National and farm level carbon footprint of milk

Life cycle inventory for Danish and Swedish milk

2005 at farm gate

Preface

This report documents the input data used in the Arla model (Schmidt and Dalgaard 2012) to calculate carbon footprint of Danish and Swedish milk in 2005. The current report includes no results or interpretations. This is presented in Schmidt and Dalgaard (2012). The current report serves as an extended appendix to Schmidt and Dalgaard (2012).

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When citing the current report, please use the following reference:

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1 Introduction

In this report input parameters used for the calculation of carbon footprints of Danish and Swedish milk are presented. It should be noticed that all results and interpretations for the carbon footprints of Danish and Swedish milk are presented in Schmidt and Dalgaard (2012). Further, the used terms, definitions and methodological framework is also described in Schmidt and Dalgaard (2012).

In **Chapter 1** general activities and data (e.g. electricity, fertilisers, capital goods etc.) are presented. In **Chapter 0** the Danish and Swedish milk and beef systems and the Brazilian beef system are presented. The plant cultivation system, which includes 12 different crops from various countries, is presented in **Chapter 4**. Finally, the food industry system is presented in **Chapter 1**.

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)

Services includes inputs to the product system which are often excluded from life cycle assessments, such as retail, wholesale, accounting, marketing, consultancy etc. Inventory data for services are obtained from the EU27 input-output (IO) database (Schmidt 2010a, Schmidt 2010b, and Schmidt et al. 2010). This database is publically available in SimaPro 7.3 (it can be freely accessed in the demo version): www.pre-sustainability.com.

Each activity in the EU27 IO-database has inputs of 132 products. The life cycle emissions related to 21 of these products is defined as the emissions related to services. The 21 products are:

- Agricultural services n.e.c.
- Recycling services
- Trade and repair of motor vehicles and service stations
- Wholesale trade
- Retail trade and repair services
- Hotels and restaurants
- Post and telecommunication
- Financial intermediation
- Insurance and pension funding
- Services auxiliary to financial intermediation
- Real estate services
- Renting of machinery and equipment etc.
- Computer and related services
- Research and development
- Business services n.e.c.
- Public service and security
- Education services
- Health and social work
- Membership organisations
- Recreational and cultural services
- Services n.e.c.

The GHG-emissions related to services are shown in the following sections.

2.2 Capital goods (general)

Capital goods include the production of machinery, buildings and infrastructure. In general, the GHG-emissions related to capital goods are obtained from the ecoinvent database v2.2 (ecoinvent 2007). SimaPro 7.3 enables for analysing products with and without capital goods. The difference between the two results represents the GHG-emissions related to capital goods.

In cases where no ecoinvent data are available, some the capital goods are estimated by use of the EU27 IO-database. Each activity in the EU27 IO-database has inputs of 132 products. The life cycle emissions related to 16 of these products are defined as the emissions related to capital goods. The 16 products are:

- Sand, gravel and stone from quarry
- Clay and soil from quarry
- Concrete, asphalt and other mineral products
- Bricks
- Fabricated metal products, except machinery
- Machinery and equipment n.e.c.
- Office machinery and computers
- Electrical machinery n.e.c.
- Radio, television and communication equipment
- Instruments, medical, precision, optical, clocks
- Motor vehicles and trailers
- Transport equipment n.e.c.
- Furniture and other manufactured goods n.e.c.
- Buildings, residential
- Buildings, non-residential
- Infrastructure, excluding buildings

The GHG-emissions related to services are shown in the following sections.

2.3 Electricity

Electricity is used in most life cycle stages of milk production. Generally, electricity at medium voltage is used in all activities. This includes production, high voltage grid and medium voltage grid. Grid losses are considered.

The methodology for the inventory of electricity is described in Schmidt et al. (2011). For the switch for ISO14040/44, i.e. consequential modelling, the affected suppliers are identified as the proportion of the growth for each suppliers in the period 2008-2020. The electricity generation in 2020 is identified by use of energy plans. The switches for average, PAS2050 and IDF all use average electricity mix in year 2008.

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

The country specific inventory data are included for the following countries and are obtained from the following data sources:

- Denmark: Merciai et al. (2011a)
- Sweden: See **Table 2.1** below
- Brazil: Merciai et al. (2011b)
- France: Merciai et al. (2011c)
- Malaysia: Merciai et al. (2011d)
- Europe: Merciai et al. (2011e)
- World: Merciai et al. (2011f)

The selection of the included countries is based on the countries in which inventoried:

- cattle farms are located (Denmark, Sweden, Brazil), and
- food industries are located (Denmark, Sweden, Brazil, France, Malaysia, Europe average. The global electricity mix is included for cases where activities outside these countries/regions are involved in the inventory)
- Further, it should be noticed that electricity in countries where only crop cultivation takes place has not been specifically inventoried because the use of electricity in crop cultivation is insignificant

It should be noted that the electricity inventories are linked to the ecoinvent database. This enables for identifying capital goods for electricity generation and transmission by use of the ecoinvent data for capital goods.

Table 2.1: Electricity mix in Sweden in year 2008 (IEA 2012) and year 2020 (European Commission 2010, p 114)

Sweden	2008	2020
Coal	1.60	1.13
Oil	0.730	0.515
Gas	1.55	1.09
Biomass	12.2	16.7
Nuclear	52.2	36.9
Hydro	66.0	68.0
Wind	2.50	12.5
Geothermal	0	0
Solar	0	0
Marine	0	0
Total	**137**	**137**

The inputs of services are obtained from the EU27 IO-database as described in **chapter 2.1** and **2.2**. The data are obtained from the following activity in the database: 'Electricity, steam and hot water'.

The GHG-emissions related to electricity in the inventoried countries are shown in **Table 2.2**.

Table 2.2: GHG-emissions related to electricity production and distribution.

Electricity GHG-emissions (kg CO_2-eq.)	Elec DK	Elec SE	Elec BR	Elec FR	Elec MY	Elec EU	GLO
Reference flow	1 kWh	1 kWh	1 kWh	1 kWh	1 kWh	1 kWh	1 kWh
Switch 1: ISO 14044/44							
Process data, ex infrastructure	0.225	0.0706	0.385	0.222	1.32	0.134	0.612
Capital goods	0.0123	0.0122	0.00640	0.0163	0.00888	0.0209	0.0107
Services	0.00195	0.00195	0.00195	0.00195	0.00195	0.00195	0.00195
Switch 2: average/allocation							
Process data, ex infrastructure	0.640	0.0514	0.248	0.0883	0.929	0.480	0.803
Capital goods	0.0100	0.00558	0.00725	0.00517	0.00607	0.00930	0.00973
Services	0.00195	0.00195	0.00195	0.00195	0.00195	0.00195	0.00195
Switch 3: PAS2050							
Process data, ex infrastructure	0.640	0.0514	0.248	0.0883	0.929	0.480	0.803
Capital goods	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Services	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Switch 4: IDF							
Process data, ex infrastructure	0.640	0.0514	0.248	0.0883	0.929	0.480	0.803
Capital goods	0.0100	0.00558	0.00725	0.00517	0.00607	0.00930	0.00973
Services	0.00195	0.00195	0.00195	0.00195	0.00195	0.00195	0.00195

2.4 Fertilisers and other chemicals

Inventory data (process data and capital goods) for fertilisers and other chemicals are obtained from ecoinvent (2007). The following fertilisers and chemicals are included in the inventory. The reference flow is shown, and the used ecoinvent-activities are specified in brackets:

- Ammonia, kg N (Ammonia, liquid, at regional storehouse/RER)*
- Urea, kg N (Urea, as N, at regional storehouse/RER)
- Ammonium nitrate (AN), kg N (Ammonium nitrate, as N, at regional storehouse/RER)
- Calcium ammonium nitrate (CAN), kg N (Calcium ammonium nitrate, as N, at regional storehouse/RER)
- Ammonium sulphate (AS), kg N (Ammonium sulphate, as N, at regional storehouse/RER)
- Triple super phosphate (TSP), kg P_2O_5 (Triple superphosphate, as P2O5)
- Rock phosphate, kg P_2O_5 (Phosphate rock, as P2O5, beneficiated, wet, at plant/US)
- Potassium chloride, kg K_2O (Potassium chloride, as K2O, at regional storehouse/RER)
- Other chemicals, kg (Chemicals inorganic, at plant/GLO)

* the ecoinvent process for ammonia has reference flow kg NH_3. This is adjusted to kg N by dividing by 0.822 which is the N content in ammonia (IFA 2012a).

The inputs of services are obtained from the EU27 IO-database as described in **chapter 2.1** and **2.2**. The data are obtained from the following activities in the database:

- N-fertilisers: 'Fertiliser, N'. N-content: 0.3 is assumed based on N-content in the most widely used N-fertilisers (IFA 2012a)
- Triple super phosphate: 'Fertiliser, other than N'. P_2O_5-content: 0.46 (IFA 2012a)
- Potassium chloride: 'Fertiliser, other than N'. K_2O-content: 0.6 (IFA 2012a)
- Rock phosphate: 'Minerals from mine n.e.c.'. P_2O_5-content: 0.309 (IFA 2012a)
- Other chemicals: 'Chemicals n.e.c.'

The GHG-emissions related to fertilisers and other chemicals are shown in **Table 2.3**.

Table 2.3: GHG-emissions related to fertiliser and other chemicals production.

Fertiliser and chemical GHG-emissions (kg CO_2-eq.)	N-fert: Ammo-nia	N-fert: Urea	N-fert: AN	N-fert: CAN	N-fert: AS	P-fert: TSP	P-fert: Rock phos-phate	K-fert	Other chemi-cals
Reference flow	1 kg N	1 kg N	1 kg N	1 kg N	1 kg N	1 kg P_2O_5	1 kg P_2O_5	1 kg K_2O	1 kg
All switches									
Process data, ex infrastructure	2.43	3.07	8.16	8.20	2.39	1.74	0.199	0.364	1.74
Infrastructure	0.116	0.233	0.391	0.449	0.306	0.277	0.0138	0.134	0.117
Services	0.0332	0.0332	0.0332	0.0332	0.0332	0.0412	0.00222	0.0316	0.171

2.5 Fuels and burning of fuels

Inventory data (process data and capital goods) for fuels are obtained from ecoinvent (2007). The following fuels are included in the inventory. The reference flow is shown, and the used ecoinvent-activities are specified in brackets:

- Diesel, MJ (Diesel, at regional storage/RER U)*
- Natural gas, MJ (Natural gas, high pressure, at consumer/RER U)
- Light fuel oil, MJ (Light fuel oil, at regional storage/RER U)*
- Coal, MJ (Hard coal at regional storage, UCTE)*

* the ecoinvent processes for diesel, light fuel oil and coal have reference flows in kg. This is converted to MJ by dividing with calorific values of the fuels, see '**Appendix A: Fuel and substance properties**'.

The inputs of services are obtained from the EU27 IO-database as described in **chapter 2.1** and **2.2**. The data are obtained from the following activities in the database:

- Coal, lignite, peat
- Refined petroleum products and fuels
- Gas

As for some of the ecoinvent processes above, the reference flows in the EU27 IO-table is in kg. This is converted to MJ by dividing with calorific values of the fuels, see '**Appendix A: Fuel and substance properties**'.

The GHG-emissions related to the burning of the fuels are obtained from NERI (2010, pp 641-646).

The GHG-emissions related to the production and burning of fuels are shown in **Table 2.4**.

Table 2.4: GHG-emissions related to production and burning of fuels.

Fuels GHG-emissions	Diesel	Natural gas	Light fuel oil	Coal
Reference flow	MJ	MJ	MJ	MJ
All switches				
Process data, ex infrastructure, kg CO_2-eq.	0.0100	0.0108	0.010	0.011
Infrastructure, kg CO_2-eq.	0.00194	0.000599	0.0019	0.0007
Services, kg CO_2-eq.	0.000126	0.000200	0.000126	0.000027
Burning fuel, kg CO_2	0.0740	0.0570	0.0740	0.0950
Burning fuel, kg CH_4	0.00000150	0.000465	0.00000150	0.00000150
Burning fuel, kg N_2O	0.00000200	0.00000140	0.00000300	0.00000200

2.6 Transport

Inventory data (process data and capital goods) for transport are obtained from ecoinvent (2007). The following transport activities are included in the inventory. The reference flow is shown, and the used ecoinvent-activities are specified in brackets:

- Road transport/lorry, tkm (Transport, lorry 16-32t, EURO3/RER)
- Ship transport, tkm (Transport, barge/RER)

The inputs of services are obtained from the EU27 IO-database as described in **chapter 2.1** and **2.2**. The data are obtained from the following activities in the database:

- Land transport and transport via pipelines
- Transport by ship

The reference flow of the transport activities in the EU27 IO-database is EUR2003. This is converted to tkm by use of prices. The price of road transport is estimated by comparing the total monetary value of road transport in EU27 in 2003 (495.5 thousand MEUR2003, data are available in the EU27 IO-database in SimaPro) by the total transport in EU27 in 2003 in units of tkm (1625 billion tkm of which road transport is 68.8%, Eurostat, 2009). The price of ship transport is calculated relative to road transport; according to Rodrigue et al. (2009), the price of ship transport is 2.79% of the price of road transport. The prices of road and ship transport are 0.210 EUR2003/tkm and 0.00585 EUR2003/tkm respectively.

The GHG-emissions related to transport are shown in **Table 2.5**.

Table 2.5: GHG-emissions related to transport.

Transport GHG-emissions (kg CO2-eq.)	Lorry	Ship
Reference flow	1 tkm	1 tkm
All switches		
Process data, ex infrastructure	0.153	0.0347
Infrastructure	0.0313	0.0117
Services	0.0138	0.000229

2.7 Capital goods and services in cattle and crop farms

Capital goods and service inputs to cattle farms and crops farms are obtained from the EU27 IO-database as described in **chapter 2.1** and **2.2**. The data are obtained from the following two activities in the database:

- Bovine meat and milk
- Grain crops

The reference flow for the 'Bovine milk and meat' activity in the database is dry matter meat (live weight) plus dry matter milk. The EU27 total production volume in 2003 is 37.35 million tonne (data available in the database in SimaPro). The GHG-emissions from this quantity for capital goods and services are then normalised by the total number of cattle in EU27 in 2003. According to FAOSTAT (2012), this is 92.8 million heads. In

Table 2.6, the GHG-emissions for capital goods and services are shown per head. This can be linked in the model, where number of heads is a parameter in the animal activities.

The reference flow for the 'Grain crops' activity in the database is dry matter crops. The EU27 total production volume in 2003 is 728 million tonne (data available in the database in SimaPro). The GHG-emissions from this quantity for capital goods and services are then normalised by the total cultivated area of grain crops in EU27 in 2003. According to FAOSTAT (2012), this is 55.5 million ha. In

Table 2.6, the GHG-emissions for capital goods and services are shown per ha. This can be linked in the model, where the cultivated area is a parameter in the crop cultivation activities.

Table 2.6: GHG-emissions for capital goods and services in animal and crop farms

Capital goods and services GHG-emissions (kg CO2-eq.)	Animal farm	Crop farm
Reference flow	1 head	1 ha
All switches		
Capital goods	95.1	108
Services	126	126

Notice that no distinction between GHG-emissions related to capital goods and services is considered for animal farms and crop farms. Further, it should be noted that no distinction between countries is considered, and that capital goods and services per hectare of grain crops are assumed to be representative for all crops.

2.8 Capital goods and services in the food industry activities

The following activities in the food industry are involved in the inventory:

- Vegetable oil mills (palm oil, soybean oil, palm kernel oil, rapeseed oil, sun flower oil)
- Refinery of vegetable oil (palm oil, palm kernel oil, soybean oil, rapeseed oil)
- Sugar manufacturing
- Flour mill
- Destruction of dead animals

Data on capital goods are based on
- Vegetable oil mills (Schmidt 2007, p 154)
- Refinery of vegetable oil (Schmidt 2007, p 187)
- Sugar manufacturing ('Sugar, from sugar beet, at sugar refinery/CH U', ecoinvent 2007)
- Flour mill (Assumed same per kg flour as per kg sugar from sugar manufacturing)
- Destruction of dead animals (Assumed same per kg flour as per kg sugar from sugar manufacturing)

Service inputs to the food industry activities are obtained from the EU27 IO-database as described in **chapter 2.1** and **2.2**. The data are obtained from the following activities in the database:
- Vegetable and animal oils and fats (used for oil mils and oil refineries)
- Sugar (used for sugar manufacturing and destruction of dead animals
- Flour

In **Table 2.7**, the GHG-emissions for capital goods and services are shown per head.

Table 2.7: GHG-emissions for capital goods and services in food industry activities

Capital goods and services GHG-emissions (kg CO2-eq.)	Oil mill	Oil refinery	Sugar	Flour	Destruction
Reference flow	1 kg crude oil	1 kg refined oil	1 kg sugar	1 kg flour	1 kg animal (live weight)
All switches					
Capital goods	0.00201	0.00152	0.000477	0.000477	0.000181
Services	0.0393	0.0393	0.0380	0.0385	0.0144

Note that the inputs to the animal destruction activity are implemented as the inputs to the sugar activity multiplied with 0.38 which is the dry matter content of the treated animals (DAKA 2006). Then the output of the animal destruction is comparable with the output of the sugar manufacturing in terms of dry weight.

Notice that no distinction between GHG-emissions related to capital goods and services is considered for food industries in different countries. The general vegetable oil industry in the EU27 is regarded as representative for oil mills and refineries for soybean oil and palm oil in Brazil and Malaysia. And also inputs of capital goods and services to the sugar industry (per kg sugar) are presumed as being representative for the inputs of capital goods and services to the animal destruction industry (per kg dry by-product output). Destruction of animals in Brazil is presumed to take place without any inputs of capital goods and services.

2.9 Indirect land use changes (ILUC)

Indirect land use changes are caused by occupation of land in the animal and crop cultivation activities. The applied inventory data are obtained from the ILUC-project version 3 (Schmidt et al. 2012). The ILUC model in Schmidt et al. (2012) enables for consequential and attributional modelling.

ILUC are inventoried for three different markets for land:
- Land tenure, arable
- Land tenure, intensive forest land
- Land tenure, rangeland

It should be noticed that the ILUC inventory is linked to the ecoinvent database. This enables for identifying capital goods for ILUC by use of the ecoinvent data for capital goods.

No service inputs to ILUC have been quantified.

The reference flow for the use of land tenure is potential net primary production, NPP_0, measured in kg carbon per hectare. The GHG-emissions related to ILUC are summarized in **Table 2.8**.

Table 2.8: GHG-emissions related to ILUC.

ILUC GHG-emissions (kg CO2-eq.)	Land tenure, arable	Land tenure, intensive forest land	Land tenure, rangeland
Reference flow	1 kg C	1 kg C	1 kg C
Switch 1: ISO 14044/44			
Process data, ex infrastructure	1.26	0.463	0.238
Capital goods	0.0500	0	0
Services	0	0	0
Switch 2: average/allocation			
Process data, ex infrastructure	0.0498	0.000198	0.000275
Capital goods	0.00173	0	0
Services	0	0	0
Switch 3: PAS2050			
Process data, ex infrastructure	n.a.	n.a.	n.a.
Capital goods	n.a.	n.a.	n.a.
Services	n.a.	n.a.	n.a.
Switch 4: IDF			
Process data, ex infrastructure	n.a.	n.a.	n.a.
Capital goods	n.a.	n.a.	n.a.
Services	n.a.	n.a.	n.a.

Data on the land tenure (kg C) required for the cultivation of a given crop depends on the annual yield of the crop (kg ha^{-1} yr^{-1}) and on the potential net primary production (NPP_0) of the given field. The latter is applied as national averages. In case the countries cover significant different NPP_0 zones, the average of the relevant region, i.e. where crops are grown, in the country is considered. Data on potential net primary production (NPP_0) are obtained from a global map available in Haberl et al. (2007, SI figure 2). NPP0 data for the relevant countries are summarized in **Table 2.9**.

Table 2.9: Potential net primary production (NPP_0) in the relevant countries. Data are obtained from Habarl et al. (2007, SI figure 2).

Country	Potential netr primary production, NPP0 (kg C ha^{-1} yr^{-1})
Brazil (BR)	9,000
Denmark (DK)	7,000
European Union (EU)	7,000
France (FR)	7,000
Malaysia (MY)	11,000
Sweden	5,600
Ukraine (UA)	5,000

3 The cattle system

The target activity of the Arla model is the milk producing activity, i.e. the dairy cow.

3.1 Overview of the cattle system

Cattle turnover, stock and related parameters: Denmark

Figure 3.1 and **Figure 3.2** present cattle turnover and stocks in the Danish milk and beef system. For more details on the included activities see Schmidt and Dalgaard (2012, Table 6.1). Data are mainly obtained from a representative sample of Danish farm accounts from 2005. All data are collected by Kristensen (2011).

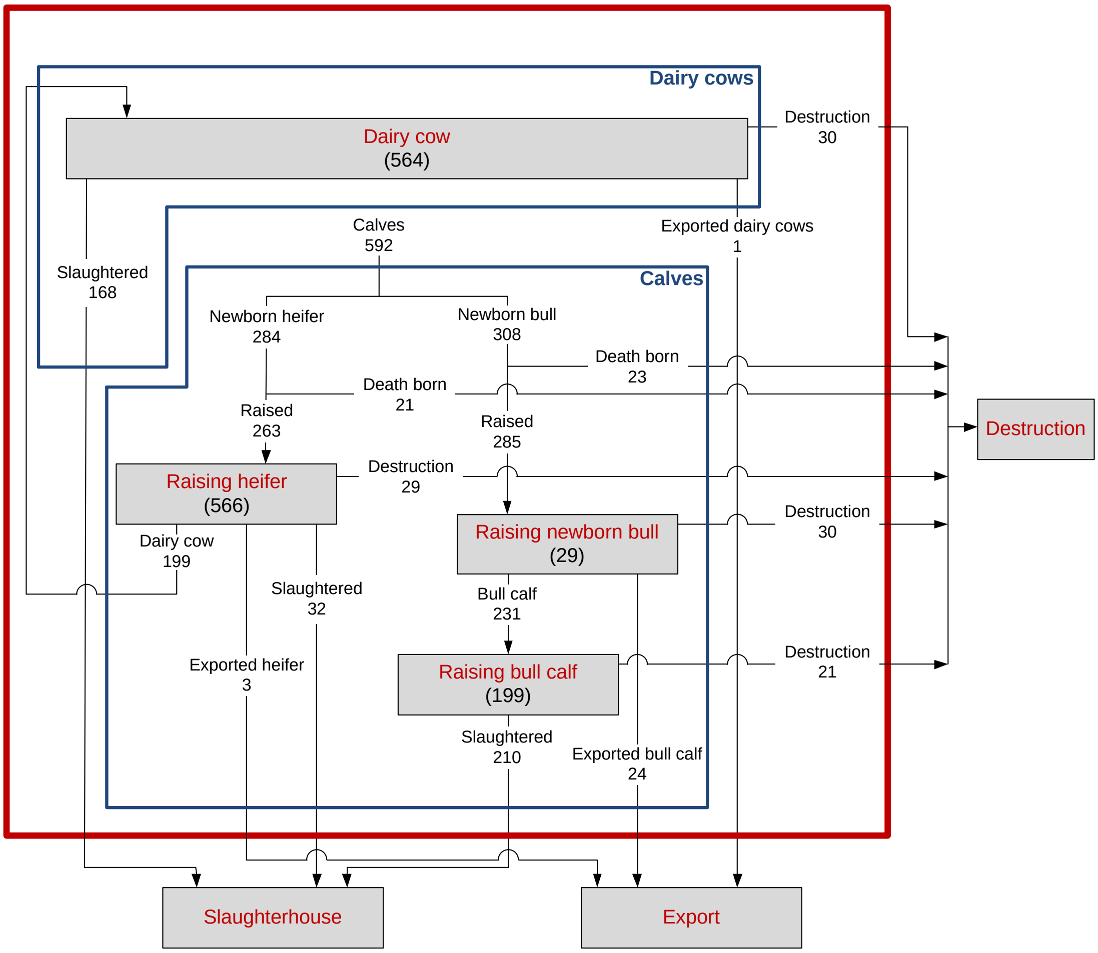

Figure 3.1: Milk system turnover in Denmark 2005. Values on arrows are flows. Bracketed values are stocks. Unit: 1000 heads.

