdoor**	**Manure land application**		
		Dung + urine	Liquid + slurry	Solid	Deep litter
Country:	Unit	UK/DE	UK/DE	UK/DE	UK/DE
Output of products					
Determining product:					
Manure for treatment	kg N	1	1	1	1
By-products:					
Market for N-fertiliser	kg N	-0.344	-0.370	-0.344	-0.238
P-fert: TSP	kg P_2O_5	-0.141	-0.152	-0.141	-0.098
K-fert: KCl	kg K_2O	-0.391	-0.421	-0.391	-0.270
Input of products	Unit:				
Diesel	MJ	0	2.585	2.677	2.064
Emissions	Unit:				
Methane	kg CH_4	0	0	0	0
Dinitrogen monoxide (direct)	kg N_2O	0.0260	0.0099	0.0103	0.0120
Dinitrogen monoxide (indirect)	kg N_2O	0.0282	0.0149	0.0141	0.0160
Ammonia	kg NH_3	0.0767	0.365	0.234	0.237

Calculations of the N emissions form the manure treatment processes are presented in **Table 3.8**.

Table 3.8: Calculation of N emissions from manure treatment processes. Reference product is 1 kg N in manure

Treatment process:		Manure deposited outdoor	Manure land application		
		Dung + urine	Liquid + slurry	Solid	Deep litter
Country:		UK/DE	UK/DE	UK/DE	UK/DE
	Unit				
Applied manure					
Manure, N	kg N	1	1	1	1
Dinitrogen monoxide (direct)					
From manure	kg N	0.0200	0.010	0.010	0.010
From displaced fertiliser	kg N	-0.00344	-0.00370	-0.00344	-0.00238
From manure treatment	Kg N	0.0166	0.00630	0.00656	0.00762
Ammonia					
From manure	kg N	0.0700	0.308	0.200	0.200
From displaced fertiliser	kg N	-0.00687	-0.00740	-0.00687	-0.00476
From manure treatment	kg N	0.0631	0.300	0.193	0.195
Nitrate					
From manure	kg N	0.300	0.300	0.300	0.300
From displaced fertiliser	kg N	-0.103	-0.111	-0.103	-0.071
From manure treatment	kg N	0.197	0.189	0.197	0.229
Dinitrogen monoxide (indirect)					
From manure treatment	kg N	0.00222	0.00495	0.00375	0.00401
Summary of N emissions					
Dinitrogen monoxide (direct)	kg N_2O	0.0260	0.0099	0.0103	0.0120
Dinitrogen monoxide (indirect)	kg N_2O	0.0022	0.0050	0.0037	0.0040
Ammonia	kg NH_3	0.0767	0.365	0.234	0.237

Destruction of fallen cattle

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

3.4 Emissions

Methane emissions from enteric fermentation: United Kingdom

The parameters used for calculation of methane emissions from enteric fermentation are presented in **Table 3.9**. The emission factor (EF) is calculated from the gross energy intake (GE), which again is calculated from the net energy intake (Schmidt and Dalgaard 2012, Section 6.4). DE% (digestibility of feed in percentage) is calculated as a weighted average of DE% for each of the used feedstuffs and therefore differs from DE% in 2005-data.

Table 3.9: Parameters used for calculating methane emissions from enteric fermentation in the United Kingdom (*): In Schmidt and Dalgaard (2012)

United Kingdom Parameters	**Unit**	**Milk system**				**Source**
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	
EF	kg CH_4 hd^{-1} yr^{-1}	95.5	33.1	10.2	37.8	Equation 6.7(*)
GE	MJ hd^{-1} day^{-1}	224	77.7	24.0	103	See text
Ym	%	6.50	6.50	6.50	6.50	IPCC (2006, Table 10.12)
NE_m	MJ day^{-1}	45.1	23.0	7.49	24.3	**Table 3.3**
NE_a	MJ day^{-1}	3.84	1.96	0.637	2.07	**Table 3.3**
NE_l	MJ day^{-1}	44.8	0	0	0	**Table 3.3**
NE_{work}	MJ day^{-1}	0	0	0	0	**Table 3.3**
NE_p	MJ day^{-1}	4.51	0	0	0	**Table 3.3**
NE_g	MJ day^{-1}	1.99	7.12	1.79	10.3	**Table 3.3**
REM	Dim. less	0.542	0.542	0.542	0.542	Equation 6.14(*)
REG	Dim. less	0.354	0.354	0.354	0.354	Equation 6.16(*)
DE%	%	75.5	75.5	75.5	75.5	See text

Methane emissions from enteric fermentation: Germany

The parameters used for calculation of methane emissions from enteric fermentation are presented in **Table 3.10**. The emission factor (EF) is calculated from the gross energy intake (GE), which again is calculated from the net energy intake (Schmidt and Dalgaard 2012, Section 6.4). DE% (digestibility of feed in percentage) is calculated as a weighted average of DE% for each of the used feedstuffs and therefore differs from DE% in 2005-data.

Table 3.10: Parameters used for calculating methane emissions from enteric fermentation in Germany (*): In Schmidt and Dalgaard (2012)

Germany Para-meters	**Unit**	**Milk system**				**Source**
		Dairy cow	Raising heifer calf	Raising bull calf	Raising litre bull	
EF	kg CH_4 hd^{-1} yr^{-1}	91.6	35.6	9.44	45.7	Equation 6.7(*)
GE	MJ hd^{-1} day^{-1}	215	83.4	22.2	107	See text
Ym	%	6.50	6.50	6.50	6.50	IPCC (2006, Table 10.12)
NE_m	MJ day^{-1}	47.3	24.0	6.75	29.0	**Table 3.4**
NE_a	MJ day^{-1}	4.02	2.04	0.574	2.46	**Table 3.4**
NE_l	MJ day^{-1}	41.9	0	0	0	**Table 3.4**
NE_{work}	MJ day^{-1}	0	0	0	0	**Table 3.4**
NE_p	MJ day^{-1}	4.73	0	0	0	**Table 3.4**
NE_g	MJ day^{-1}	1.51	8.22	1.79	12.7	**Table 3.4**
REM	Dim. less	0.541	0.541	0.541	0.541	Equation 6.14(*)
REG	Dim. less	0.353	0.353	0.353	0.353	Equation 6.16(*)
DE%	%	75.3	75.3	75.3	75.3	See text

Methane and nitrous oxide emissions from manure management: United Kingdom

The distribution of manure management systems in 1990 is based on Webb et al. (2013, page 635), who established UK Greenhouse Gas Inventory time series from 1990 to 2011. However, detailed data from 1990 were not presented in the report, but provided personally by Cardenas (2013). Based on the data from Cardenas (2013) it is estimated 45.1% of the manure from dairy cows was excreted outdoor, whereas 30.4 and 24.5% was handled as liquid/slurry and solid manure respectively (**Table 3.11**). The distribution of manure management systems for heifers and bulls is also presented in **Table 3.11**.

All parameters used for calculating CH_4 and N_20 emissions from British manure management systems are presented in **Table 3.11** and **Table 3.12**.

Table 3.11: Parameters used for calculating CH_4 emissions from British manure management systems. MMS: Manure Management System. (*): In Schmidt and Dalgaard (2012)

United Kingdom Parameters	**Unit**	**Milk system**				**Source**
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	
$EF_{(T)}$	Kg CH_4 hd^{-1} yr^{-1}	7.44	0.82	0.218	0.954	Equation 6.17(*)
$VS_{(T)}$	Kg DM hd^{-1} day^{-1}	3.18	1.10	0.341	1.26	Equation 6.18(*)
$B_{o(T)}$	m^3 CH_4 (kg VS excreted)$^{-1}$	0.240	0.180	0.180	0.180	IPCC (2006, p 10.77-8)
$MCF_{(Pasture,10°C)}$	%	1.00	1.00	1.00	1.00	IPCC (2006, Table 10.17)
$MCF_{(Liquid, 10°C)}$	%	10.0	10.0	10.0	10.0	
$MCF_{(Solid, 10°C)}$	%	2.00	2.00	2.00	2.00	
$MCF_{(Deep bed., 10°C)}$	%	17.0	17.0	17.0	17.0	
$MS_{(Pasture, 10°C)}$	Dim. less	45.1	69.0	54.8	65.4	Cardenas (2013) and Webb et al. (2013, page 635)
$MS_{(Liquid, 10°C)}$	Dim. less	30.4	4.69	0	4.68	
$MS_{(Solid, 10°C)}$	Dim. less	24.5	26.3	45.2	30.0	
$MS_{(Deep bed., 10°C)}$	Dim. less	0	0	0	0	
GE	MJ day^{-1}	224	77.7	24.0	88.8	**Table 3.9**
DE%	%	75.5	75.5	75.5	75.5	**Table 3.9**
UE	Dim. less	0.0400	0.0400	0.0400	0.0400	IPCC (2006, eq 10.24)
ASH	Dim. less	8.00	8.00	8.00	8.00	IPCC (2006, p 10.42)

Table 3.12: Parameters used for calculating N_2O emissions from British manure management systems. (*): In Schmidt and Dalgaard (2012)

United Kingdom **Parameters**	**Unit**	**Milk system**				**Source**
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	
$N_2O_{(mm)}$	kg N_2O yr^{-1}	1,391,374	334,101	4,804	101,176	Equation 6.19(*)
$N_2O_{D(mm)}$	kg N_2O yr^{-1}	1,129,831	277,311	4,021	84,054	Equation 6.20(*)
$N_2O_{G(mm)}$	kg N_2O yr^{-1}	261,543	56,790	782	17,122	Equation 6.21(*)
N_T	heads	2,870,170	3,157,181	113,000	975,000	**Table 3.1**
$N_2O_{(mm)}$/head	kg N_2O hd^{-1} yr^{-1}	0.485	0.106	0.043	0.104	$N_2O_{(mm)}$/ N_T
$Nex_{(T)}$	kg N hd^{-1} yr^{-1}	91.3	36.0	10.0	31.7	Equation 6.21 (*)
$MS_{(Liquid)}$	Dim. less	0.309	0.048	0	0.048	From MS parameters in **Table 3.11** and Poulsen et al. (2001).
$MS_{(Solid)}$	Dim. less	0.240	0.262	0	0.298	
$MS_{(Deep\ bed.)}$	Dim. less	0	0	0	0	
$EF_{3(Liquid/solid)}$	Kg N_2O-N kg N^{-1}	0.00500	0.00500	0.00500	0.00500	IPCC (2006, Table 10.21)
$EF_{3(Solid\ storage)}$	Kg N_2O-N kg N^{-1}	0.00500	0.00500	0.00500	0.00500	
$EF_{3(deep\ bed.)}$	Kg N_2O-N kg N^{-1}	0.0100	0.0100	0.0100	0.0100	
$N_{intake(T)}$	kg N hd^{-1} yr^{-1}	119	40.6	15.4	40.8	From protein content in feed
$N_{retention(T)}$	kg N hd^{-1} yr^{-1}	28.2	4.57	5.42	9.15	Equation 6.22 (*)
N_{milk}	kg N hd^{-1} yr^{-1}	27.3	0	0	0	Equation 6.22 (*)
$N_{weight\ gain}$	kg N hd^{-1} yr^{-1}	0.913	4.57	5.42	9.15	Equation 6.22 (*)
$N_{volatilization\text{-}MMS}$	Kg N hd^{-1} yr^{-1}	5.80	1.14	0.441	1.12	Equation 6.22 (*)
EF_4	Kg N_2O-N kg N^{-1}	0.0100	0.0100	0.0100	0.0100	IPCC (2006, Table 11.3)

The N inputs, outputs and emissions related to the British milk system are presented in **Table 3.13**. The N balance is calculated as N inputs minus the sum of N outputs and N emissions. When the N balance equals 0, it means all N is accounted for.

Table 3.13: N balances and emissions related to the milk system in the United Kingdom. Unit: Kg N hd^{-1} yr^{-1}

United Kingdom **Parameter**	**Milk system**			
	Dairy cow	Raising heifer calf	Raising bull calf	Raising bull
N inputs				
Feed	119	40.6	15.4	40.8
N outputs				
Milk	27.3	0	0	0
Weight gain, live weight	0.913	4.57	5.42	9.15
Manure leaving storage	44.1	10.0	4.07	9.80
Manure excreted outdoor	41.2	24.9	5.49	20.7
N emissions				
Ammonia from stable	2.99	0.508	0.181	0.492
Ammonia from storage	2.81	0.637	0.260	0.626
N_2O-N_{direct}	0.251	0.0559	0.0226	0.055
N balance*	0	0	0	0

* N balance = N inputs – N outputs – N emissions

Methane and nitrous oxide emissions from manure management: Germany

Parameters used for calculating CH_4 and N_20 emissions from manure management in Germany are presented in **Table 3.14** and **Table 3.15.** Data on distribution of different cattle housing system are not available for 1990, therefore data from Strogies and Gniffke (2011, p. 405-406) describing the distribution between different manure types are used. According to Strogies and Gniffke (2011) 18.4% of the N from dairy cows was excreted during grazing in 1990.

Table 3.14: Parameters used for calculating CH_4 emissions from German manure management systems (MMS). (*): In Schmidt and Dalgaard (2012)

Germany Parameters	**Unit**	**Milk system**				**Source**
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	
$EF_{(T)}$	Kg CH_4 hd^{-1} yr^{-1}	11.2	3.50	0.93	4.50	Equation 6.17(*)
$VS_{(T)}$	Kg DM hd^{-1} day^{-1}	3.08	1.19	0.317	1.54	Equation 6.18(*)
$B_{o(T)}$	m^3 CH_4 (kgVS excreted)$^{-1}$	0.240	0.180	0.180	0.180	IPCC (2006, p 10.77-8)
$MCF_{(Pasture,10°C)}$	%	1.00	1.00	1.00	1.00	IPCC (2006, Table 10.17)
$MCF_{(Liquid, 10°C)}$	%	10.0	10.0	10.0	10.0	
$MCF_{(Solid, 10°C)}$	%	2.00	2.00	2.00	2.00	
$MCF_{(Deep bed., 10°C)}$	%	17.0	17.0	17.0	17.0	
$MS_{(Pasture, 10°C)}$	Dim. less	18.4	13.4	13.4	13.4	Strogies and Gniffke (2011, p. 405-406)
$MS_{(Liquid, 10°C)}$	Dim. less	54.8	59.9	59.9	59.9	
$MS_{(Solid, 10°C)}$	Dim. less	26.8	26.7	26.7	26.7	
$MS_{(Deep bed., 10°C)}$	Dim. less	0	0	0	0	
GE	MJ day^{-1}	215	83.4	22.2	107	**Table 3.10**
DE%	%	75.3	75.3	75.3	75.3	**Table 3.10**
UE	Dim. less	0.0400	0.0400	0.0400	0.0400	IPCC (2006, eq 10.24)
ASH	Dim. less	8.00	8.00	8.00	8.00	IPCC (2006, p 10.42)

Table 3.15: Parameters used for calculating N_2O emissions from German manure management systems. (*): In Schmidt and Dalgaard (2012)

Germany Parameters	Unit	Milk system				Source
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	
$N_2O_{(mm)}$	kg $N_2O\ yr^{-1}$	4,403,150	2,172,499	16,232	675,951	Equation 6.19(*)
$N_2O_{D(mm)}$	kg $N_2O\ yr^{-1}$	3,553,482	1,751,435	13,086	544,941	Equation 6.20(*)
$N_2O_{G(mm)}$	kg $N_2O\ yr^{-1}$	849,668	421,064	3146	131,010	Equation 6.21(*)
N_T	heads	6,354,500	6,706,000	234,000	2,017,000	**Table 3.1**
$N_2O_{(mm)}$/head	kg $N_2O\ hd^{-1}\ yr^{-1}$	0.693	0.324	0.0694	0.335	$N_2O_{(mm)}/\ N_T$
$Nex_{(T)}$	kg N $hd^{-1}\ yr^{-1}$	87.2	38.4	8.22	39.7	Equation 6.21 (*)
$MS_{(Liquid)}$	Dim. less	0.554	0.605	0.605	0.605	From MS parameters in **Table 3.14** and Poulsen et al. (2001). See text.
$MS_{(Solid)}$	Dim. less	0.262	0.261	0.261	0.261	
$MS_{(Deep\ bed.)}$	Dim. less	0	0	0	0	
$EF_{3(Liquid/solid)}$	Kg N_2O-N kg N^{-1}	0.00500	0.00500	0.00500	0.00500	IPCC (2006, Table 10.21)
$EF_{3(Solid\ storage)}$	Kg N_2O-N kg N^{-1}	0.00500	0.00500	0.00500	0.00500	
$EF_{3(deep\ bed.)}$	Kg N_2O-N kg N^{-1}	0.0100	0.0100	0.0100	0.0100	
$N_{intake(T)}$	kg N $hd^{-1}\ yr^{-1}$	114	43.4	14.2	49.1	From protein content in feed
$N_{retention(T)}$	kg N $hd^{-1}\ yr^{-1}$	26.9	5.01	5.95	9.38	Equation 6.22 (*)
N_{milk}	kg N $hd^{-1}\ yr^{-1}$	32.7	0	0	0	Equation 6.22 (*)
$N_{weight\ gain}$	kg N $hd^{-1}\ yr^{-1}$	0.719	5.03	7.95	7.86	Equation 6.22 (*)
$N_{volatilization-MMS}$	Kg N yr^{-1}	8.81	1.99	1.67	4.30	Equation 6.22 (*)
EF_4	Kg N_2O-N kg N^{-1}	0.01	0.01	0.01	0.01	IPCC (2006, Table 11.3)

The N inputs, outputs and emissions related to the Swedish milk system in 1990 are presented in **Table 3.16**. The N balance is calculated as N inputs minus the sum of N outputs and N emissions. When the N balance equals 0, it means all N is accounted for.

