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Life cycle inventory data from farms

Need for secondary and life cycle inventory data for use in Product Environmental Footprint (PEF) of livestock products in The Nordic Countries

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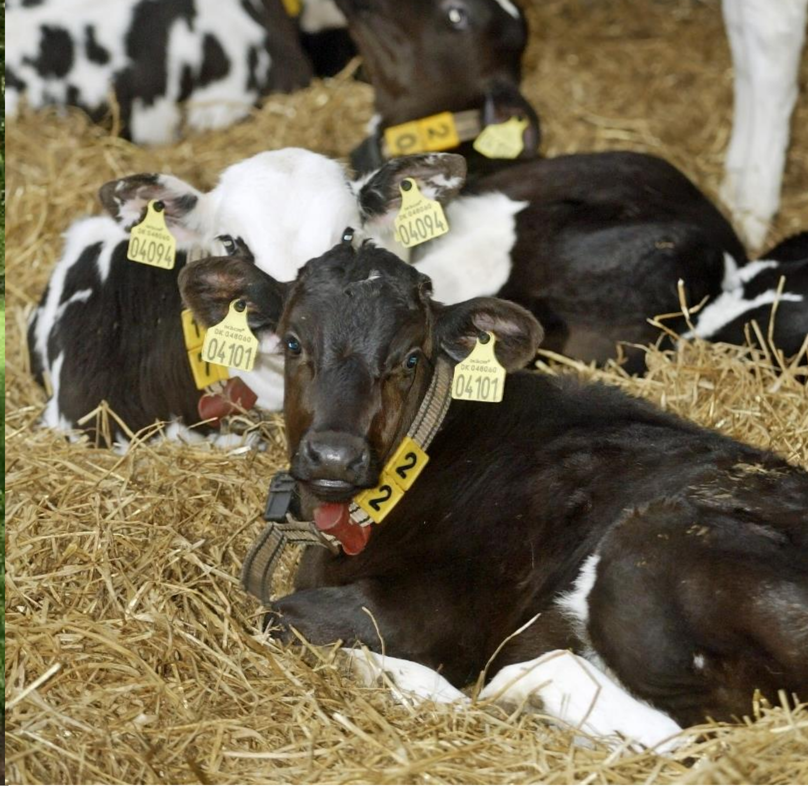

Need for secondary and life cycle inventory data for use in Product Environmental Footprint (PEF) of livestock products in the Nordic Countries

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Preface

The Nordic Council of Ministers has funded this work as part of the activities in the Nordic Environmental Footprint (NEF) group. The NEF group seeks to coordinate the Nordic input to The European Commission's initiative on developing Product Environmental Footprint (PEF). The agricultural sector was identified as a sector, where the Nordic Countries might have a particular interest. Therefore, it was agreed to ask researchers at Aarhus University, Dept. of Agroecology, Denmark, Natural Resources Institute, Finland (Luke), Ostfold Research, Norway and Research Institute of Sweden (RISE) to investigate data needs. In this respects it was identified what data that are available in the Nordic Countries and what other data that are needed at the farm level in order to support in particular the dairy and meat industry in performing a PEF, that reflects the environment impact related to the farm level production in the Nordic Countries. This report describes the main output of this work.

DISCLAIMER:

The present report has been prepared under a contract with Nordic Environmental Footprint Group. The authors of the report have the full responsibility for the present version of the text. The Nordic Environmental Footprint group is not responsible for the reports' statements and recommendations.

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1. Background and aim

At present, the Commission as part of its Sustainable Production and Consumption strategy is establishing the framework for a harmonised assessment and communication of the environmental impact of products – the Product Environmental Footprint (PEF) – based on a life cycle approach (EC 2017). The overall idea is to support competition of environmental performance on a sound and fair basis. This also includes methodologies for foods, including livestock products, and dairies and slaughterhouses has been involved in the development of the methodologies in order to gain a wide acceptance of the approaches and take into account the practical needs.

Since for livestock based foods, the farming stage typically is by far the largest contributor to the environmental profile of the food, it is important to have sound data representing this stage. Further, since a relatively strict environmental regulation in the Nordic countries may result in a reduced footprint and thereby represent a competitive advantage, it is important that the farm production stage in the Nordic Countries are described in sufficient detail to document that. Therefore, The Nordic Environmental Footprint group (Nordic PEF, 2017) supported an activity in 2016 to map existing relevant data and the accessibility for companies that would perform a PEF. The results of this mapping are reported in Hermansen et al. (2017) and included here as Appendix 1). In this report, it was concluded that:

- It will be far too simplistic to rely on generic secondary farm data which will make the PEF meaningless for meat and dairy
- A lot of farm data is available on agricultural structure, production level etc, but
- No valid data on typical feed composition, which is critical to the total footprint
- Present international databases on footprint of feed does not cover the Nordic situation very well
- There ia a need for better feed LCA data
- There is a need for regionalized secondary data

On this background, the aim of the present work was to analyse and set up an appropriate concept for regional LCI datasets and secondary data based on the practical needs.

2. Overall needs for Nordic livestock activity and LCI data

It is clear from the PEFCR's for milk and red meat and our previous analyses that there is a need to establish targeted/regional LCI datasets that can support Nordic business in dairy and red meat to establish that the agricultural stage for Nordic farm products are represented as complete and close to reality as possible. In addition, these datasets could also be used by the poultry sector.

In the PEFCR's for milk and red meat it is acknowledged that a significant part of farm data should be primary data in order to assure that improved environmental farm practise also is reflected in the environmental footprint of the foods produced. However, while some farm activity data may be reasonable easy to obtain from farms or existing databases, many data needed are not available or will require excessive efforts to collect from a representative share of farms.

Therefore, in the following we identified sources for performing a PEF in a Nordic context grouped into

1) primary farm activity data that is perceived relatively easy to collect
2) secondary farm activity data representing typical production, incl. emissions factor
3) life cycle inventory data (LCI) for inputs to the system not available at present

3. Farm activity data

One of the characteristics for livestock products is the large number of farm units connected to a product, and at the same time a large variation in the way of farming. Therefore, it is a challenge to gather data that represent the overall farming stage. In the PEF guidelines (EC, 2017) guidance is given regarding sampling of production units (farms) in such cases. Mostly, the recommendation is that a random sampling should include the number of farms that represent as much as 50 percent of the total production. It is, however, recommended to stratify the sampling to into subsamples with similar production conditions. In this case, the sample size should be the square root of the number of farms in the subsample in order to represent a given type of product.

In the following, we have considered for dairy, beef, pig and poultry production what type of data that we perceive manageable to monitor for a relatively large sample of farms and what type of additional supplementary data and life cycle inventory datasets that are needed in order to perform a valid PEF. In addition, we have indicated with a 'G' the possible criteria for grouping in order to make subsamples, and which require corresponding secondary dataset. Thus, the following tables shows what type of primary data we think will be available in practical sampling, what default data for system description that might be relevant in some case, the need for system or site specific emissions factors, and finally what supplementary LCI's, that are needed.

As mentioned earlier the environmental impact related to feed production is an important aspect in the environmental impact of livestock products and this may vary considerable between farms. However, the data for making farm specific LCI's for on-farm feed production are typically not easily accessible at the moment. Therefore, we suggest LCI's for this to be produced, while acknowledging that this aspects should be developed further in future, due to its importance.

Dairy

Dairy farming in the Nordic countries is rather homogenous and a majority of the dairy farms participates in milk data recording systems including animal turnover, feed planning or even registration of feed use. These data are backbones in the assessment.

Table 1 shows what type of primary data that is expected to be available at farm level for a relevant sample and how these data can be complemented with secondary systems data or LCI's in order to achieve a good representation of the environmental impact of dairy production.

The proportion of the different feed items in the bought-in concentrate mix and use of water, energy and bedding material is identified as areas where there is a need for secondary/default activity data.

For purchased animals, there is a need for LCI data. Dairy farms are often self-supplying with replacement animals, but some purchasing occurs and there is an increasing specialization with heifers reared at other farms. Therefore, there is need for LCI data for raising a heifer. In order to make it flexible, it might be possible to do that by a standard emission for one "life" combined with a per kg emission.

Also direct energy use for feeding and milking are not typically available but some variation can be expected according to stable- and manure system and perhaps across the Nordic region due to local production and climate.

Beef

Beef production includes a range of cattle systems, from intensive feeding of dairy bull calves to extensive cow-calf (suckler) systems based on grazing. There is a large variation both within and between the Nordic countries in important production parameters like daily gain, weaning and slaughter age, feed items and land use. In table 2 we have presented data to be achieved from farms based on suckler systems or farms having only the fattening phase, and what type of secondary data and LCI's that are needed. A main issue here is that there is a need for grouping of farms according to the specific beef production systems and corresponding breed.

Mogensen et al. (2015) has defined typical systems in Sweden and Denmark grouped after dairy or beef cattle and within this grouping, sub-groups based on age at slaughter, entire or castrated bulls in dairy, and intensity of feeding in beef systems. These are examples of how grouping can be performed.

Table 1. Dairy systems - primary data available in the Nordic countries and identified areas with need for estimation of secondary data (G denotes criteria for grouping in relation to secondary data).