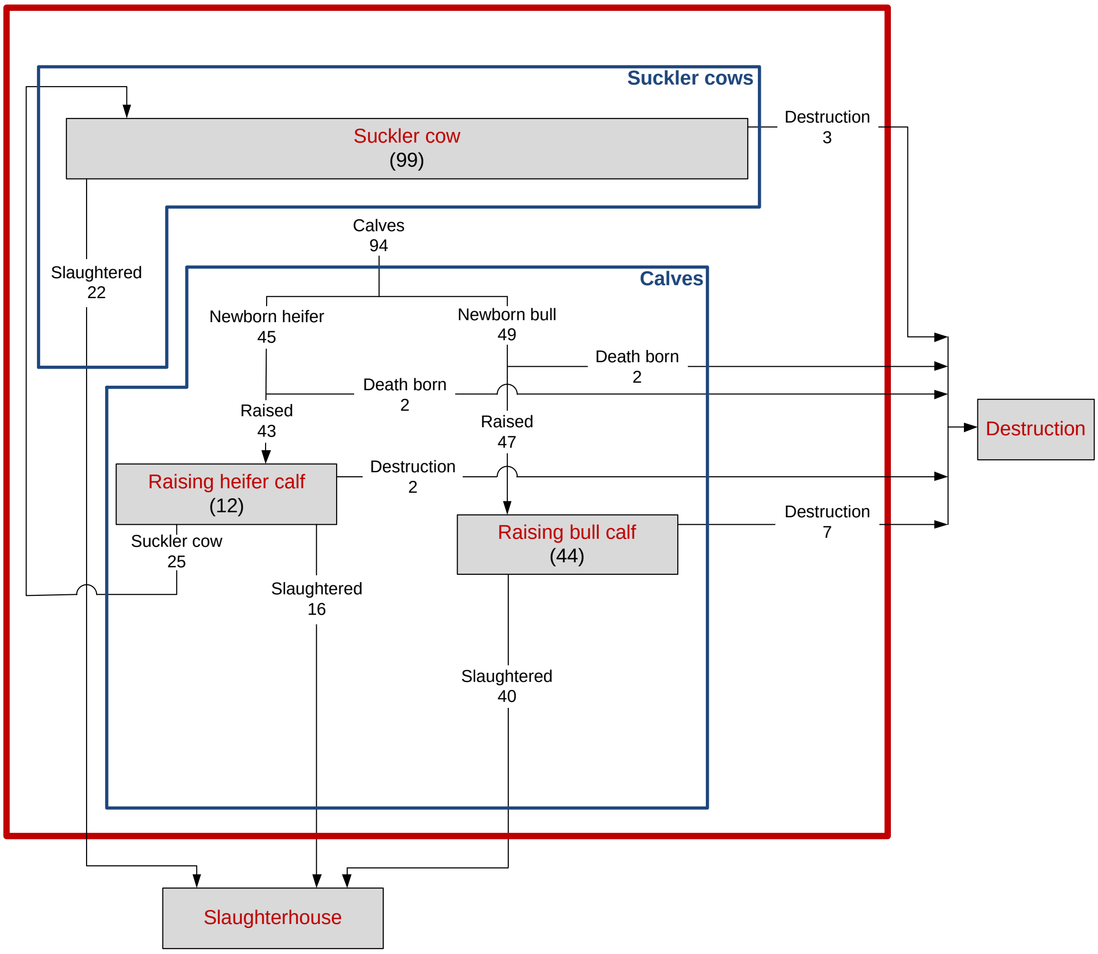

Figure 3.2: Beef system turnover in Denmark 2005. Values on arrows are flows. Bracketed values are stocks. Unit: 1000 heads.

The inflow and outflows for each animal activity are presented in **Table 3.1** together with data on weights etc.

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

Denmark	Unit	Milk system				Beef system		
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull
Stock (annual average)	heads	563,500	566,000	29,000	198,500	98,500	94,500	44,000
Weight gain	kg day^{-1} head^{-1}	0.104	0.532	0.420	1.062	0.075	0.588	1.218
Period in activity*	days	1103	869	48	339	1598	816	392
Inflow								
Cow or calf	heads	199,000	263,000	285,000	231,000	25,000	43,000	47,000
Outflows								
Newborn heifers	heads	284,000				45,000		
Newborn bulls	heads	308,000				49,000		
Death born heifers	heads	21,000				2,000		
Death born bulls	heads	23,000				2,000		
Fallen heads	heads	30,000	29,000	30,000	21,000	3,000	2,000	7,000
Slaughtered heads	heads	168,000	32,000	0	210,000	22000	16,000	40,000
Exported heads	heads	1,000	3,000	24,000	0	0	0	0
Weights								
When entering activity	kg head^{-1}	460	38	40	60	480	40	42
When leaving activity	kg head^{-1}	575	500	60	420	600	520	520
Death born	kg head^{-1}	40						
Fallen animal	kg head^{-1}	525	102	50	110	500	100	105
Slaughtered animal	kg head^{-1}	575	500	NA	420	600	550	520

*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: Sweden

The turnovers, stocks (annual average) and the fate of cattle leaving the activities in the Swedish milk system and beef system are presented in **Figure 3.3** and **Figure 3.4** respectively. The two figures are established based on an iterative approach, where some parameters (see **Table 3.2**) have been held constant, and other adjusted in order to achieve balance and at the same time to arrive as close as possible to characteristic figures for the Swedish cattle system.

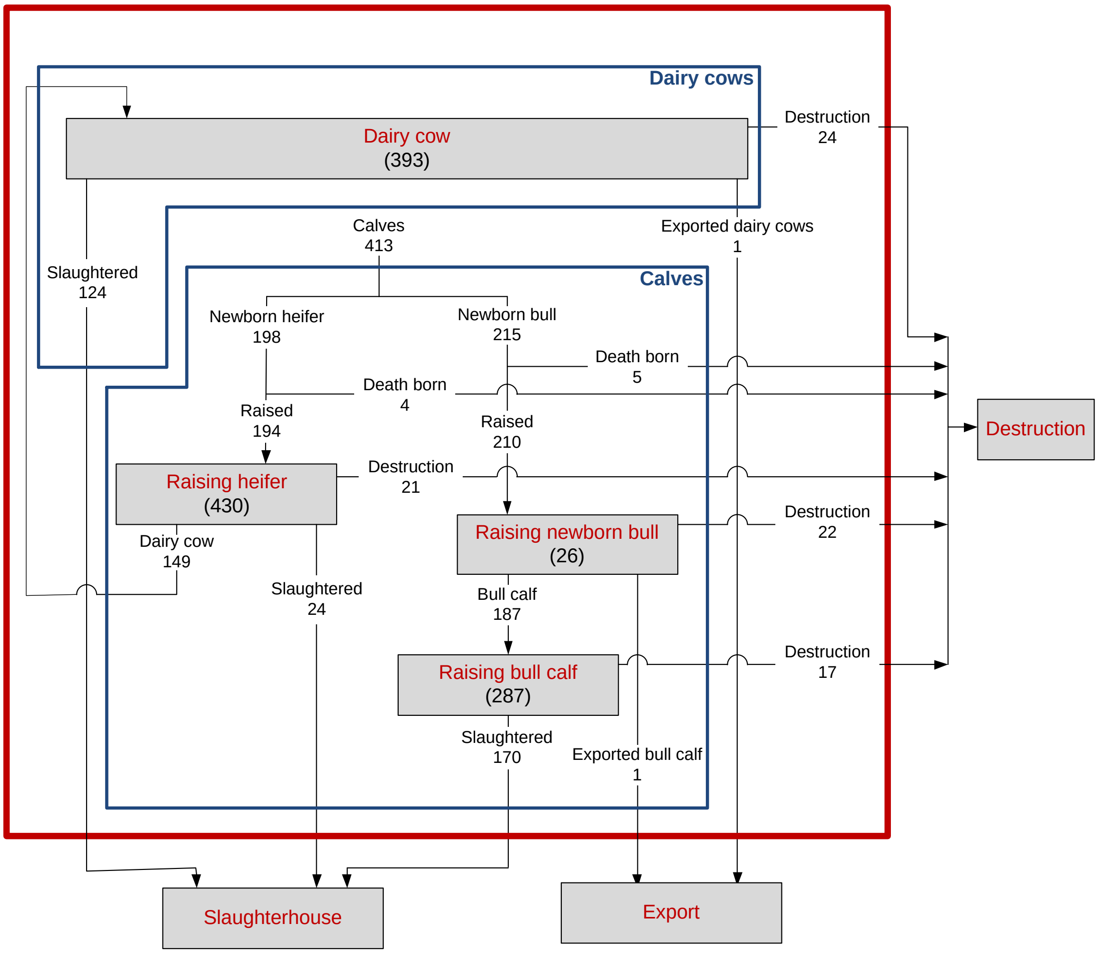

Figure 3.3: Milk system turnover in Sweden 2005. Values on arrows are flows. Bracketed values are stocks. Unit: 1000 heads.

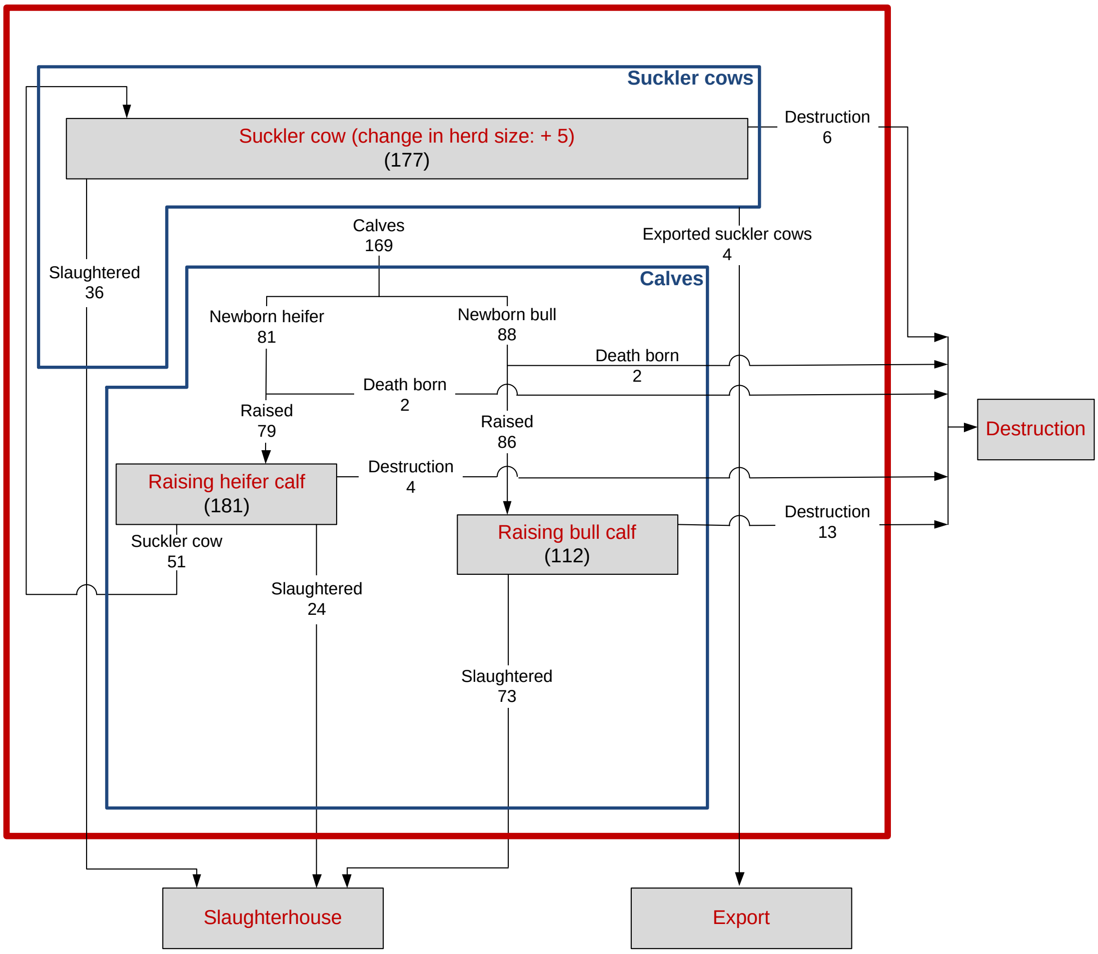

Figure 3.4: Beef system turnover in Sweden 2005. Values on arrows are flows. Bracketed values are stocks. Unit: 1000 heads.

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

Sweden	**Unit**	**Milk system**				**Beef system**		
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull
Stock (annual average)	heads	393,268	429,851	25,593	286,717	177,000	181,286	111,742
Weight gain	kg day^{-1} head^{-1}	0.076	0.530	0.837	0.828	0.064	0.530	1.035
Period in activity*	days	961	854	47	587	1891	854	513
Inflow								
Cow or calf	heads	149,000	194,438	209,795	186,711	51,200	79,327	85,938
Outflows								
Newborn heifers	heads	198,204				80,863		
Newborn bulls	heads	214,954				88,051		
Death born heifers	heads	3,766				1,536		
Death born bulls	heads	5,159				2,113		
Fallen heads	heads	24,000	21,440	22,084	16,974	6,000	3,690	12,799
Slaughtered heads	heads	124,000	24,000	0	169,738	36,000	24,637	73,138
Exported heads	heads	1,000	0	1,000	0	4,000	0	0
Weights								
When entering activity	kg head^{-1}	453	40	40	79	453	40	40
When leaving activity	kg head^{-1}	525	493	79	565	575	493	571
Death born	kg head^{-1}	40				40		
Fallen animal	kg head^{-1}	489	266	60	322	514	266	305
Slaughtered animal	kg head^{-1}	525	493	79	565	575	493	571

*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).

Stock (annual average) and live weight animals to slaughter are numbers that determines most of the environmental efficiency (enteric fermentation, manure emissions, and feed intake) of cattle production in Sweden. Other parameters in **Figure 3.3** and **Figure 3.4** are just intermediate flows, e.g. animal transactions between animal activities, which do not influence the result of the model. These intermediate flows have been included in order to ensure that the modelled system reflects the actual system, e.g. it is ensured that the number of born calves is higher than the number of slaughtered heads (given that the system is in a steady-state mode). Further, relationships between slaughtered weight, number of slaughtered animals, total live weight meat production, life times of cattle, weight gain etc. have been ensured.

The starting point for establishment of the turnover and stock is data from Flysjö et al. (2011) and Cederberg et al. (2009a). However, calves, heifers, bulls and steers from these data sources are not divided into milk and beef system. Thus, it is necessary to adjust data before entering them into the model. To improve the quality of these adjustments, data on number of slaughtered heads disaggregated in different cattle races from Taurus (2007) are used. These data represent slaughtering statistic from 2006, and are used because data from 2005 not are available. Data on calf mortality are from Svensson (2007). Data on calves born per cow per year, percentage of destructed/discarded cattle are assumed equal to the Danish cattle system due to data lack.

To ensure coherency in the established flow and stock data, these were checked against data on cattle stock from UNFCCC (2007), in which it is reported that the stock in Sweden in 2005 was 393,000 dairy cows and 1,212,000 other cattle (heifers, bulls, steers). For each of the activities, the relationship between the flow of animals, the stock and the time period in which each animal is in the activity can be described by the following equation:

Equation 3.1

$$\text{Stock} = \text{inflow} \cdot \text{period}$$

Where:

Stock = The average number of animals in the activity during one year, animals
Inflow = The number of animals entering the activity during one year, animals year-1
Period = The average time an animal spends in the activity, year.

Only stocks of calves, heifers and bulls are calculated from **Equation 3.1**. Stocks of dairy and suckler cows are taken directly from Cederberg et al. (2009a). Periods used for the stock calculation are based on slaughter ages and other information from Cederberg et al. (2009a, p 89). It is assumed that the period of time the calves in the 'Raising newborn bull calves' is in the milk system is the same as for the Danish new born bulls (=48 days). Also it was taken into account that part of the cattle in all activities are leaving before expected. For example 24 of the 194 heifers entering the activity 'Raising heifer' in the 'Milk system' (**Figure 3.3**) are destructed**.** It is assumed all destructed cattle as an average leave an activity in the middle of the period.

A cross check of the first calculation of the total stock was performed by adding stocks from all activities and compare it to the stock data from UNFCCC (2007). It was 2.1% lower than the data from UNFCCC

(2007). To overcome this discrepancy, the time bulls from milking and suckler cows spend in the activity is prolonged by 9.6%. By this adjustment 100% accordance to the data from UNFCCC (2007) is obtained.

The coherency of the established data is also checked against data on the total production of beef meat as of Cederberg et al. (2009a, p 38), and it is found the data are underestimated by 0.9 %. This is considered to be low, and indicates the established flows and stocks are representative for the Swedish cattle production.

Cattle turnover, stock and related parameters: Brazil

The animal turnover in the Brazilian beef system is presented in **Figure 3.5**. The figure show the cattle flows between the activities and the fate of cattle leaving the activities.

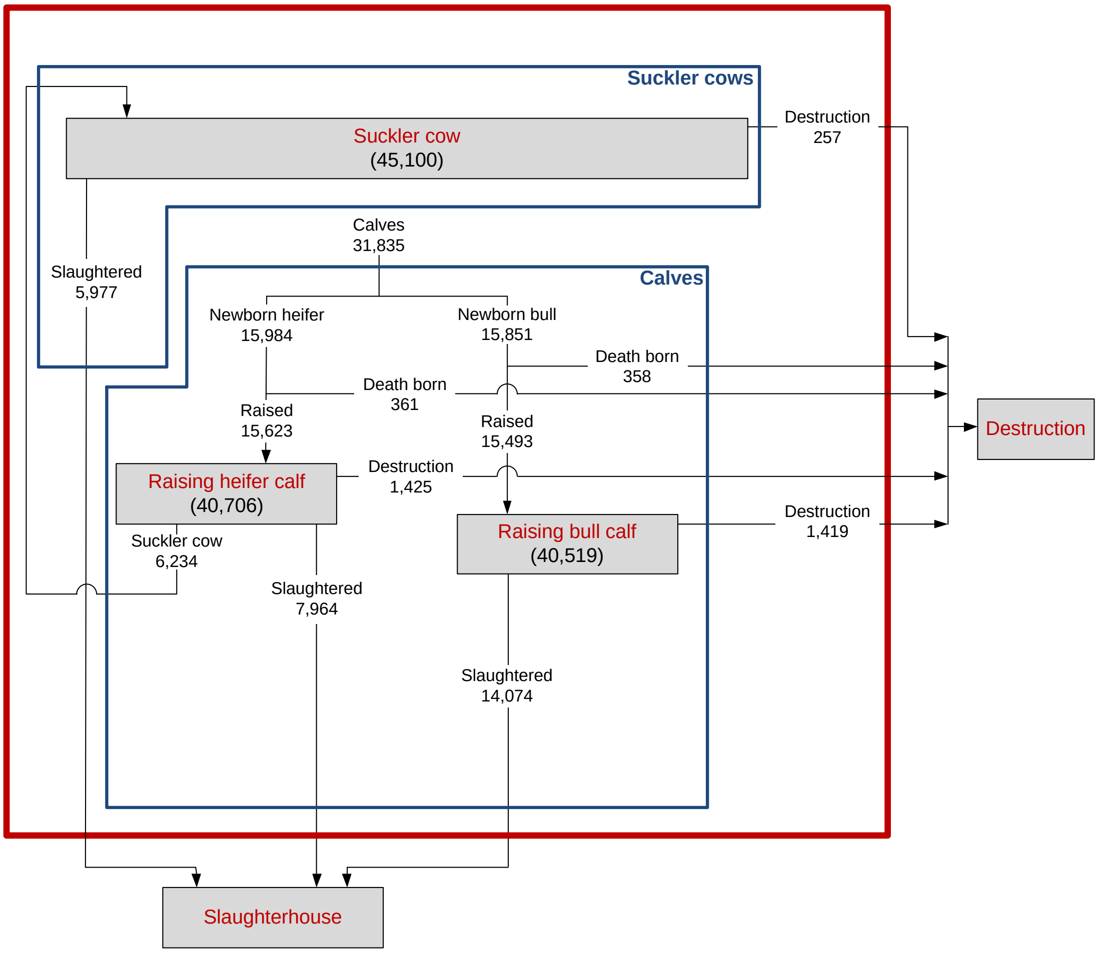

Figure 3.5: Beef system turnover in Brazil 2005. Values on arrows are flows. Bracketed values are stocks. Unit: 1000 heads.

Table 3.3: Parameters used for accounting for flows and stocks of animals in Brazil.

Brazil	**Unit**	**Beef system**		
Parameters		Suckler cow	Raising heifer calf	Raising bull
Stock (annual average)	heads	45,100,000	40,705,816	40,518,838
Weight gain	kg day^{-1} $head^{-1}$	0.074	0.237	0.275
Period in activity*	days	2190	1095	1278
Inflow				
Cow or calf	heads	6,234,000	15,623,004	15,492,812
Outflows				
Newborn heifers	heads	15,984,248		
Newborn bulls	heads	15,851,046		
Death born heifers	heads	361,244		
Death born bulls	heads	358,234		
Fallen heads	heads	256,619	1,425,343	1,418,796
Slaughtered heads	heads	5,976,953	7,964,090	14,074,017
Exported heads	heads	0	0	0
Weights				
When entering activity	kg head-1	260	40	40
When leaving activity	kg head-1	422	300	391
Death born	kg head-1	40		
Fallen animal	kg head-1	400	190	209
Slaughtered animal	kg head-1	422	351	391

*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).

Figure 3.5 is established based on an iterative approach where some important parameters have been held constant, and other adjusted in order to achieve balance and at the same time to arrive as close as possible to characteristic figures for the Brazilian beef system.

The important parameters, which have been held constant, are:

- Number of heads in the herd (annual average)
- Live weight animals to slaughterhouse

In the model, these numbers determine most of the environmental efficiency (enteric fermentation, manure emissions, and feed intake) of beef production in Brazil. Other parameters in **Figure 3.5** are just intermediate flows, e.g. animal transactions between animal activities, which do not influence the result of the model. These intermediate flows have been included in order to ensure that the modelled system reflects the actual system, e.g. it is ensured that the number of born calves is higher than the number of slaughtered heads (given that the system is in a steady-state mode). Further, relationships between slaughtered weight, number of slaughtered animals, total live weight meat production, life times of cattle, weight gain etc. have been ensured.

The number of heads in the herd is based on figures from Cederberg et al. (2009b). The total herd has been allocated to the beef and dairy systems as of **Table 3.4**. The 73% allocation of the cows and bulls in the herd to the beef system is calculated based on figures in Cederberg et al. (2009b, p 20). The 71% allocation of the younger animals to the beef system is calculated based on the total number of suckler cows and dairy cows and calving intervals (months between calving) for suckler cows and dairy cows in Denmark. All older steers are presumed to belong to the beef system.

Table 3.4: Allocation of the total cattle herd to the beef and milk system.

Category	Age	Heads (million)	Beef system	Milk system
Cows (suckler + dairy)		61.6	73%	27%
Bulls		2.3	73%	27%
Calves (heifer)	0-12 months	24	71%	29%
Calves (bulls)	0-12 months	23.8	71%	29%
Heifers, younger	1-2 years	20.5	71%	29%
Heifers, older	2-3 years	13.1	71%	29%
Bulls and steers, younger	1-2 years	17	71%	29%
Bulls and steers, older	2-3 years	9.2	71%	29%
Steers, older	3-4 years	2.9	100%	0%
Steers, older	>4 years	0.6	100%	0%
Total		**175**		

The weight gain in **Table 3.3** is calculated as the difference in weight when the animals are leaving and entering the activity divided by the 'period in activity'.

In **Table 3.3**, the 'period in activity' for the three animal categories in the beef system is based on estimated figures:

- 6 years for suckler cows
- 3 years for heifer calves
- 3.5 years for bull calves

The number of newborn calves (bulls and heifers) in **Table 3.3** is based on an estimated calving interval in the Brazilian beef system at 17 months and the number of cows in the beef system. Cederberg et al. (2009b) specify a calving interval at 21 months. However, when applying this number it is difficult to make the animal turnover balance because there are too few calves for maintaining the herd and for producing the meat as of the statistics.

The total number of fallen heads is based on a 'mortality to weaning and post weaning' rate of 12% according to Landers (2007). The 12% is applied to the number of newborn calves. This total is subdivided into death born calves, and fallen cows, heifer calves and bull calves. The number of death born calves and cows is based on same mortality rates as for Denmark and Sweden (average). The remaining fallen heads are heifer calves and bull calves. The distribution between heifers and bulls is based on **Table 3.4**.

The numbers of slaughtered heads are determined as follows:

- Annual suckler cows to slaughterhouse:
    - Stock divided with period of time the suckler cows are in the activity
    - minus fallen heads during the time the cows are in the activity
- Annual heifer calves to slaughterhouse:
    - Animals entering the activity
    - minus heifers to suckler cow: calculated to ensure balance in the suckler cow category; heifers in = slaughtered and fallen out
    - minus fallen heifers
- Annual bull calves to slaughterhouse:
    - Animals entering the activity
    - minus fallen heifers

The slaughtered animal weights are calculated iteratively to ensure that the total number of slaughtered animals multiplied with weights equals the total supply of beef (live weight) from the beef system. In this iteration it has been assumed that the ratio between the slaughtered weight of suckler cows, heifer calves and bull calves is the same as in Denmark. According to Cederberg et al. (2009b, **appendix 2**), the total Brazilian supply of cattle meat in 2005 is 8.152 million tonne CW (carcass weight). It is assumed that 73% of this is supplied by the beef system, and that the rest is supplied by the milk system (the 73% is explained in relation to **Table 3.4**). The carcass weight (CW) to live weight (LW) ratio is 0.55. Hence the supply of cattle meat from the beef system can be determined as 10.82 million tonne live weight.

The other weights have been estimated.

3.2 Inventory of feed inputs to the cattle system

The parameters used for calculation of net energy requirements are presented in the two following sections. One method (Kristensen, 2011) is used for the milking cows in Denmark and Sweden and another method (IPCC 2006) is used for all other cattle activities. However, IPCC parameters are also presented for the milking cows because they are used for the calculation of methane emission from enteric fermentation.

Determination of feed requirements: Denmark

Parameters used for calculation of net energy requirements are presented in **Table 3.5.** The total net energy (NE) is calculated as a sum of net energy used for maintenance, activity, lactation, growth etc. and is highest for the milking and suckler cows. More than 50% of total net energy (NE) required by the dairy cows derives from net energy for lactation (NE_l). For the other cattle types, net energy required for maintenance (NE_m) is the largest contributor. Net energy for work (NE_{work}) is 0 for all bovines, because it is not relevant for commercial milk and beef cattle. The net energy parameters (NE_m, NE_a, NE_l, NE_{work}, NE_p and NE_g) are calculated from IPCC (2006) formulas.

The parameters 'FEreq' are used for calculation of feed intake and as explained previously 'FEreq' for dairy cows are calculated from the milk yield (Schmidt et al. 2012, Equation 6.2), whereas 'FEreq' for all other categories of cattle are calculated according to IPCC (2006), see Schmidt and Dalgaard (2012, Equation 6.1).