Table 3.16: N balances and emissions related to the German milk system. Unit: Kg N $hd^{-1}\ yr^{-1}$

Germany Parameter	Milk system			
	Dairy cow	Raising heifer calf	Raising bull calf	Raising bull
N inputs				
Feed	114	43.4	14.2	49.1
N outputs				
Milk	26.2	0	0	0
Weight gain, live weight	0.683	5.01	5.95	9.38
Manure leaving storage	62.3	29.1	6.23	30.1
Manure excreted outdoor	16.0	5.14	1.10	5.32
N emissions				
Ammonia from stable	4.53	2.14	0.458	2.21
Ammonia from storage	3.98	1.86	0.397	1.92
N_2O-N_{direct}	0.356	0.166	0.0356	0.172
N balance*	0	0	0	0

* N balance = N inputs – N outputs – N emissions

3.5 Summary of the LCI of cattle system

Summaries of LCI of the British and German milk systems are presented in **Table 3.17** and **Table 3.18.**

Table 3.17: LCI for the activities in the British milk system. The data represent 1 dairy cow during one year

United Kingdom Exchanges	**Activity: Unit:**	**LCI data per dairy cow incl. offspring during one year**			
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull
Output of products					
Determining product:					
Milk	kg	5,082			
Animals to raising	p		1.10	0.0394	0.340
By-product:					
Meat, live weight	kg	148	28.5	0	127
Exported animals for raising, live weight	kg	0.597	1.24	2.19	0
Material for treatment:					
Manure deposited outdoor	kg N	36.2	24.4	0	6.28
Manure land application, liquid/slurry	kg N	24.8	0	0	0.463
Manure land application, solid	kg N	19.3	9.27	0	2.87
Manure land application, deep litter	kg N	0	0	0	0
Destruction of fallen cattle	kg	36.5	5.26	2.25	3.22
Input of products					
Barley	kg	548	209	2.31	74
Wheat	kg	548	209	2	74
Fodder beet	kg	-	-	0	0
Corn	kg	0	0	0	0
Soybean meal	kg	313	119.5	1.32	42.1
Rapeseed cake/meal	kg	313	119.5	1.32	42.1
Imported Sunflower meal	kg	313	119.5	1.32	42.1
Beet pulp, dried	kg	0	0	0	0
Beet pulp	kg	0	0	0	0
Molasses	kg	0	0	0	0
Palm oil	kg	0	0	0	0
Palm kernel meal	kg	0	0	0	0
Wheat bran	kg	0	0	0	0
Feed urea	kg	6.03	2.30	0	0.812
Minerals, salt etc.	kg	9.30	3.55	0	1.25
Permanent grass	kg	565	216	2.38	76.1
Ensilage	kg	6,367	2,428	26.9	857
Rotation grass	kg	1,747	666	7.37	235
Lorry	tkm	410	156	1.73	55.2
Electricity	kWh	675	0	0	0
Diesel	MJ	613	165	8.60	56.8
Emissions					
Methane	kg CH_4	103	37.3	0.411	13.2
Dinitrogen monoxide (direct)	kg N_2O	0.394	0.0966	0.0014	0.0293
Dinitrogen monoxide (indirect)	kg N_2O	0.0911	0.0198	0.000273	0.00597
Ammonia	kg NH_3	7.04	1.53	0.0211	0.461

Table 3.18: LCI for the activities in the German milk system. The data represent 1 dairy cow during one year.

Germany **Exchanges**	**Activity:** **Unit:**	**LCI data per dairy cow incl. offspring during one year**			
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull
Output of products					
Determining product:					
Milk	kg	4,730			
Animals to raising	p		1.06	0.0368	0.317
By-product:					
Meat, live weight	kg	168	31.9	0	158
Exported animals for raising, live weight	kg	0.57	1	1.37	0
Material for treatment:					
Manure deposited outdoor	kg N	14.0	4.75	0	1.48
Manure land application, liquid/slurry	kg N	42.3	21.5	0.160	6.67
Manure land application, solid	kg N	20.0	9.24	0.0690	2.87
Manure land application, deep litter	kg N	0	0	0	0
Destruction of fallen cattle	kg	13.0	15.3	1.84	8.44
Input of products					
Barley	kg	847	347	3.22	134
Wheat	kg	0	0	0	0
Fodder beet	kg	0	0	0	0
Corn	kg	43	17.4	0	6.74
Soybean meal	kg	305	125	1.16	48.2
Rapeseed cake/meal	kg	323	132	1.23	51.2
Imported Sunflower meal	kg	253	104	0.962	40.2
Beet pulp, dried	kg	94	38.5	0	14.9
Beet pulp	kg	0	0	0	0
Molasses	kg	31.1	12.7	0.118	4.93
Palm oil	kg	24	9.94	0.0921	3.84
Palm kernel meal	kg	0	0	0	0
Wheat bran	kg	29.5	12.1	0.112	4.68
Feed urea	kg	6	2	0	0.944
Minerals, salt etc.	kg	9.2	3.76	0.035	1.45
Permanent grass	kg	446	183	1.69	70.6
Ensilage	kg	5,914	2,423	22.4	937
Rotation grass	kg	2,032	832	7.71	322
Lorry	tkm	393	161	1.49	62.3
Electricity	kWh	1,300	-	0	-
Diesel	MJ	560	441	15.4	133
Emissions					
Methane	kg CH4	103	41.2	0.382	15.9
Dinitrogen monoxide (direct)	kg N2O	0.559	0.276	0.00206	0.0858
Dinitrogen monoxide (indirect)	kg N2O	1.34E-01	0.0663	0.000495	0.0206
Ammonia	kg NH3	10.33	5.12	0.0383	1.59

3.6 Parameters relating to switch between modelling assumptions

The allocation factors used for switching between the four modelling assumptions are presented in **Table 3.19**.

Switch 1: Allocation is avoided by substitution. Consequently, milk production results in avoided production of e.g. cattle meat and fertilisers.

Switch 2: Co-products are modelled using allocation at the point of substitution. The allocation factors are obtained by combining the product amounts (**Section 3.4 and 3.6**) with the relevant product prices from **Appendix C: Prices**.

Switch 3 and 4: Co-products are modelled using allocation at the point of substitution or at other points as defined in PAS2050 and IDF. The allocation factors are obtained by combining the product amounts (**Section 3.4 and 3.6**) with the relevant product prices from **Appendix C: Prices**. However, the allocation factor between milk and meat for IDF is special, i.e. it is based on the supply of milk and meat and the following formula (IDF 2010, p 20):

Equation 3.2

$$\mathrm{af} = 1 - 5.7717 \cdot \frac{\mathrm{M_{meat}}}{\mathrm{M_{milk}}}$$

where:
- af is the allocation factor for milk
- M_{meat} is the sum of live weight of all animals sold including bull calves and culled mature animals
- M_{milk} is the sum of ECM sold milk

Table 3.19: Allocation factors used for allocation of products produced in the milk and beef systems. Unit: Fraction

System:	**Milk system**	
Country:	**UK**	**DE**
Switch 1: ISO 14040/44 consequential		
Determining product:		
Milk	1	1
Meat		
Switch 2: Average/allocation attributional		
Determining product:		
Milk	0.743	0.756
Meat		
By-products at point of substitution:		
Cattle meat, live weight	0.224	0.221
Exported animals for raising, live weight	0.0130	0.00488
N fert as N	0.00658	0.00675
P fert as P_2O_5	0.00241	0.00272
K fert as K_2O	0.00441	0.00423
Heat	0	0
Burning coal	0.00000456	0.00000371
Burning fuel oil	0.000276	0.000157
Switch 3: PAS2050		
Determining product:		
Milk	0.758	0.770
Meat		
By-products:		
Cattle meat, live weight	0.229	0.225
Exported animals for raising, live weight	0.0133	0.00497
Switch 4: IDF		
Determining product:		
Milk	0.799	0.756
Meat		
By-products:		
Cattle meat, live weight	0.201	0.244
Exported animals for raising, live weight		

4 The plant cultivation system

The geographical delimitation for the plant cultivation system is the same as for 2005 as described by Schmidt and Dalgaard (2012, p 60). The geographical delimitation regarding the origin of the cattle feed is the same applied in Schmidt and Dalgaard (2012, p 62).

Land tenure is an input to all crop inventories. The amount of land required for cultivation depends on the land productivity, here measured as land Net Primary Productivity (NPP). Based on the distribution of cow's milk production on farm in the United Kingdom and Germany from Eurostat (2013), a value for the land NPP is chosen from Haberl et al. (2007). In Germany the milk production on farm is rather equally distributed on the national land, therefore all the national land is considered. The NPP in Germany is 600 kg C/ha y and slightly higher in the central and southern regions. Hence, the NPP value assumed for Germany is 650 kg C/ha year. In the UK the milk production on farm takes place mainly on the west and south coast while the NPP is slightly above the national average (500 kg C/ha y) on the south coast. Hence, for the UK a value of NPP of 550 kg C/ha year is assumed.

Barley is regarded as the most competitive and thereby the most relevant source of feed energy to be considered, when inventorying the global market for feed energy. Data on amount of barley produced in different countries in 1980'ies and 1990'ies are of low quality, so identification of the marginal barley producer is related to significant uncertainties. It is assumed, Ukraine is the marginal producer. However, it should be noticed that the global market for barley is not widely affected in the model; it is only affected in cases where the generic global market for feed energy is affected, and this is only the case when either constrained feedstuff is used (e.g. when rapeseed meal is used; rapeseed meal is constrained by the demand for rapeseed oil) or when the used feedstuff is associated with the production of by-products of feed energy (Schmidt and Dalgaard 2012).

4.1 Inputs and outputs of products

General description of 1990-data on inputs and outputs

A general overview of data on inputs and outputs used for modelling 1990-results for the plant cultivation system is presented in the following. For more detailed information on 1990-data see the subsections, where crop specific data are presented.

The amount of mineral N fertiliser and manure applied to crop fields and grass is a determining parameter, when calculating greenhouse gases emitted from crop cultivation while P and K artificial fertiliser have a lower impact in terms of GHG emissions. Due to their minor impact, data on P and K fertilizer application has been assumed as equal to the figures used in Schmidt and Dalgaard (2012). Data concerning fertiliser application for specific crops in 1990 are based on the British Survey of Fertilizer Practice (British Survey 1993). When data on fertiliser application on a crop type were not available, an average value of fertiliser was used, calculated as the average of the available value relative to other crops. **Table 4.1** shows this average value for the UK and the default value used for P and K fertiliser.

The British Survey of Fertilizer Practice was not available for 1990. The 1992 survey is based on information collected between September 1991 and September 1992 and it is therefore reasonable to assume the fertilizer application in 1990 was in the same range of values as in 1991**.**

Table 4.1: Calculated average value of artificial N fertiliser used per ha in the United Kingdom in 1992. Source: British Survey of fertilizer practice (British Survey 1993)

	Kg N per ha	Kg P_2O_5 per ha	Kg K_2O per ha
United Kingdom			
1992	155	38	45

German data regarding fertilizer application on crop fields and grass in 1990 seem not to be available, thus it is assumed that the same amount of fertilizer applied in the UK was also applied in Germany for each crop. However, different crops were grown in Germany (FAOSTAT 2013). Therefore the calculated average value of mineral fertiliser for Germany is 153 Kg N per ha while the default value for P and K are equal to data shown in **Table 4.1**.

Data concerning the total N mineral fertiliser applied in 1990 in Germany and the UK are based on IFA (2013). The distribution of both mineral N and manure applied on crops for each country is calculated based on data from the British Survey of fertiliser Practice (British Survey 1993) and the area occupied by agricultural land, excluding meadows and pasture (both permanent and rotation grass) from FAOSTAT. The percentage of this land occupied by a crop or a plantation is the distribution key of the total fertiliser available applied on this crop or plantation. For each crop and plantation is assumed that both mineral fertiliser and manure follows this distribution. The distribution of N fertiliser between different fertiliser types is based on data from IFA (2013) and presented in **Table 4.2**. Data from Ukraine are not available from FAOSTAT (2013), hence data from Russia are used.

Table 4.2: Distribution of N between different types of artificial N fertiliser types. Based on IFA (2013)

Fertiliser types	UK	DE	UA	EU
N-fert: Ammonia	0.40%	0%	0%	1.45%
N-fert: Urea	15.8%	14.1%	14.6%	22.5%
N-fert: AN	78.4%	0%	82.5%	37.3%
N-fert: CAN	5.4%	84.2%	0%	34.4%
N-fert: AS	0%	1.7%	2.89%	4.36%
Total	100%	100%	100%	100%

Data on N excreted yearly per animal type in 1990 shown in **Table 4.3** are calculated in Dalgaard and Schmidt (2012a) and are here assumed to be representative for animals in Germany and the United Kingdom. The total N excretion form livestock in both countries can then be calculated by multiplying the value per animal with number of animals obtained from FAOSTAT (2013).

Table 4.3: N excretion per animal. Calculated from Mikkelsen et al. (2006) and FAOSTAT (2013)

Animal type	N excretion, kg N per animal
Cattle	67.8
Pigs	12.1
Poultry	0.60
Horses	157
Sheep	12.2 (12.4)

The total manure excreted indoor is calculated subtracting the manure excreted outdoor to the total manure. The manure excreted outdoor is instead accounted as manure directly applied on pasture, (permanent and rotation grass) and calculated by using data about animal grazing time. The amount of manure applied per hectare for specific crops in the UK and Germany follows the same distribution of the mineral fertilizer. When specific data on fertiliser application on a crop were not available, the average value calculated from all the available specific fertiliser data was used. The average value of manure applied calculated for the UK and Germany are presented in **Table 4.4**. Values for other countries are the same as for Dalgaard and Schmidt (2012a).