	Primary data			Secondary data		Need for LCI's
	Cows	Heifers	Others	System default data (by region and type of production)	System- or site specific emissions factors	
Location/Region **G**						
Type of production						
Organic or conventional **G**	X	X	X			
System, % of time or amount						
Type of stable, incl pasture	X	X	X	(X) [3]	X	
Type of manure system, indoor	X	X	X	(X)	X	
Type of manure system storage	X	X	X	(X)	X	
Data, sum or mean per year						
Animal breed, **G**	X	X	X			
Number of animals	X	X	X			
average live weight, kg	(X)	(X)	(X)	X		
Milk production, delivered kg	X					
protein %	X					
fat %	X					
Animals sold, number and kg	X	X	X			
Animals purchased number and kg	X	X	X			LCI per category of animal [1)]
Feed use, [2)]						
DM or kg feed	X	(X)	(X)	X		
Protein content	(X)	(X)	(X)	X		
Feed items % of DM						LCI per feed item
Origin of bought-in feed	X	(X)	(X)	X		
Manure, produced (mass balance)	X	(X)	(X)			
Drinking water kg				X		
Bedding material				X		LCI per type
Energy use for feeding and milking				X	X	

1) Heifers, mature cows
2) This includes an estimation of intake of grazed grass
3) X in (X) indicates that although primary data is available, secondary data can be accepted and might be needed in some cases

Table 2. Beef systems - primary data available in the Nordic countries for beef systems and identified areas with need for estimation of secondary data (G denotes criteria for grouping in relation to secondary data).

	Primary data		Secondary data		Need for LCI's
	Suckler cows	Fattening phase only	System default data (by region and type of production)	System- or site specific emissions factors	
Location/Region **G**					
Type of production					
Organic or conventional **G**	X	X			
System, % of time or amount					
Type of stable, incl pasture	X	X	(X)	X	
Type of manure system, indoor	X	X	(X)	X	
Type of manure system storage	X	X	(X)	X	
Data, sum or mean per year					
Animal breed, types **G**	X	X			
Number of animals	X	X			
average weight, kg	(X)	(X)	X		
Animals sold, number and kg	X	X			
Animals purchased number and kg	X	X			LCI per category of animal
Grazing land use, m^2					Yield (DM) and LCI per kg DM per land type
-arable	X		(X)		
-permanent grassland	X		(X)		
- semi natural grassland	X		(X)		
Supplementary feed use, [1)]					
DM or kg feed		X	X		
Protein content	(X)	X	X		
Feed items in sup. feed % of DM					LCI per feed item
Origin of bought-in feed	(X)	(X)	X		
Manure, produced (mass balance)	X	(X)			
Drinking water kg			X		
Bedding material			X		LCI per type
Energy use for feeding and milking			X	X	

1) This includes an estimation of intake of grazed grass

Pork

Table 3 shows data sampling and need for supplementary data for sow and slaughter pig production, respectively. Main issues here are the need for LCI's of gilts in the sow system, and piglets as input to the grower/finisher system in addition to LCI's for feed.

Table 3. Pig systems – indoor - primary data available in the Nordic countries and identified areas with need for estimation of secondary data (G denotes criteria for grouping in relation to secondary data).

	Primary data		Secondary data		Need for LCI's
			System default data (by region and type of production)	System- or site specific emissions factors	
	Sows	Grower/ finishers			
Location/Region G					
Type of stable	X	X	(X)	X	
Type of manure system, indoor	X	X	(X)	X	
Type of manure system storage	X	X	(X)	X	
Data, sum or mean per year					
Animals sold, no and kg	X	X			
Animals purchased, no and kg	X	X			LCI per category of animal [1)]
Feed use,					
DM or kg feed	X	X			
Protein content	X	X	(X)		
Feed items					
% of DM					
Origin of bought-in feed	X	(X)	X		LCI per feed item
Manure, produced (mass balance)	X	X			
Drinking water kg			X		
Bedding material			X		LCI per type
Energy use in stable			X	X	

1) Gilts/reproductive animals and piglets, respectively

Poultry

Table 4 shows data sampling and need for supplementary data for broiler and egg production, respectively. Main issues here are the need for LCI's of day-old chicks in the broiler system and of pullets in the layer system.

Table 4. Broiler and layer systems – indoor - primary data available in the Nordic countries and identified areas with need for estimation of secondary data (G denotes criteria for grouping in relation to secondary data).

	Primary data		Secondary data		Need for LCI's
			System default data (by region and type of production)	System- or site specific emissions factors	
	Broiler	Layers			
Location/Region G					
Type of stable Type of manure system, indoor Type of manure system storage	X X X	X X X	(X) (X) (X)	X X X	
Data, sum or mean per year Animals or egg sold, no and kg Animals purchased, no and kg	X X	X X			LCI per category of animal [1]
Feed use, DM or kg feed Protein content	X X	X X	(X)		
Feed items [2], % of DM Origin of bought-in feed	X	(X)	X		LCI per feed item
Manure, produced (mass balance) Drinking water kg Bedding material Energy use in stable	X X	X	X X X	X	LCI

1) Day old chicks and pullets, respectively

4. Life cycle inventory for Nordic feed

From the above it is clear that there is a need for life cycle inventory results for Nordic feed – "Feed LCI's" However, crop production is heavy influenced by variation in climate and soil type as well as management and environmental regulation across the Nordic region. Henriksson et al. (2012) has illustrated the impact of cultivation and climate in five different dairy production regions in Sweden showing a variation in CF from 0.48 to 0.63 kg CO_2 eq per kg silage DM. So, both type of feed as well as the conditions by which it is produced is important.

Therefore, there is a need for identifying the most important type of feed used in each livestock sector and based on that to identify the relevant granularity in relation to the pedo-climatic conditions in Nordic countries.

4.1. Most important feed items in the Nordic countries

Table 5 shows the most important feed items in the Nordic countries and the amount produced in the country and imported, respectively. Feed produced nationally forms an important part of total feed consumption and is therefore very important in all countries.

Table 5. Commonly used feed items in the Nordic countries, in- country produced and imported, respectively.

Feed item	Denmark – average 2011-2016 (mio SFU)	Finland – mostly average 2015-2017 (1000 ton DM)	Norway (1000 ton)	Sweden (1000 ton)
In-country	11963	4606	4552	7009
Winter wheat	3413		130	1686
Spring wheat		404		
Spring barley	2125	811	518	674
Oat	164	479		
Other cereals	463	62	270	440
Oil seed and broad beans	202	54 + 38	10	242+73
Peas		12	3	84
Grass – permanent	295		563	(Incl in ley)
Grass ley pasture/hay/grass silage	2469	256 + 2180	2866 + 192	3796
Whole crop silage and fresh silage crops	282	310		
Maize silage	1614		-	14
Beets pulp	167		-	
Import	3457	~227	230	448
Soya bean meal	1795	~150-200		350
Rape seed meal (	269	45		
Other oilseeds	359	7		
Molasses			68	19
Wheat			60	
Maize			102	19
Beet pulp				60

In Denmark, according to the national statistic, the major type of feed used in the livestock sector is cereals from wheat and barley. Cattle also use grassland and maize primarily as silage grown as part of the arable land and to less extent pasture from more permanent grassland areas.

In Norway, only 3% of the total land area is used to agriculture of which approximately 30% of the agricultural area is used to grow cereals (both food grain and feed production) and 66% are pastures and grass production.

In Sweden 38% of the agricultural area is used to produce silage and green forage, 15% are pastures and 35% is used to grow cereals, where 70% is used for animal feed.

In Finland 30 % of the agricultural area is used to produce grass silage, 3% are pastures and 49% is used to grow cereals, where around half is used for animal feed. In Finland there are no large grazing areas or permanent grasslands and in the cattle sector practically no soy products are used.

4.2.Granularity

Denmark

Across Denmark there is, compared to the other Nordic countries, only limited variation in temperature and rainfall, while there is some variation in soil type. Still these conditions contributes to the variation in crop yield between the regions with “Nordjylland” being coldest “Vestjylland” sandy soil, while “Sjælland” is warmest and less sandy soils. For cereals and maize this gives a range of +20 %-units from the lowest to the highest region, while the range for grassland is lower 10 %-units.

The variation between type of permanent grassland is expected to be far higher than the regional difference (20 %-units in DK) and a range from 500 to 3500 kg DM per ha for different type of natural pasture and for more cultivated permanent pasture are reported.

LCI’s are suggested for the average situation in Denmark for the less important crops used for feeding (table 5). Average will include consideration in relation to productions factors like irrigation, proportion of straw removed from cereals, soil type and catch crop in order to give average crop production for most important crop or by-product produced in Denmark. In addition, for the most commonly used grains and roughage, LCI’s should be produced for different soil types, since yield as well as accepted level of fertilizer is determined by that:

- Sandy soils – no irrigation,
- Fine sandy soils – no irrigation
- Sandy soils – irrigated
- Loamy soils – no irrigation

Organic farming has an increasing importance – in 2016, 8 % of the agricultural area was organic certified. Across the different livestock systems, organic farming has the largest proportion of the national production in egg and dairy (10 %). Thus, there is a need for estimating the impact from organic produced crops.

Norway

Norway has a short growing season and much land is steep, and the cultivated area is fragmented and scattered. This limits the crops that can be grown and the yield. Most of the country has sufficient rainfall during the growing season. Large parts of the country have a climate best suited for growing grass, mostly pasture, hay and silage for livestock. Crop cultivation takes place essentially in the lowlands in Eastern Norway, Jæren and in Trøndelag, which is considered the best agricultural districts.

