BIOECONOMY AND HEALTH
AGRIFOOD AND BIOSCIENCE

Carbon footprint report on organic dairy products of Arla Biologisch on the Dutch market - Public

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RISE project 2P02002

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November 2020

Content

Abbreviations

AR4 & AR5	Assessment report 4 respective 5 (IPCC)
C	Carbon
CO2e	Carbon dioxide equivalents
CH_4	Methane
DEFRA	Department for Environment Food & Rural Affairs
EF	Emission factor
EDA	the European Dairy Association
EPD	Environmental Product Declaration
FAO	Food and Agriculture Organization of the United Nations
FPCM	Fat and Protein Corrected Milk
GWP	Global Warming Potential
GHG	Greenhouse gas
GHGP	Greenhouse gas protocol
HCFC	Hydrogen Chloro Fluoro Carbon compounds
IDF	International Dairy Federation
ISO	ISO - International Organization for Standardization
LCA	Life cycle assessment
LEAP	Livestock environmental assessment and performance partnership
LU	Land-use
LUC	Land-use change
MS	Milk solids
N	Nitrogen
N_2O	Dinitrogen oxide
NIR	National Inventory Report
PCR	Product Category Rule
PEF	Product Environmental Footprint
PFAD	Palm Fatty Acid Distillate
UHT	Ultra High Temperature
UN NIR	United Nations National Inventory Reports
UNFCCC	United Nations Framework Convention on Climate Change

1 Summary

Arla Foods amba commissioned RISE to assess the carbon footprint of the Arla Biologisch (hereafter Arla Bio) product segment provided the Netherland market in 2019. The assessed product carbon footprints are in accordance with ISO 14067:2018 Carbon footprint of products. The calculations and reporting also follow the Greenhouse Gas (GHG) Protocol Corporate Standard and Greenhouse Gas Protocol Value Chain (Scope 3) Reporting and Accounting as well as the methodology in the IDF guide to standard life cycle assessment methodology for carbon footprint. The methodology recommended in the IDF guide is also to a large part adopted by the in the Product Environmental Footprint Category Rules for dairy products (EDA, 2018).

The calculations are based on specific data representing the production of the organic Arla Bio products in the Netherlands in 2019, supplied by Arla. The base year for the assessment starts 1st of January and ends 31st of December 2019. Furthermore, information has been collected from suppliers, official statistics in combination with generic data and emission factors. The results in the present report will be used to forecast the carbon footprint for the coming year, and it is therefore not relevant to include products that are no longer in the product assortment 2020.

Table 1. Summary of project details

Project details	
Client company	Arla Foods amba
Performing company	RISE Agriculture and Food
Goal	Assessing the carbon footprint of the organic product brand Arla Bio in 2019.
Scope	The complete value chain, from cradle to grave, of Arla's organic products Arla Bio provided to the Dutch market
Standard for calculation	ISO 14067 Carbon footprint of products, Greenhouse Gas Protocol Corporate Standard, IDF guide to standard life cycle assessment methodology
Base year	Production year 2019 from 1st January to 31st of December.
Type of control	Operational control approach (Arla has full authority to introduce and implement its operating policies to any process)
Method for revision	Third party review by EY Godkendt Revisionspartnerselskab
Validation	A Limited Assurance engagement has been undertaken by EY Godkendt Revisionspartnerselskab in accordance with ISAE 3410 assessing the greenhouse gas inventory and reporting, as well as the use of the Greenhouse Gas Protocol's Corporate Standard as reporting framework including the Scope 2 Guidance and the Corporate Value Chain (Scope 3) Standard. See pages 50-52 for EY Godkendt Revisionspartnerselskab Independent practitioner's review report.

The scope of the assessment is cradle-to-grave i.e. the assessment includes all activities in the dairy product value chain staring with the dairy farm and ending after consumption at household.

The contribution to climate impact from the Arla Bio product segment was 44 920 tonnes of CO2e. The farm step (including land use and peat soil) stand for 77.2 % of the contribution. Contribution from Arla's own activities (dairies, capital goods, business travel and commuting) stands for 8.5 % of total climate impact. Detailed information can be seen in Table 22.

The product segment fresh milk stands for 61.4 % of total climate impact for the Arla Bio product segment. The average product carbon footprint for fresh fat and protein corrected milk is 1.38 kg CO2e/kg. The average product carbon footprint for all products is 1.34 kgCO2e/kg.

The GHG calculations per se are subject to inherent uncertainties due to made assumptions and immature scientific knowledge. But since the method for GHG calculation in this assessment follows both GHG Protocol Corporate Standard and Value Chain (Scope 3) as well as the ISO standard 14067:2018 Carbon footprint of products together with transparent reporting of assumptions and methodological choices the result carbon footprint is considered representing the Arla Bio product segment of 2019.

2 Introduction

Arla Foods Amba (Arla) has together with RISE carried out the carbon footprint assessment in accordance with ISO 14067:2018 Carbon footprint of products. The calculations and reporting also follow the Greenhouse Gas (GHG) Protocol Corporate Standard and GHGs Protocol Value Chain (Scope 3) Reporting and Accounting as well as the methodology in the IDF guide to standard life cycle assessment methodology for carbon footprint. The methodology recommended in the IDF guide is also to a large part adopted in the Product Environmental Footprint Category Rules for dairy products (EDA, 2018).

The calculations are based on specific data representing the production of the organic Arla Bio products in the Netherlands in 2019 supplied by Arla. Furthermore, information has been collected from suppliers, in combination with generic data and emission factors from recognized life cycle assessment databases, scientific articles and other published studies.

3 Scope of the assessment

The carbon footprint of the Arla Bio product segment provided to the Dutch market in 2019 and still in product portfolio 2020 have been assessed, in total 18 SKU:s. The product segment includes milk, yoghurt, fermented products and butter milk. The scope of the assessment includes contribution from the complete value chain: from field for feed production, resource use at farm and dairy, packaging, transports, retail and up to consumer at final day of shelf life for the products and waste handling (of food waste and packaging). Specific information on production, packaging and transportation have been gathered for all products in the Arla Bio product segment and the product carbon footprint has been assessed according to the standard ISO 14067. The product carbon footprints together with total production volumes in 2019 were used to assess the carbon footprint of the total Arla Bio product segment and is reported according to the GHG protocol Corporate standard and Value Chain (Scope 3). System boundaries of the assessed system are given in Figure 1, with indication on data included in each step. Upper part of the figure shows the scope from a product perspective (according to ISO 14067). Both parts together, Figure 1, describe the system included in the assessment of the Arla Bio product segment according to GHG protocol (GHGP, 2011). Green ovals indicate data provided by Arla and orange ovals data gathered by RISE. The assessment applies the operational control approach since Arla has full authority to introduce and implement its operating policies to any process.

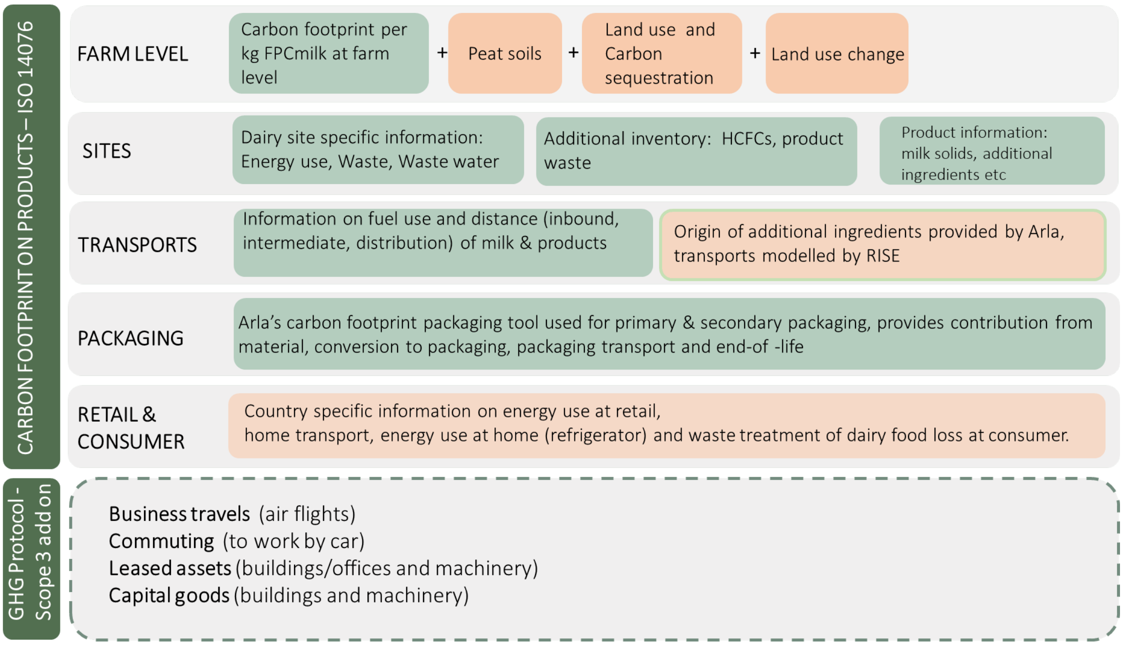

Figure 1. System boundaries for the assessment of carbon footprint of Arla Bio products and Bio dairy product segment as a whole in the Netherlands. Upper part show the scope from a product perspective and together with lower part, the complete system included in the assessment according to GHG protocol is described. Green ovals indicate data provided by Arla and orange ovals data from RISE.

3.1 Methodology

The assessment of carbon footprint of the Arla Bio products and product segment follow the ISO 14067 standard for carbon footprint of products (ISO, 2018), the GHG Protocols standards for Corporate and for Scope 3 (GHG protocol, 2011) as well as the IDF guide to standard life cycle assessment methodology (IDF, 2015) . The characterisation method for GHGs used as default is AR5 (IPCC 2013), with feedback loops.

3.2 Aim of the study

The aim of the study has been to quantify the carbon footprint of the product's full life cycle, cradle to grave, of the total Arla Bio product segment provided the Dutch market in 2019.

3.3 Arla Biologisch brand

Eighteen SKUs of the Arla Bio product segment sold in 2019, are included in the assessment. Fifteen of the SKUs are produced in the Netherlands, one (Biomilch) is produced in Germany, another one (Kefir) is produced in Sweden and a third one (Skyr) in Denmark. All eighteen products are sold in the Netherlands. The calculation has been carried out based on specific information on every product and production sites.