Table 3.5: Parameters used for calculating feed requirements in Denmark. (*): In Schmidt and Dalgaard (2012).

Denmark Parameters	Unit	Milk system				Beef system			Source
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull	
NE	MJ hd^{-1} day^{-1}	128	30.6	8.74	35.1	44.1	33.4	41.1	Equation 6.1(*)
NE_m	MJ hd^{-1} day^{-1}	41.9	21.4	6.96	22.6	36.1	22.9	25.4	Equation 6.9(*)
NE_a	MJ hd^{-1} day^{-1}	3.56	1.82	0.591	1.92	3.07	1.95	2.16	Equation 6.10(*)
NE_l	MJ hd^{-1} day^{-1}	76.7	0	0	0	0	0	0	Equation 6.11(*)
NE_{work}	MJ hd^{-1} day^{-1}	0	0	0	0	0	0	0	Equation 6.12(*)
NE_p	MJ hd^{-1} day^{-1}	4.19	0	0	0	3.61	0	0	Equation 6.13(*)
NE_g	MJ hd^{-1} day^{-1}	2.01	7.37	1.19	10.7	1.41	8.54	13.5	Equation 6.15(*)
FEreq	million MJ yr^{-1}	27,704	6,316	92.5	2,546	1,587	1,152	659	Equation 6.2(*)
FEreq/hd	MJ hd^{-1} yr^{-1}	49,164	11,159	3,189	12,824	16,114	12,193	14,984	Equation 6.2(*)
FEreq/hd/day	MJ hd^{-1} day^{-1}	135	30.6	8.74	35.1	44.1	33.4	41.1	Equation 6.2(*)
ECM	million kg yr^{-1}	4,756	0	0	0	0	0	0	Kristensen (2011) XXXStatistikbanken?? XXX
ECM/head	kg hd-1 yr^{-1}	8,440	0	0	0	0	0	0	Kristensen (2011) XXXStatistikbanken?? XXX
C_{fi}	MJ day^{-1} kg^{-1}	0.386	0.322	0.370	0.370	0.322	0.322	0.370	IPCC (2006, Table 10.4)
Weight	kg	518	269	50.0	240	540	295	281	**Table 3.1.** See text
C_a	Dim. less	0.085	0.085	0.085	0.085	0.085	0.085	0.085	See text
Milk	kg day^{-1}	24.0	0	0	0	0	0	0	Kristensen (2011) XXXStatistikbanken?? XXX
Fat	%	4.30	0	0	0	0	0	0	Kristensen (2011) XXXStatistikbanken?? XXX
$C_{pregnancy}$	Dim. less	0.100	0	0	0	0.100	0	0	IPCC (2006, Table 10.7)
BW	kg	518	269	50.0	240	540	295	281	**Table 3.1.** See text
C	Dim. less	0.800	0.800	1.20	1.20	0.800	0.800	1.20	IPCC (2006, p 10.17)
MW	kg	575	575	575	575	600	600	600	Estimated
WG	kg day^{-1}	0.104	0.532	0.420	1.06	0.075	0.588	1.22	**Table 3.1.** See text

The last 10 parameters in **Table 3.5** are further described in **Section 6.5** (Inventory of methane from enteric fermentation) in Schmidt and Dalgaard (2012). The parameters 'Weight' and 'BW' are both calculated as an average of the parameters 'When entering activity' and ' When leaving activity' from **Table 3.1**. The parameter C_a, which is used for calculation of net energy for animal activity (NE_a), is calculated as an average for 'Stall' (C_a =0.00) and 'Pasture' (C_a =0.17) (IPCC, 2006, Table 10.5). The parameter 'WG' is equal to 'Weight gain' in **Table 3.1**.

Determination of feed requirements: Sweden

Parameters used for calculation of net energy requirements are presented in **Table 3.6**. The total net energy (NE) is calculated as a sum of net energy used for maintenance, activity, lactation, growth etc. and is highest for the milking and suckler cows. More than 50% of total net energy (NE) required by the dairy cows derives from net energy for lactation (NE_l). For the other cattle types, net energy required for maintenance (NE_m) is the largest contributor. Net energy for work (NE_{work}) is 0 for all bovines, because it is not relevant for commercial milk and beef cattle. The net energy parameters (NE_m, NE_a, NE_l, NE_{work}, NE_p and NE_g) are calculated from IPCC (2006) formulas.

The parameters 'FEreq' are used for calculation of feed intake and as explained previously 'FEreq' for dairy cows are calculated from the milk yield (Schmidt et al. 2012, Equation 6.2), whereas 'FEreq' for all other categories of cattle are calculated according to IPCC (2006), see Schmidt and Dalgaard (2012, Equation 6.1).

Table 3.6: Parameters used for calculating feed requirements in Sweden. (*): In Schmidt and Dalgaard (2012).

Sweden	Unit	Milk system				Beef system			Source
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull	
NE	MJ hd^{-1} day^{-1}	124	30.3	11.5	40.7	42.3	30.1	41.4	Equation 6.1(*)
NE_m	MJ hd^{-1} day^{-1}	40.1	21.2	7.9	28.2	34.7	21.2	27.0	Equation 6.9(*)
NE_a	MJ hd^{-1} day^{-1}	3.41	1.80	0.675	2.39	2.95	1.80	2.30	Equation 6.10(*)
NE_l	MJ hd^{-1} day^{-1}	74.7	0	0	0	0	0	0	Equation 6.11(*)
NE_{work}	MJ hd^{-1} day^{-1}	0	0	0	0	0	0	0	Equation 6.12(*)
NE_p	MJ hd^{-1} day^{-1}	4.01	0	0	0	3.47	0	0	Equation 6.13(*)
NE_g	MJ hd^{-1} day^{-1}	1.36	7.29	2.89	10.1	1.14	7.06	12.0	Equation 6.15(*)
FEreq	million MJ yr^{-1}	18,995	4,757	108	4,255	2,734	1,991	1,687	Equation 6.2(*)
FEreq/hd	MJ hd^{-1} yr^{-1}	48,300	11,067	4,201	14,841	15,444	10,984	15,095	Equation 6.2(*)
FEreq/hd/day	MJ hd^{-1} day^{-1}	132	30.3	11.5	40.7	42	30.1	41.4	Equation 6.2(*)
ECM	million kg yr^{-1}	3,253	0	0	0	0	0	0	Cederberg et al. (2009a)
ECM/head	kg hd-1 yr^{-1}	8,271	0	0	0	0	0	0	Cederberg et al. (2009a)
C_{fi}	MJ day^{-1} kg^{-1}	0.386	0.322	0.370	0.370	0.322	0.322	0.370	IPCC (2006, Table 10.4)
Weight	kg	489	266	59.7	322	514	266	305	**Table 3.2.** See text
C_a	Dim. less	0.085	0.085	0.085	0.085	0.085	0.085	0.085	See text
Milk	kg day^{-1}	23.6	0	0	0	0	0	0	Cederberg et al. (2009a)
Fat	%	4.25	0	0	0	0	0	0	Cederberg et al. (2009a)
$C_{pregnancy}$	Dim. less	0.100	0	0	0	0.100	0	0	IPCC (2006, Table 10.7)
BW	kg	489	266	59.7	322	514	266	305.5	**Table 3.2.** See text
C	Dim. less	0.800	0.800	1.20	1.20	0.800	0.800	1.20	IPCC (2006, p 10.17)
MW	kg	575	575	575	575	600	600	600	Estimated
WG	kg day^{-1}	0.076	0.530	0.837	0.828	0.064	0.530	1.04	**Table 3.2.** See text

The last 10 parameters in **Table 3.6** are further described in **Section 6.5** (Inventory of methane from enteric fermentation) in Schmidt and Dalgaard (2012). The parameters 'Weight' and 'BW' are both calculated as an average of the parameters 'When entering activity' and ' When leaving activity' from **Table 3.2**. The parameter C_a, which is used for calculation of net energy for animal activity (NE_a), is calculated as an average for 'Stall' (C_a =0.00) and 'Pasture' (C_a =0.17) (IPCC, 2006, Table 10.5). The parameter 'WG' is equal to 'Weight gain' in **Table 3.2**.

Determination of feed requirements: Brazil

Parameters used for calculation of net energy requirements are presented in **Table 3.6**. The total net energy (NE) is calculated as a sum of net energy used for maintenance, activity, lactation, growth etc. The net energy required for maintenance (NE_m) is the largest contributor the total net energy (NE). Net energy for work (NE_{work}) is 0 for all bovines, because it is not relevant for commercial milk and beef cattle. The net energy parameters (NE_m, NE_a, NE_l, NE_{work}, NE_p and NE_g) are calculated from IPCC (2006) formulas.

The parameters 'FEreq' are used for calculation of feed intake and as explained previously 'FEreq' for dairy cows are calculated from the milk yield (Schmidt et al. 2012, Equation 6.2), whereas 'FEreq' for all other categories of cattle are calculated according to IPCC (2006), see Schmidt and Dalgaard (2012, Equation 6.1).

Table 3.7: Parameters used for calculating feed requirements in Brazil. (*): In Schmidt and Dalgaard (2012).

Brazil Parameters	Unit	Beef system			Source
		Suckler cow	Raising heifer calf	Raising bull	
NE	MJ hd^{-1} day^{-1}	35.2	20.1	24.2	Equation 6.1(*)
NE_m	MJ hd^{-1} day^{-1}	28.8	16.5	20.3	Equation 6.9(*)
NE_a	MJ hd^{-1} day^{-1}	2.45	1.40	1.73	Equation 6.10(*)
NE_l	MJ hd^{-1} day^{-1}	0	0	0	Equation 6.11(*)
NE_{work}	MJ hd^{-1} day^{-1}	0	0	0	Equation 6.12(*)
NE_p	MJ hd^{-1} day^{-1}	2.88	0	0	Equation 6.13(*)
NE_g	MJ hd^{-1} day^{-1}	1.10	2.27	2.11	Equation 6.15(*)
FEreq	million MJ yr^{-1}	579,925	298,955	357,584	Equation 6.2(*)
FEreq/hd	MJ hd^{-1} yr^{-1}	12,859	7,344	8,825	Equation 6.2(*)
FEreq/hd/day	MJ hd^{-1} day^{-1}	35.2	20.1	24.2	Equation 6.2(*)
C_{fi}	MJ day^{-1} kg^{-1}	0.322	0.322	0.370	IPCC (2006, Table 10.4)
Weight	kg	400	190	209	**Table 3.2.** See text
C_a	Dim. less	0.085	0.085	0.085	See text
$C_{pregnancy}$	Dim. less	0.100	0	0	IPCC (2006, Table 10.7)
BW	kg	400	190	209	**Table 3.2.** See text
C	Dim. less	0.800	0.800	1.20	IPCC (2006, p 10.17)
MW	kg	600	600	600	Estimated
WG	kg day^{-1}	0.074	0.237	0.275	**Table 3.2.** See text

The last 10 parameters in **Table 3.7** are further described in **Section 6.5** (Inventory of methane from enteric fermentation) in Schmidt and Dalgaard (2012). The parameters 'Weight' and 'BW' are both calculated as an average of the parameters 'When entering activity' and ' When leaving activity' from **Table 3.3**. The parameter C_a, which is used for calculation of net energy for animal activity (NE_a), is calculated as an average for 'Stall' (C_a =0.00) and 'Pasture' (C_a =0.17) (IPCC, 2006, Table 10.5). The parameter 'WG' is equal to 'Weight gain' in **Table 3.3**.

Distribution of total feed on different feedstuffs: Denmark

Firstly, the amount of purchased feed is determined. Secondly, the amount of home-grown feed is calculated by subtracting the purchased feed from the feed requirement determined in the previous section.

Data on grain and soybean meal purchased to the activities within the cattle systems are provided by Kristensen (2011), and accordingly they are aggregated into 'Milk system' and 'Beef system'. Feed concentrates used on Danish farms contain various ingredients, of which the most important are grain, by-products from food industry and meals from rape seed, soybean and sunflower. Feed concentrate can basically be divided into two types: A-mix with a low protein level (18-26% of dry matter) and C-mix with a high protein level (35-37% of dry matter). Mogensen (2011) has collected ingredients list of feed concentrates from cattle farms and based on these ingredient lists and the amount of feed concentrates purchased by each farm, a typical Danish A-mix and a typical Danish C-mix has been established. They are made of 14-15 different components, and as presented in **Table 3.8** the A-mix contains less soybean, rape seed and sunflower meal compared to the more protein rich C-mix. According to the data from Kristensen (2011), the protein content of the purchased feed to the milk system is higher than the A-mix, but lover than the C-mix. Therefore, the A-mix and C-mix have been mixed in ratio 20:80 to ensure the input of protein and net energy to the milk system are in accordance to the data provided by Kristensen (2011). In order to limit the LCIs of purchased feed components, only feed components which contribute with more than 5% to the A-mix, C-mix or the Swedish feed concentrates are modeled. This means feed components contributing with less than 5% are presented with a different crop LCI. E.g. 'Distillers grains, barley based, dried' is modeled as 'Soybean meal' as shown in **Table 3.8.** When an alternative crop LCI is applied in the model it is selected according protein and energy content to ensure that the characteristics of the original feed ingredient are as far as possible identical to the characteristics of the chosen alternative crop ingredient.

Table 3.8: Composition of feed concentrates used in Danish cattle production (Mogensen 2011) and name of applied LCI in the current model.

Feed concentrate used on Danish dairy farms (Mogensen 2011)			**LCI applied in the current model**
Ingredients	A-mix, % (weight)	C-mix, % (weight)	Ingredients
Barley	19.3	12.0	Barley
Rapeseed cake/meal	17.5	26.0	Rapeseed cake/meal
Beet pulp, dried	15.8	5.0	Beet pulp, dried
Corn	8.3	2.0	Corn
Soybean meal	8.0	26.0	Soybean meal
Wheat bran	7.3	1.0	Wheat bran
Sunflower meal/cake	6.0	22.5	Sunflower meal
Distillers grains, barley based, dried	4.3	0.0	Soybean meal
Citrus pulp, dried	4.0	0.0	Barley
Soya bean hulls etc	3.6	0.0	Barley
Dried grass pellets	2.0	0.0	Rapeseed cake/meal
Molasses, beet	1.8	2.5	Molasses, beet
Palm fat and vegetable fat	1.2	2.0	Palm oil
Fodder Urea	0.0	0.5	Other chemicals. **Section 2.4**
Minerals	1.1	0.5	Other chemicals. **Section 2.4**

By combining the data from Kristensen (2011) with the data on feed concentrate ingredients (Mogensen, 2011) the feed inputs to the 'Milk system' and 'Beef system' are obtained as presented in **Table 3.9**. 'FEreq' for 'Milk system' and 'Beef system' equal the sum of 'FEreq' parameters in **Table 3.5.** The intake of feed urea and minerals are presented in **Table 3.28** and **Table 3.29**.

Table 3.9: Feed requirement and intake. Denmark.

Denmark Feed requirement/intake	Milk system		Beef system	
	TJ net energy	1000 tons protein	TJ net energy	1000 tons protein
Feed requirement				
FEreq	36,658		3,399	
FPreq		799,596		78,933
Feed intake				
Barley	6,965	86,664	638.19	7,940.38
Corn	396	3,983	0	0
Soybean meal	3,246	158,642	245	11,982
Rape seed/cake	2,979	112,025	0	0
Sunflower meal	2,103	104,803	0	0
Beet pulp, dried	731	8,976	0	0
Molasses	197	3,334	0	0
Palm oil	590	0.00	0	0
Wheat bran	199	5,242	0	0
Feed urea	0	15,131	0	308
Permanent grass	601	17,875	746	22,175
Maize ensilage	15,058	172,867	923	10,602
Rotation grass	3,592	110,055	846	25,927
Total feed intake	**36,658**	**799,596**	**3,399**	**78,933**

Distribution of total feed on different feedstuffs: Sweden

Like the Danish data, the amount of purchased feed is firstly determined. Secondly, the amount of home-grown feed is calculated by subtracting the purchased feed from the feed requirement (FEreq) presented in **Table 3.6**. Data are based on Cederberg et al. (2009a, p 69-71), but the number of different ingredients in the feed concentrate have been reduced, so only feed ingredients contributing with more than 5% are modelled. Feed ingredients contributing with less than 5% are represented by LCI shown in **Table 3.10**.

Table 3.10: Ingredients in feed concentrates used in Swedish cattle production (Cederberg et al. 2009a) and name of applied LCI in the current model

Ingredients in feed concentrate used on Swedish cattle farms (Cederberg et al. 2009a)	LCI applied in the current model
Wheat	Wheat
Trical, rye	Wheat
Barley	Barley
Oat	Oat
Grain midlings	Wheat bran
Grain bran	Wheat bran
Maize gluten	Corn
DDGS	Soybean meal
Bakery pasta prod.	Rapeseed cake/meal
Beet pulp	Beet pulp
Molasses	Molasses, beet
Beet sugar	Beet pulp
Rapeseed, whole	Rapeseed cake/meal

Ingredients in feed concentrate used on Swedish cattle farms (Cederberg et al. 2009a)	LCI applied in the current model
Rapeseed, meal	Rapeseed cake/meal
Soymeal	Soybean meal
Potatoe protein	Soybean meal
Lucernemeal	Soybean meal
Grassmeal	Soybean meal
Peas /horsebean	Soybean meal
Palm kernel	Palm kernel cake
Fatty acids	Palm oil
Milk powder	Palm kernel cake
CaCO3	Other chemicals
Salt	Other chemicals
Div minerals	Other chemicals

The feed intake of the Swedish ‘Milk system’ and ‘Beef system’ is presented in **Table 3.11**. The intake of feed urea and minerals are presented in **Table 3.30** and **Table 3.31.**

Table 3.11: Feed requirement and intake. Sweden.

Sweden Feed requirement/intake	Milk system		Beef system	
	TJ net energy	1000 tons protein	TJ net energy	1000 tons protein
Feed requirement				
FEreq	28,115		6,412	
FPreq		606,742		146,184
Feed intake				
Barley	3,164	39,373	120	1,487
Wheat	1,034	12,561	188	2,287
Oat	2,193	31,437	32.7	468
Corn	35.5	357	5.43	54.6
Soybean meal	1,489	72,745	264	12,905
Rape seed/cake	1,568	58,963	277	10,424
Beet pulp	116	1,509	20.5	267
Molasses	154	2,617	27.2	462
Palm oil	556.71	0	98.24	0
Palm kernel meal	488	12,784	108	2,834
Wheat bran	495	13,006	84.6	2,224
Permanent grass	3,139	93,341	1,526	45,393
Maize ensilage	7,891	90,590	2,335	26,808
Rotation grass	5,792	177,459	1,324	40,571
Total feed intake	**28,115**	**606,742**	**6,412**	**146,184**

Distribution of total feed on different feedstuffs: Brazil

The feed intake of Brazilian ‘Beef system’ is based on Cederberg et al. (2009b) and is presented in **Table 3.12**. According to Cederberg et al. (2009b) the Brazilian beef system is almost purely feed by permanent grass. Therefore, in accordance, the feed intake is based on 100% permanent grass. Only some minor additional supplements of mineral feed are included. This is presented in **Table 3.32.**

Table 3.12: Feed intake. Brazil.

Sweden Feed requirement/intake	Beef	system
	TJ net energy	1000 tons protein
Feed requirement		
FEreq	1,236,465	
FPreq		36,771,087
Feed		
Permanent grass	1,236,465	36,771,087
Total feed intake	**1,236,465**	**36,771,087**

3.3 Inventory of other inputs to the cattle system

It is assumed the same amount of diesel and electricity is used in Denmark and Sweden. Data on diesel use in stables for feeding, handling of manure and straw, livestock management etc. are from Cederberg et al.

(2009a, p 17). For dairy cows 0.0032 litre diesel is used per kg milk and for other cattle 13 litre per head * year is used. The use of electricity is also based on Cederberg et al. (2009a, p 18).

All purchased feed is assumed to be transported 200 km by lorry.

The uses of diesel, electricity and lorry in the Danish, Swedish and Brazilian cattle system are presented in the summary of LCI in **Section 3.5**.

Manure treatment

Within the cattle system there are two types of treatment activities. These two types receive manure for treatment and fallen cattle for destruction respectively. There are six processes for manure treatment and one process for destruction of fallen cattle.

The manure treatment processes are presented in **Table 3.13**. The two first two processes are used when manure is deposited outdoor as dung and urine. The next three manure treatment processes are used when manure from storage (as liquid/slurry, solid or deep litter) is used for fertilisation of crops. The last treatment process is applied when liquid /slurry from storage is used for biogasification and subsequently used for fertilisation of crops. The reference flow is 1 kg manure N for all manure treatment process.

The manure treatment processes are to be considered as treatment processes representing the difference of using manure and artificial fertiliser for fertilisation of crops. E.g. the application of manure, which is a by-product from milk and meat production, results in displacement of fertiliser, see by-products in **Table 3.13**. The unit for manure treatment is one kg N, but the P and K content in the manure is also taking into account resulting in a displacement of P-fert and K-fert.

Table 3.13: Manure treatment processes. Reference product is 1 kg N in manure.

Treatment process:		Manure deposited outdoor		Manure land application			Manure biogas and land application
Type of manure:		Dung + urine		Liquid + slurry	Solid	Deep litter	Liquid + slurry
Country:		DK/SE	BR	DK/SE	DK/SE	DK/SE	DK/SE
Unit							
Output of products							
Determining product:							
Manure for treatment	kg N	1	1	1	1	1	1
By-products:							
Market for N-fertiliser	kg N	-0.650	0	-0.700	-0.650	-0.450	-0.700
P-fert: TSP	kg P_2O_5	-0.267	0	-0.288	-0.267	-0.185	-0.288
K-fert: KCl	kg K_2O	-0.739	0	-0.796	-0.739	-0.512	-0.796
Elec DK/SE	kWh	0	0	0	0	0	9.22
Distr. heat	MJ	0	0	0	0	0	34.4
Input of products	Unit:						
Elec DK/SE	MJ	0	0	0	0	0	0.348
Diesel	MJ	0	0	2.585	2.677	2.064	2.59
Emissions	Unit:						
Methane	kg CH_4	0	0	0	0	0	-0.171
Dinitrogen monoxide (direct)	kg N_2O	0.0212	0.0314	0.0047	0.0055	0.0086	-0.177
Dinitrogen monoxide (indirect)	kg N_2O	0.0227	0.0345	0.0074	0.0075	0.0112	-0.0027
Ammonia	kg NH_3	0.0692	0.0850	0.2075	0.1299	0.1348	0.2075

The amount of the by-product N fertiliser (named 'Market for N-fertiliser') produced per kg N in manure is from Plantedirektoratet (2004) and express the expected plant available N per kg manure N. This means for each kg N deposited outdoor, as urine and dong, 0.65 kg N in fertiliser is displaced. In other words, the farmer can apply 0.65 kg N fertiliser less, every time a cow excretes 1 kg N on pasture. Liquid/slurry has the highest level of plant available N (=0.7 kg N/kg N) whereas deep litter has the lowest (=0.45 kg N/kg N). Permanent grass areas in Brazil are much more extensively used compared to permanent grass areas in Denmark and Sweden, and it is assumed permanent grass in Brazil not is fertilised. Hence, the deposition of dung and urine in Brazil does not displace fertiliser. Displaced P-fert and K-fert is calculated on basis of N, P and K content in manure (Poulsen et al. 2001, Table 11.7 – 11.10) and are assumed to have the same displacement rates as N. For example 1 kg N in 'Liquid/slurry' displaces 0.288 kg P_2O_5, because 1 kg N in corresponds to 0.188 kg P, of which 0.7 is plant available for plants, and the molar conversion factor is 2.29 P_2O_5 per P_2O_5-P (1*0.18 * 0.7 * 2.29 = 0.288 kg P_2O_5).

The by-products Elec DK/SE and Distr. heat are from energy production based on biogas from manure, and the input of Elec DK/SE to 'Manure biogas and land application' is for processing manure in the biogas plant. Energy outputs and inputs related to manure based biogas production are based on Nielsen et al. (2005). The diesel use for application of manure to fields is 0.4 litres per ton is from Cederberg et al. (2009a, p 19). The methane emitted from land application of manure is calculated as part of the cattle system (**section 3.4**) according to IPCC (2006, p 10-35). Mikkelsen et al. (2011, p 67) conclude that the methane emission from slurry applied to fields is reduced by 77% if it is treated in a biogas plant. This is included in the calculations by a negative methane emission from the manure treatment process, and thereby it is subtracted from the manure deposited on pasture calculated in the cattle activites. N emissions from manure treatment processes are presented in **Table 3.13** and are more deeply described in **Table 3.14**.

Table 3.14: Calculation of N emissions from manure treatment processes. Reference product is 1 kg N in manure.