Organic farming accounts for 4.9% of total agricultural area and has not increased significantly over the past 10 years, and shows now a decreasing trend, measured in area. Nevertheless, the sale of organic products increases but it is mainly eggs, fruit and vegetables.

Sweden

In densely forested Sweden, farming and forestry are often combined. In the North of Sweden the farms mostly have small areas of arable land. The conditions for crop production display great differences between the North and South of Sweden. About 60 % of the arable land is found on the fertile plains of southern Sweden. The crop production is strongly dominated by cereals and by leys, the former mainly being wheat. The proportion of leys increases towards the north of Sweden and makes up most of the area of arable land in Norrland. Oil seed production is mainly located on the plains in Götaland and Svealand. Potatoes are grown throughout the entire country. Sugar beet is grown mainly in the counties of Skåne, Halland, Blekinge and Kalmar. In 2016, the arable land amounted to 2.6 million hectares (Swedish Board of Agriculture, 2017). In 2016 organic farming accounted for 18% of the total agricultural area, an increase of 6.5% from 2015. 23% of the permanent pastures are organic and for crop production oats represents the highest organic fraction of 15% of the total oats hectares followed by winter wheat and spring barley where 5% of the cultivated area is organic.

Finland

Finland has a short growing season, which limits the crops that can be grown and the yield. In addition, the conditions for crop production display great differences comparing the coastal regions of south and southwestern Finland and Ostrobothnia to Lapland and Eastern Finland, which is also clearly depicted in the average yields in different regions. Wheat and rye is mainly grown in Southern and Southwestern Finland, barley in Ostrobothnia and Southwest Finland. Oats are produced in all coastal regions, while grass production is concentrated in the cattle producing regions of Ostrobothnia and North Savo.

In 2017, the arable area amounted to 2.3 million hectares. Cereals are cultivated on half of the area, but their area decreased in 2017. The area under broad beans (22,000 ha) is estimated to increase by 35% in 2017. Most of the country has sufficient rainfall during the growing season.

The difference between the best and the worst quartile yields on oats is nearly 100%, on barley over 100% and on grass production 160%. On cereals this is not reflected by a difference of nitrogen inputs, but in grass production the best quartile also applies twice as much nitrogen per hectare. (Pro Agria extension service)

In Finland, on average 14% of agricultural land is peat soils, which increases ghg-emissions remarkably and also yields and accepted level of fertilizer is determined by that. Thus, LCI's should be produced for minerals soils and organic soil separately.

In 2017 organic farming accounts for 12% of total agricultural area, an increase of 10% from 2016. Half of the area is used for grass production or pastures. The most important organic crop is oat, which cultivation area was estimated to increase nearly by one fourth in 2016.

In conclusion, there is a need for country specific LCI for most type of feed items, as there is only few feed item that seems to be grown under similar conditions across Nordic countries. Table 6 gives a first overview of LCI's needed by country and granularity. This needs to be refined at a later stage.

Table 6. Need for LCI's of domestically produced feed in different Nordic countries (+/- organic)

a) Denmark

Feed item	Sandy soil No irrigation	Irrigation	Fine sandy soil	Loamy soil	National average
Winter wheat			X	X	X
Spring barley	X	X	X	X	X
Oat					X
Rape seed					X
Grass permanent (grazed)					X
Grass, ley- (grazed)	X	X	X	X	X
(Silage)	X	X	X	X	X
Whole silage	X	X	X	X	X
Maize silage	X	X	X	X	X

b) Finland

Feed item	Coastal regions South & South west	Northern regions Mineral soils	Peat soil
Rye	X		
Spring barley	X		
Oat	X	X	X
Grass, ley (grazed)	X	X	X
(silage)	X	X	X
Whole crop silage	X		

c) Norway

Feed item	South & East	Central (Trøndelag)	North & West
Wheat	X		
Spring barley	X	X	
Oat	X	X	
Grass permanent (grazed)	X	X	X
Grass ley (grazed)	X	X	X
Silage	X	X	X

d) Sweden

Feed item	Southern fertile plain	Northern part
Winter wheat	X	
Spring barley	X	X
Oat	X	X
Rape seed	X	
Peas	X	
Broad bears	X	
Grass permanent (grazed)	X	X
Grass ley (grazed)	X	X
Grass ley (silage)	X	X
Maize silage	X	

In addition to the home grown feed, there is a need to establish LCI's for important by-products relevant in the Nordic countries, like potato starch and whey, and we recognise that vitamins and minerals as well synthetic amino-acids are poorly documented so far in the EU relevant databases.

5. Livestock LCI's

Tables 2-4 also illustrates the needs for livestock LCI's, in particular for recruitment animals either for breeding or for further fattening. In table 7 we have detailed this.

Cattle

Heifer, or even cows, and bull calves of different breeds, both dairy and beef, in different regions (representing different feeding and rearing conditions) will typically have very different environmental impact, as illustrated by Mogensen et al. (2015). A specific topic here is how to deal with a variation in age and size of the animals when purchased. Probably it will be too 'rough' not to take into account the actual weight at purchase. A suggestion to be further developed would be to divide the impact in a constant part related to the "life" and a variable part related to the weight. This is a known procedure in pricing when e.g. trading piglets.

Pig and poultry

For weaners and chickens, we would expect that Nordic LCI's would be sufficient given the variation between countries and their impact on the final product. Like for cattle, there is a need to take into account the actual weight of piglets. It is acknowledged that there might be differences in the piglets production efficiency and type of housing between the Nordic countries, but the overall impact on the final product of such differences are considered low.

Across species, there is a need for LCI data from both organic and conventional production systems due to huge differences in production conditions.

Table 7. Need for livestock LCI's either Nordic or by country. In most cases, LCI's are needed for conventional and organic production.

Type	Nordic LCI	Denmark	Finland	Norway	Sweden
Dairy- heavy breeds (Holstein)					
-Bulls calves	X				
-Heifers		X	X	X	X
Dairy – other types					
-Bull calves	X				
-Heifers		X	X	X	X
Beef-robust breeds (Highland)					
-Bull calves		X	X	X	X
-Heifers		X	X	X	X
Beef (Limousine)					
-Bull calves		X	X	X	X
-Heifers		X	X	X	X
Pork					
-weaners	X				
-gilts	X				
Poultry					
-chicken - Broiler	A				
-chicken - layer	A				

6. System defaults data and emission factors

According to Tables 2-4 there is a need for typical data describing the system. An important issue here is the typical share of different feedstuffs (and their origin) that appears in the concentrates mix used for different animals in the different countries. It is evident from earlier work that concentrates mixture differ very much between countries in terms of share in the mix and the origin of the feedstuffs. Such data are not necessarily disclosed to the individual farmer. However, an estimate can be derived from national statistics and be used to calculate the environmental profile of the concentrate.

Housing system and manure handling data are available at each farm, but it can be difficult in practise to have them described in sufficient detail to model the emissions related hereto. Therefore, typical data by country may be needed.

Losses of nitrogen by leaching or volatilization and losses of phosphorous are important factors contributing to the environmental impact of livestock based foods. In the PEF guidelines there is no clear guidance as how to model these losses, and this may also differ between the different Nordic countries. There is need to setup the most relevant models for this, e.g. taking departure from national inventories.

7. Conclusion

For livestock based foods, the farming stage is by far the largest contributor to the environmental profile of the food. Therefore, it is important to have sound data representing this stage in an implementation of a Product Environmental Footprint (PEF) for livestock products. While many farm data exist regarding livestock in the Nordic Counties, these are not sufficiently complete for making a valid PEF and/or difficult accessible in practise for the food industry that are sourcing the raw material from many farms. Thus, there is need to complement the easily accessible farm data with other data sources at a sufficient granularity to reflect the actual production conditions for different types of livestock production.

A main challenge is to have access to representative life cycle inventory data regarding the feed use representing the growing conditions in the Nordic countries. Such LCI's need to be developed by country and according to different production conditions within each country, and representing organic and conventional production, respectively. Likewise, there is a need for LCI's of recruitment animals like heifers for milk production, bull calves, piglets and day old chicks for further fattening as well as pullets for egg production. There is also a need to establish the relevant emission factors - in particular for loss of nitrogenous substances at the farms related to housing, manure handling and nitrogen leaching, since this aspect is poorly documented in the PEF guidelines, and these may well differ between different countries. Furthermore, there is need to establish system default data for minor inputs.

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9. Appendix

Data acquisition in Product Environmental Footprint Category Rules regarding milk, beef and pork.

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Data acquisition in Product Environmental Footprint Category Rules regarding milk, beef and pork

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DISCLAIMER:

The present report has been prepared under a contract with Nordic Environmental Footprint Group. The report authors have the full responsibility for the present version of the text. The Nordic Environmental Footprint group is not responsible for the reports' statements and recommendations.

1. Background and aim

This report includes input to the Commission's work to develop the framework for environmental assessment of products, The Product Environmental Footprint initiative (PEF), for dairy and red meat products. Since 2014, pilot projects on developing Product Environmental Footprint Category Rules (PEFCRs) for dairy and red meat products are carried out within the PEF pilot phase. The PEFCRs take the departure from the dairy and meat processing companies as the operator of the PEF and therefore primary data should be used for processing. For the farming stage, guidance is given on how to obtain data to represent the environmental impact.