Table 4.4: Calculated average manure application in 1990 at arable land in different countries. Unit: kg N ha^{-1} yr^{-1}

Country:	UK	DE	UA	FR	EU
Manure applied	77	112	49	99	105

Data on pesticide use are the same used in Schmidt and Dalgaard (2012) for the following reasons:

- The contribution from pesticides to greenhouse gas emission per kg crop is very low. Corn cultivated in EU is the most pesticide using crop according to Dalgaard and Schmidt (2012b). Despite that, the contribution to global warming potential from pesticides is less than 0.06% per kg corn cultivated.
- No data are apparently available.
-

Data on use of ‘light fuel for drying’, ‘pesticides’ and ‘lorry’ are assumed to be the same as the data used in Dalgaard and Schmidt (2012b).

Barley

The inputs and outputs of products related to barley cultivation are presented in **Table 4.5**. Data on yields are obtained from FAOSTAT (2013). The barley yields are calculated by linear regression over the period 1980-1995. The yield of barley cultivated in Ukraine is calculated as an average of the yields over the period 1992-1995. Yields for the specific year 1990 are not used because yields can vary considerable amongst years due to drought, diseases etc.

Table 4.5: Outputs and inputs of products. Barley cultivation. The data represent 1 ha year

	Crop:	**Barley**			
Outputs and inputs of products	**Country:** **Unit:**	UK	DE	UA	EU
Output of products					
Barley	kg	5,219	5,139	3,156	3,807
Input of products					
N-fert: Ammonia	kg N	0.327	0	0	1.01
N-fert: Urea	kg N	12.9	8.36	8.76	15.6
N-fert: AN	kg N	64.0	0	49.5	25.9
N-fert: CAN	kg N	4.41	49.7	0	23.9
N-fert: AS	kg N	0	1.00	1.74	3.02
Manure	Kg N	58.1	86.6	49.2	105
P fert: TSP	kg P_2O_5	42.7	42.7	137	42.8
K fert: KCl	kg K_2O	56.0	56.0	167	185
Pesticides	kg (a.s.)	0.509	0. 509	0.509	0.509
Lorry	tkm	84.7	79.0	119	80.6
Diesel	MJ	3,046	3,046	3,046	3,046
Light fuel oil for drying	MJ	1.10	1.10	1.10	1.10
Land tenure, arable	kg C	5,500	6,500	5,000	7,000

The amount of mineral fertiliser and manure applied is presented in **Table 4.5.** Data are obtained from:

- United Kingdom: the value of average mineral N fertiliser application for barley (118 kg N in 1993) is reported in the British Survey of fertiliser Practice (British Survey 1993). Distribution of the total N fertiliser applied among different crops is calculated based on data from the British Survey of fertiliser Practice (British Survey 1993) and the area occupied by crops (FAOSTAT 2013), as explained above in the general description.
- Germany: data concerning mineral fertilizer application in 1990 were not available for Germany. Therefore it has been assumed the mineral N fertilizer application per crops was equal to the application in the UK. Distribution of mineral N fertiliser between different fertiliser types is based on IFA (2013), as presented in **Table 4.2**.
- Application of manure is calculated by using the procedure described above, but taking into account the country specific manure application rates.
- Data concerning the application of P and K fertiliser to barley are assumed to be equal to Dalgaard and Schmidt (2012a). The recommended amount depends on the crop cultivated the previous year, and the figures used in the model are an average of all. The impact from P and K fertiliser use on the result is very small (Schmidt and Dalgaard 2012).

For further explanation see the section ‘General description of 1990-data on inputs and outputs ‘.

Wheat, corn and soybean

The inputs and outputs of products related to wheat, corn and soybean cultivation are presented in **Table 4.6**. The yields are calculated by linear regression over the period 1980-1995. Data on yields are obtained from FAOSTAT (2013). Yields for the specific year 1990 are not used because yields can vary considerable amongst years due to drought, diseases etc.

Table 4.6: Outputs and inputs of products. Wheat, corn and soybean cultivation. The data represent 1 ha year

	Crop:	**Wheat**		**Corn**	**Soybean**
Outputs and inputs of products	**Country:** **Unit:**	UK	DE	EU	BR
Output of products					
Wheat/corn/soybean	kg	6,918	6,242	5,248	1,873
Input of products					
N-fert: Ammonia	kg N	0.521	-	1.96	-
N-fert: Urea	kg N	20.5	13.3	30.4	-
N-fert: AN	kg N	102	-	50.5	-
N-fert: CAN	kg N	7.03	79	46.6	-
N-fert: AS	kg N	0	1.60	5.90	-
Manure	Kg N	92.7	138	105	-
P fert: TSP	kg P_2O_5	50.0	50.0	87.8	36.6
K fert: KCl	kg K_2O	64.8	64.8	221	-
Pesticides	kg (a.s.)	0.60	0.60	3.53	2.50
Lorry	tkm	119	110	198	17.4
Diesel	MJ	3.30	3.30	3.30	1.70
Light fuel oil for drying	MJ	1.10	1.10	1.10	1.10
Land tenure, arable	kg C	5,500	6,500	7,000	9,000

The amount of fertiliser and manure applied are presented in **Table 4.6.** Details concerning data sources are presented below:

- Wheat cultivated in the UK: The same procedure to calculate the N application as for barley cultivation is used. The recommended fertiliser use for wheat is 188 kg N.
- Wheat cultivated in Germany: The same procedure is used as for barley cultivation. The recommended fertiliser use for wheat is assumed equal to the UK data.
- Corn cultivated in EU: Data are assumed equal to the data calculated in Dalgaard and Schmidt (2012a).
- Soybean: Data are assumed equal to the data calculated in Dalgaard and Schmidt (2012a).
- Data concerning the application of P and K fertiliser are assumed to be equal to Dalgaard and Schmidt (2012a)

Distribution of N fertiliser between different fertiliser types is based on IFA (2013), as presented in **Table 4.2**. For further explanation see the section ‘General description of 1990-data on inputs and outputs ‘.

Rapeseed, sugar beet, sunflower and oil palm

The inputs and outputs of products related to rape seed, sugar beet, oil palm and sunflower cultivation are presented in **Table 4.7.** The yields are calculated by linear regression over the period 1980-1995. Data on yields are obtained from FAOSTAT (2013). Yields for the specific year 1990 are not used, because yields can vary considerable amongst years due to drought, diseases etc.

Table 4.7: Outputs and inputs of products. Rapeseed, sugar beet, sunflower and oil palm. The data represent 1 ha year

Outputs and inputs of products	Crop:	Rapeseed		Sugar beet	Sunflower	Oil palm
	Country: Unit:	UK	DE	DE	FR	MY
Output of products						
Rapeseed/sugar beet/sunflower/oil palm	kg	2,929	2,880	47,452	2,223	17,803
Input of products						
N-fert: Ammonia	kg N	0.546	0	0	3.73	0
N-fert: Urea	kg N	21.6	14.0	8.64	27.9	67.2
N-fert: AN	kg N	107	0	0	116	5.65
N-fert: CAN	kg N	7.37	83.1	51.5	0	0
N-fert: AS	kg N	0	1.67	1.04	4.86	88.7
Manure	Kg N	97.1	144.6	89.5	99.0	0
P fert: TSP	kg P_2O_5	64.9	22.9	87.8	61.5	0
K fert: KCl	kg K_2O	121	20.5	191	90.4	268
Pesticides	kg (a.s.)	0.270	0.802	2.74	0.270	2.60
Lorry	tkm	147	86	146	144	243
Diesel	MJ	3,195	3,195	8,581	3,306	1,710
Light fuel oil for drying	MJ	1.10	1.10	0	1.10	0
Land tenure, arable	kg C	5,500	6,500	6,500	7,000	11,000

The amount of fertiliser and manure applied are presented in **Table 4.7**. Details concerning data sources are presented below:

- Rapeseed cultivated in the UK: The same procedure to calculate the N application as for barley cultivation is used. The N fertiliser used for rapeseed cultivation in 1992 was 197 kg N (British Survey 1993).
- Rapeseed cultivated in Germany: The N fertiliser use for rapeseed is assumed equal to the UK data.
- Sunflower: The application of fertiliser to sunflower cultivation is assumed to equal to the amount calculated in Dalgaard and Schmidt (2012a).
- Sugar beet cultivated in Germany: The same procedure to calculate the N application as for barley cultivation is used. The recommended fertiliser use for sugar beet in 1992 was 122 kg N, assumed equal to the N fertilizer applied in the UK for that cultivation (British Survey 1993).
- Data concerning the application of P and K fertiliser are assumed to be equal to Dalgaard and Schmidt (2012a)
- Oil Palm cultivated in Malaysia: data about fertilizer application to oil palm cultivation are assumed to be equal to the data used in Dalgaard and Schmidt (2012a).

Distribution of N fertiliser between different fertiliser types based on IFA (2013), as presented in **Table 4.2**. For further explanation see the section ‘General description of 1990-data on inputs and outputs‘.

Permanent grass incl. grass ensilage

The inputs and outputs of products related production of ‘Permanent grass incl. grass ensilage’ are presented in **Table 4.8**. The yields of permanent grass are seldom measured, thus these yields might be less precise, compared to the previously presented yields.

Based on the NPP values the yields in the UK and in Germany are assumed to be respectively 21% and 7% lower than the Danish yield used in Dalgaard and Schmidt (2012b) as the potential net primary production (NPP_0) is lower in cultivated regions in Germany and the United Kingdom.

The amount of fertiliser and manure applied are presented in **Table 4.8**. The N application on permanent grass is considered as contained in the manure excreted outdoor. The fertiliser applied on permanent grass is calculated based on the distribution of fertiliser between permanent and rotation grass (**Table 4.10**). Grass area is split in permanent and rotation grass area according to the percentages registered for the year 1992 by the British Survey of Fertiliser Practices (British Survey 1993). The distribution between permanent and rotation grass is also used to distribute the manure excreted outdoor between the two categories. Only the remaining amount is considered as provided by mineral fertiliser. The recommended application of fertiliser is assumed to be 125 kg N (British Survey 1993). Data concerning the application of P and K fertiliser are assumed to be equal to Dalgaard and Schmidt (2012a).

Table 4.8: Outputs and inputs of products. Permanent grass incl. grass ensilage cultivation. The data represent 1 ha year

Outputs and inputs of products	**Crop:** **Country:** **Unit:**	**Permanent grass incl. grass ensilage** UK	 DE
Output of products			
Permanent grass incl. grass ensilage	kg	9,136	10,797
Input of products			
N-fert: Ammonia	kg N	0.229	0
N-fert: Urea	kg N	9.06	14.2
N-fert: AN	kg N	44.9	0
N-fert: CAN	kg N	3.10	84.3
N-fert: AS	kg N	0	1.70
Manure	Kg N	90.9	54.2
P fert: TSP	kg P_2O_5	35.1	35.1
K fert: KCl	kg K_2O	109	109
Lorry	tkm	85	122
Diesel	MJ	557	557
Land tenure, arable	kg C	5,500	6,500

Distribution of N fertiliser between different fertiliser types is based on IFA (2013), as presented in **Table 4.2**. Only one type of P fertiliser and one type of K fertiliser is used.

For further explanation see the section ‘General description of 1990-data on inputs and outputs‘.

Rotation grass incl. grass ensilage and roughage, ensilage

The inputs and outputs of products related to production of rotation grass and roughage are presented in **Table 4.9.** The amount of fertiliser and manure applied are also shown. The N application on permanent grass is considered as contained in the manure excreted outdoor. Only the remaining amount is considered as provided by mineral fertiliser. The recommended application of fertiliser is assumed to be 181 kg N (British Survey 1993).

Table 4.9: Outputs and inputs of products. Rotation grass incl. grass ensilage and roughage ensilage. The data represent 1 ha year

Outputs and inputs of products	Crop: Country: Unit:	Rotation grass incl. grass ensilage		Roughage, ensilage	
		UK	DE	UK	DE
Output of products					
Rotation grass/roughage	kg	35,077	41,454	30,498	36.043 36,043
Input of products					
N-fert: Ammonia	kg N	0.495	0	0.431	0
N-fert: Urea	kg N	19.5	23.9	17.0	10.8
N-fert: AN	kg N	97.0	0	84.4	0
N-fert: CAN	kg N	6.68	143	5.81	64.5
N-fert: AS	kg N	0	2.88	0	1.30
Manure	Kg N	90.9	54.2	76.6	112
P fert: TSP	kg P_2O_5	80.2	0	57.3	57.3
K fert: KCl	kg K_2O	196	0	181	181
Lorry	tkm	172	119	147	139
Diesel	MJ	2,415	2,415	3,715	3,715
Land tenure, arable	kg C	5,500	6,500	5,500	6,500

The yield in the UK and Germany are assumed to be 21% and 7% lower than the Danish yield used in Dalgaard and Schmidt (2012) as the potential net primary productivity (NPP_0) is lower in cultivated regions in Germany and the United Kingdom (see Land tenure in **Table 4.21**).

Data concerning area covered with permanent, rotation grass and fodder crops (ensilage) are shown in **Table 4.10**. The data are not directly available from FAOSTAT. Therefore they are calculated combining general data about area for crop cultivation in 1990 in both countries (FAOSTAT 2013) and data from the British Survey of Fertiliser Practices (British Survey 1993). The area covered by fodder crop is calculated as the difference between the total country arable land area and the area reported in FAOSTAT (2013) for specific cultivations. Grass area is split in permanent and rotation grass area according to the percentages registered for the year 1992 by the British Survey of Fertiliser Practices (British Survey 1993). The distribution between permanent and rotation grass is also used to distribute the manure excreted outdoor between the two categories.

Table 4.10: Hectares of permanent grass, rotation grass and fodder crops in Germany and the United Kingdom. Source: own elaboration from FAOSTAT (2013)

Country	Crop:	Permanent grass	Rotation grass	Fodder crops (ensilage)
Germany				
Area	Ha	4,573,052	1,044,948	5,668,292
United Kingdom				
Area	Ha	9,374,838	2,142,162	1,729,809

Distribution of N fertiliser between different fertiliser types based on IFA (2013), as presented in **Table 4.2**.

For further explanation see the section ‘General description of 1990-data on inputs and outputs.

4.2 Utilisation of crop residues

It is assumed the crop residues not are removed.

4.3 Emissions

Barley

The parameters used for calculation of emissions from cultivation of barley are presented in **Table 4.11**.

Table 4.11: Parameters used for calculation of emissions from cultivation of barley. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006)

Parameter	Crop:	Barley				Source
	Country: Unit:	UK	DE	UA	EU	
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	1.90	1.95	1.42	2.12	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	0.625	0.671	0.477	0.757	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	1.90	1.95	1.42	2.12	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	0	Equation 7.3(*)
$N_2O\text{-}N_{PRP}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	0	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	81.7	59.1	60.0	69	**Table 4.5**
F_{ON}	kg N ha^{-1} yr^{-1}	58.2	86.6	49.2	105	**Table 4.5**
F_{CR}	kg N ha^{-1} yr^{-1}	49.8	49.1	32.4	37.9	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	4,436	4,368	2,683	3,236	Table 11.2 (**)
Slope	Dim. less	0.980	0.980	0.980	0.980	Table 11.2 (**)
Intercept	Dim. less	0.590	0.590	0.590	0.590	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	4,937	4,871	3,219	3,761	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.007	0.007	0.007	0.007	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0	0	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.220	0.220	0.220	0.220	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.014	0.014	0.014	0.014	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	0	0	See text
F_{OS}	ha	0	0	0	0	See text
F_{PRP}	kg N yr^{-1}	0	0	0	0	No grazing
EF_1	kg N_2O–N kg N^{-1}	0.01	0.01	0.01	0.01	Table 11.1 (**)
EF_2	kg N_2O–N ha^{-1} yr^{-1}	8.00	8.00	8.00	8.00	Table 11.1 (**)
EF_{3PRP}	kg N_2O–N kg N^{-1}	0.02	0.02	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	0.10	0.10	0.10	Table 11.3 (**)
$Frac_{GASM}$	kg N kg N^{-1}	0.20	0.20	0.20	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	0.30	0.30	0.30	Table 11.3 (**)
EF_4	kg N_2O–N kg N^{-1}	0.01	0.01	0.01	0.01	Table 11.3 (**)
EF_5	kg N_2O–N kg N^{-1}	0.0075	0.0075	0.0075	0.0075	Table 11.3 (**)

F_{SOM} is assumed to be $F_{SOM} = 0$. This is in line with the assumption for changes of carbon on mineral soils: Change of carbon content in mineral soils is not included because it is argued that the changes only occur in a limited period after establishment of a certain crop.