3.4 Functional unit

The functional unit from a product segment perspective is 33 613 ton of products ready for distribution including packaging, downstream transports, storage during complete shelf life and waste treatment of packaging and potential food waste.

The functional unit from a product perspective is 1 kg of product produced at dairy including also all value chain steps downstream i.e. packaging, distribution, retail and consumer (according to ISO 14067).

3.5 Reference flow

The reference flow is 26 580 854 kg of fat and protein corrected milk (FPCM) from farm to production of the Arla Bio products of the year 2019. This equal 3 229 626 kg milk solids (MS). Most milk used in the products are milk from the Netherlands, except 1 849 922 kg (7.0 %) that are milk from Germany, Sweden and Denmark. This milk was used in three products, ambient semi-skimmed milk, Skyr and Kefir, products which are also produced in each country respectively.

3.6 System description

The defined Arla Bio brand product system is based on a product perspective which follows the methodology in the product carbon footprint ISO 14067 standard and is reported with a business perspective according to Greenhouse Gas Protocol, Scope 3 Reporting, Figure 1.

From a product perspective (ISO 14067) the processes included in the product system, Figure 2, are divided in:

- Upstream processes, mainly farm activities (cradle-to-gate),
- Core processes, activities at Arla´s sites and facilities (gate-to-gate),
- Downstream processes, activities in the value chain between dairy and consumer (gate-to-grave).

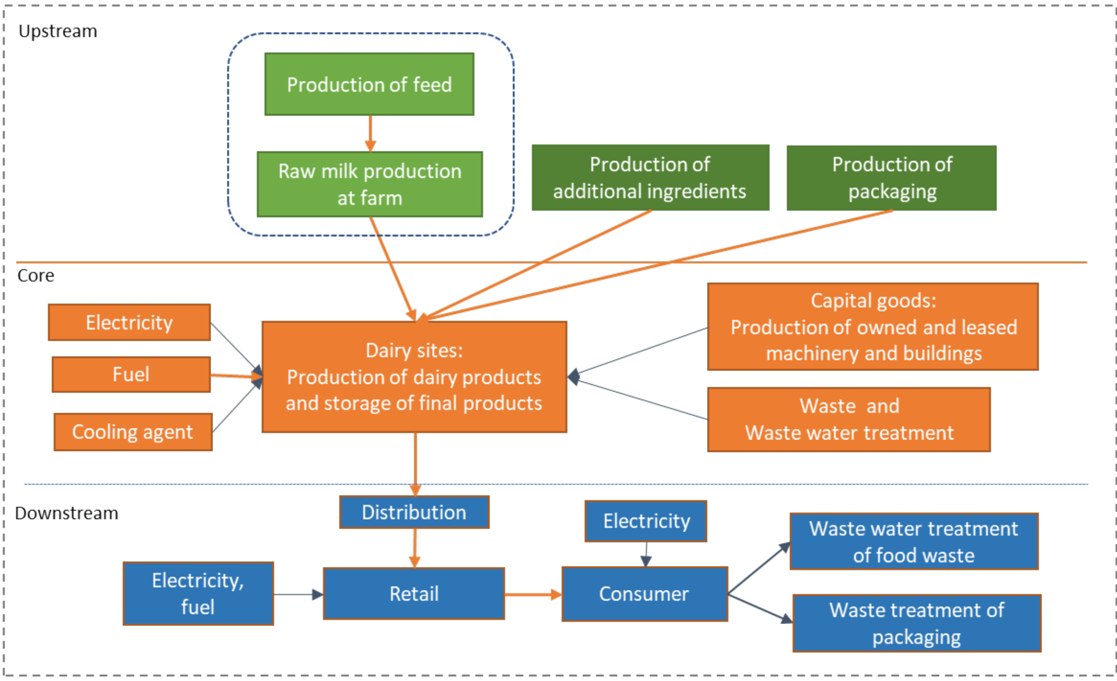

Figure 2. Simplified flowchart of the Arla Bio product system, orange arrows indicate transports.

From a business perspective (Greenhouse Gas Protocol) all relevant scope 3 categories are covered and the emissions are reported in relevant scopes and categories. Emissions of cooling agents and emissions from combustion of fuels in Arla owned assets are reported in scope 1 and emissions from production of purchased energy (electricity and district heating) used in Arla owned or leased facilities is reported in scope 2. The remaining emissions are reported in scope 3.

3.6.1 Included processes

All processes included in the assessment are listed in Table 2.

Table 2. Processes representing the Arla Bio products included in the assessment. Indication is given from where in the value chain and what scope the emissions are allocated to.

Category	**Emissions to Scope**	**Processes**
Upstream processes	3	All farm activities (on and off farm): - Inbound transports of feed and inputs to farm - Methane emissions from cow enteric fermentation - Feed cultivation, production and consumption, on farm and imported - Emissions from peat soils at farm - Production and use of electricity and energy at farm - Manure handling, storage and spreading - Sequestration and emissions from land use
	3	Milk collection of Arla milk, external transports, from farms to dairies.
	3	Production of and inbound transports of ingredients and packaging
Core processes	3	Extraction and distribution of energy to Arla sites
	1	Combustion of fuels at Arla dairy sites to production of the final product (e.g. skimming, homogenization, pasteurization, packing, cooling)
	2	Emissions from the generation of purchased electricity used at Arla dairy sites
	3	Waste management of all waste fractions and wastewater treatment of wastewater from Arla production sites
	3	Intermediate transport (external) between Arla dairies
	3	Production of capital goods and leased assets at Arla sites.
	3	Business travels and commuting
Downstream processes	3	Distribution transport (external) from dairy or warehouse to retail
	3	Retail: Energy and electricity use
	3	Retail: Waste treatment of dairy waste
	3	Consumer: transport from retail
	3	Consumer: energy use due to cold storage
	3	Consumer: waste treatment of dairy food loss in households
	3	End-of -life treatment of packaging

The defined production system is also based on the Greenhouse Gas Protocol Value Chain Scope 3 Reporting Standard. Table 3 gives information on how the different life cycle stages correlate to scopes and categories according to the GHG Scope 3 standard, and whether they are included or not in the assessment.

Table 3. The different lifecycle stages correlation to Scope and Categories of GHG Protocol with comments whether included or excluded in the carbon footprint assessment of the Arla Bio product segment.

Scope	**Categories**	**Included/excluded and life cycle stage**
Scope 1	Direct emissions	Included in Dairy sites and Transports: Inbound and Distribution + intermediate from Arla owned vehicle
Scope 2	Indirect emissions from purchased energy	Included in Dairy sites
Scope 3	**Categories for scope 3 as defined in GHG Protocol**	
Scope 3 - Upstream	1. Purchased goods and services	Included in Farm, Additional Ingredients and Packaging
	2. Capital goods	Included are Arla's buildings and machinery (forklifts and filling machines) are included, remaining capital goods are excluded
	3. Fuel-and energy-related activities (not included in scope 1 or scope 2)	Included in Retail, Consumer energy Transport- Inbound, Distribution+ Intermediate (purchased transports), Consumer transport
	4. Upstream transportation and distribution	Included in Transports: Inbound, Intermediate and Distribution from external transports and in Packaging
	5. Waste generated in operations	Included in Dairy and in Packaging
	6. Business travel	Included in Business travel are air flights, business travels with other transport modes are excluded.
	7. Employee commuting	Included as Commuting, car commuting by Arla employees
	8. Upstream leased assets	n/a, see 3.9
Scope 3 - Downstream	9. Downstream transportation and distribution	Included in Transport: Consumer transport
	10. Processing of sold products	Excluded, see 3.9
	11. Use of sold products	Included in Consumer energy
	12. End-of-life treatment of sold product	Included in Consumer waste treatment and in Packaging
	13. Downstream leased assets	n/a, see 3.9
	14. Franchises	n/a, see 3.9
	15. Investments	Excluded, see 3.9

3.7 Time and geographical representativeness

The assessment represents the production of the Arla Bio product segment in 2019 at one dairy in the Netherlands, Germany, Sweden, and Denmark respectably. 92.5 % of the raw milk used is produced in the Netherlands, 5.3% in Sweden, 1.5% in Germany and 0,2% in Denmark.

3.8 Allocation

The emissions at farm level is allocated between milk and meat (from slaughtered dairy cows and surplus calves) based on the feed energy, as recommended in the methodology by IDF (IDF 2015). The allocations of the contribution from both farm level and dairy site to the different dairy products and product segment are done based on the content of milk solids (MS; fat, protein and lactose) in the final product and product segment (IDF, 2015). The above mentioned allocation methods are proposed in the product-category rules for dairy products in the European work on Product Environmental Footprint (PEF), (EDA,2018).

3.9 Exclusions and delimitations

Contribution from all major impacting steps in the dairy product values chain is included in the assessment, in alignment with ISO 14067 (ISO, 2006). Four of the fifteen activities in Scope 3 GHGP standard (Greenhouse gas protocol, 2011) have been excluded in the assessment since they are of no relevance for the Arla Bio product segment:

10. Processing of sold product. Processing of sold product is not relevant since products are mainly consumed directly without processing at home or in food service.

13. Downstream leased assets. Contributions of Downstream leased assets have been left out since Arla have no downstream leased assets.

14. Franchise. Contributions of franchise have been left out since Arla have no franchise organisation.

15. Investments. Investments are not relevant for Arla since Arla Foods' is a cooperative and all excess of money returns to the farmers as an extra payment to them. In a GHGP assessment done 2019 on the Arla organic product segment for the Swedish market the contribution from investments (represented by pension funds to Arla employees) was shown to be very minor (U&We, 2019).

In the two Scope 3 categories below, the following delimitations were done:

11. Use of sold product. Contribution from the activity Use of sold product is represented by the refrigerator storage at home. No direct energy use is related to Arlas' products at household except refrigeration.

12. End of life for sold products. Contribution of the activity End of life for sold products is represented by waste treatment of packaging and wastewater treatment from household (dairy product waste at household in the Netherlands).

3.10 Cut offs used in the system

Dairy waste from dairy and from retail goes to production of biogas. A cut off has been used for this waste treatment i.e. the user of the biogas gets the contribution from the biogas production.