For dairy and meat products, the main contributor to the environmental profile is the farming stage, and therefore this stage determines to a wide extent the overall environmental profile of the final food product. However, in the PEFCRs, there is still considerable room for interpretation on how to assess and document the environmental impact of the farming stage. This is not satisfactory from a Nordic point of view, where the ambition is to have the farming stage represented as close as practically possible to reality in order to promote initiatives and practices that reduce the environmental impact of the meat and dairy products.

Therefore a Nordic project coordinated by the NEF group[1] was established to investigate how best to assess and document the environmental impact of the farming stage with the purpose to identify critical aspects and suggest a more consolidated approach for data acquisition to be used in the PEFCRs for red meat and milk. The work was carried out by Aarhus University, Denmark as project leader and in co-operation with SP (Technical Research Institute of Sweden), Luke (Natural Resource Institute Finland) and Østfold-forskning, Norway. The project was funded partly by the national environmental agencies in Denmark, Norway and Sweden as well as the Finnish Ministry of Agriculture and Forestry, partly by the Nordic Council of Ministers.

The project activities were carried out during 2016 concomitantly with but independent of the development of the PEFCRs for dairy and red meat. It has included detailed review on the PEFCRs, literature reviews, and interviews with stakeholders, collection of primary data from pork production, sensitivity analysis of previous studies on pork and beef, and a Nordic stakeholder workshop in Copenhagen in August 2016. The key messages from the interviews, pork data analysis and the workshop are presented in the appendices to this report. In the following sections – and based on the activities mentioned - we summarize the availability of data that describes the production on farms in the Nordic countries, analyse the critical aspects of importance for the environmental impact and come up with a preliminary suggestion on how to improve use of primary data for the farming stage.

2. General availability of activity data on farm level

A large proportion of the farmers in the Nordic countries have good records on primary production activity data of their farms, but some critical exceptions exists such as yields of forages. Some of the activity data are also already stored in central databases. Data at this level has a spe-

[1] The NEF group is a network group established in 2015 under Nordic Council of Ministers (NMR). The aim of the group is to coordinate the Nordic countries authority work within PEF and to disseminate knowledge regarding PEF to Nordic stakeholders.

cific farm id, which means that they would be accessible without direct contact to the farmer. Use of this kind of data as input to PEF will need to be approved by data owner (the farmer) and the authority needs to ensure data security. Regardless of whether the data is from a farmer or from a database, for most of the data there is a need for major data filtering and additional calculations, also across some of the sources before they can be use in a PEF study. Secondary data at national level is also available from national statistic and reports.

There are some differences across the Nordic countries, especially in the primary data, which is shown briefly in the next sections.

2.1 Denmark

Table 1 gives an overview of the most important farm specific data sources in four groups. The "Farm level" group is data that is general for all type of farming, while the next three groups are specific for dairy cattle, beef cattle and pig.

Table 1 Overview of the most important farm specific data sources in Denmark.

Name	**Availability**	**Voluntary reporting**	**Geographic area covered**	**Type of data**	% of producers	
Farm level						
Cropping plan	at farm	yes	DK	Ha, crop type, expected yield, planned use of manure & fertilizer	90	
Nutrient account	from central data base	no	DK	Ha, crop type, animal unit, manure (amount, housing & storage system), fertilizer	100	
Pesticide account	from central data base	no	DK	ha, crop type, use of pesticide (per area and farm level)	100	
Land use	from central data base	yes- but part of EU sub	DK	ha, land use	98	
Economic account	from central data base	no	DK	economic turn over - farm level data	60	all farm have but only some upload
Animal ID	from central data base	no	DK	animal no (annual update by farmer	100	
Cattle - Dairy			DK			
Animal recording	from central data base	no	DK	animal turn over (numbers and kg)	100	
Milk recording	from central data base	yes	DK	individual animal information	90	
DMS	from central data base	yes	DK	Feeding plan, feed intake	25	
Key figures	from central data base	yes	DK	Feed use, herd turnover and production by period	10	
Cattle - beef			DK			
Animal recording	from central data base	no	DK	animal turn over (numbers and kg)	100	
DMS	from central data base	yes	DK	Feeding plan, feed intake	few	only intensive beef, none beef cattle
Pig			DK			
Efficiency report	at farm	yes	DK	production and feed use (kg and type) by period	30	

Regulation of agriculture and EU subsidies mean that information related to animal numbers (herd size), farmed area, crop type, pesticide use and nutrient use - fertilizer as well as manure - is possible to get annually from all farms. However, management related data such as productivity of each crop as well as manure application method is not available. For some of the information there is also a problem between planned and implemented actions. Thus, what is controlled is the total use of fertilizer, not its distribution between different crops. Information about productivity at crop level is not included in any of the dataset, but for some farms it is part of the data in the economic accounting. Especially for crops used as feed at the farm, like forage, the uncertainty at farm level can be high.

More specific information in relation to livestock can be obtained from dairy cattle and pig farming, whereas there is limited data from suckler beef systems. For dairy there is data from the voluntary milk yield recording that is supplying individual data about production for a major part of the farms, while data in relation to feeding is more scarce. For pig production a number of farms, representing around 30 % of produced piglets and 20% of produced slaughter pigs, have reports with herd turn over (kg and numbers) as well as feeding

Data in relation to use of fossil energy can be taken from the economic accounting systems, but at farm level, meaning that it is often difficult to distribute to the specific outputs. Also the use of contractors and cooperation between farmers for especially field work can make it difficult to get the exact figures. In addition, the development towards more business based farming means that a farm can be part of a company running several farm units, with the same problems identifying the production process and resources.

A significant part of the data in table 1 is used to calculate national secondary data which can be found in the annual updated information, like the national inventory – latest version Nielsen et al, 2016 (DCE scientific report no 189) and with some additional information for agriculture in Mikkelsen et al., 2014 (DCE scientific report no 108).

2.2 Sweden

In Sweden there are some potentially important farm data sources that can be tapped for a coming implementation of PEFstudies. At present, individual farmers have access to their own data, but very limited data is openly available.

The probably most important source is data collected through the project "Greppa näringen" (Focus on Nutrients, www.greppa.nu). Greppa näringen is the largest single undertaking in Sweden to reduce losses of nutrients to air and water from livestock and crop production. Greppa Näringen is a joint venture between The Swedish Board of Agriculture, The County Administration Boards, The Federation of Swedish Farmers and a number of companies in the farming business. The purpose of the project is to:

- reduce losses of the greenhouse gases; nitrous oxide, methane and carbon dioxide
- reduce losses of nitrate from farmland
- reduce ammonia emissions from manure
- reduce losses of phosphorus from farmland
- avoid losses of pesticides into surface and groundwater
- increase energy efficiency on farms

As part of the project farmers that become members are offered free advice on how to meet the objectives listed above. Plant nutrient balances and energy mapping are examples. In this process data on the individual farms are collected, but as said above not publicly available. In order to use this data for PEFpurposes contracts with each farmer would be needed. According to the interviews that were done in this project (Appendix I), there are probably possibilities for food industry to get the data from their suppliers, but there are variations in accessibility between companies and also between dairy and beef sector. These differences mainly exist as a result of the relationship between supplier and industry, where dairy suppliers generally have a closer connection to their clients than the average beef producer. Focus on Nutrients is more wide-spread in the south and central parts of Sweden, as it started as a means to reduce problems with eutrophication, which is not as important in the northern part of Sweden. In recent years, however, the project is active throughout Sweden. There is no public obligation for farmers to be members, but in some cases the buying food industry demands that.

A second potential source of PEF-relevant data is "Kokontrollen" (The cow control) and KAP (production management software for dairy and beef producers respectively). These two tools are offered by the advisory service Växa in the extension services, but farmers can use the systems themselves and up-load data on a web-portal. The data in Kokontrollen and KAP covers production data on farm level on production efficiency and animal stocks, including bought-in and sold animals. As for Greppa Näringen the systems are not compulsory, but have a wide coverage among especially the larger producers.

2.3 Norway

A number of activity data are stored in central databases, which means that they are accessible without direct contact to the farmer. To use these data as input to PEF, data can be available only in accumulated or averaged form. If more specific data are needed it is possible to get access if the link between the data and farm id is removed or use of data is approved by the farmer. Table 2 gives an overview of the most important farm specific data sources.

Table 2 Overview of the most important farm specific data sources in Norway.

Name	Availability	Voluntary reporting	Geographic area covered	Type of data	% of producers	
Farm level						comment
Norwegian Agriculture Agency (Landbruks direktoratet[2])	Public	Yes	Norway	Number and weight of slaughtered calves, cows, heifers, bulls and pigs. Amount of milk produced	99%	
Cattle dairy						
Cow efficiency report (husdyr kontrollen[3])	Key figures are public. Data at farm level can be available if farm id are removed.	Yes	Norway	Milk yield at the individual cow level, amount of feed, recruitment and slaughter weight cows, bulls and heifers.	98%	
Cattle beef						
Beef efficiency report (Storfekjøtt[4])	Statistics public	Yes	Norway	Calving, growth and carcass weight	60%	
Pig						
Ingris[5]	Statistics public	Yes	Norway	comprehensive statistics for sows, piglets and fattening pigs and feeding and growth	34%	

[2] http://statistikk.landbruksdirektoratet.no/skf/prodrapp.htm
[3] Nøkkeltall fra Husdyrkontrollen 2015
[4] Storfekjøttkontrollen årsmelding 2015
[5] Ingris årsstatistikk 2015

Agricultural production subsidies contain a number of information in relation to animal number (herd size), farmed area and crop type. However, management related data as productivity of each crop and manure application method is not available. Especially for crops used as feed at the farm, like forage, the uncertainty at farm level can be high.