Treatment process:		Manure deposited outdoor		Manure land application			Manure biogas and land application
Type of manure:		Dung + urine		Liquid + slurry	Solid	Deep litter	Liquid + slurry
Country:		DK/SE	BR	DK/SE	DK/SE	DK/SE	DK/SE
	Unit						
Applied manure							
Manure, N	kg N	1	1	1	1	1	1
Dinitrogen monoxide (direct)							
From manure	kg N	0.0200	0.0200	0.010	0.010	0.010	0.010
From displaced fertiliser	kg N	-0.0065	0	-0.007	-0.0065	-0.0045	-0.007
From biogasification	kg N						-0.0064
From manure treatment	Kg N	0.0135	0.0200	0.003	0.0035	0.0055	-0.0034
Ammonia							
From manure	kg N	0.070	0.070	0.185	0.120	0.120	0.185
From displaced fertiliser	kg N	-0.010	0	-0.014	-0.013	-0.009	-0.014
From manure treatment	kg N	0.060	0.070	0.171	0.107	0.111	0.171
Nitrate							
From manure	kg N	0.300	0.300	0.300	0.300	0.300	0.300
From displaced fertiliser	kg N	-0.195	0	-0.210	-0.195	-0.135	-0.210
From manure treatment	kg N	0.105	0.300	0.090	0.105	0.165	0.090
Dinitrogen monoxide (indirect)							
From manure treatment	kg N	0.001	0.003	0.003	0.002	0.003	0.003
Summary of N emissions							
Dinitrogen monoxide (direct)	kg N_2O	0.0212	0.0314	0.0047	0.0055	0.0086	-0.0053
Dinitrogen monoxide (indirect)	kg N_2O	0.0015	0.0031	0.0027	0.0020	0.0025	0.0027
Ammonia	kg NH_3	0.0692	0.0850	0.2075	0.1299	0.1348	0.2075

The direct dinitrogen monoxide emission from manure are calculated using the emission factors from IPCC (2006, Table 11.1). The emission factor from manure deposited outdoor and fertiliser is 0.02 and 0.01 kg N_2O-N per kg N respectively. The emissions named 'From manure treatment' are calculated as the difference of emissions from manure and fertiliser. Treatment of manure in a biogas plant reduces the dinitrogen monoxide emission by 64% (Mikkelsen et al. 2011, p 81) and this is accounted for by subtracting the reduced emission from direct dinitrogen monoxide.

Ammonia and nitrate emissions are calculated in order to enable calculation of indirect dinitrogen monoxide emissions. The fraction of N lost as ammonia and nitrate is based on the following Danish data sources:

- Ammonia from manure deposited outdoor: 0.07 (Mikkelsen et al. 2011, p 49).
- Ammonia from manure land application, liquid + slurry: 0.18. Based on Hansen et al. (2008).
- Ammonia from manure land application, solid and deep litter: 0.12. Based on Hansen et al. (2008).
- Ammonia from N fertiliser: 0.02 (Mikkelsen et al. 2011, p 49).
- Nitrate from all types of manure/fertiliser: 0.30 (IPCC 2006, Table 11.3).

The emission factors for calculating the indirect dinitrogen monoxide emission related to ammonia and nitrate are the following:

- 0.01 kg N_2O-N per kg NH_3-N + NO_x-N volatilized (IPCC 2006, Table 11.3). The emissions of NO_x-N is taking into account using data from IFA (2001) as explained in Schmidt and Dalgaard (2012, Section 7.4).
- 0.0075 kg N_2O-N per kg N leaching/runoff (IPCC 2006, Table 11.3)

Destruction of fallen cattle

The inventory of fallen animals in Denmark and Sweden is based on DAKA (2006). In Brazil, the only considered input in the destruction activity is transport. The inventory data are summarised in **Table 3.15**.

Table 3.15: Destruction of fallen animals. Reference product is 1 kg live weight (LW) animal.

Treatment process:		Destruction of fallen animals (industry)	Destruction of fallen animals (low tech.)
Country:		DK/SE	BR
Output of products	Unit:		
Determining product:			
Destruction of fallen animals	kg LW	1	1
By-products:			
Distr. heat	MJ	0.0202	
Burning coal	MJ	4.45	
Burning fuel oil	MJ	4.93	
Input of products	Unit:		
Elec DK/SE	MJ	0.0223	
Natural gas	MJ	0.0197	
Fuel oil	MJ	0.0219	
Lorry	tkm	0.200	0.200

3.4 Emissions

Methane emissions from enteric fermentation: Denmark

The parameters used for calculation of methane emissions from enteric fermentation are presented in **Table 3.16**.The emission factor (EF) is calculated from the gross energy intake (GE), which again is calculated from the net energy intake (Schmidt et al. 2012, Section 6.4). DE% (digestibility of feed in percent) is calculated as a weighted average of DE% for each of the used feedstuffs. The parameter C_a, which is used for calculation of net energy for animal activity (NE_a), is calculated as an average for 'Stall' (C_a =0) and 'Pasture' (C_a =0.17) (IPCC, 2006, Table 10.5).

Table 3.16: Parameters used for calculating methane emissions from enteric fermentation in Denmark. (*): In Schmidt and Dalgaard (2012).

Denmark	Unit	Milk system				Beef system			Source
Para-meters		Dairy cow	Raising heifer calf	Raising bull calf	Raising litre bull	Suckler cow	Raising heifer calf	Raising bull	
EF	kg CH_4 hd^{-1} yr^{-1}	140	31.72	9.06	36.5	47.3	35.8	44.0	Equation 6.7(*)
GE	MJ hd^{-1} day^{-1}	328	74.4	21.3	100	111	84.0	103.2	See text
Ym	%	6.50	6.50	6.50	6.50	6.50	6.50	6.50	IPCC (2006, Table 10.12)
NE_m	MJ day^{-1}	41.9	21.4	6.96	22.6	36.1	22.9	25.4	**Table 3.5**
NE_a	MJ day^{-1}	3.56	1.82	0.591	1.92	3.07	1.95	2.16	**Table 3.5**
NE_l	MJ day^{-1}	76.7	0	0	0	0	0	0	**Table 3.5**
NE_{work}	MJ day^{-1}	0	0	0	0	0	0	0	**Table 3.5**
NE_p	MJ day^{-1}	4.19	0	0	0	3.61	0	0	**Table 3.5**
NE_g	MJ day^{-1}	2.01	7.37	1.19	10.7	1.41	8.54	13.5	**Table 3.5**
REM	Dim. less	0.541	0.541	0.541	0.541	0.540	0.540	0.540	Equation 6.14(*)
REG	Dim. less	0.353	0.353	0.353	0.353	0.350	0.350	0.350	Equation 6.16(*)
DE%	%	75.3	75.3	75.3	75.3	74.4	74.4	74.4	See text

Methane emissions from enteric fermentation: Sweden

The parameters used for calculation of methane emissions from enteric fermentation are presented in **Table 3.17**.The emission factor (EF) is calculated from the gross energy intake (GE), which again is calculated from the net energy intake (Schmidt et al. 2012, Section 6.4). DE% (digestibility of feed in percent) is calculated as a weighted average of DE% for each of the used feedstuffs. The parameter C_a, which is used for calculation of net energy for animal activity (NE_a), is calculated as an average for 'Stall' (C_a =0) and 'Pasture' (C_a =0.17) (IPCC, 2006, Table 10.5).

Table 3.17: Parameters used for calculating methane emissions from enteric fermentation in Sweden. (*): In Schmidt and Dalgaard (2012).

Sweden	Unit	Milk system				Beef system			Source
Para-meters		Dairy cow	Raising heifer calf	Raising bull calf	Raising litre bull	Suckler cow	Raising heifer calf	Raising bull	
EF	kg CH_4 hd^{-1} yr^{-1}	141	32.4	12.3	43.5	46.6	33.1	45.5	Equation 6.7(*)
GE	MJ hd^{-1} day^{-1}	332	76.0	28.9	102	109	77.7	107	See text
Ym	%	6.50	6.50	6.50	6.50	6.50	6.50	6.50	IPCC (2006, Table 10.12)
NE_m	MJ day^{-1}	40.1	21.2	7.94	28.2	34.7	21.2	27.0	**Table 3.6**
NE_a	MJ day^{-1}	3.41	1.80	0.675	2.39	2.95	1.80	2.30	**Table 3.6**
NE_l	MJ day^{-1}	74.7	0	0	0	0	0	0	**Table 3.6**
NE_{work}	MJ day^{-1}	0	0	0	0	0	0	0	**Table 3.6**
NE_p	MJ day^{-1}	4.01	0	0	0	3.47	0	0	**Table 3.6**
NE_g	MJ day^{-1}	1.36	7.29	2.89	10.1	1.14	7.06	12.0	**Table 3.6**
REM	Dim. less	0.539	0.539	0.539	0.539	0.537	0.537	0.537	Equation 6.14(*)
REG	Dim. less	0.348	0.348	0.348	0.348	0.345	0.345	0.345	Equation 6.16(*)
DE%	%	74.0	74.0	74.0	74.0	73.2	73.2	73.2	See text

Methane emissions from enteric fermentation: Brazil

The parameters used for calculation of methane emissions from enteric fermentation are presented in **Table 3.18**.The emission factor (EF) is calculated from the gross energy intake (GE), which again is calculated from the net energy intake (Schmidt et al. 2012, Section 6.4). DE% (digestibility of feed in percent) is calculated as a weighted average of DE% for each of the used feedstuffs. The parameter C_a, which is used for calculation of net energy for animal activity (NE_a), is calculated as an average for 'Stall' (C_a =0) and 'Pasture' (C_a =0.17) (IPCC, 2006, Table 10.5).

Table 3.18: Parameters used for calculating methane emissions from enteric fermentation in Brazil. (*): In Schmidt and Dalgaard (2012).

Brazil	Unit	Beef system			Source
Para-meters		Suckler cow	Raising heifer calf	Raising bull	
EF	kg CH_4 hd^{-1} yr^{-1}	41.3	23.6	28.3	Equation 6.7(*)
GE	MJ hd^{-1} day^{-1}	96.8	55.3	66.4	See text
Ym	%	6.50	6.50	6.50	IPCC (2006, Table 10.12)
NE_m	MJ day^{-1}	28.8	16.5	20.3	**Table 3.7**
NE_a	MJ day^{-1}	2.45	1.40	1.73	**Table 3.7**
NE_l	MJ day^{-1}	0	0	0	**Table 3.7**
NE_{work}	MJ day^{-1}	0	0	0	**Table 3.7**
NE_p	MJ day^{-1}	2.88	0	0	**Table 3.7**
NE_g	MJ day^{-1}	1.10	2.27	2.11	**Table 3.7**
REM	Dim. less	0.533	0.533	0.533	Equation 6.14(*)
REG	Dim. less	0.339	0.339	0.339	Equation 6.16(*)
DE%	%	71.44	71.44	71.44	See text

Methane and nitrous oxide emissions from manure management: Denmark

The distribution of manure management system within each activity is from Nielsen et al. (2011, p. 1075-1075) as presented in **Table 3.19**. Data represent year 2005 and show e.g. 66% of the dairy cows were stabled in loose-holding system, and deep litter systems were preferred for suckler cows, heifers and bulls.

Table 3.19: Distribution of cattle between different manure management systems within each activity. Source: Nielsen et al. (2011, p. 1075-1078).Unit: %

Denmark System:	Milk system				Beef system		
Activity: / Manure management system	Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull
Deep litter (all)	2	30	0	47	35	30	47
Deep litter (boxes)	0	0	95	0	0	0	0
Deep litter, long eating space	0	1	0	0	0	1	0
Deep litter, slatted floor	4	3	0	1	0	3	1
Deep litter, slatted floor, scrapes	2	3	0	0	0	3	0
Deep litter, solid floor	0	0	5	8	35	0	8
Deep litter, solid floor, scrapes	0	2	0	2	0	2	2
Loose-holding with beds, slatted floor	44	19	0	0	0	19	0
Loose-holding with beds, slatted floor, scrapes	11	0	0	0	0	0	0
Loose-holding with beds, solid floor	11	0	0	0	0	0	0
Loosing-holding with beds, solid floor with tilt	0	0	0	0	0	0	0
Slatted floor-boxes	0	23	0	31	0	23	31
Tethered urine and solid manure	12	14	0	9	30	14	9
Tethered with slurry	14	5	0	2	0	5	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

The parameters used for calculating CH_4 emissions from manure management in Denmark are presented in

Table 3.20. The CH_4 emission factor ($EF_{(T)}$) is 23.5 kg CH_4 per head per year for dairy cows, but considerable lower for the other types of cattle. This is to a large extent because the feed intake and thereby the volatile solid excreted ($VS_{(T)}$) is highest for the dairy cows. Furthermore, the type of manure managements system also has an impact. The parameter $MS_{(Pasture,\ 10°C)}$ shows that the dairy cows were on pasture 15% of the year, whereas heifer calves raised in the milk system and all cattle in the beef systems were on pasture 54% and 61% of the year respectively. The other MS parameters ($MS_{(Liquid,\ 10°C)}$ $MS_{(Solid,\ 10°C)}$ $MS_{(Deep\ bed.,\ 10°C)}$) are calculated from **Table 3.19** and the percentages of manure types from each manure management system presented by Schmidt and Dalgaard (2012, Table 6.5).

Table 3.20: Parameters used for calculating CH_4 emissions from Danish manure management systems. MMS: Manure Management System. (*): In Schmidt and Dalgaard (2012).

Denmark	Unit	Milk system				Beef system			Source
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull	
$EF_{(T)}$	Kg CH_4 hd^{-1} yr^{-1}	23.5	2.82	2.28	7.32	4.29	2.86	3.96	Equation 6.17(*)
$VS_{(T)}$	Kg DM hd^{-1} day^{-1}	4.69	1.06	0.304	1.22	1.64	1.24	1.52	Equation 6.18(*)
$B_{o(T)}$	m^3 CH_4 (kgVS $excreted)^{-1}$	0.240	0.180	0.180	0.180	0.180	0.180	0.180	IPCC (2006, p 10.77-8)
$MCF_{(Pasture,10°C)}$	%	1	1	1	1	1	1	1	IPCC (2006, Table 10.17)
$MCF_{(Liquid,\ 10°C)}$	%	10	10	10	10	10	10	10	
$MCF_{(Solid,\ 10°C)}$	%	2	2	2	2	2	2	2	
$MCF_{(Deep\ bed.,\ 10°C)}$	%	17	17	17	17	17	17	17	
$MS_{(Pasture,\ 10°C)}$	Dim. less	15.0	54.0	0	0	61.0	61.0	61.0	Nielsen et al. (2011, p. 1075) Illerup et al. (2005, p. 361-2)
$MS_{(Liquid,\ 10°C)}$	Dim. less	75.7	26.7	0	39.0	5.85	22.6	15.2	
$MS_{(Solid,\ 10°C)}$	Dim. less	5.10	3.22	0	4.50	5.85	2.73	1.76	
$MS_{(Deep\ bed.,\ 10°C)}$	Dim. less	4.25	16.1	100	56.5	27.3	13.7	22.0	
GE	MJ day^{-1}	328	74.4	21.3	85.5	111	84.0	103	**Table 3.16**
DE%	%	75.3	75.3	75.3	75.3	74.4	74.4	74.4	**Table 3.16**
UE	Dim. less	0.04	0.04	0.04	0.04	0.04	0.04	0.04	IPCC (2006, eq 10.24)
ASH	Dim. less	8.00	8.00	8.00	8.00	8.00	8.00	8.00	IPCC (2006, p 10.42)

The parameter values used for calculation of N_2O emissions from manure management systems are presented in **Table 3.21**. The direct N_2O ($N_2O_{D(mm)}$) comprises 84-91% of the N_2O emissions from manure management systems, leaving the indirect N_2O ($N_2Og_{(mm)}$) to be of minor importance.

Table 3.21: Parameters used for calculating N_2O emissions from Danish manure management systems. (*): In Schmidt and Dalgaard (2012).

Denmark	Unit	Milk system				Beef system			Source
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull	
$N_2O_{(mm)}$	kg N_2O yr^{-1}	582,089	108,206	4,722	80,867	38,812	16,549	7,796	Equation 6.19(*)
$N_2O_{D(mm)}$	kg N_2O yr^{-1}	498,464	96,537	4,378	73,308	35,719	14,764	7,067	Equation 6.20(*)
$N_2O_{G(mm)}$	kg N_2O yr^{-1}	83,625	11,669	344	7,560	3,093	1,785	729	Equation 6.21(*)
N_T	heads	563,500	566,000	29,000	198,500	98,500	94,500	44,000	**Table 3.1**
$N_2O_{(mm)}$/head	kg N_2O hd^{-1} yr^{-1}	1.03	0.191	0.163	0.407	0.394	0.175	0.177	$N_2O_{(mm)}$/ N_T
$Nex_{(T)}$	kg N hd^{-1} yr^{-1}	125	33.6	9.61	29.0	67.7	36.3	32.4	Equation 6.21 (*)
$MS_{(Liquid)}$	Dim. less	0.749	0.246	0	0.342	0.050	0.208	0.133	From MS parameters in **Table 3.20** and Poulsen et al. (2001). See text.
$MS_{(Solid)}$	Dim. less	0.049	0.029	0	0.038	0.048	0.024	0.015	
$MS_{(Deep\ bed.)}$	Dim. less	0.053	0.186	1.00	0.620	0.292	0.157	0.242	
$EF_{3(Liquid/solid)}$	Kg N_2O-N kg N^{-1}	0.005	0.005	0.005	0.005	0.005	0.005	0.005	IPCC (2006, Table 10.21)
$EF_{3(Solid\ storage)}$	Kg N_2O-N kg N^{-1}	0.005	0.005	0.005	0.005	0.005	0.005	0.005	
$EF_{3(deep\ bed.)}$	Kg N_2O-N kg N^{-1}	0.01	0.01	0.010	0.01	0.01	0.01	0.01	
$N_{intake(T)}$	kg N hd^{-1} yr^{-1}	174	38.7	13.6	39.1	68.4	41.9	43.9	From protein content in feed
$N_{retention(T)}$	kg N hd^{-1} yr^{-1}	49.0	5.05	3.99	10.1	0.713	5.58	11.6	Equation 6.22 (*)
N_{milk}	kg N hd^{-1} yr^{-1}	48.0	0	0	0	0	0	0	Equation 6.22 (*)
$N_{weight\ gain}$	kg N hd^{-1} yr^{-1}	0.990	5.05	3.99	10.1	0.713	5.58	11.6	Equation 6.22 (*)
$N_{volatilization\text{-}MMS}$	Kg N hd^{-1} yr^{-1}	9.44	1.31	0.755	2.42	2.00	1.20	1.05	Equation 6.22 (*)
EF_4	Kg N_2O-N kg N^{-1}	0.01	0.01	0.01	0.01	0.01	0.01	0.01	IPCC (2006, Table 11.3)

The parameters $MS_{(Liquid)}$, $MS_{(Solid)v}$ and $MS_{(Deep\ bed.)}$ describe the share of indoor deposited manure-N handled as liquid (incl. slurry), solid and deep bedding respectively. They are calculated on basis of $MS_{(Pasture,\ 10°C)}$ $MS_{(Liquid,\ 10°C)}$ and $MS_{(Solid,\ 10°C)}$ from **Table 3.20** by taking into account the N-contents vary amongst the three types of manure. The N- contents used were: 5.75 kg N per ton liquid/slurry, 5.55 kg N per ton solid manure and 7.20 kg N per ton deep litter. These values were calculated on basis of Poulsen et al. (2001, Table 11.7 and Table 11.8).

The amount of N that is lost due to volatization ($N_{volatilization\text{-}MMS}$) is calculated on basis $\mathrm{Frac}_{\mathrm{GasMS}}$ (Schmidt et al. 2012, Table 7.4) from the respective manure management systems. Furthermore it was assumed all slurry tanks were covered.

The N inputs, outputs and emissions related to the Danish milk and beef system are presented in **Table 3.22**. 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 3.22: N balances and emissions related to the Danish milk and beef system. Unit: Kg N hd^{-1} yr^{-1}.

Denmark	Milk system				Beef system		
Parameter	Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull
N inputs							
Feed	174	38.7	13.6	39.1	68.4	41.9	43.9
N outputs							
Milk	48.0	0	0	0	0	0	0
Weight gain, live weight	0.990	5.05	3.99	10.1	0.713	5.58	11.6
Manure leaving storage	96.0	14.0	8.75	26.4	24.2	12.9	11.5
Manure excreted outdoor	18.7	18.2	0	0	41.3	22.2	19.7
N emissions							
Ammonia from stable	7.48	1.03	0.576	1.89	1.50	0.939	0.820
Ammonia from storage	1.96	0.287	0.179	0.538	0.493	0.263	0.234
$N_2O\text{-}N_{direct}$	0.563	0.109	0.096	0.235	0.231	0.099	0.102
N balance*	0	0	0	0	0	0	0

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

Methane and nitrous oxide emissions from manure management: Sweden

Parameters used for calculating CH_4 emissions from manure management in Sweden are presented in **Table 3.23**. Many of the parameters are from IPCC (2006) and are equal to the parameters used in the Danish LCI (**Table 3.20**). The most remarkable difference is the MS parameters that describe the handling of manure. In Sweden less of the dairy cow manure is handled as slurry (56% versus 76% in Denmark). On the other hand more of the manure from beef system is handled as slurry in Sweden (33% versus 6-23% in Denmark). The MS parameters ($MS_{(Pasture,\ 10°C)}$, $MS_{(Liquid,\ 10°C)}$, $MS_{(Solid,\ 10°C)}$, $MS_{(Deep\ bed.,\ 10°C)}$) from Sweden were taken directly from Cederberg et al. (2009a, p 78), because Swedish data on the prevalence of the different manure management systems (as presented for Denmark in **Table 3.19)** not were available. Data are less detailed compared to the Danish. E.g. the MS parameters for bull calves and bulls in the milk system and all cattle in the beef system are identical.

Table 3.23: Parameters used for calculating CH_4 emissions from Swedish manure management systems (MMS). (*): In Schmidt and Dalgaard (2012).

Sweden	Unit	Milk system				Beef system			Source
Parameters		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull	
$EF_{(T)}$	Kg CH_4 hd^{-1} yr^{-1}	18.3	2.40	1.77	6.24	6.86	4.88	6.71	Equation 6.17(*)
$VS_{(T)}$	Kg DM hd^{-1} day^{-1}	4.97	1.14	0.432	1.53	1.68	1.19	1.64	Equation 6.18(*)
$B_{o(T)}$	m^3 CH_4 (kgVS $excreted)^{-1}$	0.240	0.180	0.180	0.180	0.180	0.180	0.180	IPCC (2006, p 10.77-8)
$MCF_{(Pasture,10°C)}$	%	1	1	1	1	1	1	1	IPCC (2006, Table 10.17)
$MCF_{(Liquid, 10°C)}$	%	10	10	10	10	10	10	10	
$MCF_{(Solid, 10°C)}$	%	2	2	2	2	2	2	2	
$MCF_{(Deep\ bed., 10°C)}$	%	17	17	17	17	17	17	17	
$MS_{(Pasture, 10°C)}$	Dim. less	20.0	46.0	30.0	30.0	30.0	30.0	30.0	Cederberg et al. (2009a, p 78)
$MS_{(Liquid, 10°C)}$	Dim. less	56.0	35.0	33.0	33.0	33.0	33.0	33.0	
$MS_{(Solid, 10°C)}$	Dim. less	24.0	16.0	4.0	4.0	4.0	4.0	4.0	
$MS_{(Deep\ bed., 10°C)}$	Dim. less	0	3.0	33.0	33.0	33.0	33.0	33.0	
GE	MJ day^{-1}	332	76.0	28.9	101.9	109.2	77.7	106.8	**Table 3.17**
DE%	%	74.0	74.0	74.0	74.0	73.2	73.2	73.2	**Table 3.16**
UE	Dim. less	0.04	0.04	0.04	0.04	0.04	0.04	0.04	IPCC (2006, eq 10.24)
ASH	Dim. less	8.00	8.00	8.00	8.00	8.00	8.00	8.00	IPCC (2006, p 10.42)

Parameters used for calculation of N_2O emissions from Swedish cattle are presented in **Table 3.24.** The fractions of N excreted handled as liquid, solid and deep bedding are calculated from the MS parameters in **Table 3.23** by using same procedure as in the Danish LCI.

Table 3.24: Parameters used for calculating N_2O emissions from Swedish manure management systems. (*): In Schmidt and Dalgaard (2012).

Sweden Parameters	Unit	Milk system				Beef system			Source
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull	
$N_2O_{(mm)}$	kg N_2O yr^{-1}	338,875	73,855	3,679	106,027	113,714	58,674	38,039	Equation 6.19(*)
$N_2O_{D(mm)}$	kg N_2O yr^{-1}	302,311	65,178	3,062	88,246	94,643	48,834	31,659	Equation 6.20(*)
$N_2O_{G(mm)}$	kg N_2O yr^{-1}	36,563	8,677	617	17,782	19,071	9,840	6379	Equation 6.21(*)
N_T	heads	393,268	429,851	25,593	286,717	177,000	181,286	111,742	**Table 3.2**
$N_2O_{(mm)}$/head	kg N_2O hd^{-1} yr^{-1}	0.862	0.172	0.144	0.370	0.642	0.324	0.340	$N_2O_{(mm)}$/ N_T
$Nex_{(T)}$	kg N hd^{-1} yr^{-1}	124	33.3	10.0	37.4	64.9	32.7	34.4	Equation 6.21 (*)
$MS_{(Liquid)}$	Dim. less	0.560	0.35	0.42	0.29	0.29	0.29	0.29	From MS parameters in **Table 3.23** and Poulsen et al. (2001). See text.
$MS_{(Solid)}$	Dim. less	0.232	0.15	0.05	0.03	0.03	0.03	0.03	
$MS_{(Deep\ bed.)}$	Dim. less	0	0.04	0.53	0.36	0.36	0.36	0.36	
$EF_{3(Liquid/solid)}$	Kg N_2O-N kg N^{-1}	0.005	0.005	0.005	0.005	0.005	0.005	0.005	IPCC (2006, Table 10.21)
$EF_{3(Solid\ storage)}$	Kg N_2O-N kg N^{-1}	0.005	0.005	0.005	0.005	0.005	0.005	0.005	
$EF_{3(deep\ bed.)}$	Kg N_2O-N kg N^{-1}	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
$N_{intake(T)}$	kg N hd^{-1} yr^{-1}	171	38.3	17.9	45.2	65.6	37.7	44.2	From protein content in feed
$N_{retention(T)}$	kg N hd^{-1} yr^{-1}	47.2	5.03	7.95	7.86	0.611	5.03	9.8	Equation 6.22 (*)
N_{milk}	kg N hd^{-1} yr^{-1}	46.5	0	0	0	0	0	0	Equation 6.22 (*)
$N_{weight\ gain}$	kg N hd^{-1} yr^{-1}	0.719	5.03	7.95	7.86	0.611	5.03	9.83	Equation 6.22 (*)
$N_{volatilization\text{-}MMS}$	Kg N yr^{-1}	5.92	1.28	1.53	3.95	6.86	3.45	3.63	Equation 6.22 (*)
EF_4	Kg N_2O-N kg N^{-1}	0.01	0.01	0.01	0.01	0.01	0.01	0.01	IPCC (2006, Table 11.3)

The N inputs, outputs and emissions related to the Swedish milk and beef system are presented in **Table 3.25**. 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 3.25: N balances and emissions related to the Swedish milk and beef system. Unit: Kg N hd^{-1} yr^{-1}.