4 Inventory

4.1 Organic milk farms in the Netherlands

Information of all activities on farm correlated to milk production has been gathered by Arla from literature and provided RISE with data representing organic milk production in the Netherlands. RISE has then added emissions from peat soils using latest updated emission factors (see section 4.1.2). Emissions and uptakes in relation to land use are added by RISE (see section 4.1.3).

The main share of the milk to produce organic dairy products at the Dutch Arla dairy comes from suppliers, i.e. non-Arla owners. The number of organic Arla farmer owners (in 2020) are six in the Netherlands, while the rest of the organic farmers are suppliers (Eko Holland farmers).

The carbon footprint of milk at farm level used in the present study is an average for large organic farms in the Netherlands and is considered representative for the organic farms in the present study (based on e.g. milk yield). Arla is currently rolling out and making carbon assessments available for all owner farms in all countries (i.e. Denmark, Sweden, UK, Germany, Netherlands, Belgium and Luxembourg). Hence, no carbon footprint assessments have been done on the specific farms, but the plan is to conduct carbon assessments on all the organic farms, both owners and none owners, delivering milk to the Arla dairy site in the Netherlands during 2020/2021 using the carbon footprint farm tool developed by Arla (for more information on Arla farm tool see appendix **Fel! Hittar inte referenskälla.**). Thus, in the future Arla will have better and more detailed knowledge about the carbon footprint on the specific farms.

The carbon footprint of Dutch organic milk is 1.24 kg CO2e per kg FPCM[1] (WUR, 2020), which is slightly higher than the number of the average carbon footprint of Dutch milk, corresponding to 1.195 kg CO2 per kg FPCM (Doornewaard *et al.,* 2018). Both numbers are based on the same methodology, described in Doornewaard *et al.* (2018). Generally, it is concluded that there is no significant difference in carbon footprint[1] between organic and non-organic farms (Van Wagenberg *et al.,* 2017; Thomassen *et al.,* 2008). However, the slightly higher number is used in the present study to also have a conservative approach. The split on emissions are based on Doornewaard *et al.,* 2018. The carbon footprint includes all emissions both on farm and off farm: methane (CH4) emissions on farm level from enteric fermentation from animals (cows and heifers), CH4 and nitrous oxide (N2O) emissions related to manure handling and storage (CH4 and N2O), both direct and indirect N2O emissions from feed cultivation, and fossil CO2 emissions from diesel and other energy use at farm, also emission from production of imported feed, transportation and other inputs are included. The method used to calculate the carbon footprint (in WUR, 2020) is based on PEF (EDA, 2018) and IDF (2015) and the GWP including feedback loops are used (Doornewaard *et al.,* 2018). Emissions from potential land use change from imported feed are included (based on the FeedPrint database

[1] Excluding emissions from land use and land use change, carbon sequestration and peat soils.

(Vellinga, 2013)), while carbon sequestration is not included. The contribution from sequestration has been added separately and is included in the assessment.

Additional contribution from peat soil and land use are then added and taken into account in the assessment as described below, see 4.1.2 and 4.1.3

4.1.1 Contribution from land use change -NL

Feed to organic dairy production does generally not come from areas where deforestation has taken place. However, the numbers from WUR (2020) is based on FeedPrint (Vellinga 2013), which includes emissions from land use change. No further adjustments are done in relation to this in the present study.

4.1.2 Contribution from organic soils (peat soils)

The share of peat soils of the grassland and cropland in the Netherlands are 12.9% and 5.9% respectively according to the report on GHG emissions from the land use, land use change and forest sector (LULUCF) used in the national inventory report, NIR, for the Netherlands (Arets et al, 2016). The information on share of grassland and cropland in agriculture in the Netherland is given by a reference to be 7,0 % cropland and 93% grassland (including grassland in rotation), (WUR, 2020). Information on land use for organic farms in the Netherlands was provided by Arla (based on data from owners and suppliers), Table 4. An average organic dairy farm uses 81.53 ha, and the area of peat soil of this land is 1,4 ha of cropland (including grass land in rotation) and 7.4 ha of grassland. The choice of including the area of Grassland in rotation, into the Cropland category is that a rotation of crop or grass both needs a mechanical treatment of the soil which contributes to increased emissions.

Table 4. Land use at an average organic dairy farm in the Netherlands in 2019.

	Annual crops	**Grass, clover, lucerne in rotation**	**Permanent pastures (>5 years)**	**Fallow land**
Share of land (%)	9.18	15.01	57.34	0
Land use in assessment (%)	29.7*		70.3	0
Peat soil on an average organic dairy farm in NL (ha)	1.4		7.4	0

* Cropland includes grassland in rotation

To account for the carbon loss from peat soils, emission factors for carbon dioxide from the National Inventory Report (NIR) for the Netherlands (UNFCCC, 2020, representing 2018) has been used, Table 5.

Besides emission of carbon dioxide, peat soil also emits dinitrogen oxide (N2O) and methane (CH4). Latest emission factors from IPCC (IPCC, 2014) have been used to account for these emissions. The IPCC report specify emission factors for different type of land in different climate zones. The emission factors for the land category "Inland drained organic soils from Wetland, temperate" has been used, to represent the Netherlands. All emissions factors used to calculate the emissions from peat soils are summarised in Table 5, divided in contribution from cropland and grassland.

Table 5. Emission factors from peat land use in the Netherlands, for cropland and grassland. EF for CO2 from NL NIR (National Inventory Report) representing 2018 and EFs for N2O and CH4 from IPCC supplement.

	Cropland			Grassland		
	t CO2/ha yr	kg N2O-N /ha yr	kg CH4/ ha yr	t CO2/ha yr	kgN2O-N /ha yr	kg CH4/ ha yr
Emission factors relevant for NL	17.70	13.0	0	17.70	4.3	1.8

4.1.3 Contribution from sequestration - NL

Carbon sequestration is when CO_2 from the atmosphere is stored in soil and plants. Carbon sequestration can be both above ground (e.g. trees, hedges) and below ground (i.e. in the soil). In the present study, a conservative approach is taken and only carbon sequestration in soil is included.

According to a soil science expert (Kätterer, pers. Comm., 2020), there are currently too few studies to make it possible to distinguish between sequestration in different countries, so the carbon uptake/release figures from land use that we apply for Netherlands, may also be used for other markets. Hence, focus is on the different types of land used at Arla organic dairy farms in this assessment.

The effect of manure has not been accounted for as a separate sequestration impact. However, it is reasonable that this has already been taken into account in the carbon uptake/release-figures in Table 6.

Grassland is a natural part of dairy farms, for pasture, hay and silage production. Grasslands have proven to sequester carbon from the atmosphere to the soil, due to its extensive root system, were both fresh and decayed roots contribute to the soil carbon pool. The sequestration has been measured in several long-term field trials, and although the reported amount of carbon varies in the scientific literature, there is strong agreement that there is a net sequestration (Soussana et al., 2007,Bolinder et al., 2017). A few exceptions can be seen on soils with very high initial carbon content, were grassland as well as cropland loose carbon, however grassland in a much lesser extent than annual crops.

One important aspect that greatly affects the sequestration figures is which reference use of land has been considered. In some field trials, the sequestration in grassland is compared to a reference plot where annual crops are grown, in other experiments it is the actual sequestration in the same grassland plot measured each year.

In this study, the change in carbon soil in comparison to annual crops is chosen. The reasoning for this, is to consider what the land would be used for if Arla did not use it for organic dairy production. A likely scenario here is that the land would be used for annual crops, so we have chosen annual cropland as the "reference" land use. Our assumption is however that annual crops are in steady state i.e. there is no net carbon sequestration. This means that the grassland carbon sequestration is the same as the actual sequestered carbon in the grassland (the reference is zero).

Another way to consider sequestration is to actual measure greenhouse gas fluxes from land during a year. This was done in a study by Soussana et al. (2007) at nine grassland sites in Europe. By measuring CO2 fluxes, and other greenhouse gases, the average carbon storage can be calculated. The grasslands varied from being intensively to extensively managed. This study found a net carbon uptake in grasslands. In an intensive permanent grassland site located in the Netherlands, the carbon storage was estimated to 330 kg C/ha and year. This method avoids using annual crops as reference but there can be other restraints when using this type of atmospheric measurement techniques.

There are several important aspects that we have focused on in order to account for carbon sequestration; our reasoning for each type of land is summarised below used:

Annual crops in rotation. Since we have chosen this as our reference there is no net carbon soil change for this land type. Further, this is in line with figures reported for ley in literature, which is often compared to annual crops.

Annual crops, no rotation. There are no published studies on sequestration for this type of crops but Kätterer (pers. comm., 2020) argues that it is reasonable to expect similar uptake as for annual crops in rotation; we assumed this in the assessment.

Grass and clover/lucerne in rotation with annual crops There is great variation for this type of crop in literature. Soussana et al (2007) states 310 kg C, Kätterer et al (2013) states 500 kg C, and Bolinder 645 kg C. Kätterer is currently conducting a study which gives preliminary findings of 570 kg C per ha and year. Furthermore, according to Kätterer, it is reasonable to expect little difference between a 2-year crop and a multi-year crop, since in the 2-year crop there will be a large carbon supply when the crop is ploughed down into the field. Still, we have used the lower figure, in order to be conservative and not overestimate the sequestration.

Permanent grass (>5y). There is a study from north European countries that states 500 kg C per ha and year (Kätterer et al, 2013), with annual crops as reference state. We have used this value in the assessment.

Permanent grassland with high nature value. For this type of land there is only one study based on Swedish conditions, and the variations are expected to be large between different countries. However, due to lack of other data, we have used the value 30 kg C/hand year reported in this study (Karltun et al, 2010).

Fallow land. When the land is not used, i.e. fallow land, there will be a release of carbon. According to Bolinder et al (2017) a bare fallow land emits 530 kg C per ha and year. Kätterer (pers. Comm, 2020) estimates that fallow land for weed regulation in organic farming should release less, about half of this amount; 250 kg has been used in the assessment.

The first column in Table 6 shows the share of different types of land an average organic dairy farm in the Netherlands uses to produce the organic dairy products on the Dutch market. For each type of land, a carbon uptake (sequestration), or release, has been considered in the assessment, summarised in the second column in Table 6.

Table 6. Area (ha) of different types of land at an average organic dairy farms in the Netherlands in 2019, and factors used to account for sequestration for each type of land. A negative sequestration factor indicates carbon emission instead of sequestration.