Specific information in relation to livestock can be obtained from the different efficiency reports for each production branch, i.e. milk and dairy cattle, beef and pig production, as described in table 2. Data in relation to use of energy can be taken from the economic accounting systems, but at farm level that it is often difficult to distribute to the specific output.

2.4 Finland

In Finland, about 90% of farms are covered by environmental subsidy program, and thus have cultivation information in field parcel level. This information includes:

- Cultivation area and soil type, soil nutrients
- Crop type and yield
- Fertilizer and manure use
- Lime use
- Seed amount
- Pesticide use
- Nitrogen and phosphorus balance

However, even if the data is supposed to be on field parcel level, the farmer may not have all information in that level, e.g. yield, so it is only average of all field parcels. Especially for crops used as feed at the farm like forage, the uncertainty at farm level can be high.

Data is stored at the farm without any central database, which means that the access has to go through the farmers. However, it is possible that the farmer sends their information to an extension service, Pro Agria, database. Use of data as input to PEF would for these types of data need to be approved by the farmer and Pro Agria.

Regulation of agriculture and EU subsidies means that information in relation to animal numbers per animal (and cattle and pigs by age), farmed area, crop type, and nutrient use, dived in fertilizer and manure, and manure storage is registered at annual level on all farms.
More specific information in relation to livestock can be obtained from dairy cattle and pig farming, while there is limited data from beef. Dairy farms plan their feeding carefully and have the data on feeding available.

Data in relation to use of fossil energy can be taken from the economic accounting systems, but at farm level meaning that it is often difficult to distribute to the specific outputs, or even between agriculture, forestry and housing of the farmer.

In addition, national surveys on manure storages, application methods, pasturing, drains, irrigation, spring/autumn ploughing and cover crops are conducted, but not on a yearly basis. Cattle amounts are based on animal register where every farmer has to register all changes in animal amounts, so this information is very reliable. Amounts of pigs and hens are based on survey made for farmers. Every farmer does not answer the survey, so this information is not as reliable as cattle information. Also, there are differences between fattening pig farms e.g. production breaks, so farms in sample may not be reliable. Statistics on animal housing and manure storage exists with high response rate (95%), but there are challenges to specify them to certain animal production.

3. Farm data inventory and conversion to emissions and environmental impacts

Above, we found that a variety of data exist describing farm activities in the Nordic countries, but they are typically not all available for open use, they are not complete enough for a PEF and they are typically not available for all farms that provide milk and animals to a dairy or a slaughterhouse. The draft PEFCR on dairy products states that "raw milk used in dairy products generally comes from multiple dairy farms. A representative sample of farms in the supply chain should be defined, in a way that properly represents the variability of the dairy." In part 3.1, we discuss these issues.

In part 3.2 critical farm data on pork and beef production affecting emissions and environmental impacts are identified to illustrate what kind of data is crucial for a PEF study on animal products.

In part 3.3 discrepancies between the two PEFCRs (red meat and dairy) on how to convert inventory data into emissions is further highlighted, and challenges for the impact assessment to be conducted in line with the two PEFCRs are pointed out.

3.1 Sampling issues – illustrated in dairy production

The PEFCR for dairy products lists main aspects influencing variability, aspects which should be considered when defining the samples. Regarding sampling period and frequency, it points out that, "given the seasonal variability, all data should be collected for a minimum of 1 year of exploitation of each dairy farm. Average data collected over 4+ years is preferable, when available. Special attention should be paid on the origin of feed used in the rations." (Product Footprint Category Rules for Dairy Products, Updated DRAFT for public consultation, 28 July 2016, p 56).

As a basis for addressing the sampling issues, we have used The Guidelines for the Carbon Footprinting of dairy products in the UK (Dairy UK, DairyCO & Carbon Trust, 2010), below referred to also as the CFP guidelines. This document underlines that it is important to be clear on the objective of the footprint assessment and conclude that different objectives will have different sampling requirements:

1. If the purpose of the assessment is to calculate the **footprint of each farm and/or to help individual farms reduce their footprint**, data must be collected from each farm (100% sampling).
2. If the purpose of the assessment is to calculate the **footprint across all farms or to prove reduction of their average footprint**, data must be collected from at least a recommended minimum number of farms (for a lower error margin, sampling from a larger number of farms is required)

3. If the purpose is to provide **generic reduction advice for all farms (or for a particular type of farms)**, the minimum sample across all farms (or across all farms of the particular type) would be of some use, but sampling from a larger number of farms is recommended). This is also the case when **comparing farming practice impacts on footprint**.

(CFP guidelines, p 12-13)

These different purposes were also acknowledged during the project stakeholder workshop in August 2016 (see Appendix X), when it was concluded that farm specific data is an important driver for benchmarking; the use of secondary data will not drive towards lower emissions at individual farms. However, there can be a second-order effect if well-performing farms get a stronger market position, which could lead to incentives for others to improve. Furthermore, sampling can be enough to point out hot spots on which to concentrate. Still, there seem to be a need for high quality semi-primary data, corresponding to national, regional and/or local conditions, to allow for both accurate footprinting with reasonable efforts and for mitigation and benchmarking.

In the CFP guidelines, there are several possible scopes to consider when carrying out any dairy footprinting exercise:

a) Milk from a single farm
b) Milk from a "milk pool", i.e. all farms supplying milk to a single dairy processing plant – a representative sample of the farms would need to be measured
c) Milk from a single farm to more than one dairy – the farm would need to be included when measuring the footprint of any milk pools it belongs to
d) Milk (partly or entirely) from the "spot market" – a default value would need to be used (the CFP guidelines refer to a default UK value provided within the Footprint Expert™ Reference Database).

(CFP guidelines, p 8-9)

Below, we will describe the sampling strategies mentioned in the CFP guidelines for the purpose in paragraph 2 above and the scope in situation b above, a combination that corresponds to the overall objective of the current project.

3.1.1 Random sampling without grouping

Random sampling without grouping follows a statistical approach, described in the CFP guidelines, annex E. An equation determines how many farms must be sampled as a function of total number of farms, confidence interval, standard deviation and margin of error. With a confidence interval of 95%, a standard deviation of 0.25 and a margin of error of 5%, the equation generates the following result for some numbers of farms (table 3).

Table 3 Extract of table for random sampling of farms without grouping (Dairy UK, DairyCO & Carbon Trust, 2010).

Total number of farms	Random sample size	Percentage sampling rate
5	5	100%
10	9	90%
50	33	66%
100	49	49%
200	65	33%
1000	88	9%
5000	94	2%

Thus, as intended, the use of a statistical approach means that the percentage sampling rate declines as the population rises.

3.1.2 Grouping and then sampling

As explained in the CFP guidelines, this approach is more refined than sampling without grouping, and it reduces the sample size even further. However, it requires knowledge of some high level information about **all** of the farms, data that is usually available or accessible for a dairy processor. This data is used to create groups of farms expected to have similar characteristic, in this case carbon footprint. This way, the standard deviation within each group is reduced, thereby decreasing the number of farms, which must be sampled to achieve an acceptable margin of error. For carbon footprinting purposes, the CFP guidelines propose to group the farms according to data on:

- Average milk yield per cow
- Ratio of forage to concentrates used
- Proportion of the year animals are grass fed (out to pasture)
- Amount of fertilizer used on-farm for dairy feed
- Herd replacement rate
- Manure management system
- Irrigation used
- Total annual milk production

The data can be either binary (high/low) or discrete continuous values, except for total annual milk production which has to be provided in liters to calculate the weighting of the groups. The full table from the CFP guidelines, with parameters, types of data and notes on data requirements, is found in annex IV.

The grouping process should aim for five groups but result in at least three groups. If the number of three groups is not achieved, the grouping needs to be modified (redefine binary ranges or adjust separation factors in the clustering algorithm). The grouping can be carried out manually or automatically:

- Manual grouping (a person manually examining data) is possible in simple situations and when using binary data on the parameters above.

- Automated clustering means that a calculator, using so called stratification algorithms, will be needed. (The theory behind the automated clustering process is found in the CFP guideline, Annex A6.)

After stratification, the “root N” sampling method within a group shall be used, which means that the sample size is the square root of the population in the group. While the “root N” method is not based directly on mathematical theory, there is evidence to support its use (Saranadasa, in Dairy UK, DairyCO & Carbon Trust, 2010).

For ten farms and below, it is not appropriate to apply the grouping method – the random sampling method should be used. Above ten farms, a minimum of ten farms should be sampled. Table 4 provides the result from sampling following grouping for some numbers of farms.

Table 4 Extract of table for sampling of farms following grouping (Dairy UK, DairyCO & Carbon Trust, 2010).

Total number of farms	Random sample size	Percentage sampling rate
5	5	100%
10	9	90%
50	10	20%
100	10	10%
200	14	7%
1000	32	3%
5000	71	1%

The milk volume from the different groups of farms, in relation to total milk volume, is used to allocate total number of farms to be sampled between the groups. If a group represents less than 3% by volume of the total milk supply, sampling from that group is not necessary. A minimum sample of two farms per group is recommended.