The N inputs, outputs and emissions related to barley cultivation are presented **Table 4.12**. $N_{surplus}$ equals the sum of the N emissions, and the N balance is calculated as N surplus minus N emissions. When the N balance equals 0, it means all N is accounted for.

Table 4.12: N balances and emissions related to barley cultivation. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}

Parameter	**Barley**				**Source**
	UK	DE	UA	EU	
N inputs					
N_{input}	190	195	148	142	Equation 7.1(*)
N-fert: Ammonia	0.327	0	0	1.01	**Table 4.5**
N-fert: Urea	12.9	8.36	8.76	15.6	**Table 4.5**
N-fert: AN	64.1	0	49.5	25.9	**Table 4.5**
N-fert: CAN	4.41	49.8	0	23.9	**Table 4.5**
N-fert: AS	0	1.00	1.74	3.02	**Table 4.5**
Manure	58.2	86.6	49.2	105	**Table 4.5**
Crop residues left in field	49.8	49.1	32.4	37.9	**Table 4.5**
N outputs					
N_{output}	76.7	75.5	46.4	55.9	Equation 7.1(*)
Harvested crop	76.7	75.5	46.4	55.9	**Table 4.5**
Crop residues removed	0	0	0	0	**Table 4.5**
N inputs - N outputs					
$N_{surplus}$	113	119	95.3	156	Equation 7.1(*)
N emissions					
NH_3-N	16.8	19.7	13.4	23.7	Section 7.4 (*)
NO_x-N	2.97	3.49	2.38	4.19	Section 7.4 (*)
N_2O-N_{direct}	1.90	1.95	1.42	2.12	Equation 7.3(*)
N_2-N	34.4	35.7	35.5	62.6	Section 7.4 (*)
NO_3-N	56.9	58.5	42.5	63.7	Section 7.4 (*)
N balance	0	0	0	0	See text

Wheat, corn and soybean

The parameters used for calculation of emissions from cultivation of barley are presented in **Table 4.13.**

Table 4.13: Parameters used for calculation of emissions from cultivation of wheat, corn and soybeans. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006)

Parameter	Crop: Country: Unit:	Wheat		Corn	Soybean	Source
		UK	DE	EU	BR	
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	3.00	3.02	2.81	0.278	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	0.990	1.049	0.976	0.063	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	3.00	3.02	2.81	0.278	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	0	Equation 7.3(*)
$N_2O\text{-}N_{PRP}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	0	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	130	94	135	0	**Table 4.6**
F_{ON}	kg N ha^{-1} yr^{-1}	92.7	138	105	0	**Table 4.6**
F_{CR}	kg N ha^{-1} yr^{-1}	76.7	69.6	40.3	27.8	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	5,880	5,306	4,592	1,693	Table 11.2 (**)
Slope	Dim. less	1.51	1.51	1.03	0.930	Table 11.2 (**)
Intercept	Dim. less	0.520	0.520	0.610	1.35	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	9,399	8,532	5,340	2,925	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.006	0.006	0.006	0.008	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0	0	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.240	0.240	0.220	0.190	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.009	0.009	0.007	0.008	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	0	0	See text
F_{OS}	ha	0	0	0	0	See text
F_{PRP}	kg N yr^{-1}	0	0	0	0	No grazing
EF_1	kg N_2O–N kg N^{-1}	0.01	0.01	0.01	0.01	Table 11.1 (**)
EF_2	kg N_2O–N ha^{-1} yr^{-1}	8.00	8.00	8.00	16.00	Table 11.1 (**)
EF_{3PRP}	kg N_2O–N kg N^{-1}	0.02	0.02	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	0.10	0.10	0.10	Table 11.3 (**)
$Frac_{GASM}$	kg N kg N^{-1}	0.20	0.20	0.20	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	0.30	0.30	0.30	Table 11.3 (**)
EF_4	kg N_2O–N kg N^{-1}	0.01	0.01	0.01	0.01	Table 11.3 (**)
EF_5	kg N_2O–N kg N^{-1}	0.0075	0.0075	0.0075	0.0075	Table 11.3 (**)

The N inputs, outputs and emissions related to wheat, corn and soybean cultivation are presented in **Table 4.14**. $N_{surplus}$ equals the sum of the N emissions, and the N balance is calculated as N surplus minus N emissions. When the N balance equals 0, it means all N is accounted for.

Table 4.14: N balances and emissions related to wheat, corn and soybean cultivation. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}

Parameter	**Wheat**		**Corn**	**Soybean**	**Source**
	UK	DE	EU	BR	
N inputs					
N_{input}	300	302	281	27.8	Equation 7.1(*)
N-fert: Ammonia	0.521	0	1.96	0	**Table 4.6**
N-fert: Urea	20.6	13.3	30.4	0	**Table 4.6**
N-fert: AN	102	0	50.5	0	**Table 4.6**
N-fert: CAN	7.03	79.3	46.6	0	**Table 4.6**
N-fert: AS	0	1.60	5.90	0	**Table 4.6**
Manure	92.7	138	105	0	**Table 4.6**
Crop residues left in field	76.7	69.6	40.3	27.8	**Table 4.6**
N outputs					
N_{output}	108	97.6	70.5	111	Equation 7.1(*)
Harvested crop	108	97.6	70.5	111	**Table 4.6**
Crop residues removed	0	0	0	0	**Table 4.6**
N inputs - N outputs					
$N_{surplus}$	191	204.2	210	-83.5	Equation 7.1(*)
N emissions					
NH_3-N	26.8	31.5	29.3	0	Section 7.4 (*)
NO_x-N	4.73	5.55	5.18	0	Section 7.4 (*)
N_2O-N_{direct}	3.00	3.02	2.81	0.278	Equation 7.3(*)
N_2-N	67.0	73.6	88.5	-92.1	Section 7.4 (*)
NO_3-N	89.9	90.5	84.2	8.35	Section 7.4 (*)
N balance	0	0	0	0	See text

Rapeseed, sugar beet, sunflower and oil palm

The parameters used for calculation of emissions from cultivation of rapeseed, sugar beet, sunflower and oil palm are presented in **Table 4.15**.

Table 4.15: Parameters used for calculation of emissions from cultivation of rapeseed, sugar beet, sunflower and oil palm. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006)

	Crop:	Rapeseed		Sugar beet	Sunflower	Oil palm	Source
Parameter	**Country:** **Unit:**	UK	DE	DE	FR	MY	
$N_2O\text{-}N_{direct}$	kg $N_2O–N$ ha^{-1} yr^{-1}	2.64	2.74	4.22	2.77	5.13	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg $N_2O–N$ ha^{-1} yr^{-1}	0.925	1.003	1.19	0.974	0.976	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg $N_2O–N$ ha^{-1} yr^{-1}	2.64	2.74	4.22	2.77	3.61	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg $N_2O–N$ ha^{-1} yr^{-1}	0	0	0	0	1.52	Equation 7.3(*)
$N_2O\text{-}N_{PRP}$	kg $N_2O–N$ ha^{-1} yr^{-1}	0	0	0	0	0	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	136	99	61	153	162	**Table 4.7**
F_{ON}	kg N ha^{-1} yr^{-1}	97.1	144.6	89.5	99.0	0	**Table 4.7**
F_{CR}	kg N ha^{-1} yr^{-1}	30.6	30.2	271	24.8	199	Equation 7.3(*), *
Crop	kg DM ha^{-1} yr^{-1}	2,709	2,664	10,439	2,045	8,367	Table 11.2 (**)
Slope	Dim. less	1.09	109	1.09	1.09	-	Table 11.2 (**)
Intercept	Dim. less	0.880	0.880	1.06	0.880	-	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	3,833	3,784	12,439	3.109	15,113	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.006	0.006	0.019	0.006	-	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0	0	0	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.220	0.220	0.200	0.220	-	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.009	0.009	0.014	0.009	-	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	0	0	0	See text
F_{OS}	ha	0	0	0	0	0.095	See text
F_{PRP}	kg N yr^{-1}	0	0	0	0	0	No grazing
EF_1	kg $N_2O–N$ kg N^{-1}	0.01	0.01	0.01	0.01	0.01	Table 11.1 (**)
EF_2	kg $N_2O–N$ ha^{-1} yr^{-1}	8.00	8.00	800	8.00	16.0	Table 11.1 (**)
EF_{3PRP}	kg $N_2O–N$ kg N^{-1}	0.02	0.02	0.02	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	0.10	0.10	0.10	0.10	Table 11.3 (**)
$Frac_{GASM}$	kg N kg N^{-1}	0.20	0.20	0.20	0.20	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	0.30	0.30	0.30	0.30	Table 11.3 (**)
EF_4	kg $N_2O–N$ kg N^{-1}	0.01	0.01	0.01	0.01	0.01	Table 11.3 (**)
EF_5	kg $N_2O–N$ kg N^{-1}	0.0075	0.0075	0.0075	00075	0.0075	Table 11.3 (**)

The N inputs, outputs and emissions related to rapeseed, sunflower, sugar beet and foil palm cultivation are presented in **Table 4.16.** $N_{surplus}$ equals the sum of the N emissions, and the N balance is calculated as N surplus minus N emissions. When the N balance equals 0, it means all N is accounted for.

Table 4.16: N balances and emissions related rape seed, sugar beet, sunflower and oil palm cultivation. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}

Parameter	Rapeseed		Sugar Beet	Sunflower	Oil Palm	Source
	UK	DE	DE	FR	MY	
N inputs						
N_{input}	264	274	422	277	361	Equation 7.1(*)
N-fert: Ammonia	0.546	0	0	3.73	0	**Table 4.7**
N-fert: Urea	21.6	14.0	8.64	27.9	67.2	**Table 4.7**
N-fert: AN	107	0	0	116	5.65	**Table 4.7**
N-fert: CAN	7.37	83.1	51.5	0	0	**Table 4.7**
N-fert: AS	0	1.68	1.039	4.86	89	**Table 4.7**
Manure	97.1	145	90	99.0	0.581	**Table 4.7**
Crop residues left in field	30.6	30.2	271	24.8	199	**Table 4.7**
N outputs						
N_{output}	84.1	82.7	99	60.2	46.0	Equation 7.1(*)
Harvested crop	84.1	82.7	99	60.2	46.0	**Table 4.7**
Crop residues removed	0	0	0	0	0	**Table 4.7**
N inputs - N outputs						
$N_{surplus}$	180	191	323	217	315	Equation 7.1(*)
N emissions						
NH_3-N	28.1	33.0	20.42	29.8	13.8	Section 7.4 (*)
NO_x-N	4.96	5.82	3.60	5.26	2.44	Section 7.4 (*)
N_2O-N_{direct}	2.64	2.74	4.22	2.77	5.13	Equation 7.3(*)
N_2-N	65.1	67.2	169	95.6	186	Section 7.4 (*)
NO_3-N	79.2	82.1	127	83.0	108	Section 7.4 (*)
N balance	0	0	0	0	0	See text

Permanent grass incl. grass ensilage

The parameters used for calculation of emissions from cultivation of permanent grass incl. grass ensilage are presented in **Table 4.17**.

Table 4.17: Parameters used for calculation of emissions from cultivation of permanent grass incl. grass ensilage. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006)

Parameter	Crop: Country: Unit:	Permanent grass incl. grass ensilage		Source
		UK	DE	
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	2.51	2.23	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	0.600	0.588	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	0.695	1.15	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	Equation 7.3(*)
$N_2O\text{-}N_{PRP}$	kg N_2O–N ha^{-1} yr^{-1}	1.82	1.08	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	57.3	100	**Table 4.8**
F_{ON}	kg N ha^{-1} yr^{-1}	0	0	**Table 4.8**
F_{CR}	kg N ha^{-1} yr^{-1}	12.1	14.3	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	1,645	1.944	Table 11.2 (**)
Slope	Dim. less	0.300	0.300	Table 11.2 (**)
Intercept	Dim. less	0	0	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	493	583	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.0150	0.0150	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.800	0.800	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.012	0.012	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	See text
F_{OS}	ha	0	0	See text
F_{PRP}	kg N yr^{-1}	90.8	54.2	No grazing
EF_1	kg N_2O–N kg N^{-1}	0.01	0.01	Table 11.1 (**)
EF_2	kg N_2O–N ha^{-1} yr^{-1}	8.00	8.00	Table 11.1 (**)
EF_{3PRP}	kg N_2O–N kg N^{-1}	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	0.10	Table 11.3 (**)
$Frac_{GASM}$	kg N kg N^{-1}	0.20	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	0.30	Table 11.3 (**)
EF_4	kg N_2O–N kg N^{-1}	0.01	0.01	Table 11.3 (**)
EF_5	kg N_2O–N kg N^{-1}	0.0075	0.0075	Table 11.3 (**)

The N inputs, outputs and emissions related to cultivation of permanent grass incl. grass ensilage are presented in **Table 4.18**. $N_{surplus}$ equals the sum of the N emissions, and the N balance is calculated as N surplus minus N emissions.

Table 4.18: N balances and emissions related to cultivation of permanent grass incl. grass ensilage. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}

Parameter	Permanent grass incl. grass ensilage		Source
	UK	DE	
N inputs			
N_{input}	160	169	Equation 7.1(*)
N-fert: Ammonia	0.229	0	**Table 4.8**
N-fert: Urea	9.06	14.2	**Table 4.8**
N-fert: AN	44.9	0	**Table 4.8**
N-fert: CAN	3.10	84.3	**Table 4.8**
N-fert: AS	0	1.70	**Table 4.8**
Manure	90.9	54.2	**Table 4.8**
Crop residues left in field	12.1	14.3	**Table 4.8**
N outputs			
N_{output}	52.6	62.2	Equation 7.1(*)
Harvested crop	52.6	62.2	**Table 4.8**
Crop residues removed	0	0	**Table 4.8**
N inputs - N outputs			
$N_{surplus}$	108	107	Equation 7.1(*)
N emissions			
NH_3-N	20.3	17.7	Section 7.4 (*)
NO_x-N	3.59	3.13	Section 7.4 (*)
N_2O-N_{direct}	2.51	2.23	Equation 7.3(*)
N_2-N	33.2	32.8	Section 7.4 (*)
NO_3-N	48.1	50.6	Section 7.4 (*)
N balance	0	0	See text

Rotation grass incl. grass ensilage and roughage, ensilage

The parameters used for calculation of emissions from cultivation of rotation grass incl. grass ensilage and roughage, ensilage are presented in **Table 4.19**.