Sweden **Parameter**	Milk system				Beef system		
	Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Suckler cow	Raising heifer calf	Raising bull
N inputs							
Feed	171	38.3	17.9	45.2	65.6	37.7	44.2
N outputs							
Milk	46.5	0	0	0	0	0	0
Weight gain, live weight	0.719	5.03	7.95	7.86	0.611	5.03	9.83
Manure leaving storage	91.4	16.7	8.35	21.5	37.3	18.8	19.8
Manure excreted outdoor	25.7	15.3	0	11.8	20.4	10.3	10.8
N emissions							
Ammonia from stable	4.05	0.944	1.36	3.51	6.09	3.07	3.23
Ammonia from storage	1.87	0.340	0.170	0.438	0.762	0.384	0.404
N_2O-N_{direct}	0.489	0.096	0.076	0.196	0.340	0.171	0.180
N balance*	0	0	0	0	0	0	0

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

Methane and nitrous oxide emissions from manure management: Brazil

Parameters used for calculating CH_4 emissions from manure management in Brazil are presented in **Table 3.26**. Many of the parameters are from IPCC (2006) and are equal to the parameters used in the Danish and Swedish calculations (**Table 3.20** and **Table 3.23**). All Brazilian cattle are kept outdoor, so only urine and dung deposited outdoor contributes to methane emission. $MCF_{(Pasture,10°C)}$ (methane conversion factor) is lower than the MCF factors applied for indoor deposited manure (see **Table 3.20**) and therefore the methane emitted head per year ($EF_{(T)}$) is very low for the activities in the Brazilian beef system.

Table 3.26: Parameters used for calculating CH_4 emissions from Brazilian manure management systems (MMS). (*): In Schmidt and Dalgaard (2012).

Brazil Parameters	Unit	Beef system			Source
		Suckler cow	Raising heifer calf	Raising bull	
$EF_{(T)}$	kg CH_4 hd^{-1} yr^{-1}	0.768	0.439	0.527	Equation 6.17(*)
$VS_{(T)}$	kg DM hd^{-1} day^{-1}	1.57	0.897	1.08	Equation 6.18(*)
$B_{o(T)}$	m^3 CH_4 $(kgVS\ excreted)^{-1}$	0.180	0.180	0.180	IPCC (2006, p 10.77-8)
$MCF_{(Pasture,10°C)}$	%	1	1	1	IPCC (2006, Table 10.17)
$MS_{(Pasture,\ 10°C)}$	Dim. less	100	100	100	Cederberg et al. (2009b)
GE	MJ day^{-1}	96.8	55.3	66.4	**Table 3.18**
DE%	%	71.4	71.4	71.4	**Table 3.18**
UE	Dim. less	0.04	0.04	0.04	IPCC (2006, eq 10.24)
ASH	Dim. less	8.00	8.00	8.00	IPCC (2006, p 10.42)

N_2O is not emitted from Brazilian manure management systems, because all urine and dung is deposited outdoor. The N2O emitted from urine and dung is accounted for in the manure treatment processes presented in **Table 3.13**.

The N inputs, outputs and emissions related to the beef system in Brazil are presented in Table 3.27. 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 3.27: N balances and emissions related to the Brazilian and beef system. Unit: Kg N hd^{-1} yr^{-1}.

Brazil Parameter	Beef system		
	Suckler cow	Raising heifer calf	Raising bull
N inputs			
Feed	61.2	34.9	42.0
N outputs			
Milk	0	0	0
Weight gain, live weight	0.700	2.25	2.61
Manure leaving storage	0	0	0
Manure excreted outdoor	60.5	32.7	39.4
N emissions			
Ammonia from stable	0	0	0
Ammonia from storage	0	0	0
N_2O-N_{direct}	0	0	0
N balance*	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 Danish milk and beef systems are presented in **Table 3.28** and **Table 3.29**. Summaries of LCI of the Swedish milk and beef systems are presented in **Table 3.30** and **Table 3.31**. Summary of LCI of the Brazilian beef systems is in **Table 3.32.**

Notice that in the following tables for the beef systems, the meat from the raised calves is shown as if it was by-products from the 'raising heifer' and 'raising bull' activities. In reality, this meat is not by-products; it is part of the determining product output from the beef system. Hence, in the modelling, this meat is moved from the raising activities to the determining product output of the suckler cow. In the following tables, the meat from the offspring is shown as by-products only with the purpose for being able to see how much meat is supplied from the different activities in the beef system.

Table 3.28: LCI for the activities in the Danish milk system. The data represent 1 dairy cow during one year. Total is calculated by adding the four activities and up scaling them by the number of dairy cows in 2005 (= 563,500).

Denmark. Milk system. Exchanges	Activity: Unit:	LCI data per dairy cow incl. offspring during one year				LCI data per 563,000 dairy cows incl. offspring
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Total
Output of products						
Determining product:						
Milk	kg	8,440				4.76E+09
Animals to raising XXX units XXX også de andre tabeller XXX	animal days		405	24	153	3.28E8
Meat, live weight	kg					-
By-product:						
Meat, live weight	kg	171	28.4	0	157	2.01E+08
Exported animals for raising, live weight	kg	0.918	1.43	2.56	0	2.76E+06
Material for treatment:						
Manure deposited outdoor	kg N	16.9	16.6	0	0	1.89E+07
Manure land application, liquid/slurry	kg N	84.6	0	0	3.17	4.94E+07
Manure land application, solid	kg N	5.51	0.878	0	0	3.80E+06
Manure land application, deep litter	kg N	5.95	5.69	0.451	5.76	1.01E+07
Destruction of fallen cattle	kg	31.1	5.25	2.66	4.10	2.43E+07
Input of products						
Barley	kg	1,266	289	4.23	116	9.44E+08
Corn	kg	63.6	14.5	0.212	5.84	4.74E+07
Soybean meal	kg	455	104	1.52	41.8	3.39E+08
Rapeseed cake/meal	kg	483	110	1.61	44.4	3.60E+08
Sunflower meal	kg	379	86.3	1.26	34.8	2.82E+08
Beet pulp, dried	kg	140	32.0	0	12.9	1.05E+08
Molasses	kg	46.5	10.6	0.155	4.27	3.47E+07
Palm oil	kg	36.2	8.26	0.121	3.33	2.70E+07
Wheat bran	kg	44.1	10.1	0.147	4.05	3.29E+07
Feed urea	kg	8.90	2.03	2.97E-02	0.818	6.64E+06
Minerals, salt etc.	kg	13.7	3.13	4.58E-02	1.26	1.02E+07
Permanent grass	kg	666	152	2.22	61.2	4.97E+08
Maize ensilage	kg	8,893	2,027	29.7	817	6.63E+09
Rotation grass	kg	3,667	836	12.2	337	2.73E+09
Lorry	tkm	587	134	1.96	54.0	4.38E+08
Electricity	kWh	1,300	0	0	0	7.33E+08
Diesel	MJ	967	223	24.9	170	7.81E+08
Emissions						
Methane	kg CH_4	163	34.7	0.584	15.4	1.21E+08
Dinitrogen monoxide (direct)	kg N_2O	0.885	0.171	0.008	0.130	6.73E+05
Dinitrogen monoxide (indirect)	kg N_2O	0.148	2.07E-02	6.11E-04	1.34E-02	1.03E+05
Ammonia	kg NH_3	11.5	1.60	0.047	1.04	7.97E+06

Table 3.29: LCI for the activities in the Danish beef system. The data represent 1 suckler cow during one year. Total is calculated by adding the four activities and up scaling them by the number of suckler cows in 2005 (=98,500).

Denmark. Beef system. **Exchanges**	**Activity:** **Unit:**	**LCI data per suckler cow during one year**			**LCI data per 98,500 suckler cows**
		Suckler cow	**Raising heifer calf**	**Raising bull**	**Total**
Output of products					
Determining product:					
Animals to raising	p		0.959	0.447	1.39E+05
Meat, live weight	kg	134			1.32E+07
By-product:					
Meat, live weight	kg		89.3	211	4.28E+07
Material for treatment:					
Manure deposited outdoor	kg N	37.8	19.3	8.01	6.41E+06
Manure land application, liquid/slurry	kg N	3.09	6.59	1.750	1.13E+06
Manure land application, solid	kg N	2.99	0.768	0.195	3.89E+05
Manure land application, deep litter	kg N	18.1	4.98	3.18	2.59E+06
Destruction of fallen cattle	kg	16.9	2.03	7.46	2.60E+06
Input of products					
Barley	kg	410	298	170.3	8.65E+07
Soybean meal	kg	121	88.2	50.5	2.56E+07
Feed urea	kg	0.640	0.465	0.266	1.35E+05
Minerals, salt etc.	kg	0.986	0.716	0.410	2.08E+05
Permanent grass	kg	2,920	2,120	1,213	6.16E+08
Maize ensilage	kg	1,928	1,400	801	4.07E+08
Rotation grass	kg	3,054	2,217	1,269	6.44E+08
Lorry	tkm	107	77.4	44.3	2.25E+07
Electricity	kWh	90.0	0	0	8.87E+06
Diesel	MJ	188	181	84.1	4.46E+07
Emissions					
Methane	kg CH_4	51.6	37.1	21.4	1.08E+07
Dinitrogen monoxide (direct)	kg N_2O	0.363	1.50E-01	7.17E-02	5.76E+04
Dinitrogen monoxide (indirect)	kg N_2O	3.14E-02	1.81E-02	7.40E-03	5.61E+03
Ammonia	kg NH_3	2.43	1.40	0.572	4.33E+05

Table 3.30: LCI for the activities in the Swedish milk system. The data represent 1 dairy cow during one year. Total is calculated by adding the four activities and up scaling them by the number of dairy cows in 2005 (= 393,268).

Sweden. Milk system. Exchanges	Activity: Unit:	LCI data per dairy cow incl. offspring during one year				LCI data per 393,268 dairy cows incl. offspring
		Dairy cow	Raising heifer calf	Raising bull calf	Raising bull	Total
Output of products						
Determining product:						
Milk	kg	8,271				3.25E+09
Animals to raising	p		1.09	6.51E-02	0.729	7.42E+05
By-product:						
Meat, live weight	kg		30.1	0	244	1.73E+08
Exported animals for raising, live weight	kg	1.24	0	0.202	0	5.68E+05
Material for treatment:						
Manure deposited outdoor	kg N	24.1	15.4	0	7.19	1.83E+07
Manure land application, liquid/slurry	kg N	64.7	11.8	0.229	6.61	3.27E+07
Manure land application, solid	kg N	26.8	5.193	0.027	0.774	1.29E+07
Manure land application, deep litter	kg N	0	1.26	0.287	8.280	3.87E+06
Destruction of fallen cattle	kg	30.8	14.5	3.35	13.9	2.46E+07
Input of products						
Barley	kg	737	185	4.17	165	4.29E+08
Wheat	kg	221	55.3	1.25	49.5	221
Oat	kg	623	156	3.53	140	623
Corn	kg	7.30	1.83	4.13E-02	1.64	7.30
Soybean meal	kg	267	66.9	1.51	59.9	267
Rapeseed cake/meal	kg	326	81.5	1.84	72.9	326
Beet pulp	kg	215	53.8	1.22	48.1	215
Molasses	kg	46.7	11.7	0.264	10.5	46.7
Palm oil	kg	43.8	11.0	0.248	9.81	43.8
Palm kernel meal	kg	143	35.7	0.807	31.9	143
Wheat bran	kg	140	35.1	0.793	31.4	140
Minerals, salt etc.	kg	50.2	12.6	0.284	11.2	50.2
Permanent grass	kg	4,454	1,116	25.2	998	4,454
Maize ensilage	kg	5,970	1,495	33.8	1337	5,970
Rotation grass	kg	7,574	1,897	42.9	1697	7,574
Lorry	tkm	564	141	3.19	126.3	564
Electricity	kWh	1,300	-	0	0	1,300
Diesel	MJ	956	286	31.4	241	956
Emissions						
Methane	kg CH_4	160	38.0	0.916	36.2	160
Dinitrogen monoxide (direct)	kg N_2O	0.769	0.166	0.008	0.224	0.769
Dinitrogen monoxide (indirect)	kg N_2O	9.30E-02	2.21E-02	1.57E-03	4.52E-02	9.30E-02
Ammonia	kg NH_3	7.18	1.70	0.121	3.49	7.18

Table 3.31: LCI for the activities in the Swedish beef system. The data represent 1 suckler cow during one year. Total is calculated by adding the four activities and up scaling them by the number of suckler cows in 2005 (= 177,000).

Sweden. Beef system. Exchanges	Activity: Unit:	LCI data per suckler cow during one year			LCI data per 177,000 suckler cows
		Suckler cow	Raising heifer calf	Raising bull	Total
Output of products					
Determining product:					
Animals to raising	p		1.02	0.631	2.93E+05
Meat, live weight	kg	117			2.07E+07
By-product:					
Meat, live weight	kg		68.6	236	7.46E+07
Exported animals for raising, live weight	kg	11.6	0	0	2.05E+06
Material for treatment:					
Manure deposited outdoor	kg N	17.1	8.83	5.73	5.61E+06
Manure land application, liquid/slurry	kg N	15.7	8.13	5.27	5.16E+06
Manure land application, solid	kg N	1.84	0.951	0.617	6.04E+05
Manure land application, deep litter	kg N	19.7	10.2	6.60	6.46E+06
Destruction of fallen cattle	kg	18.2	5.55	22.1	8.12E+06
Input of products					
Barley	kg	39.0	28.4	24.1	1.62E+07
Wheat	kg	56.4	41.1	34.8	2.34E+07
Oat	kg	13.0	9.47	8.03	5.40E+06
Corn	kg	1.57	1.14	0.966	6.50E+05
Soybean meal	kg	66.5	48.4	41.0	2.76E+07
Rapeseed cake/meal	kg	80.7	58.8	49.8	3.35E+07
Beet pulp	kg	53.2	38.8	32.8	2.21E+07
Molasses	kg	11.6	8.42	7.13	4.80E+06
Palm oil	kg	10.8	7.90	6.69	4.50E+06
Palm kernel meal	kg	44.3	32.3	27.3	1.84E+07
Wheat bran	kg	33.6	24.5	20.7	1.40E+07
Minerals, salt etc.	kg	12.3	8.94	7.57	5.09E+06
Permanent grass	kg	3,037	2,212	1,874	1.26E+09
Maize ensilage	kg	2,477	1,804	1,528	1.03E+09
Rotation grass	kg	2,428	1,769	1,498	1.01E+09
Lorry	tkm	84.6	61.6	52.2	3.51E+07
Electricity	kWh	90.0	0	0	1.59E+07
Diesel	MJ	331	339	209	1.56E+08
Emissions					
Methane	kg CH_4	53.4	38.9	33.0	2.22E+07
Dinitrogen monoxide (direct)	kg N_2O	0.535	0.276	0.179	1.75E+05
Dinitrogen monoxide (indirect)	kg N_2O	0.108	0.056	0.036	3.53E+04
Ammonia	kg NH_3	8.33	4.30	2.79	2.73E+06

Table 3.32: LCI for the activities in the Brazilian beef system. The data represent 1 suckler cow during one year. Total is calculated by adding the four activities and up scaling them by the number of suckler cows in 2005 (= 45,100,000).

Brazil. Beef system. Exchanges	Activity: Unit:	LCI data per suckler cow during one year			LCI data per 45,100,000 suckler cows
		Suckler cow	Raising heifer calf	Raising bull	Total
Output of products					
Determining product:					
Animals to raising	p		0.903	0.898	8.12E+07
Meat, live weight	kg	55.9			2.52E+09
By-product:					
Meat, live weight	kg		61.9	122	1.08E+10
Material for treatment:					
Manure deposited outdoor	kg N	60.5	29.5	35.4	5.65E+09
Destruction of fallen cattle	kg	2.91	5.99	6.57	6.98E+08
Input of products					
Minerals, salt etc.	kg	16.6	8.54	10.2	1.59E+09
Permanent grass	kg	10,622	5,476	6,550	1.02E+12
Lorry	tkm	3.31	1.71	2.04	3.18E+08
Electricity	kWh	38.0	0	0	1.71E+09
Emissions					
Methane	kg CH_4	42.0	21.7	25.9	4.04E+09

3.6 Parameters relating to switch between modelling assumptions

The allocation factors used for switching between the four modelling assumptions are presented in **Table 3.33**. Overviews of the milk and beef system are presented in Schmidt and Dalgaard (2012, Figure 6.1 and 6.2).

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

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

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

Table 3.33: Allocation factors used for allocation of products produced in the milk and beef systems. Unit: Fraction

System:	Milk system		Beef system		
Country:	**DK**	**SE**	**DK**	**SE**	**BR**
Switch 1: ISO 14040/44 consequential					
Determining product:					
Milk	1	1			
Meat			1	1	1
Switch 2: Average/allocation attributional					
Determining product:					
Milk	0.816	0.839			
Meat			0.889	0.782	1
By-products at point of substitution:					
Cattle meat, live weight	1.43E-01	1.25E-01			
Exported animals for raising, live weight	7.90E-03	1.74E-03		9.48E-02	
N fert as N	1.72E-02	1.61E-02	5.83E-02	5.67E-02	
P fert as P_2O_5	3.29E-03	7.26E-03	1.11E-02	2.56E-02	
K fert as K_2O	1.16E-02	9.56E-03	3.94E-02	3.37E-02	
Heat	3.78E-06	5.72E-06	1.18E-05	2.74E-05	
Burning coal	1.25E-04	3.51E-04	3.90E-04	1.68E-03	
Burning fuel oil	6.03E-04	1.05E-03	1.88E-03	5.03E-03	
Switch 3: PAS2050					
Determining product:					
Milk	0.844	0.869			
Meat			1.00	0.892	1
By-products:					
Cattle meat, live weight	0.148	0.130			
Exported animals for raising, live weight	8.17E-03	1.80E-03		0.108	
Switch 4: IDF					
Determining product:					
Milk	0.863	0.863			
Meat			1.00	0.892	1
By-products:					
Cattle meat, live weight	0.137	0.137			
Exported animals for raising, live weight				0.108	

4 The plant cultivation system

The plant production activities supplies the main feedstock input to the cattle system. It is also the plant production activities that occupy the most land, i.e. these activities causes the indirect land use change effects.

4.1 Inputs and outputs of products

The inputs and outputs of products related to grass, ensilage and crop cultivation are presented and documented in the following sections.

Barley

The inputs and outputs of products related to barley cultivation are presented in **Table 4.1**. The barley yields are calculated by linear regression over the period 1995-2009. Data on yields are obtained from FAOSTAT (2012). Yields for the specific year 2005 are not used because yields can vary considerable amongst years due to drought, diseases etc. As seen in the table, yields in Ukraine (UA) are lower compared to the yields in the European countries.

Material for treatment is straw and it only includes straw used for energy purposes. Straw used for bedding is not presented in **Table 4.1**. The amount of straw produced in the fields is calculated according to Schmidt and Dalgaard (2012, eq. 7.4). According to Statistics Denmark (2012), 75.0 % of the straw from spring barley was removed from the field and 40.4% of all straw removed was used for energy purposes. The same percentages are used for Swedish straw use. The use of straw for energy purposes in the other countries is considered negligible.

Table 4.1: Outputs and inputs of products. Barley cultivation. The data represent 1 ha year.

Outputs and inputs of products	Crop: Country: Unit:	Barley			
		DK	SE	UA	EU
Output of products					
Determining product: Barley	kg	5,157	4,198	2,191	4,259
Material for treatment: Straw	kg	1,741	1,456	-	-
Input of products					
N-fert: Ammonia	kg N	2.83	0	0	0.070
N-fert: Urea	kg N	4.53	0	8.76	16.5
N-fert: AN	kg N	6.23	6.45	49.5	19.2
N-fert: CAN	kg N	42.5	63.7	0	22.9
N-fert: AS	kg N	1.70	4.84	1.74	3.35
Manure	Kg N	99.2	0	21.3	93.1
P fert: TSP	kg P_2O_5	50.4	50.4	137	50.4
K fert: KCl	kg K_2O	66.3	66.3	72.3	66.3
Pesticides	kg (a.s.)	0.509	0.509	0.509	0.509
Lorry	tkm	83.8	100	119	83.1
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	7,000	5,600	5,000	7,000

The amount of fertiliser and manure applied are also presented in **Table 4.1.** Data are obtained from:
- Sweden: N fertiliser is from Cederberg et al. (2009a). Distribution of N –fertiliser between different fertiliser types is based on IFA (2012b), as presented in **Table 4.2**. P and K fertiliser is assumed equal to Danish data.
- Ukraine: FAO (2005, p 40))
- Denmark and EU: See explanation below.

Table 4.2: Distribution of N between different types of artificial n fertiliser types. Based on IFA(2012b).

Fertiliser types	DK	SE	UA	EU
N-fert: Ammonia	4.90%	0%	0%	0%
N-fert: Urea	7.84%	0%	14.6%	26.6%
N-fert: AN	10.8%	8.60%	82.5%	30.9%
N-fert: CAN	73.5%	84.9%	0%	36.9%
N-fert: AS	2.94%	6.45%	2.89%	5.41%
Total	100%	100%	100%	100%

Only one type of P fertiliser and one type of K fertiliser is used. For further details see **section 2.4**.

The amount of N fertiliser applied per hectare is correlated to the amount of manure applied. In general, fields that receive a lot of manure will not require as much N fertiliser as fields that not receive manure. To account for this, the manure applied per hectare in each country is estimated. Firstly, default values on N ab storage per animal in Denmark are estimated. Data on N excreted yearly per animal type (Mikkelsen et al. 2006) are divided by number of animals (stocks of cattle, pigs, poultry, horses and sheep) obtained from FAOSTAT (2012). These default data on N excreted per animal in Denmark (see **Table 4.3**) are then assumed to be representative for animals in the other countries and the total N excretion form livestock in each country can then be calculated by multiplying with number of animals from FAOSTAT (2012).

Table 4.3: N excretion per animal. Calculated from Mikkelsen et al. (2006) and FAOSTAT (2012).

Animal type	N excretion, kg N per animal
Cattle	74.0
Pigs	9.22
Poultry	0.80
Horses	129
Sheep	12.4

Obviously a calf excretes much less N per year than a cow. But by using data from FAO (2012) these differences are counterbalanced, because the population distribution of cattle of different size and age are most likely to be the same in all countries.

Afterwards, the N losses from stable and storage based on Poulsen et al. (2001) is deducted the N excretion, which again is divided by the arable land area (FAOSTAT 2012). The results are presented in **Table 4.4**.

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

	DK	SE	RU	UA	FR	EU
Manure applied	99.2	54.8	18.5	21.3	95.0	93.1

The amount of N fertiliser applied in DK and EU are based on Danish regulation and guidelines regarding fertiliser application to arable land in the 2005 (Plantedirektoratet, 2004, Table 1). The N quota for barley is 127 kg N and the recommended use of P and K is 22 kg P and 55 kg K per ha. However, for each kg N in manure applied per ha, 0.7 kg less N fertiliser can be applied. Consequently, the Danish barley can be applied 58 kg N fertiliser per ha (=127 – (0.7*99)). The same procedure is used for Swedish barley, but taking into account the manure application only is 54 kg N per ha.

The distribution of N fertiliser between different fertiliser types is based on data from IFA (2012b) and presented in **Table 4.2**. Data from Ukraine are not available from FAOSTAT (2012), hence data from Russia are used.

Amount of pesticides are from Flysjö et al. (2008, p 31) and same amount are applied for barley cultivation in all countries. Fertilisers and pesticides are assumed to be transported 200 km by lorry. The mass of pesticides is 3 kg pesticide per kg active ingredient (a.s), and is estimated based on pesticide use for different crops in Schmidt (2007). The total mass to nutrient content (N, P_2O_5 or KCl) ratio of fertilisers are based on IFA (2012a).

The diesel used per ha for field operations is obtained from Cederberg et al (2009a, p 66) and equals 82 litres per ha. Same amount is used for barley cultivation in all countries.

Light fuel oil for drying barley is from Cederberg et al. (2009a, p 19). Same amount is used for barley cultivation in all countries regardless of the yield and differences in moisture content.

The input of land tenure is obtained from **Table 2.9**.

Wheat, oat, corn and soybean

The inputs and outputs of products related to wheat, oat, corn and soybean cultivation are presented in **Table 4.5**. All yields are calculated by linear regression over the period 1995-2009. Data on yields are obtained from FAOSTAT (2012). As seen in the table, yields in Sweden are lower than yields in Denmark.