3.1.3 Frequency of sampling and sampling in subsequent years

In the CFP guidelines (Dairy UK, DairyCO & Carbon Trust, 2010, p 18), the minimum requirement for data sampling is every two years, and the recommendation is annual data sampling. Regarding communication of footprints, both an annual footprint figure and a five year rolling figure are recommended, considering the variability from year to year. Furthermore, to maintain comparability and consistency, the farms sampled in subsequent years should correlate closely with the original sample: if a farm drops out from a sample group, it should be replaced by a similar farm (size, production system etc.).

3.1.4 Applicability in the PEF context

The grouping process above was developed based on the requirements for **carbon** footprinting of **dairy** products. However, whether the parameters used in the grouping process (annex IV) are valid for the other impact categories that are defined as most relevant in the PEFCR for dairy products (water resource depletion, freshwater eutrophication, marine eutrophication, terrestrial eutrophication, freshwater eco-toxicity, land use and acidification) has not been assessed or verified in the current project. How the table in annex IV should be modified and what parameters should be added to account for farm characteristics that may lead not only to similar carbon footprints but also other similar environmental impact, is yet to be looked into. However, the PEFCR for dairy products has introduced some indicators as an attempt to semi-quantitatively capture the potential impact of dairy products on biodiversity and land use change in the European dairy farming context. The indicators might be suited to use in the grouping process:

- Share of grass from pasture in the feed ration (% of dry matter intake, DMI)
- Semi-natural habitats (% of the dairy farm area)
- Share of feed with possible risk of deforestation[6] in its supply chain within the feed ration (% of DMI)
- Schemes (certified or not) in the raw milk supply chain with a description of relevance (% of raw milk in the product recipe within each scheme)
- Land use change and deforestation as "Land use change related CO_2 emissions"

From a Nordic dairy farming perspective, it is a shortcoming that these indicators do not distinguish between ley and semi-natural pastures, neither between fertilized and unfertilized pasture, systems with different contributions to biodiversity. Regional datasets for feed production could give better representation of these aspects.

We have made no attempt to carry out the corresponding grouping exercise for red meat, but the next following section gives information about some of the important variables for the variation in the impact from pork and beef, respectively, which could be used as input to grouping.

3.2 Most critical farm data affecting emissions and environmental impacts

This section is based on results from a supporting study on pork in the red med pilot and a sensitivity analysis based on a previous work in Finland regarding environmental foot print of beef.

Pork production

Danish Crown, Denmark, is part of the pilot for red meat with focus on pork. In relation to that a supporting study on the implementation of the draft PEFCR for red meat was conducted. The supporting study included aspects on how to include the farming stage in the assessment. That part was conducted in a co-operation between Aarhus Universality (as part of the present project) and Danish Crown. The full report is given in appendix III, while some main findings are presented below.

In this work a national average of pig production in Denmark was established covering both the piglet production stage as well as the slaughter pig production stage. In addition data from 10 slaughter pig units with different technologies and technical efficiencies were collected and the environment impact evaluated at farm level basis assuming a standard Danish piglet production.

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[6] Non-certified soybean from Brazil and Argentina, non-certified palmmeal from Southeast Asia

In table 6 is shown the overall results.

Table 6. Environmental impact of pork, typical Danish production conditions and results from 10 case studies, per kg live weight.

Impact category	Unit	DK standard	10 sampled slaughter units		
			average	Min	Max
Global warming potential	kg CO2 eq	2.5	2.5	2.2	3.7
Marine eutrophication	g N eq	30	31	20	39
Freshwater eutrophication	g P eq	0.59	0.76	0.40	2.49
Acidification	molc H	0.043	0.042	0.037	0.063
Land use	m^2	5.0	5.2	4.2	6.0
Mineral, fossil & ren resource depletion	mg Sb eq	8,2	14.6	6.1	73.6
Freshwater ecotoxicity	CTUe	20	25	18	70

The average of the 10 farms was close to the national average but with huge differences between individual farms. For some impact like freshwater eutrophication, resource depletion, and fresh water eco-toxicity one or two farms had deviating results. This was mainly due to the impact related to some imported feed stuff, where the (secondary) data used were probably not realistic.

It is well known that for several impact categories, the main contributors are related to feed production (at farm and bought in), feeding, and manure management. The feed conversion rate in slaughter pig production is therefore one of the most critical input as this parameter includes some of the variation related to all three areas (Nguyen et al 2011). However, even if feed conversion – all other things equal – is very important, other aspects at the particular farm may this relation. This is illustrated in Figure 1 showing the impact on GHG emission per kg live weight of pig delivered to the slaughterhouse in relation to feed conversion (kg feed per kg gain) but also grouped after the use of manure technology.

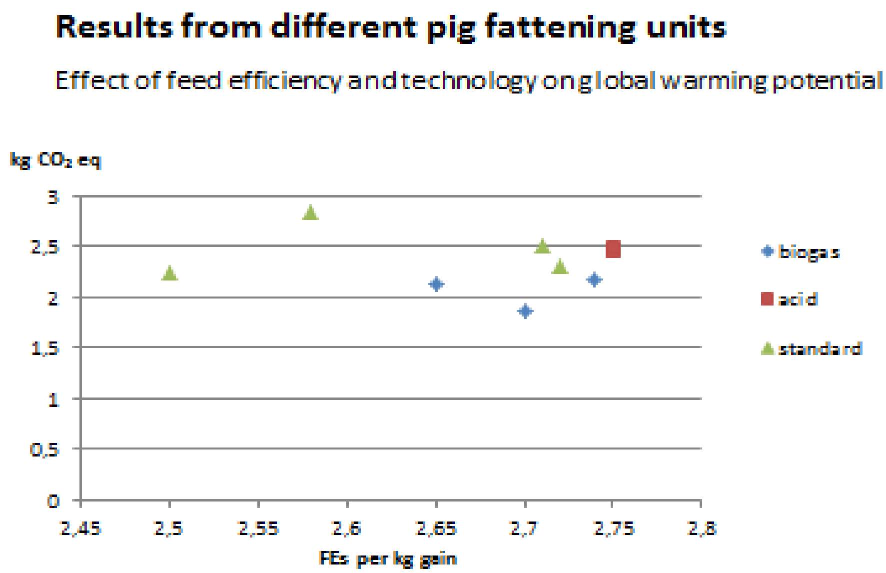

Figure 1 Effect of feed efficiency in slaughter pig production and manure technology on global warming impact per kg pork from 10 different pig production systems in Denmark

It is clear that no clear picture of the effect of feed utilization is seen, meaning that other factors (eg feed composition) mask this effect. The three farms where the manure is utilized for biogas production the GHG emissions is relatively lower than other farms despite a lower technical efficiency (higher feed per kg gain).

Systems where animals are housed on fully slatted floors tend to have a higher impact on acidification potential, due to higher emissions of ammonia at stable level, than from animals housed on deep litter. Conversely, housing of animals on deep litter has considerable contribution on the overall impact on GHG emissions since the level of nitrous oxide emissions is double compared to slurry based systems. In addition, the use of cover during storage of slurry is important in relation to the reduction of level of emissions.

Taken together it is very important to have good estimates for feed conversion ratio. However, this is not sufficient. The manure handling technology is also very important. This includes whether manure is used for biogas production or not, the lay-out of the stables, and whether the manure is protected through coverage or not. In addition the composition of feed is important and not least that good data exists on all relevant feed items imported to the farm.

Beef production

In FootprintBeef-project (2013-2015) a detailed environmental impact assessment on Finnish beef production was conducted. The study was based on statistics and expert evaluations on average Finnish production. Thus, similar variability as in the previous chapter on pork was not possible to conduct, but instead, to evaluate systematically what are the most critical parameters affecting the LCA results, a sensitivity analysis was conducted on fattening dairy bull using selected variables.

As real variation in parameters was not known, values for the variables were set either to 10 percent over or below the present baseline, which describes Finnish average production. If 10 percent change was not seen realistic or possible in the model, other kind of changes (e.g. one class lower or higher digestibility of feeds, +/- one year of slaughter age) were assessed.

Tested variables were slaughter age, slaughter weight, feed composition, barley yield, silage yield, share of cultivation on organic soil, electricity use, emission factor of electricity, fuel use, amount of peat in bedding materials, injection of slurry, nitrogen fertilization rate, emission factor of nitrogen fertilizer, and digestibility of organic matter in grass silage.

As concluded also in the pork production, also in beef production the main driving factor for emissions is the feed conversion rate followed by N and P balances, represented by the slaughter age and weight, feed composition and digestibility of feeds.

Figure 2 shows the results of the sensitivity assessment. The slaughter age had the largest effect on all three included impact categories (climate, eutrophication and acidification impact) with approximately 8 percent increase in all impact categories with a 10 percent increase in the slaughter age. The longer the growing period, the more feed energy consumed by animals is used for maintenance, the feed conversion rate increases and emission per kg carcass weight get larger.