	Land use in ha (% in brackets), Arla organic farms 2019	**Kg C /ha/yr**	**Reference**	**Comment**
Annual crops in rotation	9.18 (11.3%)	0	Steady state has been assumed.	Chosen as reference state so no net carbon soil change.
Annual crops no rotation	0	0	The same as for crops in rotation.	
Grass and clover/lucerne in rotation	15.01 (18.4%)	310	Soussana et al, 2007	Based on 2-year test for different types of ley in different European countries, both forage and pasture, and fertilised and non-fertilised.
Permanent grass (>5y)	57.37 (70.3%)	500	Kätterer et al, 2013	Compared to annual crop, average value from different north European countries.
Permanent grassland with high nature value	0	30	Karltun et al, 2010	Based on study from the Swedish board of agriculture, C/N method, valid for Swedish natural grassland, but no other study available, so used also for DK.
Fallow land	0	-250	Bolinder et al, 2017, Kätterer, pers. comm., 2020	Bolinder states 530 kg C for bare fallow land, and Kätterer estimates that fallow land with weed in organic farming should emit about half of this.

4.2 Organic milk farms in Germany

The input of German milk to the Arla Bio product segment in the Netherlands is minor and only used in the aseptic ambient milk product. The carbon footprint of milk at farm level is based on the carbon footprint assessment conducted by external advisers using the carbon assessment tool developed by Arla and provided to RISE. RISE has then adjusted these numbers to comply with ISO 14067 (i.e. using GWP factors including feedback loops) and added emissions from peat soils which is not included in the German carbon footprint (see section 4.1.2). Further on, emissions and uptakes in relation to land use is added by RISE (see section 4.1.3).

The data for carbon footprint of milk at farm level used in the present study are based on 100 assessments in Germany conducted in 2019 (based on the Arla carbon assessment tool), representing data for 2018. These assessments are both from organic and non-organic farms. There is no significant difference in the carbon footprint per kg milk of non-organic and organic (excluding impact from land use, land use change and peat soils at farm), as concluded in several studies (e.g. Van Wagenberg *et al.,* 2017; Thomassen *et al.,* 2008; Landquist et al., 2016 and Cederberg, 2011). Also, in the carbon assessments on Arla farms, no significant difference has been identified between organic and non-organic farms. Thus, the average carbon footprint of all farms was selected in the present study in order to have a larger sampling size. The carbon footprint number has also been verified with preliminary data from this years' (2020) carbon assessments of organic farms. The data from the carbon assessments conducted in 2020 is not finalised when conducting the present study, why these are not used, but a comparison of the preliminary results has been conducted with the carbon footprint of milk used in the present study, and it is concluded that the carbon footprint number used is reasonable.

The recalculated carbon footprint of German milk, IPCC 2013 including feedback loops, is 1.24 kg CO_2e per FPCM (without contribution of emissions from peat soils and land use). Contribution from peat soil and land use are then added and taken into account in the assessment as described below, in sections 4.2.2 and 4.2.3.

The contribution from the greenhouse gases CO2, N2O and CH4 for one kg of fat-and-protein corrected milk (FPCM) with a milk solid content of 12 % was provided by Arla and used as contribution from farm level. A 12 % content of milk solids in FPCM is compliant with recommendation by IDF (IDF, 2015). Contribution from peat soil and land use are then added and taken in to account in the assessment as described below, in sections 4.2.3 and 4.2.3

4.2.1 Contribution from land use change -DE

No contribution from land use change is included from feed production, in alignment with the system described for the feed to organic milk cows, see section 4.1.1.

4.2.2 Contribution from organic soils (peat soils) -DE

The share of peat soils in Germany is 5 % of the cropland and 10% of the grassland according to the German NIR report representing 2018 (UNFCCC, 2020) and verified by the consultants LCA 2.0 (developer of Arla farm tool). These are the shares used for the Arla organic dairy farms in Germany. Table 7 shows the area of peat soils at Arla farms in Germany in 2019, calculated by RISE.

Table 7. Peat land use in Arla organic dairy production in Germany 2019.

	Cropland (ha)*	**Grassland (ha)**
Peat land use	219	743

* Including grassland in rotation.

To account for the carbon loss from peat soils, emission factors based on the National Inventory Report for Germany (UNFCCC, 2020, representing 2018, table 363, p. 545) have been used. The emission factors of carbon from peat soils in crop- and grassland was selected, Table 8 below.

Besides emission of carbon (-dioxide), peat soil also emits dinitrogen oxide (N2O) and methane (CH4). Latest emission factors from IPCC (IPCC et. al., 2014) have been used to account for these emissions. The IPCC report specify emission factors for different type of land in different climate zones. The emission factors for the land category "Inland drained organic soils from Wetland, temperate" has been used, to represent Germany. The emission factor for N2O emission from grassland has been calculated by LCA2.0 (manuscript, 2020). No CH4 emissions from peat soil cropland occur according to IPCC. All emissions factors used to calculate the emissions from peat soils are summarised in Table 8, divided into cropland and grassland.

Table 8. Data used for emissions from peat land use at the farm stage, for cropland and grassland, based on German NIR (National Inventory Report) representing 2018.

	Cropland			Grassland		
	t CO2/ha yr	kg N2O-N/ha yr	kg CH4/ ha yr	t CO2/ha yr	kg N2O-N/ha yr	kg CH4/ ha yr
Emission factors relevant for Germany	29.7	10.7	0	27.1	2.7	1.8

4.2.3 Contribution from sequestration - DE

The same sequestration and emission factors for sequestration as used for the Netherlands are used also for Germany, see more information in section 4.1.3. The area of different types of land on Arla organic milk farms in Germany are given in Table 9.

Table 9. Area (ha) of different types of land at Arla dairy farms in Germany in 2019, and factors used to account for sequestration for each type of land. A negative sequestration factor indicates carbon emission instead of sequestration.

	Land use in ha (% in brackets), Arla organic farms 2019	**Kg C /ha/yr**	**Reference**	**Comment**
Annual crops in rotation	2 638 (22%)	0	Steady state has been assumed.	Chosen as reference state so no net carbon soil change.
Annual crops no rotation	20 (0%)	0	The same as for crops in rotation.	
Grass and clover/lucerne in rotation	1 999 (17 %)	310	Soussana et al, 2007	Based on 2-year test for different types of ley in different European countries, both forage and pasture, and fertilised and non-fertilised.
Permanent grass (>5y)	3 782 (31 %)	500	Kätterer et al, 2013	Compared to annual crop, average value from different north European countries.
Permanent grassland with high nature value	3 575 (30%)	30	Karltun et al, 2010	Based on study from the Swedish board of agriculture, C/N method, valid for Swedish natural grassland, but no other study available, so used also for DK.
Fallow land	65 (1%)	-250	Bolinder et al, 2017, Kättere r, pers. comm., 2020	Bolinder states 530 kg C for bare fallow land, and Kätterer estimates that fallow land with weed in organic farming should emit about half of this.

4.3 Organic milk farms in Sweden

Information about milk production at dairy farms in Sweden is provided by Arla and based on specific information from Arla dairy farms and collected by Arla Farm tool. For detailed information see report on Carbon footprint on Arla Foods' Øko brand of organic dairy products on the Danish market (done by RISE; Nilsson et. al., 2020). One of the products provided the Danish market was produced of Swedish milk and in Sweden. The carbon footprint of one kg Swedish FPC- milk at farm gate is given in Table 10.

4.4 Organic milk farms in Denmark

Information about milk production at dairy farms in Denmark is provided by Arla and based on specific information from Arla dairy farms and collected by Arla Farm tool. For detailed information see report on Carbon footprint on Arla Foods' Øko brand of organic dairy products on the Danish market (done by RISE; Nilsson et. al., 2020). The carbon footprint of one kg Danish FPC-milk at farm gate is given in Table 10.

4.5 Carbon footprint of milk at farmgate in the Netherlands, Germany, Sweden, and Denmark

Summary of contribution to carbon footprint of 1 kg FPC milk from farm level in the Netherlands, Germany, Sweden and Denmark is given in Table 10. The figures include some uncertainty in data especially regarding share of peat soils. Arla will perform on farm carbon assessments using the Arla climate check tool in all countries, work that will be finalised in beginning of 2021 (on owner farms) and then more precise information will be available, including share of peat soils.

Table 10. The carbon footprint of 1 kg FPC milk at farm level Netherlands, Germany, Sweden and Denmark, IPCC 2013 with feedback loops. Cells in green used in calculation

Country	Total **excl.** sequestration and peat soil (kg CO2e/ kg FPC milk)	Contribution from sequestration (kg CO2e/ kg FPC milk)	Contribution from peat soil (kg CO2e/ kg FPC milk)	Total **incl.** sequestration and peat soil (kg CO2e/ kg FPC milk)
Netherlands	1.24	-0.15	0.22	1.31
Germany	1.24	-0.18	0.55	1.61
Sweden	1.19	-0.20	0.12	1.11
Denmark	1.19	-0.11	0.40	1.48

4.6 Products included in Arla Bio product segment 2019

During 2019 Arla Bio product segment contained of 18 SKUs. Some products only differ in packaging size, but contain the same dairy content, still defined here as a separate product or SKU. The 18 products can be divided in 5 different product categories of consumer products, Table 11. Nine SKU's were delisted during 2019 (equals 3% of product volume sold in 2019) and are no longer part of the assortment in 2020 and have therefore been excluded in the assessment.

The total production volume of Arla Bio products 2019 was 33 613 tons.

Table 11. Number of Arla Bio products in each product group and production sites.

Product group	Number of products	Production site
Milk (fresh)	6	Nijkerk, NL
Yoghurt, natural and flavoured	4	Nijkerk, NL
Drink yoghurts	2	Nijkerk, NL
Buttermilk (fresh)	3	Nijkerk, NL
Milk (aseptic)& Fermented products	3	Pronsfeldt, DE, Jönköping, SE and Hobro, DK

4.7 Dairy sites

Nijkerk dairy in Netherlands is the main production site for the Arla Bio product segment, 94.0% of the products (in tonnes) are produced here. Jönköping in Sweden produce 4.6%, Pronsfeld in Germany produce 1.2 % and Hobro in Denmark 0.1% of the product volume. All products are distributed from the Arla dairy to retail except the intermediate transport of the German, Swedish and Danish products to Nijkerk before distribution. The electricity, energy and resource use at each dairy is allocated to the organic products according to the amount of MS correlated to the organic products in relation to the total amount of MS handled at the dairy.