Material for treatment is straw and it only includes straw used for energy purposes. Straw used for bedding is not presented in **Table 4.5**. The amount of straw produced at the fields is calculated according to Schmidt and Dalgaard (2012, eq. 7.4). According to Statistics Denmark (2012) 54.4 % and 32.9% of wheat and oat straw respectively are removed from the field and 40.4% of all straw removed was used for energy purposes. Due to data lack the same percentages are used for Swedish straw use. The use of straw for energy purposes in the other countries is considered negligible.

Table 4.5: Outputs and inputs of products. Wheat, oat, corn and soybean cultivation. The data represent 1 ha year.

Outputs and inputs of products	Crop: Country: Unit:	Wheat		Oat		Corn	Soybean
		DK	SE	DK	SE	EU	BR
Output of products							
Determining product: Wheat/oat/corn/soybean	kg	7,296	5,986	4,646	3,817	6,577	2,575
Material for treatment: Straw	kg	2,552	2,118	700	600	-	-
Input of products							
N-fert: Ammonia	kg N	4.85	0	1.27	0	0.10	0
N-fert: Urea	kg N	7.76	0	2.04	0	23.2	0
N-fert: AN	kg N	10.7	11.6	2.80	6.02	26.9	0
N-fert: CAN	kg N	72.8	115	19.1	59.5	32.1	0
N-fert: AS	kg N	2.91	8.71	0.763	4.52	4.71	0
Manure	Kg N	99.2	0	99.2	0	93.1	0
P fert: TSP	kg P_2O_5	45.8	45.8	57.3	57.3	80.2	36.6
K fert: KCl	kg K_2O	84.4	84.4	78.3	78.3	78.3	0
Pesticides	kg (a.s.)	0.603	0.603	0.355	0.355	3.53	2.50
Lorry	tkm	116	149	68.9	103	118	17.4
Diesel	MJ	3,306	3,306	3,046	3,046	3,306	1,709
Light fuel oil for drying	MJ	1.10	1.10	1.10	1.10	1.10	1.10
Land tenure, arable	kg C	7,000	5,600	7,000	5,600	7,000	9,000

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

- Wheat and oat cultivated in Denmark: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota for wheat is 168 kg N and the recommended use of P and K is 20 kg P and 70 kg K per ha. The N quota for oat is 95 kg N and the recommended use of P and K is 25 kg P and 65 kg K per ha (Plantedirektoratet, 2004).
- Wheat and oat cultivated in Sweden: N is form Cederberg et al. (2009a). P and K fertiliser is assumed equal to Danish data.
- Corn cultivated in EU: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota for wheat is 152 kg N and the recommended use of P and K is 35 kg P and 65 kg K per ha (Plantedirektoratet, 2004).
- Soybean: According to Schmidt (2007, p 117).

Distribution of N fertiliser between different fertiliser types based on IFA (2012b), as presented in **Table 4.2**. Only one type of P fertiliser and one type of K fertiliser is used.

Amount of pesticides applied to wheat, oat and corn is from Flysjö et al. (2008, p 29; 42; 30) and same amount is applied for both Denmark and Sweden. Amount of pesticides applied to soybeans is from Schmidt (2007, p 118). Fertiliser and pesticides are assumed to be transported 200 km by lorry. The mass of pesticides is 3 kg pesticide per kg active ingredient (a.s), and is estimated based on pesticide use for different crops in Schmidt (2007). The total mass to nutrient content (N, P_2O_5 or KCl) ratio of fertilisers are based on IFA (2012a).

The diesel used per ha for field operations is obtained from Cederberg et al (2009a) and it is assumed the diesel used per ha corn, equals the amount used per ha wheat. Diesel use per ha soybean is obtained from Dalgaard et al. (2008).

Light fuel oil for drying is from Cederberg et al. (2009a, p 19) and equals 0.15 litres oil per kg water dried. Same amount is used for all crops presented in **Table 4.5**.

The input of land tenure is obtained from **Table 2.9**.

Rapeseed, sunflower, sugar beet and oil palm

The inputs and outputs of products related to rape seed, sunflower, sugar beet and oil palm cultivation presented in **Table 4.6.** All yields are calculated by linear regression over the period 1995-2009. Data on yields are obtained from FAOSTAT (2012). As seen in the **Table 4.6,** yields in Sweden are lower than yields in Denmark.

Material for treatment is straw and it only includes straw used for energy purposes. Straw used for bedding is not presented in **Table 4.6.** The amount of straw produced at the fields is calculated according to Schmidt and Dalgaard (2012, eq. 7.4). According to Statistics Denmark (2012) 13.7% of the rape seed straw is removed from the field and 40.4% of all straw removed was used for energy purposes. Due to data lack the same percentage is used for Swedish straw derived from rapeseed cultivation.

Table 4.6: Outputs and inputs of products. Rapeseed, sunflower, sugar beet and oil palm cultivation. The data represent 1 ha year.

Outputs and inputs of products	Crop:	Rapeseed		Sun-flower	Sugar beet		Oil palm
	Country: Unit:	DK	SE	FR	DK	SE	MY
Output of products							
Determining product: Rapeseed/sunflower/sugar beet/oil palm	kg	3,351	2,607	2,376	56,638	51,141	20,407
Material for treatment: Straw	kg	277	228	-	-	-	-
Input of products							
N-fert: Ammonia	kg N	4.89	0	0	2.09	0	0
N-fert: Urea	kg N	7.82	0	21.0	3.34	0	151
N-fert: AN	kg N	10.8	13.8	53.2	4.59	9.12	10.8
N-fert: CAN	kg N	73.3	136	14.7	31.3	90.0	0
N-fert: AS	kg N	2.93	10.3	1.47	1.25	6.84	0
Manure	Kg N	99.2	26.0	95.0	99.2	14.0	0
P fert: TSP	kg P_2O_5	55.0	22.9	52.7	87.0	36.6	0
P fert: Rock phosphate	kg P_2O_5	0	0	0	0	0	81.3
K fert: KCl	kg K_2O	96.4	20.5	72.3	181	53.0	268
Pesticides	kg (a.s.)	0.270	0.802	0.270	2.74	2.74	2.60
Lorry	tkm	124	136	100	129	114	198
Diesel	MJ	3,195	3,195	3,306	8,581	8,581	1,710
Light fuel oil for drying	MJ	1.10	1.10	1.10	0	0	0
Land tenure, arable	kg C	7,000	5,600	7,000	7,000	5,600	11,000

The amount of fertiliser and manure applied are presented in **Table 4.6**. Data are obtained from:

- Rapeseed cultivated in Denmark: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota for wheat is 169 kg N and the recommended use of P and K is 24 kg P and 80 kg K per ha (Plantedirektoratet, 2004).
- Rapeseed cultivated in Sweden: Flysjö et al. (2008, p 39; Crop: Höstraps. Syd).
- Rapeseed cultivated in Denmark: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota for wheat is 157 kg N and the recommended use of P and K is 23 kg P and 60 kg K per ha (Plantedirektoratet, 2004).
- Sugar beet cultivated in Denmark: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota for wheat is 112 kg N and the recommended use of P and K is 38 kg P and 150 kg K per ha (Plantedirektoratet, 2004).
- Sugar beet cultivated in Sweden: Flysjö et al. (2008, p 51).
- Oil palm cultivation: Schmidt et al. (2011)

Distribution of N fertiliser between different fertiliser types based on IFA (2012b), as presented in **Table 4.2**. Only one type of K fertiliser is used. The P fertiliser rock phosphate is used for oil palm cultivation, whereas the P fertiliser TSP is used for all other crops.

The amount of pesticides applied to rapeseeds in Denmark and Sweden are from Schmidt (2007, p 65) and Flysjö et al. (2008, p 39) respectively. Pesticide application to sunflower, sugar beet and oil palm is from Schmidt (2007, p 65), Flysjö et al. (2008, p 51) and Schmidt (2007, p 93) respectively. It was assumed the same amount of pesticides is applied to Danish and Swedish sugar beets. Fertiliser and pesticides are assumed to be transported 200 km by lorry. The mass of pesticides is 3 kg pesticide per kg active ingredient (a.s), and is estimated based on pesticide use for different crops in Schmidt (2007). The total mass to nutrient content (N, P_2O_5 or KCl) ratio of fertilisers are based on IFA (2012a).

Diesel used per ha field operations are from the following data sources:

- Rapeseed cultivated in Denmark and Sweden: Cederberg et al. (2009a, p 66).
- Sunflower: Cederberg et al (2009a, p 66). Due to data lack assumed to be the same as for winter wheat.
- Sugar beet cultivated in Denmark and Sweden: Based on the process 'Sugar beets IP, at farm/CH' from Ecoinvent (2007).
- Oil palm: Based on Schmidt (2011, p 42)

Light fuel oil for drying is from Cederberg et al. (2009, p 19) and equals 0.15 litres oil per kg water dried. Same amount is used for all crops presented in **Table 4.6**.

The input of land tenure is obtained from **Table 2.9**.

Permanent grass incl. grass ensilage

The inputs and outputs of products related production of 'Permanent grass incl. grass ensilage' are presented in **Table 4.7**. The yields of permanent grass are seldom measured, thus these yields are to be considered as less precise, compared to the previously presented yields. The Danish yields are from

Knowledge Centre for Agriculture (2012), and the Swedish yields are assumed to be 20% lower. The yield of permanent grass in Brazil is estimated based on the total pasture area for beef production at 142,000,000 ha (Cederberg et al. 2009b, p 37), the calculated net feed energy requirement (see **Table 3.3** and **Table 3.7**), the net energy content of dry matter permanent grass (see **Appendix B: Feed and crop properties**), and the dry matter content of permanent grass (see **Appendix B: Feed and crop properties**).

Table 4.7: 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 DK	SE	BR
Output of products				
Determining product: Permanent grass incl. grass ensilage	kg	11,628	9,302	7,193
Input of products				
N-fert: Ammonia	kg N	3.46	0	0
N-fert: Urea	kg N	5.53	0	0
N-fert: AN	kg N	7.61	8.74	0
N-fert: CAN	kg N	51.9	86.3	0
N-fert: AS	kg N	2.08	6.56	0
Manure	Kg N	99.2	54.8	39.8
P fert: TSP	kg P_2O_5	32.1	32.1	0
K fert: KCl	kg K_2O	121	121	0
Lorry	tkm	102	130	-
Diesel	MJ	557.2	557.2	31.4
Land tenure, arable	kg C	7,000	2,800	-
Land tenure, int. forest land	kg C	0	2,800	0
Land tenure, rangeland	kg C	0	0	9,000

The amount of fertiliser and manure applied are presented in **Table 4.7.** Data are obtained from the following sources:

- Permanent grass incl. grass ensilage in Denmark and Sweden: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota for permanent grass is 140 kg N and the recommended use of P and K is 14 kg P and 100 kg K per ha (Plantedirektoratet, 2004).
- Only dung and urine deposited from grazing cattle is applied to the permanent grass in Brazil. Based on the area of permanent grass and the amount of N excreted it is estimated to 54.8 kg N per ha.

Distribution of N fertiliser between different fertiliser types is based on IFA (2012b), as presented in **Table 4.2**. Only one type of P fertiliser and one type of K fertiliser is used.

Fertilisers are assumed to be transported 200 km by lorry. The total mass to nutrient content (N, P_2O_5 or KCl) ratio of fertilisers are based on IFA (2012a).

Diesel for fields operations in Denmark and Sweden is from Cederberg et al. (2009a, p 66) and diesel use in Brazil is based on Cederberg at al. (2009b, p 48).

The input of land tenure is obtained from **Table 2.9**.

Rotation grass incl. grass ensilage and roughage, maize ensilage

The inputs and outputs of products related production of 'Rotation grass incl. grass and ensilage' and 'Roughage, maize ensilage' are presented in **Table 4.8**. The yield of 'Rotation grass incl. grass and ensilage' cultivated in Denmark is from knowledge Centre for Agriculture (2012). The yield in Sweden has been assumed to be 20% lower. This assumption is based on the fact that the potential net primary production (NPP_0) is 20% lower in the relevant region for cultivation in Sweden (see **Table 2.9**).

Table 4.8: Outputs and inputs of products. Rotation grass incl. grass ensilage and roughage, maize ensilage cultivation. The data represent 1 ha year.

Outputs and inputs of products	Crop: / Country: / Unit:	Rotation grass incl. grass ensilage		Roughage, maize ensilage	
		DK	SE	DK	SE
Output of products					
Determining product: Rotation grass incl. grass ensilage/ roughage, maize ensilage	kg	44,643	35,714	39,097	31,278
Input of products					
N-fert: Ammonia	kg N	9.07	0	1.52	0
N-fert: Urea	kg N	14.5	0	2.43	0
N-fert: AN	kg N	19.9	4.73	3.35	5.35
N-fert: CAN	kg N	136	46.7	22.8	52.8
N-fert: AS	kg N	5.44	3.55	0.913	4.01
Manure	Kg N	99.2	93.0	99.2	54.8
P fert: TSP	kg P_2O_5	73.3	0	64.9	64.9
K fert: KCl	kg K_2O	217	0	200	200
Pesticides	kg (a.s.)	0.095	0.095	0.095	0.095
Lorry	tkm	231	40.9	116	141
Diesel	MJ	2,415	2,415	3,715	3,715
Light fuel oil for drying	MJ	0	0	0	0
Land tenure, arable	kg C	7,000	5,600	7,000	5,600

The amount of fertiliser and manure applied are presented in **Table 4.8**. Data are obtained from the following sources:

- Rotation grass incl. grass ensilage in Denmark: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota is 254 kg N and the recommended use of P and K is 32 kg P and 180 kg K per ha (Plantedirektoratet, 2004). .
- Rotation grass incl. grass ensilage in Sweden: Flysjö et al. (2008, p 20).
- Roughage, maize ensilage in Denmark and Sweden: The same procedure is used as for barley cultivated in Denmark and EU. However, the N quota is 100 kg N and the recommended use of P and K is 28 kg P and 166 kg K per ha (Plantedirektoratet, 2004).

Distribution of N fertiliser between different fertiliser types is based on IFA (2012b), as presented in **Table 4.2**. Only one type of P fertiliser and one type of K fertiliser is used.

Fertiliser and pesticides are assumed to be transported 200 km by lorry. The mass of pesticides is 3 kg pesticide per kg active ingredient (a.s), and is estimated based on pesticide use for different crops in Schmidt (2007). The total mass to nutrient content (N, P_2O_5 or KCl) ratio of fertilisers are based on IFA (2012a).

Diesel use is from Cederberg et al. (2009a, p 66) and the use of pesticides are from Flysjö et al. (2008, p 20).

The input of land tenure is obtained from **Table 2.9**.

4.2 Utilisation of crop residues

Utilisation of crop residues for energy purposes is the only treatment activity related to crop cultivation. When straw is utilised for energy purposes, it is assumed that the efficiencies (or recovery rates) are (Schmidt 2007, p 66):

- 30% of the lower heating value is converted to electricity
- 60% of the lower heating value is converted to district heating

The lower heating value for straw is 14.5 MJ/kg. Emission factors for CH_4 and N_2O when burning straw are obtained from NERI (2010).

The exchanges related to the utilisation of straw have been assumed to be similar in Denmark and Sweden. The inventory of the utilisation of straw is summarised in **Table 4.9**.

Table 4.9: Summary of the inventory of utilisation of crop residues for energy purposes.

Utilisation of straw in CHP		DK/SE
Output of products		
Determining product:		
Straw for treatment	kg	1
By-products:		
Elec DK/SE	kWh	1.21
Distr. heat	MJ	8.70
Input of products		
None		
Emissions	Unit:	
Methane	kg CH_4	6.82E-06
Dinitrogen monoxide (direct)	kg N_2O	1.60E-05

4.3 Emissions

Barley

The parameters used for calculation of emissions from cultivation of barley are presented in **Table 4.10**.

Table 4.10: Parameters used for calculation of emissions from cultivation of barley. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006).

Parameter	Crop: Country: Unit:	Barley				Source
		DK	SE	UA	EU	
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	1.95	1.06	1.06	1.97	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	0.694	0.314	0.340	0.691	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	1.95	1.06	1.06	1.97	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}	57.8	75.0	60.0	62.0	**Table 4.1**
F_{ON}	kg N ha^{-1} yr^{-1}	99.2	0	21.3	93.1	**Table 4.1**
F_{CR}	kg N ha^{-1} yr^{-1}	37.7	31.2	24.3	41.7	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	4,383	3,568	1,862	3,620	Table 11.2 (**)
Slope	Dim. less	0.98	0.98	0.98	0.98	Table 11.2 (**)
Intercept	Dim. less	0.59	0.59	0.59	0.59	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	4,886	4,087	2,415	4,138	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}	0.34	0.35	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 (**)

$Frac_{Remove}$ is from Statistics Denmark (2012), see text for **Table 4.1**.

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.

F_{OS} (annual area of managed/drained organic soils) is assumed to be 0, because only minor areas are both drained and organic.

The N inputs, outputs and emissions related to barley cultivation are presented in **Table 4.11**. $N_{surplus}$ 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 4.11: N balances and emissions related to barley cultivation. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}.

Parameter	Barley				Source
	DK	SE	UA	EU	
N inputs					
N_{input}	195	106	155	106	Equation 7.1(*)
N-fert: Ammonia	2.83	0	0	0.070	**Table 4.1**
N-fert: Urea	4.53	0	8.76	16.5	**Table 4.1**
N-fert: AN	6.23	6.45	49.5	19.2	**Table 4.1**
N-fert: CAN	42.5	63.7	0	22.9	**Table 4.1**
N-fert: AS	1.70	4.84	1.74	3.35	**Table 4.1**
Manure	99.2	0	21.3	93.1	**Table 4.1**
Crop residues left in field	37.7	31.2	24.3	41.7	**Table 4.1**
N outputs					
N_{output}	101	83.1	32.2	62.6	Equation 7.1(*)
Harvested crop	75.7	61.7	32.2	62.6	**Table 4.1**
Crop residues removed	25.7	21.5	0	0	**Table 4.1**
N inputs - N outputs					
$N_{surplus}$	93.2	23.1	73.5	134	Equation 7.1(*)
N emissions					
NH_3-N	21.8	6.38	8.72	21.1	Section 7.4 (*)
NO_x-N	3.84	1.13	1.54	3.72	Section 7.4 (*)
N_2O-N_{direct}	1.95	1.06	1.06	1.97	Equation 7.3(*)
N_2-N	7.28	-17.3	30.5	48.4	Section 7.4 (*)
NO_3-N	58.4	31.9	31.7	59.1	Section 7.4 (*)
N balance	0	0	0	0	See text

Wheat, oat, corn and soybean

The parameters used for calculation of emissions from cultivation of barley are presented in **Table 4.12**.

Table 4.12: Parameters used for calculation of emissions from cultivation of wheat, oat, corn and soybeans. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006).

Parameter	Crop: / Country: / Unit:	Wheat DK	Wheat SE	Oat DK	Oat SE	Corn EU	Soybean BR	Source
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	2.62	1.88	1.60	1.00	2.29	0.335	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	0.887	0.558	0.585	0.295	0.790	0.075	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	2.62	1.88	1.60	1.00	2.29	0.335	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	0	0	0	Equation 7.3(*)
$N_2O\text{-}N_{PRP}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	0	0	0	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	99.0	135	26.0	70.0	87.0	0	**Table 4.5**
F_{ON}	kg N ha^{-1} yr^{-1}	99.2	0	99.2	0	93.1	0	**Table 4.5**
F_{CR}	kg N ha^{-1} yr^{-1}	63.9	52.9	35.3	30.1	49.3	33.5	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	6,202	5,088	3,950	3,244	5,754	2,328	Table 11.2 (**)
Slope	Dim. less	1.51	1.51	0.910	0.910	1.03	0.930	Table 11.2 (**)
Intercept	Dim. less	0.520	0.520	0.890	0.890	0.610	1.35	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	9,884	8,203	4,484	3,842	6,537	3,515	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.006	0.006	0.007	0.007	0.006	0.008	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0.283	0.286	0.160	0.167	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.240	0.240	0.250	0.250	0.220	0.190	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.009	0.009	0.008	0.008	0.007	0.008	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	0	0	0	0	See text
F_{OS}	ha	0	0	0	0	0	0	See text
F_{PRP}	kg N yr^{-1}	0	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	0.01	Table 11.1 (**)
EF_2	kg N_2O–N ha^{-1} yr^{-1}	8.00	8.00	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	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	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	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	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	0.01	Table 11.3 (**)
EF_5	kg N_2O–N kg N^{-1}	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	Table 11.3 (**)

$Frac_{Remove}$ for wheat and oat is from Statistics Denmark (2012), see text for **Table 4.5**.

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.

F_{OS} (annual area of managed/drained organic soils) is assumed to be 0, because only minor areas are both drained and organic.

The N inputs, outputs and emissions related to wheat, oat, corn and soybean cultivation are presented in **Table 4.13**. $N_{surplus}$ 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. Wheat cultivated in Sweden and soybean cultivated in Brazil have negative N_2 emissions according to the results. This is because N_2 is calculated as the residual ($N_{surplus}$ minus all other emissions) as explained in Schmidt and Dalgaard(2012, Eq.

7.2). Nevertheless, N_2 cannot become negative, but the reasons for becoming negative in the Arla model are presumable some of the following:

- F_{SOM} is assumed to be 0, but might be higher, which will result in an increased $N_{surplus}$. In particular soil used for soybean cultivation is impoverished due to overuse.
- Atmospheric N deposition is not included in the Arla model, because it is not a consequence of crop cultivation and would have been there, although the areas not were cultivated. If atmospheric N deposition was part of the model, this would increase $N_{surplus}$.
- IPCC (2006) does not consider N-fixing crops, such as soybean.
- According to IPCC (2006) 10% and 30% of the N inputs to the fields is evaporated/leached as ammonia and nitrate respectively. These values are high, and will in reality differ amongst cultivation systems. If lower values are used, the N_2 residual will be smaller.
- It is worthwhile to notice that the negative N_2 emission not impacts the impact assessment.

Table 4.13: N balances and emissions related to wheat, oat, corn and soybean cultivation. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}.

Parameter	Wheat		Oat		Corn	Soybean	Source
	DK	SE	DK	SE	EU	BR	
N inputs							
N_{input}	262	188	160	100	229	33.5	Equation 7.1(*)
N-fert: Ammonia	4.85	0	1.27	0	0.099	0	**Table 4.5**
N-fert: Urea	7.76	0	2.04	0	23.2	0	**Table 4.5**
N-fert: AN	10.7	11.6	2.80	6.02	26.9	0	**Table 4.5**
N-fert: CAN	72.8	115	19.1	59.5	32.1	0	**Table 4.5**
N-fert: AS	2.91	8.71	0.763	4.52	4.71	0	**Table 4.5**
Manure	99.2	0	99.2	0	93.1	0	**Table 4.5**
Crop residues left in field	63.9	52.9	35.3	30.1	49.3	33.5	**Table 4.5**
N outputs							
N_{output}	146	120	74.8	61.8	88.4	153	Equation 7.1(*)
Harvested crop	114	93.6	64.5	52.9	88.4	153	**Table 4.5**
Crop residues removed	32.2	26.8	10.3	8.84	0	0	**Table 4.5**
N inputs - N outputs							
$N_{surplus}$	116	67.5	85.7	38.3	141	-120	Equation 7.1(*)
N emissions							
NH_3-N	25.3	11.5	19.1	5.95	23.2	0	Section 7.4 (*)
NO_x-N	4.46	2.03	3.37	1.05	4.10	0	Section 7.4 (*)
N_2O-N_{direct}	2.62	1.88	1.60	1.00	2.29	0.335	Equation 7.3(*)
N_2-N	4.74	-4.24	13.5	0.283	42.6	-130	Section 7.4 (*)
NO_3-N	78.6	56.4	48.1	30.0	68.8	10.0	Section 7.4 (*)
N balance	0	0	0	0	0	0	See text

Rapeseed, sunflower, sugar beet and oil palm

The parameters used for calculation of emissions from cultivation of rapeseed, sunflower, sugar beet and oil palms are presented in **Table 4.14**.

Table 4.14: Parameters used for calculation of emissions from cultivation of rape seed, sunflower, sugar beet and oil palm. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006).

Parameter	Crop: / Country: / Unit:	Rapeseed		Sunflower	Sugar beet		Oil palm	Source
		DK	SE	FR	DK	SE	MY	
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	2.32	2.13	2.11	4.61	4.10	5.13	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	0.820	0.692	0.756	1.28	1.06	0.976	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	2.32	2.13	2.11	4.61	4.10	3.61	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg N_2O–N ha^{-1} yr^{-1}	0	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	0	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	100	160	90.3	42.6	106	162	**Table 4.6**
F_{ON}	kg N ha^{-1} yr^{-1}	99.2	26.0	95.0	99.2	14.0	0	**Table 4.6**
F_{CR}	kg N ha^{-1} yr^{-1}	33.1	27.2	26.0	319	290	199	Equation 7.3(*), *
Crop	kg DM ha^{-1} yr^{-1}	3,100	2,411	2,186	12,460	11,251	9,591	Table 11.2 (**)
Slope	Dim. less	1.09	1.09	1.09	1.09	1.09	-	Table 11.2 (**)
Intercept	Dim. less	0.88	0.88	0.88	1.06	1.06	-	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	4,259	3,509	3,263	14,642	13,324	15,113	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.006	0.006	0.006	0.019	0.019	-	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0.036	0.039	0	0	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.220	0.220	0.220	0.200	0.200	-	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.009	0.009	0.009	0.014	0.014	-	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	0	0	0	0	See text
F_{OS}	ha	0	0	0	0	0	0.095	See text
F_{PRP}	kg N yr^{-1}	0	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	0.01	Table 11.1 (**)
EF_2	kg N_2O–N ha^{-1} yr^{-1}	8.00	8.00	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	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	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	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	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	0.01	Table 11.3 (**)
EF_5	kg N_2O–N kg N^{-1}	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	Table 11.3 (**)

*see text for calculation of F_{cr} for oil palm cultivation.