The second largest effect (although not achieved by 10 % change, but by change in digestibility class) was achieved with feed quality; lower digestibility of grass silage (digestibility of organic matter in DM lowered from 660 to 630) increased greenhouse gas and eutrophying emissions approximately by 5 percent each and acidifying emissions increased 1 percent. Achieved yield of feeds had also an important role. For barley, a yield decrease of 10 percent affected especially eutrophying emissions resulting in nearly 4 percent increase, but also climate impact and acidifying impacts were elevated both with nearly 2 percent. For climate impact other important variables that resulted at least in 1 percent change in the result were grass silage yield, slaughter weight, feed composition, organic soils and age of grass. For eutrophying impacts other important variables were grass silage yield and amount in feed composition, slaughter weight and N fertilisation on feed. For acidification, similarly, also feed composition, slaughter weight and silage yield were resulting at least in 1 percent change.

For identifying the most critical variables for conducting LCA on beef production, based on this sensitivity analysis, the most important variables would be slaughter age, digestibility of roughage and yields of the feeds, manure spreading, feed composition and slaughter weight. Also important, as having an effect at least in one of the three impact categories, N fertilisation of the feed, age of grass and share of organic soils. The last is particularly important in Finland, as the share of organic soils is high, around 14 percent of agricultural land. Compiling inventory data, these variables should be collected carefully and as precisely as possible as the uncertainty in these variables could result in a biased or uncertain result.

In Finland practically no soy feed is used for cattle and thus, emissions arising from land use changes were not estimated here. However, in other countries land use changes may contribute significantly and should be considered in LCA studies on beef production.

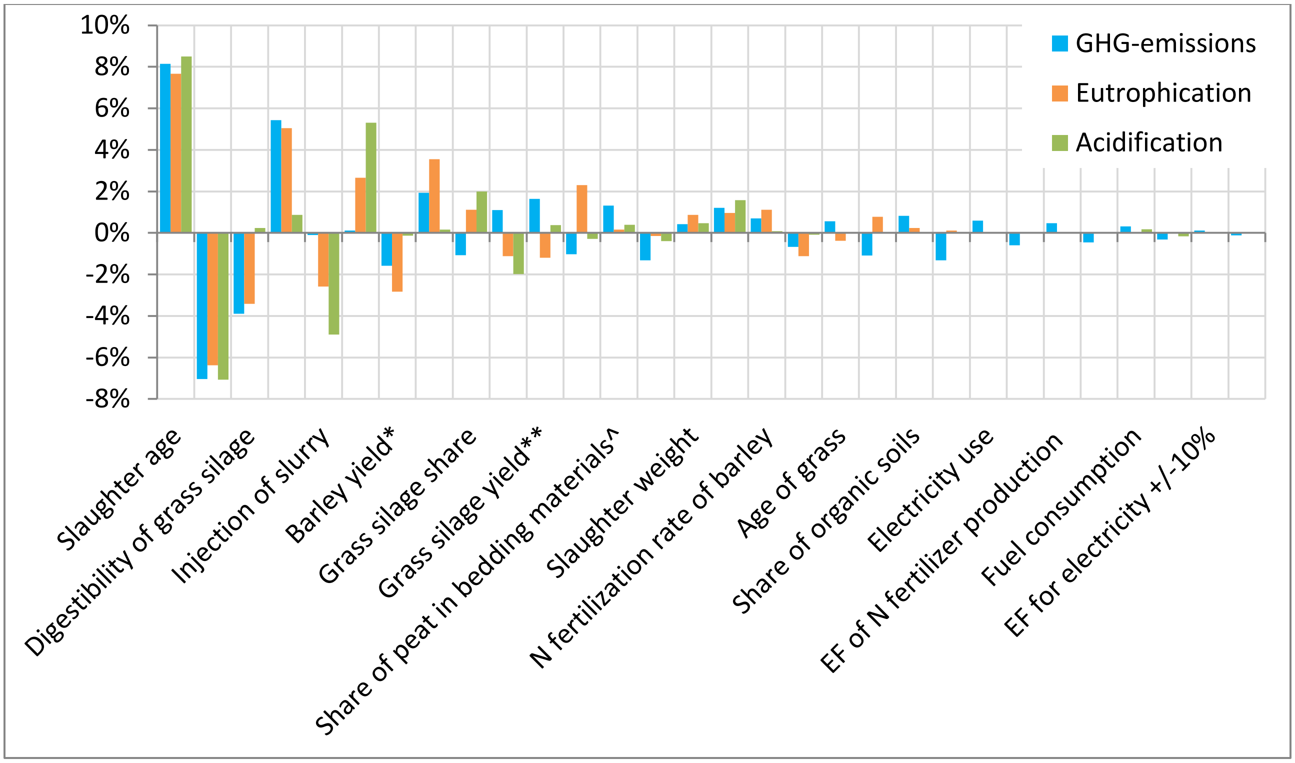

Figure 2. Effects of +/-10% changes (except digestibility and age of grass) in parameters to greenhouse gas, eutrophication and acidification of fatting dairy breed bull. *Effect of having a higher or lower yield with same inputs. **Effect of having a higher or lower yield taking into account needed additional inputs. ^ Beef breed bull with solid storage

3.3 Converting farm data to emissions and environmental impacts

The PEFCRs give recommendations of what emission factors could be used in terms of main emission sources and emissions, e.g. methane from enteric fermentation and manure management, and ammonia from manure management. Recommendations have preferred options, alternative options and minimum requirement depending on the PEPCR. In Red meat PEFCR preferred options are IPCC Tier 2 methodology (for CH_4, N_2O) or EMEP/EEA Tier 2 methodology (for ammonia, NMVOC, particulates and NO_x), while in dairy PEFCR Tier 2 is minimum requirement and Tier 3 is mentioned ‘optional’ but could be interpreted as preferred. Thus, they seem conflicting.

Tier 2 methodology means default emission factors provided by IPCC or EMEP/EEA where country specific conditions could be taken into account. However, PEFCRs always give an opportunity to use country specific emission factors either the ones used in national monitoring, policy or legislation (Tier 3) (PEFCR for red meat) or the ones used in national inventory reports (PEFCR for dairy). This can lead to the situation that research organizations can have more accurate values compared to publicly available information, e.g. for ammonia from manure applied to soil with different methods, and it can have a big effect to the results, as presented below by NH_3 emissions in pork production.

The PEFCR of dairy product also gives recommendations on how to calculate nitrate and phosphorus emissions (not available in PEFCR of red meat). Since these are important emission sources also for red meat products, guidance should be given in the PEFCR too. For nitrate in PEFCR for dairy products it is said that "Nitrate leaching is based on multiplication of the amount of nitrogen excreted or added to soils by a default fraction of leached nitrogen" (IPCC Tier 1). Also Tier 2 and 3 can be used when country-specific leaching factor (Tier 2) or alternative country-specific estimation methods are available (Tier 3) could be used. Also these different approaches can have very different results as different countries could have very different methodologies to estimate nitrogen leaching. For phosphate, the preferred option is to use amount of phosphorus applied. Again, a second option is to use country-specific estimation method for leaching.

PEFCR documents say that ReCiPe characterization factors shall be used for characterization of marine and freshwater eutrophication. In ReCiPe main report[7] , it is said that the characterization factors in ReciPe include site generic fate factors for Europe. For allowing a wider use of PEFCRs also other characterization methods should be allowed for countries outside of Europe.

In the supporting study for red meat regarding pork, the impact of using the suggested default emissions of ammonia for the typical Danish pork production versus using country specific data for emissions were analysed. The ammonia emissions based on the Danish national inventory standard compared to PEF default values are shown in Figure 3. It is clear that this choice has a major impact on the three impact categories particulate matter, acidification and terrestrial eutrophication.

[7] Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J. & van Zelm, R. 2013. ReCiPe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition (version 1.08). Report I: Characterisation.