4.7.1 Food losses at dairy

Specific information on food waste at the different dairy sites and different products was provided by Arla. This information was used in the calculation so that the amount of input milk from farm was increased with the waste percentage specific for each product and dairy.

4.7.2 Resource use at dairy

The total amount of MS in the final Arla Bio product segment is 3 230 tons. With the specific food waste percentage in the amount of milk (as MS) from farm needed to the final product volumes has been calculated and used as the contribution to the carbon footprint from farm level. The average food loss for the Arla Bio segment at the dairies is 0.95%. The total amount of MS in the in-put milk to Arla Bio product segment is 3 256 tons.

The use of energy and electricity resources to produce the Arla Bio products at the different dairies, are given in Table 12. The allocation factors for Arla Bio products specific for each dairy are used when allocating the energy use to the Arla Bio products.

Table 12. Energy use at the four dairies allocated to production of Arla Bio product segment, 2019.

2019	**Energy use at dairy, to Arla Bio product segment**	**Unit**
Natural gas	7922	MWh
Gas oil	1.7	
Biogas	0.6	MWh
Electricity	2509	MWh
District heat	6.1	MWh

The emission factors used to characterise the climate impact of using different energy types and electricity are given in Table 24 in Appendix.

4.7.3 Waste and HCFC emission generated at dairy

Contribution of incineration of waste and hazardous waste included in the assessment together with contribution of waste water treatment (regarding COD content in wastewater to external treatment) and emission of refrigerants, Table 13.

Table 13. Waste and HCFC emission at the four dairies allocated to production of Arla Bio product segment.

2019	**Waste and HCFC emission at dairy from Arla Bio product segment**	**Unit**
Waste for incineration	23.1	ton
Hazardous waste for incineration	0.06	ton
COD in wastewater to external treatment	22.1	ton
Emission of cooling media (HCFC-gas)	0.22	kg

The emission factors used to characterise the climate impact of waste treatment and leakage of cooling medium are given in

Table 25 and Table 26 in Appendix.

4.7.4 Ingredients in products

Seven of the eighteen products of the Arla Bio products contain only milk raw material, and the other eleven products contain also other non-dairy based ingredients e.g. flavoured yoghurts. In the unflavoured yoghurt and buttermilk products only, bacteria culture is added. The last three products contain organic fruit preparations.

Ingredients used in the products are listed in Table 14. Climate impact from the non-dairy ingredients are taken from the RISE Climate database for food, version 1.6, from the Ecoinvent database 3.5 (Ecoinvent Centre, 2020) and from industry data.

Table 14. Ingredients used in the products.

Ingredients	Reference to climate impact information
Enzyme	Ecoinvent database 3.5
Yoghurt bacteria culture	Industry data
Buttermilk bacteria culture	Industry data
Cane sugar	RISE Climate database for food 1.6
Raspberry	RISE Climate database for food 1.6
Maize starch	RISE Climate database for food 1.6
Natural extract	No data available. Only 0.002 % of product volume, therefore decided to exclude.
Lemon juice	Together with vanilla 0.01 % of product volume, therefore decided to exclude.
Vanilla	Together with lemon juice 0.01 % of product volume, therefore decided to exclude.
Black currant/Blackberry juice concentrate	Only 0.002 % of product volume, therefore decided to exclude.

Information was provided by Arla on the origin of the ingredients and RISE has modelled a transport route from the capital of origin country to Nijkerk, NL and included the contribution from transport in the assessment. Even though three of the products are produced elsewhere the transport distance to Nijkerk was used also for ingredients in these products. This assumption is considered to have minor impact since the additional ingredients are bacteria culture and lactate enzyme, together only 0,91% of product volume. The distances for truck transports have been taken from Google map and the sea distances from SeaDistance.org. When several origin countries are given for an ingredient, the transport contribution is modelled with equal parts taken from each of the country of origin. All truck transports are modelled with a Rigid truck 14-20 t, Diesel B7EU, Euro5, load factor 90% (NTM, 2020) and the sea transports are modelled with a Container ship, dwt 100000, load factor 90% (NTM, 2020). Contribution from capital goods and infrastructure (production and maintenance of truck and roads) are included for transport and taken from the Ecoinvent database (Ecoinvent Centre, 2020).

Information on the content of the organic fruit preparations was provided by Arla. The major part of the ingredients in the fruit preparation was matched with a carbon footprint from RISE climate database for food or Ecoinvent database and was included in the assessment but some of the minor ingredients, not found in the databases were left out. The content of the left-out ingredients in the products were low, 0.2 % of the product weight. In relation to the total Arla Bio product volume the left-out ingredients constitute of 0.02 % of segment product volume. Therefore an assumption that the impact from the ingredients also are of very minor importance is done. Still to compensate for the missing ingredient climate impact information, the content of the "known" ingredients in the product recipe was increased so that 100 % of the recipe of a product was covered. No contribution from transport of the left-out ingredients was included.

The content of non-dairy based ingredients never exceeded 12 % of a product volume. The total amount of all added non-dairy based ingredients was 575 tonnes (1,7 % of total Arla Bio product volume). The total impact of the additional ingredients to carbon footprint of the Arla Bio product segment was 295tons CO2e.

4.7.5 Capital goods at dairies

Regarding capital goods, the contribution from filling machines, forklifts as well as the buildings were included, Table 15. Information from the Nijkerk dairy was used and allocated to total MS content in production volume of the ArlaBio product segment. Capital goods in other parts of the chain have not been considered (except for transports).

The contribution was modelled based on provided numbers of machines and forklifts at Nijkerk and building areas of the Arla Nijkerk site. Then the data for climate impact contribution used in the calculation was taken from databases and literature to best match the systems. This results in larger uncertainties in the assessment of contribution from capital goods than from other parts of the assessment. Contribution from capital goods is however known to have a minor contribution to the climate impact of a product or product segment (U&We,2019). Below follows information on assumptions and models used.

For **filling machines,** we have used the carbon footprint data of two environmental product declarations (EPD) from TetraPak of filling machines as the basis representing a filling machine in the dairy sector. The EPDs give the impact from the manufacturing stage related to the filling of 1000 litres of packed liquid foods, based on 1-litre packs. The life span of the filling machines in the EDPs is 30 000 hours of active use. Arla estimated a life span of their filling machines to 20 years. In relation to the life span Tetra Pak used this would correlate to 1500 hours of use per year at Arla so probably the contribution of the filling machines is not underestimated. Then calculating the resulting total impact of Arlas filling machines can be done in two ways. The carbon footprint from the EPDs (using an average the two EPD figures) can be multiplied with either the volume of Arla organic products or by multiplying with the number of Arla products (then assuming every filling of product is the same for all products independently of product type or size). The litre volume of products gives the highest figure and is thereby used to be conservative. For more information see Appendix 8.2.1.

For **forklifts,** information on carbon footprint from the manufacture of two tractors have been used as a basis, due to lack of data on forklift production, see Table 28 in Appendix. Production of tractors have probably a higher climate impact than production of forklifts but used here as a conservative choice to represent forklifts. A six-year life span of the forklifts was given by Arla. Arla has supplied information about the number of forklifts used at each dairy and Since these forklifts are used for the total production at the dairies, allocation based on MS content in the organic products is used to allocate the share to these products. For more information see Appendix 8.2.2

For **buildings**, we have used information about the carbon footprint from the production of a block of flats, as a proxy for data on production of a dairy/storage/office building. A 60-year life span of the buildings has been assumed. Arla has supplied information about the area of buildings they use. As for forklifts, these buildings are used for the total production at the dairies, hence, allocation based on MS content in the organic products is used to allocate the share to these products. For more information see Appenix 8.2.3.

Table 15. Contribution from capital goods, number in green cell used in assessment.

	Filling machines	Forklifts	Buildings	Total contribution from capital goods
t CO2e	4.17	3.23	21.08	28.48

4.8 Shelf life of products at dairy, retail and consumer

Information on shelf life of the products was provided by Arla. Shelf life is defined as the date of the production to best-before-date printed on the packaging. This is a conservative choice since products possibly will be consumed before the last day of best-before-date. The share of shelf life (storage) allocated to dairy was given by Arla and RISE divided the remaining days equally between storage at retail and storage at the consumer.

All products except the UHT processed product need refrigerated storage. UHT needs cold storage only after opening the packaging. The product aseptic ambient milk has a long shelf life and an assumption that this product is stored in ambient temperature in retail and only four days in refrigerator in household was done (only kept chilled when opened).

4.9 Packaging

All information regarding packaging (material types and weights) for both primary and secondary packaging for all products was included and information was provided by Arla. The climate impact of the packaging was calculated either by Sphera (former Thinkstep) or by Arla using the GaBi Packaging Calculator, which is a GaBi Envision tool developed by Sphera and designed to determine the environmental impacts of product packaging. The tool is based on a fully parameterised LCA model and the methodology is verified by an independent 3rd party LCA expert. Contribution from production of packaging material, transport of packaging material, conversion of material into packaging and waste treatment at end of life of packaging are included. Since a conservative approach is applied in the assessment emissions from the part of packaging that goes to incineration are included while the energy produced at incineration is excluded. The part of the packaging that goes to recycling is also excluded. This cut-off gives the advantages of recycled material to the user of the recycled material. The characterized CO2e contribution is given divided in CO2e from fossil, biogenic and land use change sources. Contribution of land use change is from cultivation of the biobased raw material.

Seven different primary packaging was used for the Arla Bio products, Table 16.

Table 16. Primary packaging used for the Arla Bio products.

Type of primary packaging	Packaging size (kg)
Beverage carton (brown board) with small cap 250 ml	0.25
Beverage carton (brown board) with small cap 500 ml	0.5
Beverage carton (brown board) with small cap 1 litre (for drinking dairy)	1.0
Beverage carton (brown board) with big cap 1 litre (for thick dairy products)	1.0
Beverage carton (brown board) with small cap 1.5 litre	1.5
Beverage carton (brown board) for ambient product with small cap 1 litre	1.0
Plastic cup with paper sleeve 450 ml	0.45
Beverage carton (brown board) with small cap 1 litre	1.0

The secondary packaging used for the products is carton (single use). Information was provided by Arla on amount of carton used per primary packaging.