Table 4.19: Parameters used for calculation of emissions from cultivation of rotation grass incl. grass ensilage and roughage, ensilage. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006)

	Crop:	Rotation grass incl. grass ensilage		Roughage, ensilage		Source
Parameter	Country: Unit:	UK	DE	UK	DE	
$N_2O\text{-}N_{direct}$	kg $N_2O–N$ ha^{-1} yr^{-1}	3.95	3.80	2.50	2.67	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg $N_2O–N$ ha^{-1} yr^{-1}	0.989	1.01	0.824	0.901	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg $N_2O–N$ ha^{-1} yr^{-1}	2.13	2.71	2.50	2.67	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg $N_2O–N$ ha^{-1} yr^{-1}	0	0	0	0	Equation 7.3(*)
$N_2O\text{-}N_{PRP}$	kg $N_2O–N$ ha^{-1} yr^{-1}	1.82	1.08	0	0	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	124	169	108	76.6	**Table 4.9**
F_{ON}	kg N ha^{-1} yr^{-1}	0	0	76.6	112	**Table 4.9**
F_{CR}	kg N ha^{-1} yr^{-1}	89.1	101	65.8	78.0	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	6,659	7,615	10,212	12,101	Table 11.2 (**)
Slope	Dim. less	0.300	0.300	0.300	0.300	Table 11.2 (**)
Intercept	Dim. less	0	0	0	0	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	1,998	2,284	3,064	3,630	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.027	0.027	0.015	0.015	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0	0	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.800	0.800	0.540	0.540	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.022	0.022	0.012	0.012	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	0	0	See text
F_{OS}	ha	0	0	0	0	See text
F_{PRP}	kg N yr^{-1}	90.9	54.2	0	0	No grazing
EF_1	kg $N_2O–N$ kg N^{-1}	0.01	0.01	0.01	0.01	Table 11.1 (**)
EF_2	kg $N_2O–N$ ha^{-1} yr^{-1}	8.00	8.00	8.00	8.00	Table 11.1 (**)
EF_{3PRP}	kg $N_2O–N$ kg N^{-1}	0.02	0.02	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	0.10	0.10	0.10	Table 11.3 (**)
$Frac_{GASM}$	kg N kg N^{-1}	0.20	0.20	0.20	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	0.30	0.30	0.30	Table 11.3 (**)
EF_4	kg $N_2O–N$ kg N^{-1}	0.01	0.01	0.01	0.01	Table 11.3 (**)
EF_5	kg $N_2O–N$ kg N^{-1}	0.0075	0.0075	0.0075	0.0075	Table 11.3 (**)

The N inputs, outputs and emissions related to barley cultivation are presented in **Table 4.20**. $N_{surplus}$ equals the sum of the N emissions, and the N balance is calculated as $N_{surplus}$ minus N emissions. When the N balance equals 0, it means all N is accounted for.

Table 4.20: N balances and emissions related cultivation of rotation grass incl. grass ensilage and roughage, ensilage. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}

Parameter	**Rotation grass incl. grass ensilage**		**Roughage, ensilage**		**Source**
	UK	DE	UK	DE	
N inputs					
N_{input}	304	325	250	267	Equation 7.1(*)
N-fert: Ammonia	0.495	0	0.431	0	**Table 4.9**
N-fert: Urea	19.5	23.9	17.0	10.8	**Table 4.9**
N-fert: AN	97.0	0	84.4	0	**Table 4.9**
N-fert: CAN	6.68	143	5.81	64.5	**Table 4.9**
N-fert: AS	0	2.88	0	1.30	**Table 4.9**
Manure	90.9	54.2	76.6	112	**Table 4.9**
Crop residues left in field	89.1	102	65.8	78.0	**Table 4.9**
N outputs					
N_{output}	245	280	129	153	Equation 7.1(*)
Harvested crop	245	280	129	153	**Table 4.9**
Crop residues removed	0	0	0	0	**Table 4.9**
N inputs - N outputs					
$N_{surplus}$	59	45.24	121	113	Equation 7.1(*)
N emissions					
NH_3-N	26.0	23.6	22.2	25.6	Section 7.4 (*)
NO_x-N	4.58	4.17	3.91	4.52	Section 7.4 (*)
N_2O-N_{direct}	3.95	3.80	2.50	2.67	Equation 7.3(*)
N_2-N	-67.0	-84.0	17.4	1.0	Section 7.4 (*)
NO_3-N	91.1	97.6	75.0	80.0	Section 7.4 (*)
N balance	0	0	0	0	See text

4.4 Summary of the LCI of plant cultivation

LCIs of for the different crops in the plant cultivation system are presented in **Table 4.21** to **Table 4.25**. All data sources and calculations are documented in the previous sections.

Table 4.21: LCI of barley cultivation. The data represent 1 ha year

	Crop:	**Barley**			
	Country:	UK	DE	UA	EU
Exchanges	**Unit:**				
Output of products					
Barley	kg	5,219	5,139	3,156	3,807
Input of products					
N-fert: Ammonia	kg N	0.327	0	0	1.01
N-fert: Urea	kg N	12.9	8.36	8.76	15.6
N-fert: AN	kg N	64.1	0	49.5	25.9
N-fert: CAN	kg N	4.41	49.8	0	23.9
N-fert: AS	kg N	0	1.00	1.74	3.02
Manure	Kg N	58.2	86.6	49.2	105
P fert: TSP	kg P_2O_5	42.8	42.8	137	42.8
K fert: KCl	kg K_2O	56.0	56.0	167	185
Pesticides	kg (a.s.)	0.509	0.509	0.509	0.509
Lorry	tkm	84.8	79.0	119	80.6
Diesel	MJ	3,046	3,046	3,046	3,046
Light fuel oil for drying	MJ	1.10	1.10	1,10	1.10
Land tenure, arable	kg C	5,500	6,500	5,000	7,000
Emissions					
Dinitrogen monoxide (direct)	kg N_2O	2.98	3.06	2.23	3.33
Dinitrogen monoxide (indirect)	kg N_2O	0.98	1.05	0.750	1.19
Ammonia	kg NH_3	20.4	24.0	16.3	28.8
Nitrogen oxides	kg NO_x	6.37	7.47	5.09	8.97
Nitrate	kg NO_3	252	259	188	282

Table 4.22: LCI of wheat, corn and soybean cultivation. The data represent 1 ha year

Exchanges	**Crop:**	**Wheat**		**Corn**	**Soybean**
	Country: **Unit:**	UK	DE	EU	BR
Output of products					
Wheat/corn/soybean	kg	6,918	6,242	5,248	1,873
Input of products					
N-fert: Ammonia	kg N	0.521	0	1.96	0
N-fert: Urea	kg N	20.6	13.3	30.4	0
N-fert: AN	kg N	102	0	50.5	0
N-fert: CAN	kg N	7.03	79.3	46.6	0
N-fert: AS	kg N	0	1.60	5.90	0
Manure	Kg N	92.7	138	105	0
P fert: TSP	kg P_2O_5	50.0	50.0	87.8	36.6
K fert: KCl	kg K_2O	64.8	64.8	221	0
Pesticides	kg (a.s.)	0.603	0.603	3.53	2.50
Lorry	tkm	119	110	198	17.4
Diesel	MJ	3,306	3,306	3,306	1,709
Light fuel oil for drying	MJ	1.10	1.10	1.10	1.10
Land tenure, arable	kg C	5,500	6,500	7,000	9,000
Emissions					
Dinitrogen monoxide (direct)	kg N_2O	4.71	4.74	4.41	0.438
Dinitrogen monoxide (indirect)	kg N_2O	1.56	1.65	1.53	0.098
Ammonia	kg NH_3	32.6	38.2	35.6	0
Nitrogen oxides	kg NO_x	10.1	11.9	11.1	0
Nitrate	kg NO_3	398	401	373	37.0

Table 4.23: LCI of rapeseed, sugar beet, sunflower and oil palm. The data represent 1 ha year

Exchanges	Crop: Country: Unit:	Rapeseed		Sugar beet	Sunflower	Oil palm
		UK	DE	DE	FR	MY
Output of products						
Rapeseed/sugar beet/sunflower/oil palm	kg	2,929	2,880	47,452	2,223	17,803
Input of products						
N-fert: Ammonia	kg N	0.546	0	0	3.73	0
N-fert: Urea	kg N	21.6	14.0	8.64	27.9	67.2
N-fert: AN	kg N	107	0	0	116	5.65
N-fert: CAN	kg N	7.37	83.1	51.5	0	0
N-fert: AS	kg N	0	1.68	1.04	4.86	88.7
Manure	Kg N	97.1	145	90	99.0	0
P fert: TSP	kg P_2O_5	64.9	22.9	87.8	61.5	0
K fert: KCl	kg K_2O	121	20.5	191	90.4	268
Pesticides	kg (a.s.)	0.270	0.802	2.74	0.270	2.60
Lorry	tkm	147	86.5	146	144	243
Diesel	MJ	3,195	3,195	8,581	3,306	1,710
Light fuel oil for drying	MJ	1.10	1.10	0	1.10	0
Land tenure, arable	kg C	5,500	6,500	6,500	7,000	11,000
Emissions						
Dinitrogen monoxide (direct)	kg N_2O	4.15	4.30	6.63	4.35	8.07
Dinitrogen monoxide (indirect)	kg N_2O	1.45	1.58	1.87	1.53	1.53
Ammonia	kg NH_3	34.1	40.0	24.8	36.2	16.8
Nitrogen oxides	kg NO_x	10.6	12.5	7.72	11.3	5.23
Nitrate	kg NO_3	351	363	560	368	480

Table 4.24: LCI of permanent grass incl. grass ensilage cultivation. The data represent 1 ha year

Exchanges	Crop: Country: Unit:	Permanent grass incl. grass ensilage	
		UK	DE
Output of products			
Permanent grass incl. grass ensilage	kg	9,136	10,797
Input of products			
N-fert: Ammonia	kg N	0.229	0
N-fert: Urea	kg N	9.06	14.2
N-fert: AN	kg N	44.9	0
N-fert: CAN	kg N	3.10	84.3
N-fert: AS	kg N	0	1.70
Manure	Kg N	90.9	54.2
P fert: TSP	kg P_2O_5	35.1	35.1
K fert: KCl	kg K_2O	109	109
Lorry	tkm	84.7	122
Diesel	MJ	557	557
Land tenure, arable	kg C	0	0
Land tenure, int. forest land	kg C	5,500	6,500
Emissions			
Dinitrogen monoxide (direct)	kg N_2O	3.95	3.50
Dinitrogen monoxide (indirect)	kg N_2O	0.943	0.924
Ammonia	kg NH_3	24.7	21.5
Nitrogen oxides	kg NO_x	7.68	6.71
Nitrate	kg NO_3	213	224

Table 4.25: LCI of rotation grass incl. grass ensilage and roughage, ensilage cultivation. The data represent 1 ha year

	Crop:	Rotation grass incl. grass ensilage		Roughage, ensilage	
Exchanges	**Country:** **Unit:**	UK	DE	UK	DE
Output of products					
Rotation grass/roughage	kg	35,077	41,454	30,498	36,043
Input of products					
N-fert: Ammonia	kg N	0.495	0	0.431	0
N-fert: Urea	kg N	19.5	23.9	17.0	10.8
N-fert: AN	kg N	97.0	0	84.4	0
N-fert: CAN	kg N	6.68	143	5.81	64.5
N-fert: AS	kg N	0	2.88	0	1.30
Manure	Kg N	90.9	54.2	76.6	112
P fert: TSP	kg P_2O_5	80.2	0	57.3	57.3
K fert: KCl	kg K_2O	196	0	181	181
Pesticides	kg (a.s.)	0.0950	0.0950	0.0950	0.0950
Lorry	tkm	172	119	147	139
Diesel	MJ	2,415	2,415	3,715	3,715
Land tenure, arable	kg C	5,500	6,500	5,500	6,500
Emissions					
Dinitrogen monoxide (direct)	kg N_2O	6.20	5.97	3.93	4.19
Dinitrogen monoxide (indirect)	kg N_2O	1.55	1.59	1.29	1.42
Ammonia	kg NH_3	31.5	28.7	26.9	31.1
Nitrogen oxides	kg NO_x	9.82	8.93	8.39	9.68
Nitrate	kg NO_3	403	432	332	354

5 The food industry system

5.1 Inventory of soybean meal system (soybean meal)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

5.2 Inventory of rapeseed oil system (rapeseed meal)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

5.3 Inventory of sunflower oil system (sunflower meal)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

5.4 Inventory of palm oil system (palm oil and palm kernel meal)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

5.5 Inventory of sugar system (molasses and beet pulp)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

5.6 Inventory of wheat flour system (wheat bran)

Data are equal to 2005-data presented in Dalgaard and Schmidt (2012b).

5.7 Parameters relating to switch between modelling assumptions

The allocation factors used for switching between the four modelling assumptions are presented in **Table 5.1** to **Table 5.5**. They are different from 2005-data because prices from 1990 are used. For further details on prices, see **Appendix C**.

Table 5.1: Allocation factors related to products from the soybean meal system. Unit: Fraction

Products	**Soybean oil mill**	**Soybean oil refinery**
	BR	BR
Switch 1: ISO 14040/44		
Determining product:		
Soybean meal	1	
Crude soybean oil for treatment		1
Switch 2: Average/allocation		
Determining product:		
Soybean meal	0.592	
Crude soybean oil for treatment		1
By-products at point of substitution:		
NBD oil	0.405	
Feed energy	0.00203	
Switch 3: PAS2050		
Determining product:		
Soybean meal	0.755	
By-products:		
Crude soybean oil for treatment	0.245	
NBD oil		0.005
FFA		0.995
Switch 4: IDF		
Determining product:		
Soybean meal	0.755	
By-products:		
Crude soybean oil for treatment	0.245	
NBD oil		0.005
FFA		0.995

Table 5.2: Allocation factors related to products from the rapeseed oil system. Unit: Fraction

Products	**Rapeseed oil mill**	**Rapeseed oil mill**
	UK	DE
Switch 1: ISO 14040/44		
Determining product:		
Crude rapeseed oil	1	1
Switch 2: Average/allocation		
Determining product:		
Crude rapeseed oil	0.749	0.687
By-products at point of substitution:		
Feed protein	0.0688	0.0854
Feed energy	0.183	0.227
Switch 3: PAS2050		
Determining product:		
Crude rapeseed oil	0.719	0.705
By-products		
Rapeseed meal	0.281	0.295
Switch 4: IDF		
Determining product:		
Crude rapeseed oil	0.719	0.705
By-products:		
Rapeseed meal	0.281	0.295

Table 5.3: Allocation factors related to products from the sunflower oil system. Unit: Fraction

Products	Sunflower oil mill FR
Switch 1: ISO 14040/44	
Determining product:	
Crude sunflower oil	1
Switch 2: Average/allocation	
Determining product:	
Crude sunflower oil	0.607
By-products at point of substitution:	
Feed protein	0.131
Feed energy	0.262
Switch 3: PAS2050	
Determining product:	
Crude sunflower oil	0.644
By-products:	
Utilisation of sunflower meal as feed	0.356
Switch 4: IDF	
Determining product:	
Crude sunflower oil	0.644
By-products:	
Utilisation of sunflower meal as feed	0.356

Table 5.4: Allocation factors related to products from the sugar system. Unit: Fraction

Products	Sugar mill UK	Sugar mill DE
Switch 1: ISO 14040/44		
Determining product:		
Sugar	1	1
Switch 2: Average/allocation		
Determining product:		
Sugar	0.871	0.882
By-products at point of substitution:		
Feed energy	0.113	0.104
Feed protein	0.016	0.015
Switch 3: PAS2050		
Determining product:		
Sugar	0.859	0.849
By-products:		
Molasses (74% DM)	0.039	0.045
Beet pulp, dried (89.4% DM)	0.102	0.107
Switch 4: IDF		
Determining product:		
Sugar	0.859	0.849
By-products:		
Molasses (74% DM)	3.88E-02	4.45E-02
Beet pulp, dried (89.4% DM)	1.02E-01	0.107

Table 5.5: Allocation factors related to products from the wheat flour system. Unit: Fraction

	Flour mill	**Flour mill**
Products	UK	DE
Switch 1: ISO 14040/44		
Determining product:		
Flour	1	1
Switch 2: Average/allocation		
Determining product:		
Flour	0.947	0.905
By-products at point of substitution:		
Feed energy	0.042	0.0752
Feed protein	0.011	0.0198
Switch 3: PAS2050		
Determining product:		
Flour	0.922	0.843
By-products:		
Wheat bran	0.078	1.57E-01
Switch 4: IDF		
Determining product:		
Flour	0.922	0.843
By-products:		
Wheat bran	0.0777	0.1574

6 Life cycle impact assessment

In this chapter the results of the CF 1990 baseline for the United Kingdom and Germany are presented and compared. In **section 6.1** a summary of the results for the four different switch modes is presented. The contribution from indirect land use changes (iLUC) or direct land use changes (dLUC) to the GHG-emissions per kg ECM is significantly for three out of the four switch modes, and therefore the results deducted iLUC/dLUC are also presented. In **section 6.2,** the key parameters affecting the results when calculating the CF per kg ECM produced in 1990 are presented.