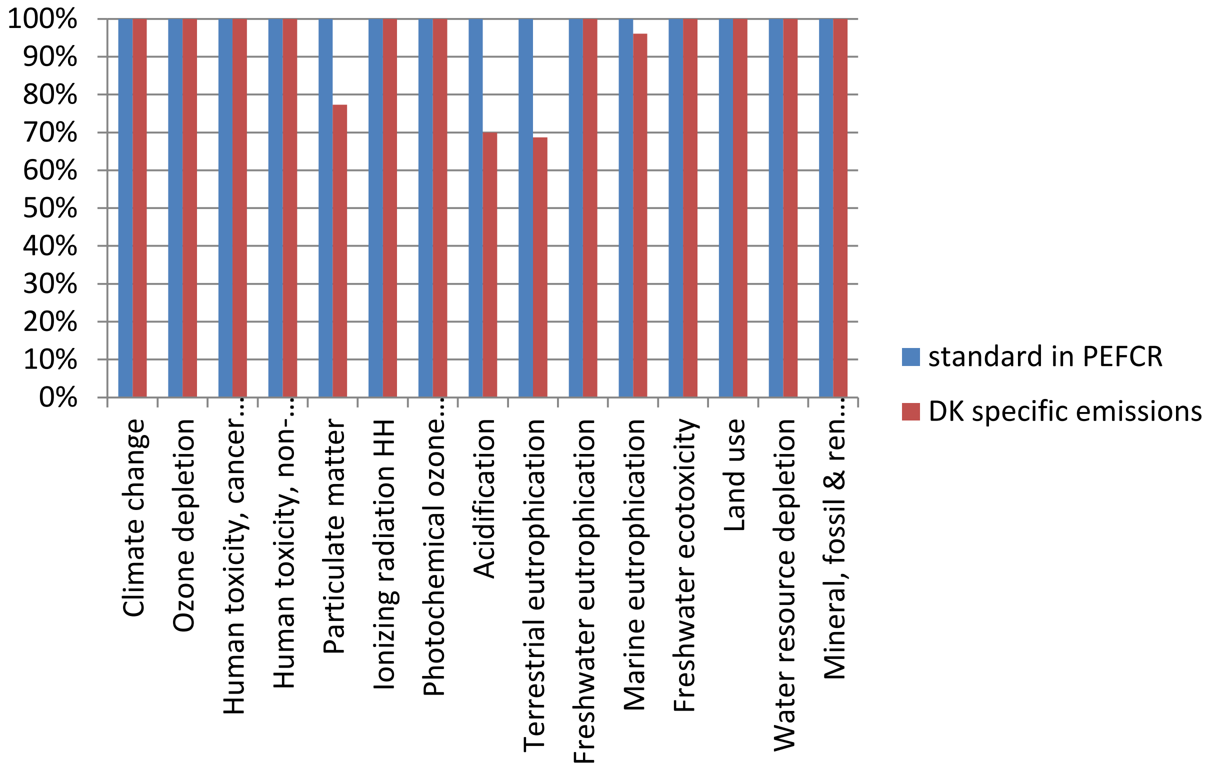

Figure 3. Relative impacts per kg pork produced using PEF default values or Danish national values for ammonia emission related to manure.

Hence, while statistics on herd sizes, feed types, housing systems, yearly production etc. can be found on national level, there is a need to disaggregate these data, "match" them with factors such as regional pedo-climatic conditions, and process them into semi-specific but still product specific emissions that would be usable in a PEF context. Software for this kind of exercise is offered by e.g. the Swedish National Board of Agriculture, responsible for the development of the system Vera. Vera is an important part of the work in Greppa Näringen (described in Section 2.2). In this software, the farmer or other user can calculate the environmental impact from and resource use at the farm (nutrient balances, manure calculations, fertilization plans and leakages, greenhouse gas emissions and energy use). Vera is offered at a moderate cost. Vera and similar software could be one element in the development of regional LCI-datasets for use in PEF calculations of primary production emissions that would comply with data quality requirements in the PEFCRs for food products.

To simplify PEF studies tools compliant with PEFCR methodology can be used, such as the one developed within the FP7 project CanTogether, where emissions from animal production and manure are quantified based on production data and where different emission factors for animal and manure are combined with ReCiPe methodology.

Given the huge impact the emission models can have on important environmental impacts, there is a need to investigate further how the PEFCR guidelines truly reflect the Nordic conditions.

3.4 Regional databases and international databases

As described earlier in this report, a variety of data exist describing farm activities in the Nordic countries, but they are typically not complete and consist mainly of key figures such as growth rate and feed consumption. Data related to feed production is often not related to the livestock production or only parts of the feed production as home-produced feed. Data for the production of the bought-in feed is generally not available. Therefore, it will often be necessary to use additional data from regional or international databases. There are several international databases. Among others can be mentioned Ecoinvent, Agri-footprint and SP`s database for feed production in Sweden. These databases, however, are not regularly updated and should be used with caution when there is considerable variation in the data. For feed production, Ecoinvent have data on a global level (GLO), for USA and some countries in Europe, while Agri-footprint also have data for the Nordic countries, using FAO statistics for country-specific crop yields and fertilizer amounts, but likely including large uncertainties.

As illustrated earlier, models for emissions may vary to a high degree impacting on the results appearing in the databases. Likewise yield of different crops may vary very much across pedo-climatic zones also within the Nordic countries. Also, as shown in the supporting study of pork the results from existing databases on some specific feed items used in Denmark are not reasonable characterised which make the overall assessment of pork questionable for some impact categories.

4. Recommendations

4.1 Sampling and system description

In addition to the feed conversion, a number of specific characteristics at the farm regarding housing and manure treatment have a significant influence on the environmental foot print – in particular emissions related to ammonia and methane and must be taken into account when a sampling is carried out. The housing and manure management practice can be fairly easily identified and used for grouping before sampling. However, a main aspect is to set the boundaries for the livestock production in question at the farm to find out what other data is needed for this grouping.

Livestock farms are in many cases very complex with many different enterprises and crops and it seems not realistic in terms of data collection to have an overall farm level lifecycle assessment approach, and this complexity may also impose a significant uncertainty in the assessment of the environmental impact of the livestock production in question. From the preceding sections it appears that the most reliable and available data at farm level is the “technical” efficiency of the livestock production (milk yield and growth rate or slaughter age, and for housed animals also to some degree the overall feed use) since these data are used for other purposes. Contrary, information of input used or on yield per ha of fodder crops and other crops are less available and likely less accurate This holds true in particular for yield of crops that are partly grazed.

From our experience it is not possible to get a valid description of the overall input and emissions from the livestock production by ‘just’ combining collected existing farm data on the livestock production and the crop production at the farm - this will require quite a lot of adjustment and assumptions in each case. Therefore, there is a need to elaborate how data collection from farms should be done in a harmonized way. The 'red meat' draft PEFCR suggests that a mass and nutrient balance should be established for the livestock production *per se*. This is a very important step and should be a mandatory requirement and included also in the dairy PEFCR. However, it is less defined how to monitor the environmental impact of the home produced feed and – in the case of grazing – how to estimate grass intake. The estimation of grass intake influences in particular methane emissions and therefore valid estimations are of obvious importance for the overall impact when considering grazing animals. Hence, ley and pasture need special attention in the quantification of feed production (see below).

We suggest considering and investigating the consequences of delineating the livestock farm to the actual area which is used for home produced feed and use best available regional secondary data for those crops taking into account that these areas are probably fully or partially fertilized with manure from the livestock production. In the case that not all manure is accounted for, the 'exported' manure can be credited described in the EC 2013 Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisation (Official Journal of the European Union L124 Vol 46, pp 43-44)

As mentioned it is important to have good estimates for grass uptake. There is no well accepted consensus method as to estimate that under practical conditions – different countries in Europe using different methodologies. We suggest that guidance is given on this estimation for growing ruminants (based on the type of animal, weight and growth rate taking into account amount of supplemental feed) as well as for grass-based dairy systems.

Another complexity is the fact that in many cases the livestock herd delivering milk or slaughter animals relies on recruiting animals from other farms – it can be heifers entering a dairy herd, calves from a suckler herd for further finishing at a fattening farm and piglets for fattening. The farms delivering those animals are not necessarily directly related to a processing company and its sampling scheme. Thus there is a need to establish relevant data for these types of animals. Ideally these farms should be sampled as well, but this can be difficult to achieve in practice. We suggest that regional secondary datasets should be produced to allow the direct supplier to the processing company to account for the impact of 'imported' animals in a harmonized way. Probably national statistical data can be used for that purpose.

4.2 Regional databases for livestock processes and emissions

As explained above we think there will be a need for supplemental regional datasets to supplement the actual data collection taking place at farms. This includes definition of relevant processes but also a need to define the most relevant emissions factors that are internationally accepted taking into account regional conditions.

The establishment of such datasets will most probably be a relatively demanding exercise of finding the right granularity (what regions have similar conditions, crucial for environmental footprints?), data corresponding to the sampling method chosen, access and right to make use of these data, and, finally, formatting and converting them to emissions. Such an exercise will need a mobilization of efforts from primary production, industry and public authorities. It will also include extended use of digitalized communication of data along the food chain. The Swedish Board of Agriculture was recently assigned the mission “Smarter food chain” with the intention to foster growth in the Swedish food chain through improved access to information for its actors. This initiative could be a starting point for developing such communication.

5 Issues that need further attention

A number of issues going beyond the issue data sampling need further attention. These are outlined below as topics that should be addressed in the further development of the PEFCRs.

- The importance of distinguishing between different types of land in terms of alternative use (arable vs permanent) and with very different productivity since this impact on many impacts.

- Handling of production taking place at peat soils. In a Nordic context, production on drained peat soil is a non-negligible source for CO_2 emissions. During the stakeholder workshop, it was questioned whether emissions from peat soil actually could be omitted from the calculation of carbon footprints of feed production, since the famer has only little influence on this. It is important here to distinguish between data used for the PEF describing the overall and collective impact for a group of milk producers and the information that is needed for practical decision making at individual farms. For the PEF these emissions probably should be included, but due to their significant effect it is important that the best possible estimates are used, accounting for specific management practices for mitigation.

- Carbon sequestration and biodiversity are two important areas that need to be included in all agriculture PEFCR, so development of measurements and methods is needed

- Special attention to outdoor livestock production (all year round as in organic pig or poultry as well as during pasture season) in relation to emissions of methane and nitrogen and impact on biodiversity.

- Biophysical allocation method introduced in the PEFCRs need to be improved and adjusted to the categories fitting the actual data.

- Due to the challenges of collecting good quality data for PEF compliant studies and in addition to development of regional datasets, new tools are needed to help food industry 1) to collect primary data from their supply chain, in particularly from farms, in a fair and reliable manner, and 2) to convert activity data into emissions and impacts.

- There is a need to develop better methods to estimate nutrient leaching, eutrophying emissions, (in particular, to be able to distinguish at least between annual and perennial crops).