4.10 Transports

4.10.1 Transports within Arla

The transport of milk and dairy products within Arla can be divided in inbound, intermediate and distribution transports, Figure 3, The arrows in the figure indicate transports. The information on distances, type of vehicle, type of fuel and load factors for all transports were provided by Arla.

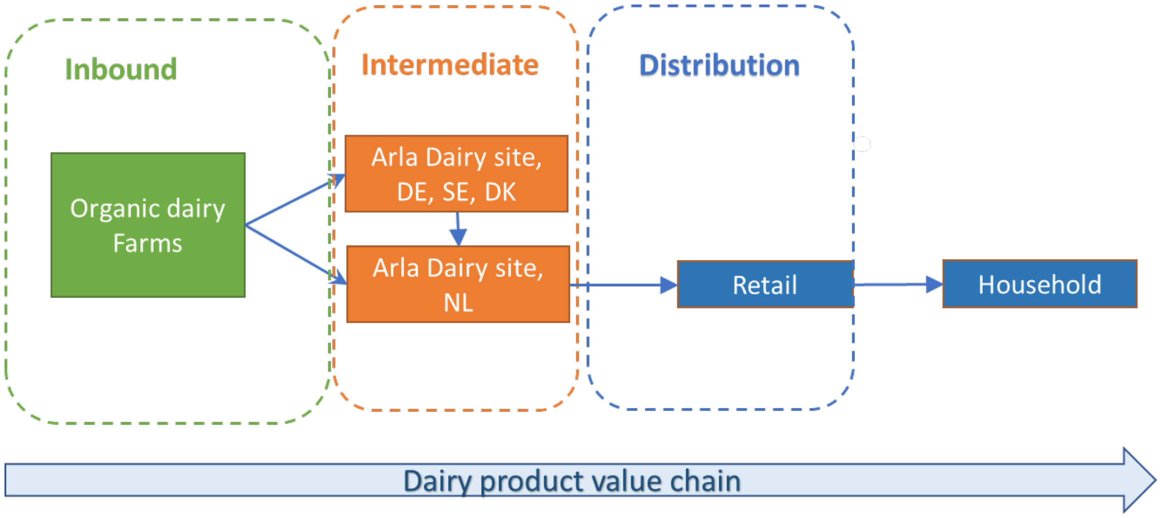

Figure 3. Simplified transport flow of milk products from farm to household. Arrows indicate transports.

Specific data on the average fuel use was used to calculate the emissions from collecting the milk at farm, i.e. the **inbound** transport. 100% of the inbound transports are run by external transport services. The contribution from the inbound (milk collection) transport is allocated regarding the content of MS in final product.

The only **intermediate** transport relevant for the Arla Bio product segment is the transport from the German, Swedish and Danish dairies for the products produced there to the Dutch dairy before distribution. Arla provided information on the intermediate transport route.

The **distributio**n of dairy products to retail is typically done directly from the dairy. Average distance from dairy to retail was provided by Arla. The intermediate and distribution transports are to 100% run by external transport services.

The truck type used in the calculations is a rigid truck 14-20 t, Euro5, Diesel B7EU with a 90% load factor (NTM, 2020). The intermediate and distribution transports are refrigerated transports and therefore use more fuel than ambient transports. A refrigeration factor of 1,15 was used for these transports. The inbound milk collection transports are not refrigerated. Capital goods and infrastructure (road and truck production and maintenance) are included (Ecoinvent centre, 2020).

The last transport along dairy product value chain is the customer transport from retail to household. For customer transport see section 4.12.1.

4.10.2 Transports of non-dairy based ingredients

The transports of all additional non-dairy based ingredients to the production sites were modelled by RISE using the information of origin (country) of the ingredients given by Arla. The specific transport distances were defined as from the capital of the origin country to the dairy in Netherland. The land-based distances were estimated using Google maps and sea distances were estimated by sea-distances.org.

The truck type used in the calculations is a rigid truck 14-20 t, Euro5, Diesel B7EU with a 90% load factor and the ship used was a container ship, 100 000 dwt, with a 90% load factor (NTM, 2020). Capital goods and infrastructure (road and truck production and maintenance as well as production and maintenance of ship) are included (Ecoinvent centre, 2020).

4.11 Retail

The energy consumption at retail was taken from national statistics on energy use at stores and retail (CBS statline, 2020). The energy consumption (natural gas and electricity) is given per square meter and year for shops, wholesales, department stores etc. The retail with cooling was selected to represent the retail-step for dairy products. The statistical report gives specified energy consumption data. The energy use used in assessment is shown in Table 17. The energy use represents the whole store facility, and in order to not underestimate the energy use from cooling a separate cooling contribution was added. Electricity consumption of retail refrigeration was taken from literature (Axell, 2001).

From the information of energy use per square meter and year RISE made the following assumption to transfer energy use to represent per kg instead of per m^2. Starting from the most common packaging type for 1 litre milk, (size: 7*7*23 cm) one square meter give space to 204 one litre packaging and a cubic meter may store 887 litres. Goods at retail is displayed from floor up to 1.8 meter in height, results in that one m^2 holds 1.8*887 ~1600kg of product. The products are stored with some space in between assuming 65% of the volume is product and 35% is air. Then the actual weight per m2 is 1600*0.65 ~1000kg.

Dutch average electricity mix has been used in the assessment of climate impact from storage at retail.

From this information the contribution of energy use per kg and day at retail was calculated, Table 17.

Table 17. Energy use in the food retail sector in the Netherlands (CBS, 2020). The electricity for cooling was taken from Axell, 2001.

Energy source	Natural gas (m3/m2*y)	Electricity (kWh/m2*y)	Electricity (Cooling) (kWh/m2*y)
Retail with cooling	2.71E-05	6.06E-04	8.6E-03

The dairy waste at retail is reported to be 0.5%, representing retails in the Western Europe (FAO,2012). The waste treatment of dairy waste from retail in Netherlands goes to production of biogas. The contribution of waste treatment of the dairy content is therefore left out (cut off from assessment, burden goes to user of the biogas). Waste treatment of packaging is included under packaging.

4.12 Consumer

The contribution from the consumer phase included in the carbon footprint of the Arla Bio dairy products are:

- the transport of produce from retail to home
- the refrigerated storage of product at home
- the treatment of wastewater from the dairy products wasted in the sink.

Waste handling of packaging is included in the section of packaging, 4.9

4.12.1 Home transport

According to a travel habit investigation done by CLO (CLO, 2019) the average distance one-way to the nearest retail is 0.9 km in 2015. Another report shows that the share of using the car when going to retail increases with the distance to retail and with a distance of 0.9 km 35 % takes the car (conservative choice from figure 24 in Veenstra, 2007). An assumption that 5 kg is the average amount of food bought at every retail trip is done by RISE. The emission factors used for the personal car is taken from NTM (NTM, 2020); Car, Passenger transport, Petrol E5, Euro 5. Capital goods (road and car, production and maintenance) is included (Ecoinvent centre 2020).

The contribution in kg CO2e per kg purchased food is seen in Table 18.

Table 18. Climate contribution from a kg of purchased food by car in the Netherlands.

Average distance to nearest retail , one-way (km)	Share of transports to retail done by car (%)	**Emission allocated to 1 kg of purchased food by car (kg CO2e)**
0.9	35	**0.0252**

The total contribution from transport of Arla Bio dairy product from retail to household is 845 ton CO2e.

4.12.2 Refrigerated storage

Energy consumption data for consumer refrigerator was taken from the site SparEnergy.dk (Spar.Energy.dk, 2020). A 200-litre fridge size was chosen, with an electricity consumption of 196 kWh per year (average between energy class A and class B fridges, 200 l) to represent the consumer cold storage of Arla Bio products. A 25% average load factor of fridge was used as a conservative approach. Dutch average electricity mix have been used in the assessment of climate impact from refrigeration storage at household.

The contribution from cold storage of one litre (kg) product one day is 0.0058 kg CO2e.

The total contribution from cold storage of Arla Bio dairy product in household is 1603 ton CO2e.

4.12.3 Wastewater treatment

No information of dairy food loss at consumer in the Netherlands was found and limited information was found in literature representing dairy food loss in other countries. According to a report about global food loss (FAO, 2012) the food loss of dairy products in Western Europe at consumer is 7 %, which is used in the assessment. Almost all products in this report is liquid dairy products and thereby wasted in the sink, washed out with water. We assume that 1 litre of water is used to every litre of dairy product and add the contribution of wastewater treatment from households. The Ecoinvent database process "Wastewater, from residence {CH}| treatment of capacity 1.1E10l/year | Cut-off," is used but modified so that Dutch electricity, instead of Swiss, is used. (Ecoinvent v 3.5, 2019).

The contribution from one litre wastewater treatment from residence in the Netherlands is 7.36E-05 kg CO2e.

The total contribution from wastewater treatment connected to Arla Bio dairy product wastewater handling in household is 2.5 ton CO2e.

4.13 Business travel

Contribution from all major sources of climate impact shall be included in the assessment according to the ISO standard 14 067 (ISO, 2018). Air flights stands for the most important contribution and therefore the air business trips Arla personnel did during 2019 was taken into account. The total mileage and corresponding GHG emissions were provided by the travel agent that Arla uses. The travel agency have used emission factors for plane travels from Defra and calculated emission factors specific for Arla flights representing different mileage trips (short, medium and long,) including radiation factors for certain flights and also distinguishes between cabin type (economy, business, other). The information provided by the travel agency represents air flights for the entire Arla corporate group global, and an allocation based on economic revenue has been used to derive the share of greenhouse gases for the Arla Bio segment. The total GHG emissions caused by Arla air business trips allocated to the Arla Bio product segment is 1.3 t CO2e.

Contribution from company cars and business trips made with other modes of transport than air travel has not been taken into account. In a previous assessment of the organic segment of Arla products on the Swedish market, these had only a minor impact (less than 0.02%), therefore they have been excluded here.

4.14 Commuting

For commuting we have taken into account the travels that Arla personnel does by car and commuting to Nijkerk dairy was assumed to represent also commuting at the three other dairies. All other modes of transport have been assumed to have minor contribution to the GHG emissions, i.e. from using public transport and/or a bicycle. The Nijkerk commuting has been correlated to the total product volume of Arla Bio segment. Table 19 shows the data used for people commuting by car at Nijkerk dairy. The number of Arla personnel that works with the organic segment on the Dutch market, was based on the share of the economic revenue of the Arla Bio products out of the total revenue of Arla. The GHG emissions from the car is based on data from NTM (NTM, 2020) for "car, passenger transport, petrol E5, euro 5". Capital goods (road and car production and maintenance) is included (Ecoinvent centre 2020).