The results for each switch mode are detailed presented in **section 6.3** to **6.6.**

6.1 Summary of results

In **Figure 6.1** the results for milk produced in 1990 in the United Kingdom are presented for each of the four switch modes. The blue bars represent the results including the land use change (LUC) effects while the red bars the results without the land use change effect.

Regardless of the switch used, the result obtained excluding land use change effect is lower.

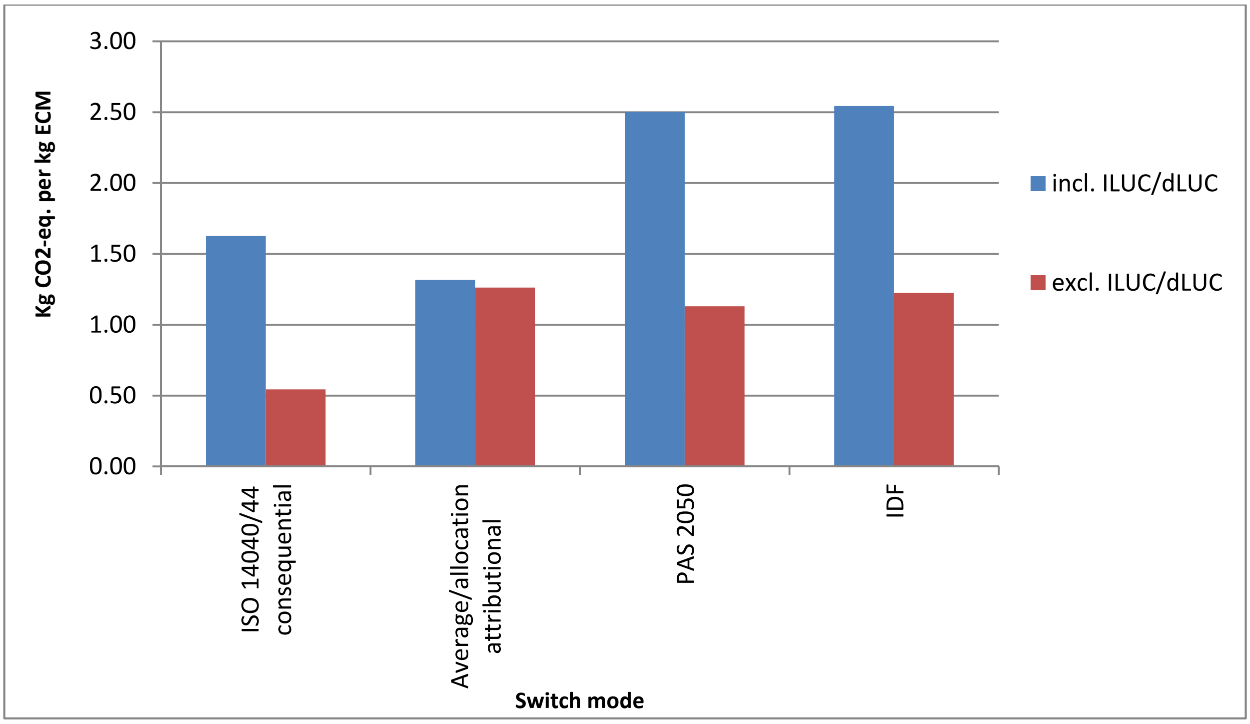

Figure 6.1: Summary of the results; GHG-emissions for 1 kg ECM production in the United Kingdom in 1990

Figure 6.2 shows the results for milk produced in 1990 in Germany are presented for each of the four switch modes. The blue bars represent the results including the LUC effects while the red represent the result excluding the LUC effect.

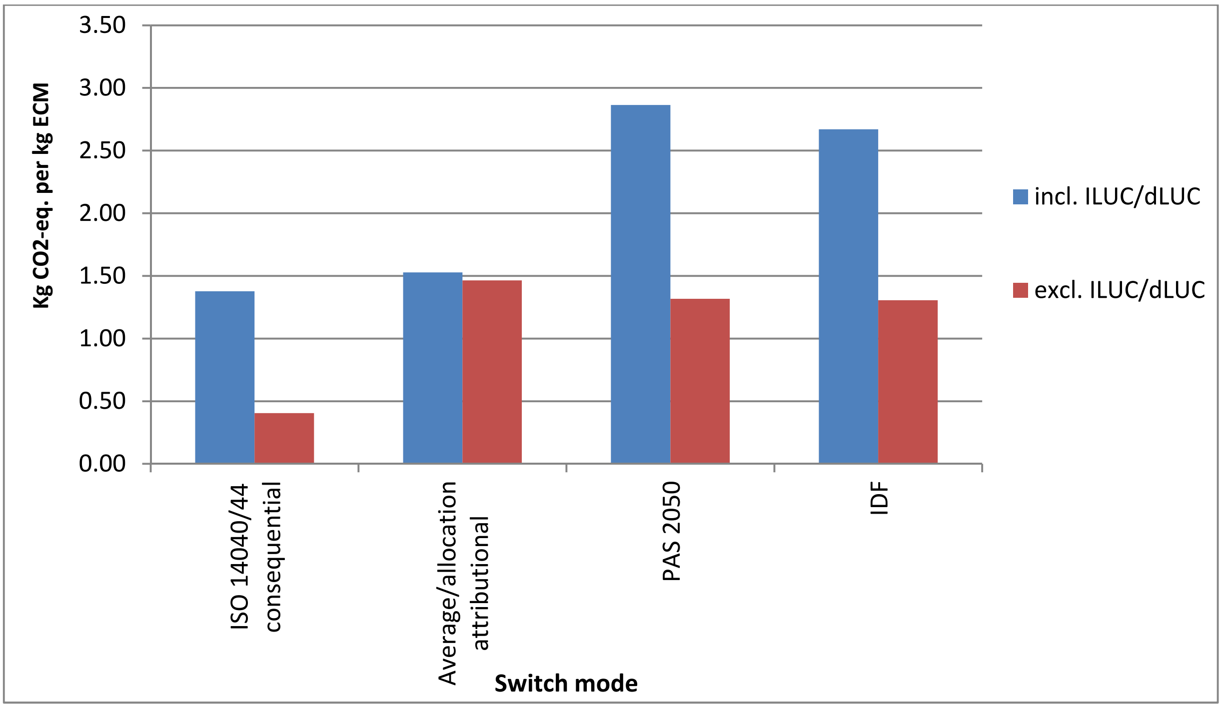

Figure 6.2: Summary of the results; GHG-emissions for 1 kg ECM in Germany 1990

6.2 Key parameters affecting the results

Although the four methodologies are very distinct considering system boundaries, system expansion/allocation, use of marginal/average data etc., they all respond to some key parameters. Key parameters that are directly related to the dairy cow efficiency and GHG-emissions are presented in **Table 6.1**. A higher feed intake means more feed is produced per kg milk and larger areas are used for feed cultivation, which again results in a higher contribution from iLUC/dLUC. An important key parameter is 'Beef produced per kg ECM' **Table 6.1.** Beef includes all meat produced from the milk system (meat from dairy cows, heifers and bulls). Whatever switch mode is used, a high beef production per kg ECM will reduce the GHG-emissions per kg ECM.

Table 6.1: Dairy cow key parameters for 1990

	United Kingdom	**Germany**
Parameter	**1990**	**1990**
Inputs and outputs per cow per year		
Net energy intake, MJ per cow	33,814	32,261
Milk ex cow, kg ECM per cow	5,314	4,927
Net energy intake, MJ per kg ECM	6.36	6.55
Beef produced, g live weight per kg ECM	60.5	76.5
Direct emissions, kg CO_2 eq per cow per year		
CH_4, enteric fermentation	2,389	2,291
CH_4, manure handling and storage	186	280
N_2O direct	117	167
N_2O indirect	27.2	39.8
Total	2,719	3,467

6.3 ISO14040/44 – consequential modelling

Table 6.2 and **Table 6.3** present the British and German 1990 baselines for GHG-emissions. The total GHG-emissions related to 1 kg British and German ECM are 1.63 kg CO_2-eq. and 1.38 kg CO_2-eq. respectively.

Of the total GHG-emissions at 1.63 kg CO_2-eq., 0.795 kg CO_2-eq. is direct emission in the four animal activities in the milk system. 3.50 kg CO_2-eq. relates to upstream activities, and the avoided emissions related to the substituted beef system accounts for -2.66 kg CO_2-eq. **Table 6.2** shows the following as the most important contributions to the carbon foot-printing analysis: the iLUC effect (sum of iLUC caused by crops/grass), avoided beef (sum of contributions from several activities within the beef system), direct emissions from the animal activities (where enteric fermentation is the most important), and the production of feedstuff (sum of all feedstuff incl. Upstream activities such as diesel for traction, farm capital goods and services, and production of fertiliser and pesticides). The bottom line in **Table 6.2** presents the results obtained excluding the iLUC effect. As expected, the results without accounting for the iLUC effect are significantly lower than the results obtained including iLUC. The iLUC effect includes contributions from transformation of land not in use (primary and secondary forest) to arable land and from intensification of land already in use. The major contribution is provided by intensification, where the emissions from additional fertiliser application are the most significant source of GHG-emissions. The inventory of iLUC (consequential modelling) is further described in Schmidt and Dalgaard (2012).

Table 6.2: GHG-emissions for 1 kg ECM milk, British 1990 baseline. Switch: ISO14044: consequential. Unit: Kg CO_2-eq. per kg ECM

United Kingdom	**Milking cow**	**Raising heifer**	**Raising newborn bull**	**Raising bull**	**Total**	**Total**
Direct emissions						
CH_4, enteric fermentation	0.470	0.179	0.00198	0.0632	**0.714**	**0.795**
CH_4, manure handling and storage	0.037	0.00443	0.0000422	0.0016	**0.0426**	
N_2O direct	0.0231	0.00567	0.0000822	0.00172	**0.0305**	
N_2O indirect	0.00534	0.00116	0.0000160	0.000350	**0.00687**	
Emissions outside the animal activities (incl. capital goods and services)						
Feed inputs, excl. iLUC	0.272	0.104	0.00103	0.0366	**0.414**	**3.50**
ILUC related to feed	1.83	0.699	0.00697	0.247	**2.79**	
Manure land appl. incl. subst. mineral fert.	0.0559	0.0323	0.00115	0.00844	**0.0978**	
Fuels incl. combustion	0.0105	0.00281	0.000147	0.000970	**0.0144**	
Electricity	0.059	0	0	0	**0.0588**	
Transport	0.0160	0.00611	0.0000676	0.00216	**0.0244**	
Destruction of fallen cattle incl. subst. energy	-0.00609	-0.000878	-0.000376	-0.000537	**-0.00788**	
Farm, capital goods	0.0187	0.0206	0.000737	0.00636	**0.0464**	
Farm, services	0.0248	0.0272	0.000975	0.00841	**0.0614**	
Substituted beef system (incl. capital goods and services)						
Direct emissions (CH_4 and N_2O)					**-0.567**	**-2.66**
Feed inputs, excl. iLUC					**-0.0460**	
iLUC related to feed					**-1.70**	
Other					**-0.348**	
Total						**1.63**

Results with lower degree of completeness	
Total (result without iLUC)	**0.542**

The GHG-emissions for German milk produced in 1990 are presented in **Table 6.3**. Of the total GHG-emissions at 1.38 kg CO_2-eq., 0.920 kg CO_2-eq. is direct emission in the four animal activities in the milk system. 3.83 kg CO_2-eq. relates to upstream activities, and the avoided emissions related to the substituted beef system accounts for -3.36 kg CO_2-eq. The bottom line in **Table 6.3** presents the results obtained excluding the iLUC effect. As explained for the British system, when the iLUC effect is excluded, the GHG emissions result significantly lower than compared to the GHG emissions obtained including iLUC. Further considerations regarding the German milk system presented in **Table 6.3** are similar to the ones for British milk in **Table 6.2** and are therefore not further elaborated.

Table 6.3: GHG-emissions for 1 kg ECM milk, German 1990 baseline. Switch: ISO14044: consequential. Unit: Kg CO_2-eq. per kg ECM

Germany	**Milking cow**	**Raising heifer**	**Raising new born bull**	**Raising bull**	**Total**	**Total**
Direct emissions						
CH_4, enteric fermentation	0.484	0.198	0.00184	0.0767	**0.761**	**0.920**
CH_4, manure handling and storage	0.059	0.0195	0.000181	0.00755	**0.086**	
N_2O direct	0.0352	0.0174	0.000130	0.00540	**0.0581**	
N_2O indirect	0.00842	0.00417	0.000031	0.00130	**0.0139**	
Emissions outside the animal activities (incl. capital goods and services)						
Feed inputs, excl. iLUC	0.277	0.1135	0.00105	0.0439	**0.436**	**3.83**
ILUC related to feed	1.99	0.814	0.00754	0.315	**3.12**	
Manure land appl. incl. subst. mineral fert.	0.0370	0.0155	0.000116	0.00483	**0.0574**	
Fuels incl. combustion	0.01027	0.00809	0.000282	0.00243	**0.0211**	
Electricity	0.0586	0	0	0	**0.059**	
Transport	0.0165	0.00676	0.0000626	0.00261	**0.0259**	
Destruction of fallen cattle incl. subst. energy	-0.00234	-0.002769	-0.000333	-0.001524	**-0.00696**	
Farm, capital goods	0.0201	0.0212	0.000740	0.00638	**0.0484**	
Farm, services	0.0266	0.0281	0.000979	0.00844	**0.0641**	
Substituted beef system (incl. capital goods and services)						
Direct emissions (CH_4 and N_2O)					**-0.716**	**-3.36**
Feed inputs, excl. iLUC					**-0.0579**	
iLUC related to feed					**-2.15**	
Other					**-0.440**	
Total						**1.38**

Results with lower degree of completeness	
Total (result without iLUC)	**0.410**

6.4 Average/allocation – attributional modelling

In **Table 6.4** and **Table 6.5** the GHG-emissions for the British and German 1990 baselines are presented for the average/allocation switch mode. The total GHG-emissions related to 1 kg British and German ECM are 1.32 kg CO_2-eq. and 1.53 kg CO_2-eq. respectively.

The contribution from iLUC is significant lower than in the ISO 14040/44 consequential switch mode. The reason is that the attributional modelling of iLUC considers all inputs to the market for land (land tenure) as flexible and a market average mix is applied. The major source of arable land is the land which is already in use (Schmidt et al. 2012) and therefore the share of virgin area, which results in high GHG-emissions, is very small.

The major contributors to GHG-emissions from British and German milk are direct emissions of CH_4 from enteric fermentation and feed inputs.