$Frac_{Remove}$ for rape seed is from Statistics Denmark (2012), see text belonging to **Table 4.6**.

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.

F_{OS} (annual area of managed/drained organic soils) is assumed to be 0, because only minor areas are both drained and organic.

F_{CR} from oil palm cultivation is obtained directly from Schmidt (2011) where this is determined based on a detailed crop balance. Hence, the parameters for calculating F_{CR} (slope, intercept, N_{AG}, $R_{BG\text{-}BIO}$ and N_{BG}) are not presented for oil palm.

The N inputs, outputs and emissions related to rapeseed, sunflower, sugar beet and oil palm cultivation are presented in **Table 4.15**. $N_{surplus}$ 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 4.15: N balances and emissions related to rapeseed, sunflower, sugar beet and oil palm cultivation. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}.

Parameter	Rapeseed		Sun-flower	Sugar beet		Oil palm	Source
	DK	SE	FR	DK	SE	MY	
N inputs							
N_{input}	232	213	211	461	410	361	Equation 7.1(*)
N-fert: Ammonia	4.89	0	0	2.09	0	0	**Table 4.6**
N-fert: Urea	7.82	0	21.0	3.34	0	151	**Table 4.6**
N-fert: AN	10.8	13.8	53.2	4.59	9.12	10.8	**Table 4.6**
N-fert: CAN	73.3	136	14.7	31.3	90.0	0	**Table 4.6**
N-fert: AS	2.93	10.3	1.47	1.25	6.84	0	**Table 4.6**
Manure	99.2	26.0	95.0	99.2	14.0	0.581	**Table 4.6**
Crop residues left in field	33.1	27.2	26.0	319	290	199	**Table 4.6**
N outputs							
N_{output}	99.7	77.7	64.4	118	106	52.8	Equation 7.1(*)
Harvested crop	96.2	74.9	64.4	118	106	52.8	**Table 4.6**
Crop residues removed	3.50	2.89	0	0	0	0	**Table 4.6**
N inputs - N outputs							
$N_{surplus}$	132	135	147	343	304	309	Equation 7.1(*)
N emissions							
NH_3-N	25.3	18.0	23.8	20.5	11.4	13.8	Section 7.4 (*)
NO_x-N	4.47	3.18	4.20	3.61	2.01	2.44	Section 7.4 (*)
N_2O-N_{direct}	2.32	2.13	2.11	4.61	4.10	5.13	Equation 7.3(*)
N_2-N	30.6	48.2	53.4	176	164	179	Section 7.4 (*)
NO_3-N	69.6	64.0	63.4	138	123	108	Section 7.4 (*)
N balance	0	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 4.16**.

Table 4.16: 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 DK	SE	BR	Source
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	1.85	1.69	0.494	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	0.686	0.591	0.191	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	1.85	1.69	0.494	Equation 7.3(*)
$N_2O\text{-}N_{OS}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	Equation 7.3(*)
$N_2O\text{-}N_{PRP}$	kg N_2O–N ha^{-1} yr^{-1}	0	0	0	Equation 7.3(*)
F_{SN}	kg N ha^{-1} yr^{-1}	70.6	102	0	**Table 4.7**
F_{ON}	kg N ha^{-1} yr^{-1}	0	0	0	**Table 4.7**
F_{CR}	kg N ha^{-1} yr^{-1}	15.4	12.4	9.6	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	2,093	1,674	1,295	Table 11.2 (**)
Slope	Dim. less	0.30	0.30	0.30	Table 11.2 (**)
Intercept	Dim. less	0	0	0	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	628	502	388	Table 11.2 (**)
N_{AG}	kg N kg dm^{-1}	0.015	0.015	0.015	Table 11.2 (**)
$Frac_{Remove}$	kg N kg crop-N^{-1}	0	0	0	See text
$R_{BG\text{-}BIO}$	kg dm kg dm^{-1}	0.800	0.800	0.800	Table 11.2 (**)
N_{BG}	kg N kg dm^{-1}	0.012	0.012	0.012	Table 11.2 (**)
F_{SOM}	kg N yr^{-1}	0	0	0	See text
F_{OS}	ha	0	0	0	See text
F_{PRP}	kg N yr^{-1}	0	0	0	No grazing
EF_1	kg N_2O–N kg N^{-1}	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	Table 11.1 (**)
EF_{3PRP}	kg N_2O–N kg N^{-1}	0.02	0.02	0.02	Table 11.1 (**)
$Frac_{GASF}$	kg N kg N^{-1}	0.10	0.10	0.10	Table 11.3 (**)
$Frac_{GASM}$	kg N kg N^{-1}	0.20	0.20	0.20	Table 11.3 (**)
$Frac_{EACH}$	kg N kg N^{-1}	0.30	0.30	0.30	Table 11.3 (**)
EF_4	kg N_2O–N kg N^{-1}	0.01	0.01	0.01	Table 11.3 (**)
EF_5	kg N_2O–N kg N^{-1}	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.

F_{OS} (annual area of managed/drained organic soils) is assumed to be 0, because only minor areas are both drained and organic.

The N inputs, outputs and emissions related to cultivation of permanent grass incl. grass ensilage are presented in **Table 4.17**. $N_{surplus}$ 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. The N2 emission from Permanent grass in Brazil is negative. The most likely reason for this is that the non-fertilised rangeland is impoverished due to overuse.

Table 4.17: 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
	DK	SE	BR	
N inputs				
N_{input}	185	169	49.4	Equation 7.1(*)
N-fert: Ammonia	3.46	0	0	**Table 4.7**
N-fert: Urea	5.53	0	0	**Table 4.7**
N-fert: AN	7.61	8.74	0	**Table 4.7**
N-fert: CAN	51.9	86.3	0	**Table 4.7**
N-fert: AS	2.08	6.56	0	**Table 4.7**
Manure	99.2	54.8	39.8	**Table 4.7**
Crop residues left in field	15.4	12.4	9.56	**Table 4.7**
N outputs				
N_{output}	67.0	53.6	41.4	Equation 7.1(*)
Harvested crop	67.0	53.6	41.4	**Table 4.7**
Crop residues removed	0	0	0	**Table 4.7**
N inputs - N outputs				
$N_{surplus}$	118	115	7.9	Equation 7.1(*)
N emissions				
NH_3-N	22.9	18.0	6.77	Section 7.4 (*)
NO_x-N	4.03	3.17	1.19	Section 7.4 (*)
N_2O-N_{direct}	2.84	2.24	0.892	Equation 7.3(*)
N_2-N	32.9	41.2	-15.7	Section 7.4 (*)
NO_3-N	55.6	50.6	14.8	Section 7.4 (*)
N balance	0	0	0	See text

Rotation grass incl. grass ensilage and roughage, maize ensilage

The parameters used for calculation of emissions from cultivation of rotation grass incl. grass ensilage and roughage, maize ensilage are presented in **Table 4.18**.

Table 4.18: Parameters used for calculation of emissions from cultivation of rotation grass incl. grass ensilage and roughage, maize ensilage. (*): Schmidt and Dalgaard (2012). (**): IPCC (2006).

Parameter	Crop: Country: Unit:	Rotation grass incl. grass ensilage DK	Rotation grass incl. grass ensilage SE	Roughage, maize ensilage DK	Roughage, maize ensilage SE	Source
$N_2O\text{-}N_{direct}$	kg N_2O–N ha^{-1} yr^{-1}	3.89	2.32	2.13	1.83	Equation 7.3(*)
$N_2O\text{-}N_{indirect}$	kg N_2O–N ha^{-1} yr^{-1}	1.26	0.762	0.710	0.584	Equation 7.5(*)
$N_2O\text{-}N_{N\ input}$	kg N_2O–N ha^{-1} yr^{-1}	3.89	2.32	2.13	1.83	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}	185	55.0	31.0	62.1	**Table 4.8**
F_{ON}	kg N ha^{-1} yr^{-1}	0	0	99.2	54.8	**Table 4.8**
F_{CR}	kg N ha^{-1} yr^{-1}	105	83.6	83.1	66.5	Equation 7.3(*)
Crop	kg DM ha^{-1} yr^{-1}	7,813	6,250	12,902	10,322	Table 11.2 (**)
Slope	Dim. less	0.30	0.30	0.30	0.30	Table 11.2 (**)
Intercept	Dim. less	0	0	0	0	Table 11.2 (**)
AG_{DM}	kg dm ha^{-1} yr^{-1}	2,344	1,875	3,871	3,097	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}	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.

F_{OS} (annual area of managed/drained organic soils) is assumed to be 0, because only minor areas are both drained and organic.

The N inputs, outputs and emissions related to barley cultivation are presented in **Table 4.19**. $N_{surplus}$ 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. The N_2 emissions are negative, se text belonging to **Table 4.13** for further details.

Table 4.19: N balances and emissions related cultivation of rotation grass incl. grass ensilage and roughage, maize ensilage. (*): Schmidt and Dalgaard (2012). Unit: kg N ha^{-1} yr^{-1}.

Parameter	Rotation grass incl. grass ensilage		Roughage, maize ensilage		Source
	DK	SE	DK	SE	
N inputs					
N_{input}	389	232	213	183	Equation 7.1(*)
N-fert: Ammonia	9.07	0	1.52	0	**Table 4.8**
N-fert: Urea	14.5	0	2.43	0	**Table 4.8**
N-fert: AN	19.9	4.73	3.35	5.35	**Table 4.8**
N-fert: CAN	136	46.7	22.8	52.8	**Table 4.8**
N-fert: AS	5.44	3.55	0.91	4.01	**Table 4.8**
Manure	99.2	93.0	99.2	54.8	**Table 4.8**
Crop residues left in field	105	83.6	83.1	66.5	**Table 4.8**
N outputs					
N_{output}	288	230	163	130	Equation 7.1(*)
Harvested crop	288	230	163	130	**Table 4.8**
Crop residues removed	0	0	0	0	**Table 4.8**
N inputs - N outputs					
$N_{surplus}$	101	2	50.3	53	Equation 7.1(*)
N emissions					
NH_3-N	32.6	20.5	19.5	14.6	Section 7.4 (*)
NO_x-N	5.75	3.62	3.44	2.58	Section 7.4 (*)
N_2O-N_{direct}	4.88	3.25	2.13	1.83	Equation 7.3(*)
N_2-N	-58.6	-95.2	-38.8	-21.1	Section 7.4 (*)
NO_3-N	117	69.5	64.0	55.0	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 4.20** to **Table 4.24**. All data sources and calculations are documented in the previous sections.

Table 4.20: LCI of barley cultivation. The data represent 1 ha year.

Exchanges	Crop: Country: Unit:	Barley DK	SE	UA	EU
Output of products					
Determining product: Barley	kg	5,157	4,198	2,191	4,259
Material for treatment: Straw	kg	1,741	1,456	-	-
Input of products					
N-fert: Ammonia	kg N	2.83	0	0	0.070
N-fert: Urea	kg N	4.53	0	8.76	16.5
N-fert: AN	kg N	6.23	6.45	49.5	19.2
N-fert: CAN	kg N	42.5	63.7	0	22.9
N-fert: AS	kg N	1.70	4.84	1.74	3.35
Manure	Kg N	99.2	0	21.3	93.1
P fert: TSP	kg P_2O_5	50.4	50.4	137	50.4
K fert: KCl	kg K_2O	66.3	66.3	72.3	66.3
Pesticides	kg (a.s.)	0.509	0.509	0.509	0.509
Lorry	tkm	83.8	1.00E+02	1.19E+02	83.1
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	7,000	5,600	5,000	7,000
Emissions					
Dinitrogen monoxide (direct)	kg N_2O	3.06	1.67	1.66	3.09
Dinitrogen monoxide (indirect)	kg N_2O	1.09	0.493	0.535	1.09
Ammonia	kg NH_3	26.4	7.74	10.6	25.6
Nitrogen oxides	kg NO_x	8.23	2.41	3.30	7.98
Nitrate	kg NO_3	259	141	140	262

Table 4.21: LCI of wheat, oat corn and soybean cultivation. The data represent 1 ha year.

Exchanges	Crop: Country: Unit:	Wheat		Oat		Corn	Soybean
		DK	SE	DK	SE	EU	BR
Output of products							
Determining product: Wheat/oat/corn/soybean	kg	7,296	5,986	4,646	3,817	6,577	2,575
Material for treatment: Straw	kg	2,552	2,118	700	600	-	-
Input of products							
N-fert: Ammonia	kg N	4.85	0	1.27	0	0.10	0
N-fert: Urea	kg N	7.76	0	2.04	0	23.2	0
N-fert: AN	kg N	10.7	11.6	2.80	6.02	26.9	0
N-fert: CAN	kg N	72.8	115	19.1	59.5	32.1	0
N-fert: AS	kg N	2.91	8.71	0.763	4.52	4.71	0
Manure	Kg N	99.2	0	99.2	0	93.1	0
P fert: TSP	kg P_2O_5	45.8	45.8	57.3	57.3	80.2	36.6
K fert: KCl	kg K_2O	84.4	84.4	78.3	78.3	78.3	0
Pesticides	kg (a.s.)	0.603	0.603	0.355	0.355	3.53	2.50
Lorry	tkm	116	149	68.9	103	118	17.4
Diesel	MJ	3,306	3,306	3,046	3,046	3,306	1,709
Light fuel oil for drying	MJ	1.10	1.10	1.10	1.10	1.10	1.10
Land tenure, arable	kg C	7,000	5,600	7,000	5,600	7,000	9,000
Emissions							
Dinitrogen monoxide (direct)	kg N_2O	4.12	2.95	2.52	1.57	3.61	0.526
Dinitrogen monoxide (indirect)	kg N_2O	1.39	0.876	0.920	0.464	1.24	0.118
Ammonia	kg NH_3	30.7	13.9	23.2	7.23	28.2	0
Nitrogen oxides	kg NO_x	9.56	4.34	7.21	2.25	8.78	0
Nitrate	kg NO_3	348	250	213	133	305	44.5

Table 4.22: LCI of rapeseed, sunflower, sugar beet and oil palm cultivation. The data represent 1 ha year.

Exchanges	Crop: Country: Unit:	Rapeseed		Sunflower	Sugar beet		Oil palm
		DK	SE	FR	DK	SE	MY
Output of products							
Determining product: Rapeseed/sunflower/sugar beet/fresh fruit bunches	kg	3,351	2,607	2,376	56,638	51,141	20,407
Material for treatment: Straw	kg	277	228	-	-	-	-
Input of products							
N-fert: Ammonia	kg N	4.89	0	0	2.09	0	0
N-fert: Urea	kg N	7.82	0	21.0	3.34	0	151
N-fert: AN	kg N	10.8	13.8	53.2	4.59	9.12	10.8
N-fert: CAN	kg N	73.3	136	14.7	31.3	90.0	0
N-fert: AS	kg N	2.93	10.3	1.47	1.25	6.84	0
Manure	Kg N	99.2	26.0	95.0	99.2	14.0	0
P fert: TSP	kg P_2O_5	55.0	22.9	52.7	87.0	36.6	0
P fert: Rock phosphate	kg P_2O_5	0	0	0	0	0	81.3
K fert: KCl	kg K_2O	96.4	20.5	72.3	181	53.0	268
Pesticides	kg (a.s.)	0.270	0.802	0.270	2.74	2.74	2.60
Lorry	tkm	124	136	100	129	114	198
Diesel	MJ	3,195	3,195	3,306	8,581	8,581	1,710
Light fuel oil for drying	MJ	1.10	1.10	1.10	0	0	0
Land tenure, arable	kg C	7,000	5,600	7,000	7,000	5,600	11,000
Emissions							
Dinitrogen monoxide (direct)	kg N_2O	3.65	3.35	3.32	7.24	6.45	8.07
Dinitrogen monoxide (indirect)	kg N_2O	1.29	1.09	1.19	2.01	1.66	1.53
Ammonia	kg NH_3	30.8	21.9	28.9	24.9	13.8	16.8
Nitrogen oxides	kg NO_x	9.58	6.81	9.01	7.75	4.31	5.23
Nitrate	kg NO_3	308	283	281	612	545	480

Table 4.23: LCI of permanent grass incl. grass ensilage cultivation. The data represent 1 ha year.

Exchanges	Crop: Country: Unit:	Permanent grass incl. grass ensilage		
		DK	SE	BR
Output of products				
Determining product: Permanent grass incl. grass ensilage	kg	11,628	9,302	7,193
Input of products				
N-fert: Ammonia	kg N	3.46	0	0
N-fert: Urea	kg N	5.53	0	0
N-fert: AN	kg N	7.61	8.74	0
N-fert: CAN	kg N	51.9	86.3	0
N-fert: AS	kg N	2.08	6.56	0
Manure	Kg N	99.2	54.8	39.8
P fert: TSP	kg P_2O_5	32.1	32.1	0
K fert: KCl	kg K_2O	121	121	0
Lorry	tkm	102	130	-
Diesel	MJ	557.2	557.2	31.4
Light fuel oil for drying	MJ	0	0	0
Land tenure, arable	kg C	7,000	2,800	-
Land tenure, int. forest land	kg C	0	2,800	0
Land tenure, rangeland	kg C	0	0	9,000
Emissions				
Dinitrogen monoxide (direct)	kg N_2O	4.47	3.51	1.402
Dinitrogen monoxide (indirect)	kg N_2O	1.08	0.929	0.300
Ammonia	kg NH_3	27.8	21.8	8.22
Nitrogen oxides	kg NO_x	8.65	6.79	2.56
Nitrate	kg NO_3	246	224	65.6

Table 4.24: LCI of rotation grass incl. grass ensilage and roughage, maize ensilage cultivation. The data represent 1 ha year.

Exchanges	Crop: Country: Unit:	Rotation grass incl. grass ensilage DK	Rotation grass incl. grass ensilage SE	Roughage, maize ensilage DK	Roughage, maize ensilage SE
Output of products					
Determining product: Rotation grass/roughage	kg	44,643	35,714	39,097	31,278
Input of products					
N-fert: Ammonia	kg N	9.07	0	1.52	0
N-fert: Urea	kg N	14.5	0	2.43	0
N-fert: AN	kg N	19.9	4.73	3.35	5.35
N-fert: CAN	kg N	136	46.7	22.8	52.8
N-fert: AS	kg N	5.44	3.55	0.913	4.01
Manure	Kg N	99.2	93.0	99.2	54.8
P fert: TSP	kg P_2O_5	73.3	0	64.9	64.9
K fert: KCl	kg K_2O	217	0	200	200
Pesticides	kg (a.s.)	0.095	0.095	0.095	0.095
Lorry	tkm	231	41	116	141
Diesel	MJ	2,415	2,415	3,715	3,715
Light fuel oil for drying	MJ	0	0	0	0
Land tenure, arable	kg C	7,000	5,600	7,000	5,600
Emissions					
Dinitrogen monoxide (direct)	kg N_2O	7.67	5.10	3.35	2.88
Dinitrogen monoxide (indirect)	kg N_2O	1.98	1.20	1.12	0.918
Ammonia	kg NH_3	39.6	24.9	23.7	17.7
Nitrogen oxides	kg NO_x	12.3	7.75	7.38	5.52
Nitrate	kg NO_3	516	308	284	244

4.5 Parameters relating to switch between modelling assumptions

The allocation factors used for switching between the four modelling assumptions are presented in **Table 4.25** and **Table 4.26**. Allocation factors are only relevant, when more than one product is produced. Therefore, data are only presented for crops, where the straw is removed. Point of displacement is more detailed explained in Schmidt and Dalgaard (2012, Figure 3.2).

Switch 1: Allocation is avoided by substitution. Consequently, production of 1 kg crop displaces electricity and heat due to utilisation of straw in CHP.

Switch 2: Co-products are modelled using allocation at the point of substitution. The allocation factors are obtained by combining straw/crop ratio (e.g. barley: **Table 4.1**), energy/straw ratio (**Table 4.9**) with the relevant 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 straw/crop ratio (e.g. barley: **Table 4.1**) with the relevant prices from **Appendix C: Prices**.

Table 4.25: Allocation factors used for allocation of products from barley and wheat cultivation. Unit: Fraction

Allocation factors	Barley		Wheat	
	DK	SE	DK	SE
Switch 1: ISO 14040/44				
Determining product: Barley/wheat	1	1	1	1
Switch 2: Average/allocation				
Determining product: Barley/wheat	0.602	0.564	0.584	0.573
By-product at point of subst.: Elec DK/SE	0.170	0.186	0.177	0.182
By-product at point of subst.: Distr. heat	0.229	0.250	0.239	0.245
Switch 3: PAS2050				
Determining product: Barley/wheat	0.826	0.803	0.815	0.808
Material for treatment: Straw	0.174	0.197	0.185	0.192
Switch 4: IDF				
Determining product: Barley/wheat	0.826	0.803	0.815	0.808
Material for treatment: Straw	0.174	0.197	0.185	0.192

Table 4.26: Allocation factors used for allocation of products from oat and rapeseed cultivation. Unit: Fraction

Allocation factors	Oat		Rapeseed	
	DK	SE	DK	SE
Switch 1: ISO 14040/44				
Determining product: Oat/rapeseed	1	1	1	1
Switch 2: Average/allocation				
Determining product: Oat/rapeseed	0.763	0.733	0.923	0.923
By-product at point of subst.: Elec DK/SE	0.101	0.114	0.033	0.033
By-product at point of subst.: Distr. heat	0.136	0.153	0.044	0.044
Switch 3: PAS2050				
Determining product: Oat/rapeseed	0.910	0.896	0.974	0.974
Material for treatment: Straw	0.090	0.104	0.026	0.026
Switch 4: IDF				
Determining product Oat/rapeseed	0.910	0.896	0.974	0.974
Material for treatment: Straw	0.090	0.104	0.026	0.026

5 The food industry system

The activities in the food industry system supplies several concentrate feed input to the cattle system. All activities in the food industry are characterised by being multiple product output activities.

Opposed to the milk and beef systems and the plant cultivation system, the inventories of the food industry system are based on other life cycle assessments. Therefore, compared to chapter 0 and 4, this chapter contains less parameters and calculations and more literature references.

5.1 Inventory of soybean meal system (soybean meal)

The inventories for activities in the soybean meal system are presented in **Table 5.1**. An overview of transactions within the production system is presented in Schmidt and Dalgaard (2012, section 8.3). The inventory is based on Dalgaard et al. (2008) and Schmidt (2010c). The utilisation of FFA activity is established based on data in **Appendix B: Feed and crop properties**.

Table 5.1: LCI of soybean meal activities. FFA: Free fatty acids. NBD oil: neutralized, bleached and deodorized oil.

	Activity:	Soybean oil mill	Soybean oil refinery	Utilisation of FFA as feed
Exchanges	Country: Unit:	BR	BR	GLO
Output of products				
Determining product:				
Soybean meal	kg	0.773		
Crude soybean oil for treatment	kg		1	
FFA for treatment	kg			1
By-product:				
Crude soybean oil for treatment	kg	0.192		
FFA for treatment	kg		1.18E-02	
NBD oil	kg		0.983	
Feed energy	MJ net energy			18.0
Input of products/material for treatment				
Soybeans	kg	1		
Lorry	tkm	6.96E-04	6.10E-03	
Other chemicals	kg	4.02E-4	1.36E-2	
Electricity	kWh	1.22E-02	2.87E-02	
Natural gas, burned	MJ	0.282		
Fuel oil, burned	MJ	0.145	0.247	
Oil mill, capital goods	kg	0.192		
Oil mill, services	kg	0.192		
Oil refinery, capital goods	kg		0.983	
Oil refinery, services	kg		0.983	

5.2 Inventory of rapeseed oil system (rapeseed meal)

The inventories for activities in the rapeseed oil system are presented in **Table 5.2**. An overview of transactions within the production system is presented in Schmidt and Dalgaard (2012, section 8.4). The inventory is based on Schmidt (2010c). The utilisation of rapeseed meal activity is established based on data in **Appendix B: Feed and crop properties**.

Table 5.2: LCI of rapeseed oil activities. FFA: Free fatty acids. NBD oil: Neutralized, bleached and deodorized oil.

	Activity:	Rapeseed oil mill	Utilisation of rapeseed meal as feed
	Country:	DK/SE	GLO
Exchanges	**Unit:**		
Output of products			
Determining product:			
Crude rapeseed oil	kg	0.419	
Rapeseed meal for treatment	kg		1
By-product:			
Rapeseed meal for treatment	kg	0.564	
Feed energy	MJ net energy		8.27
Feed protein	kg		0.311
Input of products/material for treatment			
Rapeseed	kg	1	
Lorry	tkm	0.00599	
Other chemicals	kg	0.000498	
Electricity	kWh	0.0387	
Fuel oil, burned	MJ	0.761	
Oil mill, capital goods	kg	0.419	
Oil mill, services	kg	0.419	

5.3 Inventory of sunflower oil system (sunflower meal)

The inventories for activities in the sunflower oil system are presented in **Table 5.3**. An overview of transactions within the production system is presented in Schmidt and Dalgaard (2012, section 8.5). The oil extraction rate is estimated by comparing the total use of sunflower seed and the total production of sunflower oil in France in FAOSTAT (2012). The loss is estimated as being the same as for rapeseed oil mills (Schmidt 2010c) and the meal is calculated as the remaining output. Inputs of energy etc. to the sunflower oil mill are assumed to be the same per kg oil as of rapeseed mills (see **section 5.2**). The utilisation of sunflower meal activity is established based on data in **Appendix B: Feed and crop properties**.

Table 5.3: LCI of sunflower oil activities.