Table 19. Data on commuting and the corresponding GHG emissions

Commuting data	**Value**	**Unit**	**Source**
Average commuting distance	21.7	km	Based on https://www.dst.dk/en/Statistik/emner/arbejde-indkomst-og-formue/pendling Region: all Denmark, Time: 2018 (end November), but verified by Arla NL to represent also commuting at Nijkerk
Multiplied by 2 to account for trip to and from work	43.4	km	
Parts of all travel to workplace by car	75	%	According to Arla NL 75% of the employee commute by car to Nijkerk. (Similar but slightly higher than found for the danish commuter; Transportvaneundersøgelsens årsrapport for Danmark 2019, table 23b, https://www.cta.man.dtu.dk/transportvaneundersoegelsen/udgivelser)
Working days 2019 in Netherlands	220	days/ year	Assumption based on: fem day working week, five weeks of holiday a year, and 7 national holiday days that occur on a weekday.
Total distance travelled by car for commuting allocated to Arla Organic, per year	2 506 350	km/ year	Calculated by RISE
GHGs for commuting allocated to Arla organic dairy segment in 2019	500	t CO2e	Calculated by RISE
GHGs for commuting allocated to Arla organic per kg	0.0147	kg CO2e/ kg	Calculated by RISE

5 Results

The carbon footprint of the Arla Bio brand in the Netherland for the period 1st of January to 31st of December 2019 is 44 920 tonnes CO2e. Table 20 shows the results divided by scope for both location- and market-based according to GHG Protocol Scope 2 Guidance.

Table 20 Results per scope and approach, to be in line with Greenhouse Gas Protocol Scope 2 Guidance

Scope	**Method**	**Climate impact (tCO2e)**
Scope 1		1 455
Scope 2	Location based	1 181
	Market based	1 406
Scope 3		46 119
Out-of-scope		47
Removals		-4 059
Total (market based)		44 920

The largest share of the climate impact comes from Scope 3 activities, where the milk raw material is included. Market-based is taking into account market-based instruments for electricity (e.g. certificates of origin) that can prove you have purchased electricity with a lower carbon footprint than average. Location-based is the reference scenario and used if there is no such market for instruments. In the results for Arla Bio product segment below, we have chosen to report the results with market-based electricity, since Arla acts in the Netherlands, Germany, Sweden and Denmark where there are markets for electricity instruments. Since the dairies do not have certificates for green electricity in 2019, residual electricity mix was used, resulting in higher emissions, Table 20.

The contribution to climate impact from specific GHG emissions is given in Table 21. Methane, from cow enteric fermentation, is the major dominating GHG-emission to the carbon footprint, 38.0% of total climate impact, Table 21. The sequestration (the removal) has minor impact, but still removes 4 059 tonnes of CO2e during 2019. The net biogenic emission is 1 630 tonnes indicating the contribution from peat soil being 1.4 times higher than the removal due to sequestration.

Table 21 Total greenhouse gas emissions and climate impact for Arla Bio product segment divided in specific greenhouse gasses. "Unspecified" is the climate impact for processes where information on emissions distributed per gas is missing. CO2f = fossil carbon dioxide and CO2b = biogenic carbon dioxide, defined as in ISO 14067.

GHG	Emissions (ton)	Removals (ton)	Climate impact (tCO2e)	Relative contribution (%)
CO2 fossil	11 027		11 027	24.5%
CO2 biogenic*	5 689	-4 059	1 630	3.6%
CH4	502		17 059	38.0%
N2O	31		9 317	20.7%
Unspecified			5 887	13.1%
SUM			44 920	100%

* Contribution from carbon sequestration and peat soils. Contribution from these sources are in line with the reporting according to the GHGP.

The climate impact contribution from the activities on the farm (farm and land use) dominates the contribution to carbon footprint of the Arla Bio dairy product segment (77.2%), Table 22 and Figure 4. The contribution from dairies and product packaging together make up 11.3 % of the total carbon footprint are together the second largest contributor to climate impact. The consumer contribution (transport from retail, refrigeration storage and wastewater treatment) stands for 5.5 %. Retail stand for 3.7 % and all transports (except consumer transport) contributes with 1.7%.

Table 22 Climate impact divided on the different life cycle stages for Arla Bio product segment,

Life cycle stage	Climate impact (tCO2e)	Relative contribution (%)
FARM	32 898	73,2%
*Biogenic from land use (+)	5 851	13,0%
*Removals (-)	-4 059	-9,0%
FARM incl. Biogenic (+) & Removals (-)	34 690	77,2%
DAIRY SITES	3 269	7,3%
ADDITIONAL Ingredients	295	0,7%
TRANSPORT - Inbound	283	0,6%
TRANSPORT- Distribution+intermediate	481	1,1%
PACKAGING - Primary	1 025	2,3%
PACKAGING - Secondary	254	0,6%
Capital Goods	28	0,1%
Business Travel	1	0,0%
Commuting	500	1,1%
RETAIL	1 642	3,7%
CONSUMER- transport	845	1,9%
CONSUMER- energy	1 603	3,6%
CONSUMER- waste treatment	2	0,0%
TOTAL	**44 920**	**100%**

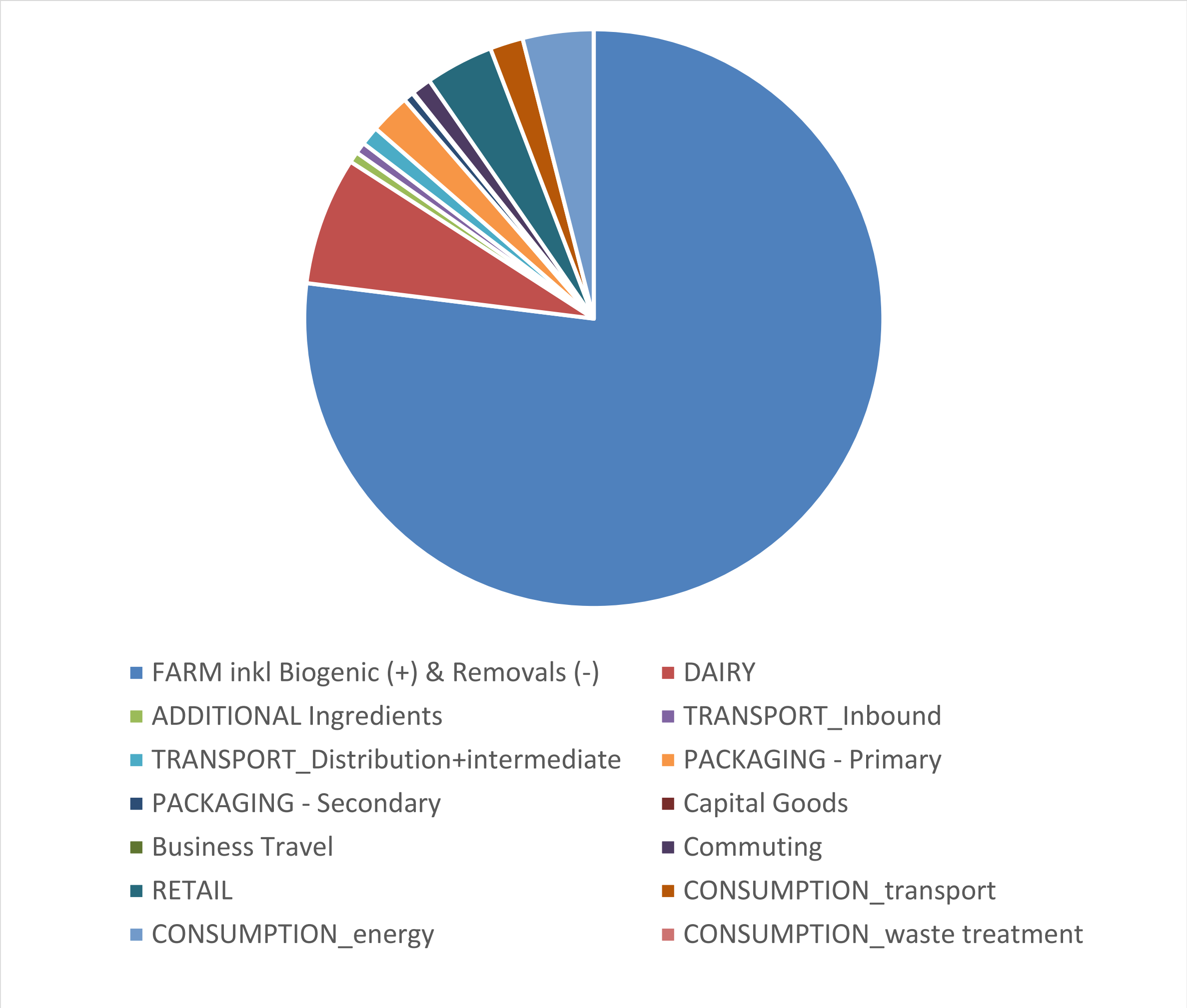

Figure 4. Distribution of CO2e of Arla BIO product segment in NL 2019

The average product carbon footprint for milk (fresh) is 1.38 kg CO2e/kg, Table 23. The average product carbon footprint for all products is 1.34 kgCO2e/kg.

Table 23. Product volumes, in tonnes, and corresponding climate impact of the nine product categories in the Arla bio product segment. Average carbon footprint of each product category is given in the column to the right.

Dairy product category	Average CF per category. (kg CO2e/kg product)
Drink Yoghurts	0.98
Milk (fresh)	1.38
Yoghurt, natural and flavoured	1.30
Buttermilk (fresh)	1.10
Milk (ambient)& Fermented products	1.52
Average	1.34

6 Discussion

The absolute major contribution to climate impact of the Arla Bio product segment comes from farm activities. The inventory data for the farm systems are provided by Arla. The data for Dutch milk are most recent average data for organic dairy farms (WUR, 2020) and data on milk from the other countries from Arla carbon assessments. These data are considered to be of good quality. The contribution both from sequestration and land use (emission from peat soils) are based on best available methods provided by scientific organisations and researchers in the field, but still there are uncertainties in the methods that probably would influence the result. How to include these biogenic carbon contributions in carbon footprint assessments are still not commonly agreed up on. The GHGP has an ongoing project, aiming for an agreed consensus methodology how to include biogenic carbon in carbon footprint assessment. This work is said to be finish in 2021. Arla foods has also together with a number of companies and organisations started a projects to develop a method and seek consensus on how to quantify carbon sequestration for dairy and a first version of the guidelines has been out for public consultation during fall of 2020. In the present assessment of the Arla Bio product segment the contribution of biogenic carbon is included according to the methods described in the report.