Table 6.4: GHG-emissions for 1 kg ECM milk, British 1990 baseline. Switch: average/allocation: attributional. 74.3% of the milk system is allocated to milk (economic allocation between milk, meat, and exported animals, fertilisers from manure land application and recovered energy from the destruction of dead animals). Unit: Kg CO_2-eq. per kg ECM

United Kingdom	Milking cow	Raising heifer	Raising new born bull	Raising bull	Total	Total
Direct emissions						
CH_4, enteric fermentation	0.349	0.135	0.001	0.0476	**0.533**	**0.593**
CH_4, manure handling and storage	0.0272	0.00333	0.000	0.00120	**0.0317**	
N_2O direct	0.0171	0.00426	0.000	0.00129	**0.0228**	
N_2O indirect	0.00397	0.000873	0.000	0.000263	**0.00512**	
Emissions outside the animal activities (incl. capital goods and services)						
Feed inputs, excl. iLUC	0.311	0.120	0.00133	0.0424	**0.475**	**0.729**
ILUC related to feed	0.0361	0.0139	0.000154	0.00492	**0.0551**	
Manure land appl.	0.00156	0.000406	0.00000584	0.000123	**0.00209**	
Fuels incl. combustion	0.00777	0.00211	0.000110	0.000730	**0.0107**	
Electricity	0.08642	0	0	0	**0.0864**	
Transport	0.0119	0.00460	0.0000508	0.00162	**0.0182**	
Destruction of fallen cattle	0.000412	0	0.0000258	0.0000368	**0.000475**	
Farm, capital goods	0.0139	0.0155	0.000554	0.00478	**0.0347**	
Farm, services	0.0184	0.0205	0.000733	0.00632	**0.0459**	
Total						**1.32**

Results with lower degree of completeness	
Total (result without iLUC)	**1.27**

Table 6.5: GHG-emissions for 1 kg ECM milk, German 1990 baseline. Switch: average/allocation: attributional. 75.6% of the milk system is allocated to milk (economic allocation between milk, meat, exported animals, fertilisers from manure land application and recovered energy from the destruction of dead animals). Unit: Kg CO_2-eq. per kg ECM

Germany	Milking cow	Raising heifer	Raising new born bull	Raising bull	Total	Total
Direct emissions						
CH_4, enteric fermentation	0.366	0.152	0.00141	0.0587	**0.578**	**0.698**
CH_4, manure handling and storage	0.0447	0.0149	0.000138	0.00578	**0.0655**	
N_2O direct	0.0266	0.0133	0.0000993	0.00414	**0.0441**	
N_2O indirect	0.00637	0.00320	0.0000239	0.000994	**0.0106**	
Emissions outside the animal activities (incl. capital goods and services)						
Feed inputs, excl. iLUC	0.313	0.130	0.00120	0.0502	**0.494**	**0.835**
ILUC related to feed	0.0405	0.0168	0.000156	0.00650	**0.0640**	
Manure land appl.	0.00232	0.00115	0.00000857	0.000357	**0.00383**	
Fuels incl. combustion	0.00776	0.00619	0.000216	0.00186	**0.0160**	
Electricity	0.152	0	0	0	**0.152**	
Transport	0.0125	0.00517	0.0000479	0.00200	**0.0197**	
Destruction of fallen cattle	0.000153	0.000184	0.0000221	0.0001013	**0.000461**	
Farm, capital goods	0.0152	0.0162	0.000567	0.00488	**0.0369**	
Farm, services	0.0201	0.0215	0.000749	0.00646	**0.0488**	
Total						**1.53**

Results with lower degree of completeness	
Total (result without iLUC)	**1.47**

6.5 PAS2050

In **Table 6.6** and **Table 6.7** the GHG-emissions for the British and German 1990 baselines are presented for the PAS2050 switch mode. The total GHG-emissions related to 1 kg British and German ECM are 2.50 kg CO_2-eq. and 2.86 kg CO_2-eq. respectively.

Table 6.6: GHG-emissions for 1 kg ECM milk, British 1990 baseline. Switch: PAS2050. 75.8% of the milk system is allocated to milk (economic allocation between milk, meat and exported animals). Unit: Kg CO_2-eq. per kg ECM

United Kingdom	**Milking cow**	**Raising heifer**	**Raising new born bull**	**Raising bull**	**Total**	**Total**
Direct emissions						
CH_4, enteric fermentation	0.356	0.136	0.00150	0.0479	**0.541**	
CH_4, manure handling and storage	0.0277	0.00335	0.0000320	0.00121	**0.0323**	
N_2O direct	0.0175	0.00429	0.0000623	0.00130	**0.0231**	
N_2O indirect	0.00405	0.000879	0.0000121	0.000265	**0.00521**	**0.602**
Emissions outside the animal activities (excl. capital goods and services)						
Feed inputs, excl. dLUC	0.273	0.206	0.00348	0.128	**0.610**	
dLUC (soybean and oil palm)	0.902	0.242	0.00147	0.0298	**1.18**	
Manure land appl.	0.00155	0.000762	0.00000717	0.000164	**0.00248**	
Fuels incl. combustion	0.00774	0.00208	0.000109	0.000717	**0.0106**	
Electricity	0.0867	0	0	0	**0.0867**	
Transport	0.00938	0.00358	0.0000396	0.00126	**0.0143**	
Destruction of fallen cattle	0.000290	0.0000418	0.0000179	0.0000256	**0.000375**	**1.90**
Total						**2.50**

Results with lower degree of completeness	
Total (result without dLUC)	**1.33**

Table 6.7: GHG-emissions for 1 kg ECM milk, German 1990 baseline. Switch: PAS2050. 77.0% of the milk system is allocated to milk (economic allocation between milk, meat and exported animals). Unit: Kg CO_2-eq. per kg ECM

Germany	**Milking cow**	**Raising heifer**	**Raising new born bull**	**Raising bull**	**Total**	**Total**
Direct emissions						
CH_4, enteric fermentation	0.373	0.153	0.00142	0.0591	**0.586**	
CH_4, manure handling and storage	0.0456	0.0150	0.000139	0.00581	**0.0665**	
N_2O direct	0.0271	0.0134	0.000100	0.00416	**0.0448**	
N_2O indirect	0.00649	0.00322	0.0000240	0.00100	**0.0107**	**0.708**
Emissions outside the animal activities (excl. capital goods and services)						
Feed inputs, excl. dLUC	0.268	0.110	0.00102	0.0425	**0.422**	
dLUC (soybean and oil palm)	0.983	0.403	0.00373	0.156	**1.55**	
Manure land appl.	0.00230	0.00149	0.00000984	0.000394	**0.00420**	
Fuels incl. combustion	0.00772	0.00608	0.000212	0.00183	**0.0158**	
Electricity	0.1526	0	0	0	**0.153**	
Transport	0.00981	0.00402	0.0000372	0.00156	**0.0154**	
Destruction of fallen cattle	0.000106	0.000125	0.0000151	0.0000690	**0.000315**	**2.16**
Total						**2.86**

Results with lower degree of completeness	
Total (result without dLUC)	**1.32**

6.6 IDF Guideline

In **Table 6.8** and **Table 6.9** the GHG-emissions for the British and German baselines are presented for the IDF switch mode. The total GHG-emissions related to 1 kg British and German ECM are 2.54 kg CO_2-eq. and 2.67 kg CO_2-eq. respectively.

Table 6.8: GHG-emissions for 1 kg ECM milk, British 1990 baseline. Switch: IDF. 79.9% of the milk system is allocated to milk (biophysical founded allocation between milk and meat). Notice that IDF does not define the raising of bulls from the milk system as part of the milk system. Unit: Kg CO_2-eq. per kg ECM

United Kingdom	**Milking cow**	**Raising heifer**	**Raising newborn bull**	**Raising bull**	**Total**	**Total**
Direct emissions						
CH_4, enteric fermentation	0.376	0.143	0.00158	n.a.	**0.521**	**0.582**
CH_4, manure handling and storage	0.0292	0.00354	0.0000337	n.a.	**0.0328**	
N_2O direct	0.0185	0.00453	0.0000657	n.a.	**0.0230**	
N_2O indirect	0.00427	0.000927	0.0000128	n.a.	**0.00521**	
Emissions outside the animal activities (incl. capital goods and services)						
Feed inputs, excl. dLUC	0.326	0.124	0.00137	n.a.	**0.452**	**1.96**
dLUC (soybean and oil palm)	0.951	0.363	0.00401	n.a.	**1.32**	
Manure land appl.	0.00168	0.000432	0.00000621	n.a.	**0.00211**	
Fuels incl. combustion	0.00836	0.00225	0.000117	n.a.	**0.0107**	
Electricity	0.093	0	0	n.a.	**0.0930**	
Transport	0.0128	0.00488	0.0000540	n.a.	**0.0177**	
Destruction of fallen cattle incl. subst. energy	-0.00481	-0.000694	-0.000297	n.a.	**-0.00580**	
Farm, capital goods	0.0198	0.0218	0.000779	n.a.	**0.0423**	
Farm, services	0.0150	0.0165	0.000589	n.a.	**0.0320**	
Total						**2.54**

Results with lower degree of completeness	
Total (result without dLUC)	**1.23**

Table 6.9: GHG-emissions for 1 kg ECM milk, German 1990 baseline. Switch: IDF. 75.6% of the milk system is allocated to milk (biophysical founded allocation between milk and meat). Notice that IDF does not define the raising of bulls from the milk system as part of the milk system. Unit: Kg CO_2-eq. per kg ECM

Germany	**Milking cow**	**Raising heifer**	**Raising new born bull**	**Raising bull**	**Total**	**Total**
Direct emissions						
CH_4, enteric fermentation	0.366	0.150	0.00139	n.a.	**0.517**	**0.626**
CH_4, manure handling and storage	0.0447	0.0147	0.000137	n.a.	**0.0596**	
N_2O direct	0.0266	0.0131	0.0000981	n.a.	**0.0398**	
N_2O indirect	0.00637	0.00316	0.0000236	n.a.	**0.00955**	
Emissions outside the animal activities (incl. capital goods and services)						
Feed inputs, excl. dLUC	0.299	0.122	0.00113	n.a.	**0.422**	**2.04**
dLUC (soybean and oil palm)	0.965	0.395	0.00366	n.a.	**1.36**	
Manure land appl.	0.00232	0.00113	0.00000846	n.a.	**0.00346**	
Fuels incl. combustion	0.00776	0.00612	0.000213	n.a.	**0.0141**	
Electricity	0.152	0	0	n.a.	**0.152**	
Transport	0.0125	0.00511	0.0000473	n.a.	**0.0176**	
Destruction of fallen cattle incl. subst. energy	-0.00174	-0.00206	-0.000248	n.a.	**-0.00405**	
Farm, capital goods	0.0201	0.0160	0.000559	n.a.	**0.0367**	
Farm, services	0.0152	0.0212	0.000740	n.a.	**0.0371**	
Total						**2.67**

Results with lower degree of completeness	
Total (result without dLUC)	**1.31**

7 Sensitivity analyses

The number of presented sensitivity analyses is limited, because the sensitivity of the model already is described in Schmidt and Dalgaard (2012b), who concluded that the region of substituted beef system has a high impact on the results, when ISO 14040/44-methodology is applied. In this study 2005-data for substituted beef system is used and it is therefore expected that the 1990-results will be significantly affected by choice of system. According to Schmidt and Dalgaard (2012), the milk yield has very little effect on the overall results and a sensitivity test is therefore not performed. The uncertainties related to crop yields are moderate as described by Schmidt and Dalgaard (2012). In the modelling with 1990-data, yields of crops, particularly 'Permanent grass', 'Rotation grass incl. grass ensilage' and 'Roughage, ensilage' are based on estimates (see **section 4.1**). It is therefore relevant to test the crop yields impact on the results.

In **Table 7.1** the impact on the results of a 25% reduction in crop yields is assessed. The detailed results are only presented for British milk modelled by using ISO14040/44 consequential methodology. **Table 7.1** shows that the results are sensitive to reduction in crop yields. The emissions are increased by 30% compared to the baseline.

Table 7.1: Sensitivity analysis for 1 kg ECM milk produced in the United Kingdom, where all crop yields are reduced by 25%. (Switch: ISO14040/44 consequential). Unit: Kg CO_2-eq. per kg ECM

Contribution	**UK - milk 1990 25% reduced crop yields**		**Explanation**
Direct emissions			
CH_4, enteric fermentation	0.714		The direct emissions are not affected by reduced crop yields.
CH_4, manure handling and storage	0.043		
N_2O direct	0.0305		
N_2O indirect	0.00687	**0.795**	
Emissions outside the animal activities (incl. capital goods and services)			
Feed inputs, excl. ILUC	0.552		The emissions from feed and iLUC are increased when the crops yields are reduced. Compared to the baseline total emission outside the animal activities (3.50), there is an increase of ~~+~~30%of emissions.
ILUC related to feed	3.72		
Manure land appl. incl. subst. mineral fertiliser	0.0969		
Fuels incl. combustion	0.0144		
Electricity	0.059		
Transport	0.0244		
Destruction of fallen cattle incl. subst. energy	-0.00788		
Farm, capital goods	0.0464		
Farm, services	0.0614	**4.56**	
Substituted beef system (incl. capital goods and services)			
Direct emissions (CH_4 and N_2O)	-0.567		Decrease compared to the baseline (-2.66): 21%.
Feed inputs, excl. iLUC	-0.0465		
iLUC related to feed	-2.32		
Other	-0.295	**-3.23**	
Total		**2.13**	**Increase compared to the baseline (1.63): 30%**

The results of the sensitivity analyses for the other switches are presented in a less detailed form in **Table 7.2**. A 25% reduction in crop yields increases the results by 10-34%. The highest changes (31 and 34%) are obtained with 'ISO14044 consequential'. This is because changes in yields also affect the substituted beef system.

Table 7.2: Sensitivity analyses. Comparison between the results obtained for the 1990 baseline with the results obtained reducing crop yields by 25%

Switch	**ISO14044: consequential**		**Average/allocation: attributional**		**PAS2050**		**IDF**	
Country	UK	DE	UK	DE	UK	DE	UK	DE
Including iLUC/dLUC								
1990 baseline	1.63	1.38	1.32	1.53	2.50	2.86	2.54	2.67
Yields reduced by 25%	2.13	1.84	1.48	1.69	3.08	3.49	3.11	3.24
Change, %	30.8%	33.8%	12.1%	10.5%	23.0%	21.9%	22.4%	21.3%
Excluding iLUC/dLUC								
1990 baseline	0.54	0.41	1.26	1.46	1.13	1.32	1.23	1.31
yields reduced by 25%	0.68	0.55	1.40	1.60	1.25	1.44	1.36	1.42
Change, %	25.9%	34.8%	11.1%	9.5%	10.5%	8.9%	10.7%	9.1%

Another source of uncertainty might be the manure data used in the model, equal to the data utilized in Dalgaard and Schmidt (2012a) and relative to animal manure excretion in Denmark in 1990. Since the dairy cow milk yield in Germany and the United Kingdom is lower than in Denmark, it might be assumed that the manure excreted from the animals would be proportionally lower. In particular, while the Danish milk yield in 1990 was 62,476 kg milk per cow per year the British and German milk yield were respectively 53,137 and 49,267 kg milk per cow per year that correspond to a 15% and 21% reduction compared to Danish data. Therefore **Table 7.3** shows the sensitivity of the results when the manure excreted by animal is reduced, according to the milk yield, by 15% in the United Kingdom and 21% in Germany compared to Danish data.

Table 7.3: Sensitivity analyses. Comparison between the results obtained for the 1990 baseline with the results obtained downscaling manure data from Dalgaard and Schmidt (2012a) according to German and British dairy cow milk production.

Switch	**ISO14044: consequential**		**Average/allocation: attributional**		**PAS2050**		**IDF**	
Country	UK	DE	UK	DE	UK	DE	UK	DE
Including iLUC/dLUC								
1990 baseline	1.63	1.38	1.32	1.53	2.50	2.86	2.54	2.67
Downscaled manure	1.62	1.36	1.31	1.51	2.49	2.85	2.54	2.66
Change, %	-0.7%	-1.4%	-0.6%	-1.0%	-0.3%	-0.4%	-0.3%	-0.4%
Excluding iLUC/dLUC								
1990 baseline	0.54	0.41	1.26	1.46	1.13	1.32	1.23	1.31
Downscaled manure	0.53	0.39	1.25	1.45	1.12	1.31	1.22	1.30
Change, %	-2.1%	-4.7%	-0.6%	-1.0%	-0.6%	-0.6%	-0.6%	-0.6%

The sensitivity analysis for the four switches shows a limited variability of the final result between 0.3% and 4.7%. Regardless of the switch selected, the final results would be slightly lower assuming a reduction of the excreted animal manure proportional to the milk yield. However, this reduction is not remarkable.