Exchanges	Activity: Country: Unit:	Sunflower oil mill	Utilisation of sunflower meal as feed
		FR	GLO
Output of products			
Determining product:			
Crude sunflower oil	kg	0.314	
Sunflower meal for treatment	kg		1
By-product:			
Sunflower meal for treatment	kg	0.669	
Feed energy	MJ net energy		7.45
Feed protein	kg		0.371
Input of products/material for treatment			
Sunflower	kg	1	
Lorry	tkm	0.00599	
Other chemicals	kg	4.98E-4	
Electricity	kWh	0.0387	
Fuel oil, burned	MJ	0.761	
Oil mill, capital goods	kg	0.314	
Oil mill, services	kg	0.314	

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

The inventories for activities in the palm oil system are presented in **Table 5.4** and **Table 5.5**. An overview of transactions within the production system is presented in Schmidt and Dalgaard (2012, section 8.6). The inventory for 'Utilisation of FFA as feed' is presented in **Table 5.1**, because it also is part of the soybean meal system. The inventory of the activities in the palm oil system is based on Schmidt (2010c). The utilisation of palm kernel meal (PKM) activity is established based on data in **Appendix B: Feed and crop properties**.

Table 5.4: LCI of palm oil activities. Part 1. POME: Palm oil mill effluent. EFB: empty fruit bunches.

	Activity:	Palm oil mill	Palm kernel oil mill	Palm oil refinery	Palm kernel oil refinery
	Country:	MY	MY	MY	MY
Exchanges	**Unit:**				
Output of products					
Determining product:					
Crude palm oil	kg	0.203			
Kernel for treatment	kg		1		
NBD oil	kg			0.953	
Crude palm kernel oil for treatment	kg				1
By-product:					
Kernel for treatment	kg	5.23E-02			
POME for treatment	kg	0.700			
EFB for treatment	kg	0.220			
Electricity	kWh	4.36E-03			
Crude palm kernel oil	kg		0.449		
Palm kernel meal	kg		0.529		
Free fatty acids	kg			4.59E-02	4.59E-02
NBD oil	kg				0.953
Input of products					
Fresh fruit bunches	kg	1			
Crude palm oil	kg			1	
Crude palm kernel oil	kg				1
Lorry	tkm	0.0174	0.0996	0.0517	0.0517
Other chemicals	kg			0.0216	0.0216
Electricity	kWh		0.0941	0.0262	0.0262
Diesel, burned	MJ	1.46		0.331	0.331
Fuel oil, burned	MJ			0.304	0.304
Oil mill, capital goods	kg	0.203	0.449	0.953	1
Oil mill, services	kg	0.203	0.449	0.953	1
Oil refinery, capital goods	kg	0.203	0.449	0.953	1
Oil refinery, services	kg	0.203	0.449	0.953	1
Emissions					
Dinitrogen monoxide	kg	8.73E-06			
Methane	kg	8.68E-03			

Table 5.5: LCI of palm oil activities. Part 2. EFB: Empty fruit bunches. POME: Palm oil mill effluent. PKM: Palm Kernel meal.

Exchanges	Activity: Country: Unit:	Utilisation of EFB as fertiliser	Utilisation of POME as fertiliser	Utilisation of PKM as feed
		MY	MY	GLO
Output of products				
Determining product:				
EFB for treatment	kg	1		
POME for treatment	kg		1	
Palm kernel meal for treatment	kg			1
By-product:				
N-fert: Urea	kg N	1.32E-03	9.50E-04	
P-fert: Rock phosphate	kg P_2O_5	3.63E-04	3.44E-04	
K-fert	kg K_2O	5.77E-03	2.05E-03	
Feed energy	MJ net energy			5.88
Feed protein	kg			0.154

5.5 Inventory of sugar system (molasses and beet pulp)

The inventories for activities in the sugar system are presented in **Table 5.6**. An overview of transactions within the production system is presented in Schmidt and Dalgaard (2012, section 8.7). The inventory is based on Nielsen et al. (2005). The utilisation of rapeseed meal activity is established based on data in **Appendix B: Feed and crop properties**.

Table 5.6: LCI of sugar system activities.

Exchanges	Activity: Country: Unit:	Sugar mill	Sugar mill	Utilisation of molasses (74.0 % DM) as feed	Utilisation of beet pulp, dried (89.4% DM) as feed
		DK	SE	GLO	GLO
Output of products					
Determining product:					
Sugar	kg	0.137	0.137		
Molasses (74% DM) for treatment	kg			1	
Beet pulp (89.4% DM) for treatment	kg				1
By-product:					
Molasses (74% DM) for treatment	kg	3.29E-02	3.29E-02		
Beet pulp, dried (89.4% DM) for treatment	kg	4.52E-02	4.52E-02		
Feed energy	MJ net energy			5.67	6.99
Feed protein	kg			9.62E-02	8.58E-02
Input of products					
Sugar beet	kg	1	1		
Lorry	tkm	0.0700	0.0700		
Electricity	kWh	0.00315	0.00315		
Natural gas, burned	MJ	0.928	0.928		
Coal, burned	MJ	0.503	0.503		
Fuel oil, burned	MJ	0.495	0.495		
Sugar mill, capital goods	kg	0.137	0.137		
Sugar mill, services	kg	0.137	0.137		

5.6 Inventory of wheat flour system (wheat bran)

The inventories for activities in the sugar system are presented in **Table 5.7**. An overview of transactions within the production system is presented in Schmidt and Dalgaard (2012, section 8.8). The inventory is based on Nielsen et al. (2005). The utilisation of wheat bran activity is established based on data in **Appendix B: Feed and crop properties**.

Table 5.7: LCI of wheat flour activities.

Exchanges	Activity: Country: Unit:	Flour mill DK/SE	Utilisation of wheat bran (87.1% DM) as feed GLO
Output of products			
Determining product:			
Wheat flour	kg	0.800	
Wheat bran for treatment	kg		1
By-product:			
Wheat bran for treatment	kg	0.200	
Feed energy	MJ net energy		6.06
Feed protein	kg		0.159
Input of products			
Wheat	Kg	1	
Lorry	tkm	7.00E-02	
Electricity	kWh	8.00E-02	
Natural gas, burned	kg	0.400	
Water	kg	1.00E-02	
Flour mill, capital goods	kg	0.800	
Flour mill, services	kg	0.800	

5.7 Parameters relating to switch between modelling assumptions

The allocation factors used for switching between the four modelling assumptions are presented in **Table 5.8** to **Table 5.13**. The point where allocation is done is described for all activities in Schmidt and Dalgaard (2012, section 8).

Switch 1: Allocation is avoided by substitution.

Switch 2: Co-products are modelled using allocation at the point of substitution. The allocation factors are obtained by combining the product flows in **Table 5.1** to **Table 5.7** with the relevant 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 flows in **Table 5.1** to **Table 5.7** with the relevant prices from **Appendix C: Prices**.

Table 5.8: 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	0.679	
Crude soybean oil for treatment		1
By-products at point of substitution:		
NBD oil	0.319	
Feed energy	2.01E-03	
Switch 3: PAS2050		
Determining product:		
Soybean meal	0.758	
By-products:		
Crude soybean oil for treatment	0.242	
NBD oil		0.990
FFA		9.69E-03
Switch 4: IDF		
Determining product:		
Soybean meal	0.758	
By-products:		
Crude soybean oil for treatment	0.242	
NBD oil		0.990
FFA		9.69E-03

Table 5.9: Allocation factors related to products from the rapeseed oil system. Unit: Fraction.

Products	Rapeseed oil mill	Rapeseed oil mill
	DK	SE
Switch 1: ISO 14040/44		
Determining product:		
Crude rapeseed oil	1	1
Switch 2: Average/allocation		
Determining product:		
Crude rapeseed oil	0.761	0.752
By-products at point of substitution:		
Feed protein	9.56E-02	9.89E-02
Feed energy	0.144	0.149
Switch 3: PAS2050		
Determining product:		
Crude rapeseed oil	0.768	0.707
By-products		
Rapeseed meal	0.232	0.293
Switch 4: IDF		
Determining product:		
Crude rapeseed oil	0.768	0.707
By-products:		
Rapeseed meal	0.232	0.293

Table 5.10: Allocation factors related to products from the sunflower oil system

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	0.706
By-products at point of substitution:	
Feed protein	0.137
Feed energy	0.156
Switch 3: PAS2050	
Determining product:	
Crude sunflower oil	0.736
By-products:	
Utilisation of sunflower meal as feed	0.264
Switch 4: IDF	
Determining product:	
Crude sunflower oil	0.736
By-products:	
Utilisation of sunflower meal as feed	0.264

Table 5.11: Allocation factors related to products from the palm oil system. Unit: Fraction.

Products	Palm oil mill	Palm kernel oil mill	Palm oil refinery	Palm kernel oil refinery
	MY	MY	MY	MY
Switch 1: ISO 14040/44				
Determining product:				
Crude palm oil	1			
Kernel for treatment		1		
NBD oil			1	
Crude palm kernel oil for treatment				1
Switch 2: Average/allocation				
Determining product:				
Crude palm oil	0.806			
Kernel for treatment		1		
NBD oil			0.975	
Crude palm kernel oil for treatment				1
By-products at point of substitution:				
NBD oil	0.143			
Feed energy	2.17E-02		2.47E-02	
Feed protein	8.94E-03			
N-fert: Urea	5.26E-03			
P fert	7.42E-04			
K fert	1.13E-02			
Elec MY	3.31E-03			
Switch 3: PAS2050				
Determining product:				
Crude palm oil	0.824			
Crude palm kernel oil for treatment		0.917		
NBD oil			0.962	
By-products:				
Kernel for treatment	0.155			
EFB for land application	7.25E-03			
POME for land application	1.05E-02			
Free fatty acids (FFA) for treatment			3.78E-02	2.48E-02
NBD oil				0.975
Elec MY	3.38E-03			
Palm kernel meal for treatment		8.33E-02		
Switch 4: IDF				
Determining product:				
Crude palm oil	0.824			
Crude palm kernel oil		0.917		
NBD oil			0.962	
By-products:				
Kernel for treatment	0.155			
EFB for land application	7.25E-03			
POME for land application	1.05E-02			
Free fatty acids (FFA) for treatment			3.78E-02	2.48E-02
NBD oil				0.975
Elec MY	3.38E-03			
Palm kernel meal for treatment		8.33E-02		

Table 5.12: Allocation factors related to products from the sugar system. Unit: Fraction.

Products	Sugar mill DK	Sugar mill SE
Switch 1: ISO 14040/44		
Determining product:		
Sugar	1	1
Switch 2: Average/allocation		
Determining product:		
Sugar	0.878	0.885
By-products at point of substitution:		
Feed energy	9.79E-02	9.20E-02
Feed protein	2.42E-02	2.28E-02
Switch 3: PAS2050		
Determining product:		
Sugar	0.839	0.828
By-products:		
Molasses (74% DM)	6.34E-02	6.31E-02
Beet pulp, dried (89.4% DM)	9.80E-02	0.109
Switch 4: IDF		
Determining product:		
Sugar	0.839	0.828
By-products:		
Molasses (74% DM)	6.34E-02	6.31E-02
Beet pulp, dried (89.4% DM)	9.80E-02	0.109

Table 5.13: Allocation factors related to products from the wheat flour system. Unit: Fraction.

Products	Flour mill DK	Flour mill SE
Switch 1: ISO 14040/44		
Determining product:		
Flour	1	1
Switch 2: Average/allocation		
Determining product:		
Flour	0.929	0.928
By-products at point of substitution:		
Feed energy	4.83E-02	4.89E-02
Feed protein	2.24E-02	2.27E-02
Switch 3: PAS2050		
Determining product:		
Flour	0.923	0.916
By-products:		
Wheat bran	7.69E-02	8.44E-02
Switch 4: IDF		
Determining product:		
Flour	0.923	0.916
By-products:		
Wheat bran	7.69E-02	8.44E-02

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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 (Danish: Foderkode) in Møller et al. (2005).

Feed:		Barley	Wheat	Oat	Corn	Soybean meal	Rapeseed cake/meal	Sunflower meal	Beet pulp, dried	Beet pulp	Molasses, beet	Palm oil	Palm kernel meal	Wheat bran	Feed urea	Minerals, salt etc.	Permanent grass	Maize ensilage	Rotation grass
	Feed code: Unit	201	203	202	204	154	144	165	283	282	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	0.115	0.740	0.990	0.906	0.871	1.000	1.000	0.180	0.330	0.175
Raw protein	kg/kg DM	0.108	0.115	0.102	0.096	0.535	0.35	0.417	0.096	0.105	0.130	0	0.170	0.183	2.28	0	0.200	0.079	0.230
Raw fat	kg/kg DM	0.031	0.024	0.053	0.046	0.028	0.105	0.030	0.012	0.016	0.001	1	0.082	0.046	0	0	0.039	0.022	0.041
Carbohydrate	kg/kg DM	0.838	0.842	0.819	0.843	0.361	0.475	0.467	0.822	0.817	0.742	0	0.707	0.713	0	0	0.661	0.863	0.633
Ash	kg/kg DM	0.023	0.018	0.026	0.015	0.076	0.07	0.086	0.07	0.062	0.127	0	0.041	0.058	1	1	0.100	0.036	0.096
Digestible energy	MJ/kg DM	15.2	16.0	13.4	16.2	18.0	16.2	15.1	14.6	14.8	13.6	32.2	12.8	13.1	0	0	13.2	13.3	14.1
Feed energy content	SFU/kg DM	1.11	1.21	0.91	1.22	1.40	1.19	1.07	1.00	1.03	0.98	2.82	0.83	0.89	0	0	0.86	0.88	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	18.2	16.9	36.6	20.2	19.3	0	0	18.5	18.7	18.8
Digestible energy *	MJ/MJ	0.79	0.83	0.69	0.83	0.87	0.77	0.76	0.81	0.81	0.80	0.88	0.63	0.68	0	0	0.71	0.71	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	8.05	7.66	22.05	6.49	6.96	0	0	6.73	6.88	7.51

*expressed as a percentage of gross energy

Appendix C: Prices

C.1 Cattle system

Cattle system				
Prices	**Unit**	**DK**	**SE**	**BR**
Milk (ECM)	EUR2005 kg ECM milk-1	0.309	0.311	
Meat live weight	EUR2005 kg live weight-1	1.28	0.872	0.631
Live animal: cow	EUR2005 kg head-1	1162	1971	
Live animal: heifer	EUR2005 kg head-1	1162	1971	
Live animal: small bull	EUR2005 kg head-1	399	125	
Live animal: bull	EUR2005 kg head-1	399	125	
Dead animal	EUR2005 kg live weight-1	0	0	0
Ammonium nitrate, as N	EUR2005 kg N-1	0.533	0.421	
Urea, as N	EUR2005 kg N-1			0.406
Triple superphosphate, as P2O5	EUR2005 kg P2O5-1	0.248	0.463	
Potassium chloride, as K2O	EUR2005 kg K2O-1	0.317	0.220	
Electricity	EUR2005 kWh electricity-1	0.0741	0.0741	
Heat	EUR2005 MJ heat-1	0.0139	0.0139	
Coal	EUR2005 MJ-1	0.00209	0.00386	
Fuel oil	EUR2005 MJ-1	0.00905	0.01044	

Cattle system			
Data sources	**DK**	**SE**	**BR**
Milk (ECM)	Production price (DK): 'Cow milk, whole, fresh'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 9/2-2012)	Production price (SE): 'Cow milk, whole, fresh'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 9/2-2012)	
Meat live weight	Production price (DK): 'Cattle Live Weight'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 9/2-2012)	Production price (SE): 'Cattle Live Weight'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 9/2-2012)	Production price (BR): 'Cattle Live Weight'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 9/2-2012)
Live animal: cow	Export price (DK): '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 9/2-2012)	Export price (SE): '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 9/2-2012)	
Live animal: heifer	Export price (DK): 'Bovine animals, live pure-bred	Export price (SE): '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 9/2-2012)	breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	
Live animal: small bull	Export price (DK): 'Bovine animals, live, except pure-bred breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	Export price (SE): 'Bovine animals, live, except pure-bred breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	
Live animal: bull	Export price (DK): 'Bovine animals, live, except pure-bred breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	Export price (SE): 'Bovine animals, live, except pure-bred breeding'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	
Dead animal	Dead animals for destruction are not paid for by descruction industry	Dead animals for destruction are not paid for by descruction industry	Dead animals for destruction are not paid for by descruction industry
Ammonium nitrate, as N	Import price (DK): '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 9/2-2012)	Import price (SE): '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 9/2-2012)	
Urea, as N			Import price (BR): 'Urea, including aqueous solution in packs >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)
Triple superphosphate, as P2O5	Import price (DK): 'Superphosphates, in packs >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	Import price (SE): 'Superphosphates, in packs >10 kg'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	
Potassium chloride, as K2O	Import price (DK): '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 9/2-2012)	Import price (SE): '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 9/2-2012)	
Electricity	DK industry use price 2005: IEA (2010, p IV.234), Electricity Information 2010. International Energy Agency	Same price as in Denmark assumed	

Heat	DK industry use of district heating in DKK and MJ in 2005: Danmarks Statistik (2012), Statistikbanken, Miljø og energi. Statistics Denmark, http://www.statistikbanken.dk (accessed February 2012)	Same price as in Denmark assumed	
Coal	Import price (DK): '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 9/2-2012)	Import price (SE): 'Bituminous coal, not agglomerated'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	
Fuel oil	Import price (DK): 'Oils petroleum, bituminous, distillates, except crude'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	Import price (SE): 'Oils petroleum, bituminous, distillates, except crude'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 9/2-2012)	

C.2 Plant cultivation system

Plant cultivation system			
Prices	**Unit**	**DK**	**SE**
Barley	EUR2005/kg crop	0.107	0.094
Wheat	EUR2005/kg crop	0.103	0.100
Oat	EUR2005/kg crop	0.102	0.091
Rapeseed	EUR2005/kg crop	0.208	0.222
Crop residue	EUR2005/kg straw	0.0669	0.0669
Electricity	EUR2005 kWh electricity-1	0.0741	0.0741
Heat	EUR2005 MJ heat-1	0.0139	0.0139

Plant cultivation system		
Data sources	**DK**	**SE**
Barley	Production price (DK): 'Barley'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)	Production price (SE): 'Barley'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)
Wheat	Production price (DK): 'wheat'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)	Production price (SE): 'wheat'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)
Oat	Production price (DK): 'oats'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)	Production price (SE): 'oats'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)
Rapeseed	Production price (DK): 'oats'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)	Production price (SE): 'oats'. FAOSTAT (2012), FAOSTAT producer prices. http://faostat.fao.org/ (Accessed 24/2-2012)
Crop residue	10% VA (rogh assumption) added to addition to costs obtained from: Hinge J and Maegaard E (2005) Prisen på halm til kraftvarme (English: The price on straw for combined heat and power). Dansk Landbrugsrådgivning, Aarhus	Assumed same price as in Denmark
Electricity	DK industry use price 2005: IEA (2010, p IV.234), Electricity Information 2010. International Energy Agency	Same price as in Denmark assumed
Heat	DK industry use of district heating in DKK and MJ in 2005: Danmarks Statistik (2012), Statistikbanken, Miljø og energi. Statistics Denmark, http://www.statistikbanken.dk (accessed February 2012)	Same price as in Denmark assumed

C.3 Food industry system

Food industry system							
Prices	**Unit**	**MY**	**BR**	**DK**	**SE**	**FR**	**GLO**
Crude palm oil	EUR/kg	0.300					
Crude palm kernel oil	EUR/kg	0.470					
Crude soybean oil	EUR/kg		0.208				
Crude rapeseed oil	EUR/kg			0.536	0.513		
Crude sunflower oil	EUR/kg					0.655	
Palm kernel meal	EUR/kg	0.037					
Soybean meal	EUR/kg		0.162				
Rapeseed meal	EUR/kg			0.120	0.157		
Sunflower meal	EUR/kg					0.110	
NBD palm oil	EUR/kg	0.313					
NBD palm kernel oil	EUR/kg	0.483					
NBD soybean oil	EUR/kg		0.448				
Sugar	EUR/kg			0.300	0.322		
Flour	EUR/kg			0.265	0.262		
Kernel	EUR/kg	0.219					
EFB for land application	EUR/kg	0.00244					
POME for land application	EUR/kg	0.00110					
Free fatty acids (FFA)	EUR/kg	0.255	0.255				
Molasses (74% DM)	EUR/kg			0.094	0.102		
Beet pulp, dried (89.4% DM)	EUR/kg			0.106	0.128		
Wheat bran	EUR/kg			0.088	0.097		
Feed energy	EUR/MJ net energy						0.00911
Feed protein	EUR/kg						0.161
Urea, as N	EUR/kg N	0.416					
Phosphate rock, as P2O5	EUR/kg P2O5	0.175					
Potassium chloride, as K2O	EUR/kg K2O	0.316					
Electricity	EUR/kWh	0.0572					

Food industry system						
Data sources	**MY**	**BR**	**DK**	**SE**	**FR**	**GLO**
Crude palm oil	MPOB (2006), MALAYSIAN OIL PALM STATISTICS 2005. Malaysian Palm Oil Board. http://econ.mpob.gov.my/economy/ei_statistics05_old.htm (accessed 1771-2012)					
Crude palm kernel oil	MPOB (2006), MALAYSIAN OIL PALM STATISTICS 2005. Malaysian Palm Oil Board. http://econ.mpob.gov.my/economy/ei_statistics05_old.htm (accessed 1771-2012)					
Crude soybean oil		Production price (Brazil): 'Oil, soya-bean, crude'. UNSD (2012), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 18/1-2012)				
Crude rapeseed oil			Export price (Denmark): 'Canola, rape, colza or mustard oil, crude'. UNSD (2012), Commodity Trade Statistics Database. United Nations	Export price (Sweden): 'Canola, rape, colza or mustard oil, crude'. UNSD (2012), Commodity Trade Statistics Database. United Nations		

			Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)	Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)		
Crude sunflower oil					Export price (France): 'Sunflower-seed or safflower oil, crude'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)	
Palm kernel meal	MPOB (2006), MALAYSIAN OIL PALM STATISTICS 2005. Malaysian Palm Oil Board. http://econ.mpob.gov.my/economy/ei_statistics05_old.htm (accessed 1771-2012)					
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 17/1-2012)				
Rapeseed meal			Export price	Export price		

			(Denmark): 'Rape or colza seed 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 17/1-2012)	(Sweden): 'Rape or colza seed 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 17/1-2012)		
Sunflower meal					Export price (France): 'Sunflower seed 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 17/1-2012)	
NBD palm oil	MPOB (2006), MALAYSIAN OIL PALM STATISTICS 2005. Malaysian Palm Oil Board. http://econ.mpob.gov.my/economy/ei_statistics05_old.htm (accessed 1771-2012)					
NBD palm kernel oil	NBD PKO: Price for refining step of 1 kg is assumed same as for crude palm oil. This is added to CPKO					

NBD soybean oil		NBD SBO: Production price (Brazil): 'Oil, soya-bean,refined'. UNSD (2012), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 18/1-2012)				
Sugar			Production price (Denmark): 'Wheat or meslin flour'. UNSD (2012), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 18/1-2012)	Production price (Sweden): 'Wheat or meslin flour'. UNSD (2012), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 18/1-2012)		
Flour			Production price (Denmark): 'Wheat or meslin flour'. UNSD (2012), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 18/1-2012)	Production price (Sweden): 'Wheat or meslin flour'. UNSD (2012), Industrial Commodity Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 18/1-2012)		
Kernel	MPOB (2006), MALAYSIAN OIL PALM STATISTICS 2005. Malaysian Palm Oil					

	Board. http://econ.mpob.gov.my/economy/ei_statistics05_old.htm (accessed 1771-2012)					
EFB for land application	Calculated based on fertiliser prices and nutrient content of EFB					
POME for land application	Calculated based on fertiliser prices and nutrient content of POME					
Free fatty acids (FFA)	MPOB (2006), MALAYSIAN OIL PALM STATISTICS 2005. Malaysian Palm Oil Board. http://econ.mpob.gov.my/economy/ei_statistics05_old.htm (accessed 1771-2012)	Assumed as same as FFA in Malaysia				
Molasses (74% DM)			Import price (Denmark): 'Molasses, except cane molasses'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)	Import price (Sweden): 'Molasses, except cane molasses'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)		
Beet pulp, dried (89.4% DM)			Import price (Denmark): 'Beet-pulp, bagasse & other waste of sugar manufacture'. UNSD	Import price (Sweden): 'Beet-pulp, bagasse & other waste of sugar manufacture'. UNSD		

			(2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)	(2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)		
Wheat bran			Import price (Denmark): 'Wheat bran, sharps, other residues'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)	Import price (Sweden): 'Wheat bran, sharps, other residues'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)		
Feed energy						Calculated based on price of soybean meal in Brazil 2005 export price (UNSD 2012, Commodity Trade Statistics Database) and price of barley, average of Russia, Ukraine and France in 2005 (FAOSTAT 2012). These data are combined with data on the content of protein and net energy in the two feed commodities.
Feed protein						Calculated based on price of soybean meal

						in Brazil 2005 export price (UNSD 2012, Commodity Trade Statistics Database) and price of barley, average of Russia, Ukraine and France in 2005 (FAOSTAT 2012). These data are combined with data on the content of protein and net energy in the two feed commodities.
Urea, as N	Import prices (Malaysia): UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)					
Phosphate rock, as P2O5	Import prices (Malaysia): UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)					
Potassium chloride, as K2O	Import prices (Malaysia): UNSD (2012), Commodity Trade Statistics					

	Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 17/1-2012)					
Electricity	Average use price in Malaysia in 2007. Wikipedia (2012), Electricity pricing, http://en.wikipedia.org/wiki/Electricity_pricing (accessed 19/1-2012)					