The inventory data used for dairy activities and packaging are specific data from each of the Arla dairies and each of the packaging. The quality of the data is also considered good.

For contribution from downstream activities (retailer, consumer) some assumptions have been made based on information from reports and statistics. In every assumption we have had a conservative approach so that the impact from that activity is not underestimated.

The average distance from retail to household and share of this transport done by car used in the assessment are taken from references valid for the Netherlands (Veenstra, 2008, CLO, 2016, Crow 2020). The average overall one-way distance is 0.9 km but reported shorter for densely populated city areas and longer for areas outside of cities. Since most people live in the cities the average distance of 0.9 km is a conservative choice of distance.

The assumption that the consumer brings home 5 kg of food on average every retail trip by car is off course also influencing the final result. In case only 1 kg (then a kg of Arla Bio product) should be bought at a time, the contribution would be five times higher from this transport. Still it is reasonable to believe that more than one kilo of food is bought when the consumer takes the car for purchase.

Since production of average Dutch electricity has a high share of fossil primary energy sources the contributions to carbon footprint from the retailer and consumer storage are relative high compared to same contributions in the assessment of Danish organic dairy segment (RISE, 2020).

Even though some estimations have been made in the assessment a major part of data used are specific for Arla Bio products and production system. This together with the conservative approach RISE have used in assumptions and models provide a result well representative for the climate impact of the Arla Bio product segment 2019.

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8 Appendix

8.1 Emission factors

Table 24. Emission factors for energy, with references

	Scope 1				Scope 2	Scope 3	"Outside of Scopes"	Total of all Scopes		
Energy Source	**CO2e (kg)**	**CO2 (kg)**	**CH4 (g)**	**N2O (g)**	**CO2e (kg)**	**CO2e (kg)**	**CO2e (kg)**	**CO2 (CO2e)**	**Unit**	**Source**
Natural gas	183,9	183,5	7,1	0,3		23,9		207,8	mass unit/ MWh	DEFRA,(2019)
Fuel oil	267,8	266,8	10,3	2,2		50,8		318,6	mass unit/ MWh	DEFRA,(2019)
Gas oil	256,8	253,6	7,9	9,7		58,9		315,6	mass unit/ MWh	DEFRA,(2019)
Petrol (average biofuel blend)	233,7	232,4	21,2	2,2		63,2		296,9	mass unit/ MWh	DEFRA,(2019)
Biogas	0,2					24,1	199,0	24,3	mass unit/ MWh	DEFRA,(2019)
Biomass e.g. woodchips	15,6					7,9	353,6	23,6	mass unit/ MWh	DEFRA,(2019)
District heating based on renewable sources					8,0			8,0	mass unit/ MWh	Ecoinvent 3.5
District heating					151,0			151,0	mass unit/ MWh	Ecoinvent 3.6

Table 25. Emission factors and electricity use for waste treatment

Waste management	EF CO2e	Unit	Reference
1 kg Hazardous waste, for incineration {Europe without Switzerland}| treatment of hazardous waste, hazardous waste incineration | Cut-off, S (of project Ecoinvent 3 - allocation, cut-off by classification - system)	2.52	kg CO2e/ kg waste	Ecoinvent 3.6
1 kg Municipal solid waste {NL| treatment of, incineration | Cut-off, S (of project Ecoinvent 3 - allocation, cut-off by classification - system)	0.52	kg CO2e/ kg waste	Ecoinvent 3.6
COD to external treatment	0.55	kWh/ kg COD	EnviDan, (2014)

Table 26. Emission factor for cooling median

Cooling media	GWP100 (kg CO2/kg media)	Reference
R404A	3 922	Swedish EPA, https://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/kemikalier/koldmedieforteckning-augusti-2019.pdf (2019)
R407A	1774	Swedish EPA, https://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/kemikalier/koldmedieforteckning-augusti-2019.pdf (2019)
R410A	2 088	Swedish EPA, https://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/kemikalier/koldmedieforteckning-augusti-2019.pdf (2019)
R452A	2 140	Swedish EPA, https://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/kemikalier/koldmedieforteckning-augusti-2019.pdf (2019)
R134a	1430	Swedish EPA, https://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/kemikalier/koldmedieforteckning-augusti-2019.pdf (2019)

8.2 Contribution from capital goods

8.2.1 Filling machines

Table 27. GHG emissions from production of filling machines , based on 30 000 hour life span.

Filling machine data	**Filling machine 1**	**Filling machine 2**	**Average of the two machines**
Machine	Tetra Pak A3/Speed filling machine	Tetra Pak A3/Speed filling machine	
Source	EPD: Tetra Pak A3/Speed, filling machine, Environmental Product Declaration Rev.0, 20-10-2005, Certification S-P-00100 (page 6)	EPD: Tetra Pak A3/Flex, filling machine, Environmental Product Declaration R ev.0, 20-10-2005 Certification S -P-00101	
Comment	The EPDs are quite old, but discussed with TetraPak who states that the environmental burden from machine use has most likely decreased since 2005, so it is a conservative measure to use these figures.		
Functional unit (FU)	1,000 packed litres of liquid food provided by Tetra Pak A3/Speed during a standard production cycle.	1,000 packed litres of liquid food provided by Tetra Pak A3/Flex during a standard production cycle.	
g CO2e/FU, manufacturing stage	67.72	190.76	129.24
kg CO2e/packed litre	0.00006772	0.00019076	0.00012924
GHG from filling machines, all products, based on litres (t CO2e)			4.17

8.2.2 Contribution from forklifts

Table 28. GHG emissions from forklifts used in assessment

Fork lift data	Tractor 1	Tractor 2	Average of the two tractors
Type of vehicle	Tractor	Tractor	
Source	Ecoinvent 2 database: "Tractor, production /CH/ I S"	Agri-footprint database: "Tractor, production, at plant /RER economic"	
Comment	Includes production, maintenance, repair and disposal. No data for production of forklift was found, we use a tractor as proxy, and assume a forklift weighs ca 2000 kg.	Includes production. No data for production of forklift was found, we use a tractor as proxy, and assume a forklift weighs ca 2000 kg. The tractor in agri-footprint weight about 5000 kg.	
Functional unit (FU) in database process	kg tractor	one tractor	
kg CO2e/FU	6.13	39 200	
kg CO2e/machine, manufacturing stage	12 260	15 680	13 970
kg CO2e/machine&year, assuming 6 year life span	1226	1568	2328

8.2.3 Contribution from buildings

Table 29. GHG emissions used in assessment for establishment of buildings

Building data	
Type of building	House of flats
Source	Larsson et al (2016)
Comment	Includes production of materials, transport to building site, building including preparation of the ground. The data is for a building of flats, and not a dairy building, but has been used due to lack of other data.
Functional unit (FU) in data source	m2
kg CO2e/FU	289
kg CO2e/m2&year, assuming 60 year life span	4.8

8.3 Emission factors for transports

		SCOPE 1 (tank to wheel)						SCOPE 3 (well to tank)						TOTAL							
Type pf transport	**Type of truck**	CO_2 total [kg]	CO_2 fossil [kg]	CO_2 biogen [kg]	CO_2e [kg]	CH_4 [g]	N_2O [g]	CO_2 total [kg]	CO_2 fossil [kg]	CO_2 biogen [kg]	CO_2e [kg]	CH_4 [g]	N_2O [g]	CO_2 total [kg]	CO_2 fossil [kg]	CO_2 biogen [kg]	CO_2e [kg]	CH_4 [g]	N_2O [g]	**Unit**	**Source**
Inbound and Additional ingredients	Rigid truck 14-20 t, Diesel B7EU, Euro5, load factor 90%	0,0601	0,0561	0,0040	0,0571	0,0000	0,0034	0,0063	0,0063	0,0000	0,0088	0,0597	0,0016	0,0664	0,0624	0,0040	0,0659	0,0597	0,0049	per tkm	NTM (2020)
Intermediate and Distrbution	Rigid truck 14-20 t, Diesel B7EU, Euro5, load factor 90% + cooling	0,0692	0,0645	0,0046	0,0657	0,0001	0,0039	0,0072	0,0072	0,0000	0,0101	0,0686	0,0018	0,0764	0,0717	0,0046	0,0758	0,0687	0,0056	per tkm	NTM (2020)
	Type of ship																				
Additional ingredients	Container ship, dwt 100000, load factor 90%	0,0131	0,0131	0,0000	0,0133	0,0001	0,0007	0,0011	0,0011	0,0000	0,0015	0,0126	0,0000	0,0142	0,0142	0,0000	0,0147	0,0127	0,0007	per tkm	NTM (2020)
	Type of car																				
Consumer	Car, Passanger transport, Petrol E5, Euro 5	0,0885	0,0856	0,0029	0,0857	0,0003	0,0002	0,0112	0,0112	0,0000	0,0140	0,0620	0,0023	0,0998	0,0968	0,0029	0,0997	0,0623	0,0025	per km	NTM (2020)

8.4 Emission factors for capital goods and infrastucture in transports (production and maintanance of vehicles and roads)

Type of truck	kg CO2 eq/kg goods trsp
Rigid truck 14-20 t, Diesel B7EU, Euro5, load factor 50%	0,025379111
Rigid truck 14-20 t, Diesel B7EU, Euro5, load factor 90%	0,025379111
Rigid truck 14-20 t, Diesel B7EU, Euro5, load factor 90% + cooling transport	0,025379111
Rigid truck 20-26 t, Diesel B7EU, Euro5, load factor 50%	0,017391945
Container ship, dwt 100000, load factor 90%	0,000447
Car, Passanger transport, Petrol E5, Euro 5	0,099958184

Source: Ecoinvent database 3.5 (Ecoinvent Centre, 2020)

9 Validation report

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