8 Sensitivity, completeness and consistency checks

See Schmidt and Dalgaard (2012).

9 Conclusion

The baseline results for British and German milk at farm gate are summarised in **Figure 9.1**.

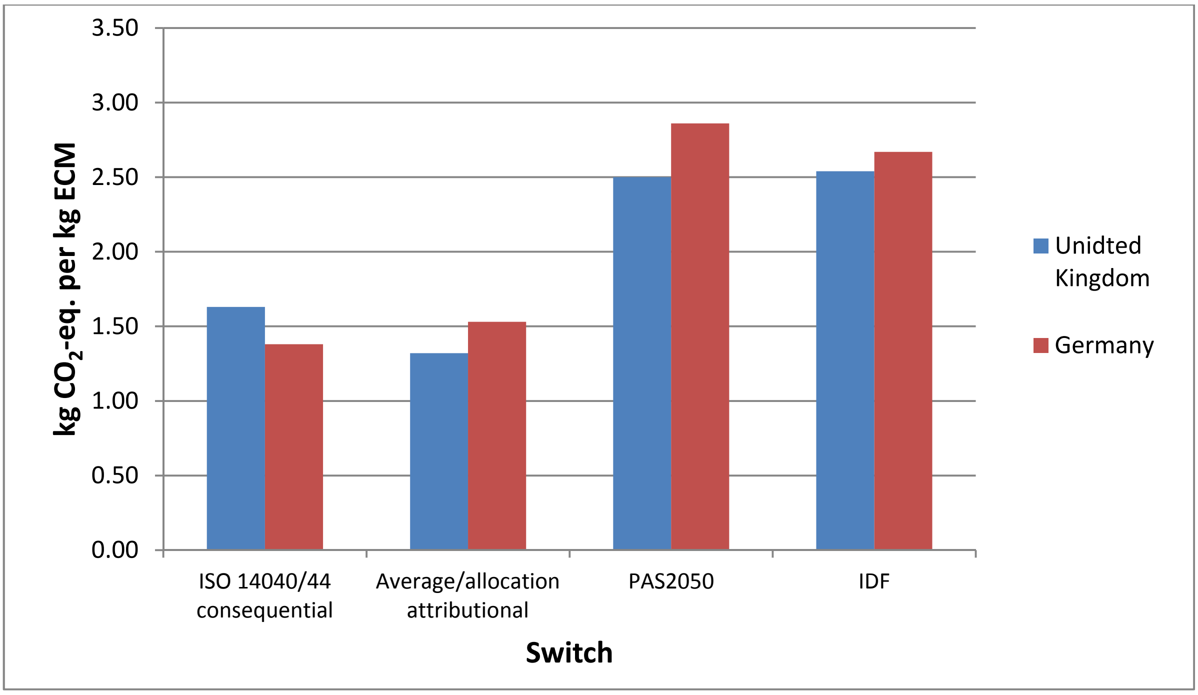

Figure 9.1: Summary of the results; GHG-emissions 1 kg British and German ECM in 1990 incl. ILUC/dLUC

Figure 9.1 that the results are highly dependent on the choice of modelling switch mode. Emissions related to the functional unit are higher in Germany than in the United Kingdom for three of the four switches. However, if the ISO 14040/44 consequential approach is adopted, the production of milk in the UK seems to perform worse than the German milk production.

The major contributions to the overall result include enteric fermentation (methane emissions from the cattle) and the cultivation and production of feed inputs. A major part of the impact related to the feed inputs is associated to land use changes.

It should be noted that there are uncertainty of the 1990 results. In particular feed composition both in Germany and the United Kingdom are related to uncertainty. Data on crop yields and fertilisation levels are more uncertain in Germany than in the UK. On the other hand, data concerning the composition of animal stocks in the United Kingdom are more uncertain than German data. Furthermore, the amount of meat produced per kg milk is also an uncertainty.

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Appendix A: Fuel and substance properties

Appendix table 1: Densities are from Andersen et al. (1981, p 119, 218) and for methane UN CDM project no 1153 (2006). Calorific values (lower heating value) are from NERI (2010, p 639-640).

Fuel	Density	Energy content	
Fuel oil	0.95 tonne/m^3	40.7 MJ/kg	38.6 MJ/litre
Diesel	0.87 tonne/m^3	42.7 MJ/kg	36.4 MJ/litre
Motor Gasoline	0.72 tonne/m^3	43.8 MJ/kg	30.8 MJ/litre
Natural gas	0.80 tonne/m^3	49.6 MJ/kg	39.7 MJ/litre
Hard coal (not for electricity plant)	-	26.5 MJ/kg	-
Methane	0.713 kg/ m^3	50.2 MJ/kg	35.8 MJ/Nm^3

Appendix table 2: Molar masses of substances.

Substances/material	Molar mass, M (g/mol)
Hydrogen (H)	1
Carbon (C)	12
Nitrogen (N)	14
Oxygen (O)	16
Phosphorus (P)	31
Sulphur (S)	32
Potassium (K)	39

Appendix B: Feed and crop properties

Appendix table 3: Feed characteristics. Feed code refers to the feed code in Møller et al. (2005).

Feed:	Unit	Barley	Wheat	Oat	Corn	Soybean meal	Rapeseed cake/meal	Sunflower meal	Beet pulp, dried	Fodder beet	Molasses, beet	Palm oil	Palm kernel meal	Wheat bran	Feed urea	Minerals, salt etc.	Permanent grass	Ensilage	Rotation grass
Feed code:		201	203	202	204	154	144	165	283		277	347	136	232	760		458	593	425
Input parameters																			
Dry matter content	kg DM/kg	0.850	0.850	0.850	0.875	0.874	0.889	0.890	0.894	0.330	0.740	0.990	0.906	0.871	1.000	1.000	0.180	0.33	0.175
Raw protein	kg/kg DM	0.108	0.115	0.102	0.096	0.535	0.35	0.417	0.096	0.111	0.130	0	0.170	0.183	2.28	0	0.200	0.111	0.230
Raw fat	kg/kg DM	0.031	0.024	0.053	0.046	0.028	0.105	0.030	0.012	0.020	0.001	1	0.082	0.046	0	0	0.039	0.020	0.041
Carbohydrate	kg/kg DM	0.838	0.842	0.819	0.843	0.361	0.475	0.467	0.822	0.810	0.742	0	0.707	0.713	0	0	0.661	0.810	0.633
Ash	kg/kg DM	0.023	0.018	0.026	0.015	0.076	0.07	0.086	0.07	0.059	0.127	0	0.041	0.058	1	1	0.100	0.059	0.096
Digestible energy	MJ/kg DM	15.2	16.0	13.4	16.2	18.0	16.2	15.1	14.6	12.2	13.6	32.2	12.8	13.1	0	0	13.2	12.2	14.1
Feed energy content	SFU/kg DM	1.11	1.21	0.91	1.22	1.40	1.19	1.07	1.00	0.76	0.98	2.82	0.83	0.89	0	0	0.86	0.76	0.96
Calculated parameters																			
Gross energy	MJ/kg DM	19.2	19.2	19.5	19.6	20.6	21.1	19.8	18.0	18.4	16.9	36.6	20.2	19.3	0	0	18.5	17.5	18.8
Digestible energy *	MJ/MJ	0.79	0.83	0.69	0.83	0.87	0.77	0.76	0.81	0.66	0.80	0.88	0.63	0.68	0	0	0.71	0.80	0.75
Feed energy (net energy)	MJ/kg DM	8.68	9.46	7.12	9.54	10.95	9.31	8.37	7.82	5.94	7.66	22.05	6.49	6.96	0	0	6.73	7.74	7.51

*expressed as a percentage of gross energy

Appendix C: Prices

C.1 Cattle system

Cattle system			
Prices	**Unit**	**UK**	**DE**
Milk (ECM)	USD90 kg ECM milk-1	0.342	0.375
Meat live weight	USD90 kg live weight-1	1.73	1.45
Live animal: cow	USD90 head-1	3241	874
Live animal: small bull	USD90 head-1	453	238
Live animal: bull	USD90 head-1	453	238
Dead animal	USD90 kg live weight-1	0	0
Ammonium nitrate, as N	USD90 kg N-1	0.328	0.351
Urea, as N	USD90 kg N-1		
Triple superphosphate, as P2O5	USD90 kg P2O5-1	0.293	0.345
Potassium chloride, as K2O	USD90 kg K2O-1	0.193	0.193
Electricity	USD90 kWh electricity-1	0.060	0.060
Heat	USD90 MJ heat-1	0.011	0.011
Coal	USD90 MJ-1	0.0031	0.0021
Fuel oil	USD90 MJ-1	0.0616	0.0616

Cattle system		
Data sources	**UK**	**DE**
Milk (ECM)	Production price (UK): 'Cow milk, whole, fresh'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 19/6-2013)	Production price (DE): 'Cow milk, whole, fresh'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 19/6-2013)
Meat live weight	Production price (UK): 'Cattle Live Weight'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 19/6-2013)	Production price (DE): 'Cattle Live Weight'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 19/6-2013)
Live animal: cow	Export price (UK): 'Bovine animals, live pure-bred breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013). Price from 1993; Weight per animal as DE 2001.	Export price (UK): 'Bovine animals, live pure-bred breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013). Weight per animal from export DE 2001.
Live animal: small bull	Export price (UK): 'Bovine animals, live, except pure-bred breeding'.	Export price (UK): 'Bovine animals, live, except pure-bred

	UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 20/6-2013). Prices from 1993; Weight per animal from export UK 2005.	breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013). Weight per animal from export DE 2005.
Dead animal	Dead animals for destruction are not paid for by destruction industry	Dead animals for destruction are not paid for by destruction industry
Ammonium nitrate, as N	Import price (UK): 'Ammonium nitrate, including solution, in pack >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013) Data from 1993	Import price (DE): 'Ammonium nitrate, including solution, in pack >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013)
Urea, as N		
Triple superphosphate, as P2O5	Import price (UK): 'Superphosphates, in packs >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013) Data from 1993	Import price (DE): 'Superphosphates, in packs >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013) Data from 1991
Potassium chloride, as K2O	Same price as in Germany assumed	Import price (DE): 'Potassium chloride, in packs >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013) Data from 1991
Electricity	DK industry use price 2005: IEA (2010, p IV.234), Electricity Information 2010. International Energy Agency	Same price as in Denmark assumed
Heat	Based on electricity prices by assuming the electricity/heat price proportion is the same as in 2005.	Same price as in Denmark assumed
Coal	Import price (UK): 'Coal except anthracite or bituminous, not agglomerate'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013) Data from 1993	Import price (DE): 'Coal except anthracite or bituminous, not agglomerate'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013) Data from 1991
Fuel oil	Same price as in Germany assumed	Import price (DE): 'Coal except anthracite or bituminous, not agglomerate'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 19/6-2013) Data from 1991

C.2 Plant cultivation system

Plant cultivation system			
Prices	**Unit**	**UK**	**DE**
Barley	USD90/kg crop	0.198	0.162
Wheat	USD90/kg crop	0.206	0.178
Oat	USD90/kg crop	0.189	0.156
Rapeseed	USD90/kg crop	0.459	0.431
Crop residue	USD90/kg straw	0.112	0.112
Electricity	USD90 kWh electricity-1	0.060	0.060
Heat	USD90 MJ heat-1	0.011	0.011

Plant cultivation system		
Data sources	**UK**	**DE**
Barley	Production price (UK): 'Barley'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)	Production price (DE): 'Barley'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)
Wheat	Production price (UK): 'wheat'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)	Production price (DE): 'wheat'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)
Oat	Production price (UK): 'oats'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)	Production price (DE): 'oats'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)
Rapeseed	Production price (UK): 'rapeseed'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)	Production price (DE): 'rapeseed'. FAOSTAT (2013), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 2/7-2013)
Crop residue	Data assumed to be equal to data used in Dalgaard and Schmidt (2012).	Same price as in UK assumed
Electricity	Data assumed to be equal to data used in Dalgaard and Schmidt (2012).	Same price as in UK assumed
Heat	Data assumed to be equal to data used in Dalgaard and Schmidt (2012).	Same price as in UK assumed

C.3 Food industry system

Food industry system						
Prices	**Unit**	**BR**	**UK**	**DE**	**FR**	**GLO**
Crude soybean oil	EUR/kg	0.240				
Crude rapeseed oil	EUR/kg		0.556	0.411		
Crude sunflower oil	EUR/kg				0.448	
Soybean meal	EUR/kg	0.184				
Rapeseed meal	EUR/kg		0.161	0.128		
Sunflower meal	EUR/kg				0.116	
NBD soybean oil	EUR/kg	0.516				
Sugar	EUR/kg		0.343	0.379		
Flour	EUR/kg		0.421	0.222		
Free fatty acids (FFA)	EUR/kg	0.202				
Molasses (74% DM)	EUR/kg		0.065	0.083		
Beet pulp, dried (89.4% DM)	EUR/kg		0.124	0.144		
Wheat bran	EUR/kg		0.142	0.166		
Feed energy	EUR/MJ net energy					0.012
Feed protein	EUR/kg					0.122

Food industry system					
Data sources	**BR**	**UK**	**DE**	**FR**	**GLO**
Crude soybean oil	Tradingcharts.com (2012): Commodity: 'Soybean oil. July 1990. http://futures.tradingcharts.com/historical/SO/1990/0/continuous.html (Accessed 8/6-2012)				
Crude rapeseed oil		Export price (UK): 'Canola, rape, colza or mustard oil, crude'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)	Export price (Germany): 'Canola, rape, colza or mustard oil, crude'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)		
Crude sunflower oil				Export price (France): 'Sunflower-seed or safflower oil, crude'. Year: 1994. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 8/6-2012)	
Soybean meal	Export price (Brazil): 'Soya-bean oil-cake and other solid residues'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 7/6-2012)				
Rapeseed meal		Export price (Uk): 'Rape or colza seed oil-cake and other solid residues'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)	Export price (Germany): 'Canola, rape, colza or mustard oil, crude'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)		
Sunflower meal				Export price (France): 'Sunflower seed oil-cake and other solid	

				residues'. Year: 1994. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 8/6-2012)	
NBD soybean oil	Relative price difference between crude and refined oil is assumed to be the same as in 2005.				
Sugar		Export price (UK): 'Refined sugar, in solid form, nes, pure sucrose'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)	Export price (Germany): 'Refined sugar, in solid form, nes, pure sucrose'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)		
Flour		Production price (UK): 'Wheat or meslin flour'. Year: 1995. UNSD (2013), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)	Production price (Germany): 'Wheat or meslin flour'. Year: 1995. UNSD (2013), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)		
Free fatty acids (FFA)	Same price assumed as FFA from oil palm. MPOB (2006), MALAYSIAN OIL PALM STATISTICS 2005. Malaysian Palm Oil Board. http://econ.mpob.gov.my/economy/ei_statistics05_old.htm (accessed 8/6-2012)				
Molasses (74% DM)		Import price (UK): 'Molasses, except cane molasses'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)	Import price (Germany): 'Molasses, except cane molasses'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)		
Beet pulp, dried (89.4% DM)		Import price (UK): 'Beet-pulp, bagasse & other waste of sugar	Import price (Germany): 'Beet-pulp, bagasse & other waste of		

		manufacture'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)	manufacture'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013		
Wheat bran		Import price (UK): 'Wheat bran, sharps, other residues'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013)	Import price (Germany): 'Wheat bran, sharps, other residues'. UNSD (2013), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 5/7-2013))		
Feed energy					Calculated from 2005-data (Dalgaard and Schmidt 2012). Assumed the feed energy price follows the price of 'Barley' (from UN: http://data.un.org/Explorer.aspx?d=ICS)).
Feed protein					Calculated from 2005-data (Dalgaard and Schmidt 2012). Assumed the protein price follows the price of 'Soya-bean oil-cake and other solid residues' (from UN: http://data.un.org/Explorer.aspx?d=ICS).