

Report

**Climate footprint of
average whole milk
3.7% fat, UK**

Oatly



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Table of contents

The climate footprint of cow milk.....	2
Approach.....	3
An attributional approach to life cycle accounting.....	3
From cradle to store.....	3
Time horizon.....	3
Unit of analysis.....	3
The weighting of greenhouse gases.....	4
Allocation.....	4
Agricultural calculation model.....	5
What is included?.....	6
What is not included?.....	6
Inventory data.....	7
Agriculture.....	7
Transport of Ingredients.....	8
Factory – Dairy.....	8
Packaging.....	9
Distribution.....	9
Results.....	10
References and data sources.....	12

The climate footprint of cow milk

The food system directly accounts for a quarter of global anthropogenic greenhouse gas emissions responsible for climate change, through biological soil organic processes, manure management, enteric fermentation, carbon leakage from organic soils, and deforestation.¹ On top of this there are emissions from fossil fuel use in machinery, fertilizer production, transports, heating, refinement, and other gases from leakage from e.g. refrigerants used in the value chain. By far the most important greenhouse gases from food production are nitrous oxide (N₂O), methane (CH₄) and carbon dioxide (CO₂).

Climate change is by no means the only negative externality associated with food production. Food production is also the main driver for antibiotic resistance, animal welfare issues, unsustainable water extraction, eutrophication, biodiversity loss from pesticide usage and habitat destruction. There are also important public health and worker-safety issues related to food production. This is not intended as a comprehensive list of food production related externalities.

Focus in this study is solely on climate change, as it is a climate footprint assessment. This focus is chosen without any ranking of the importance of climate change relative any other of the negative externalities associated with food production.

CarbonCloud has calculated the climate footprint of 1 kg of average whole milk in the UK (3.7% fat), chilled in a liquid packaging board, to be sold in the UK with the purpose to serve as a comparison number for oat products. This study concerns average conditions in the UK. This document is a summary of the results and how the calculations were done.

¹ IPCC, 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Approach

An attributional approach to life cycle accounting

CarbonCloud uses the attributional approach to life cycle accounting. This means that all processes in the production are considered, and their combined climate impact is attributed to the product. The attributional approach only accounts for emissions and removals of greenhouse gases generated during a product's life cycle and not avoided emissions or actions taken to mitigate released emissions. Carbon offsetting is not taken into account. The attributional approach as described here is in line with major standards for carbon foot-printing such as ISO 14067 and GHG Protocol.

This contrasts to the consequential approach, which is used to assess the climate impact from changing the level of output of a product. The consequential approach focuses on marginal effects linked to the production of a product.

From cradle to store

We assess the climate footprint of the product from *cradle to store*. In this case it means that we consider all steps of the life cycle from the production of agricultural inputs, through agriculture, transports, refinements and distribution up until the product reaches the shelf of the grocery store. Hence, the calculated climate footprint does not consider e.g. lighting and refrigeration at the grocery store, transport from grocery store to home, or cooking of product. Biogenic uptake of carbon stored in agricultural products is not taken into account since it is released again upon digestion.

Time horizon

Yield data represents the average of the period 2013-2017.

Unit of analysis

The unit of analysis in this study is

- One kg of packaged food product delivered to the store.

The weighting of greenhouse gases

The total climate impact is given in carbon dioxide equivalents (CO₂e). The calculation includes emissions to the atmosphere of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O). Sulfur hexafluoride (SF₆) is indirectly included in the emission factor for the electricity mix. Perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs) emissions are included in the emissions from chilled transport.

All greenhouse gases are weighted with the latest values of GWP₁₀₀ given by the IPCC (Edenhofer et al, 2014). For methane, nitrous oxide and sulphur hexafluoride we use a GWP of 34, 298 and 23 500 respectively.

Allocation

When a process generates more than one product, the climate impact from the process needs to be allocated between the products. As a general principle in this study, economic allocation is applied. This means that the climate impact from a process is allocated between the products in proportion to their economic value.

The allocation between meat and milk has been done according to the principle of economic allocation. See Table 1 for details.

Impact allocated to	Percentage impact (economic allocation)
Whole milk	82%
Meat and other products	18%

Table 1. Allocation of the climate footprint for milk

The allocation between the constituents of the whole milk is based on their relative value. Farmers get paid for the milk based on its content of protein and fat. Protein is worth 40% more than fat on a per weight basis, Flysjö et. al (2014).

Agricultural calculation model

Emissions from agriculture stem from a range of processes, such as energy related activities (like fuels for tractors), soil nitrogen processes, carbon leakage from organic soils, and biological processes from livestock. The emissions correlate with yield levels in a non-linear manner.

The emissions from the agricultural production of cow milk are calculated with ALBIO (Agricultural Land use and Biomass), a computer model that calculates all greenhouse gas (GHG) emissions related to the production of a specified food product. The model represents all major supply steps related to food production and use, from production of inputs to processing and transportation of end-use-ready food items. ALBIO takes into account factors like animal stock, such as calving rate, liveweight gain rate and milk production rate, manure system and feed.

For milk, the model accounts for:

- Emissions of nitrous oxide (N_2O) from mineral soils used for feed production and grazing
- Nitrous oxide and methane (CH_4) from manure management
- Methane (CH_4) from enteric fermentation
- *Indirect* emissions of nitrous oxide (N_2O) related to ammonia and nitrate emissions from soils
- Emissions of nitrous oxide (N_2O) and carbon dioxide (CO_2) from organic soils used for feed production and grazing
- Carbon dioxide (CO_2) emissions from production and use of fuels (e.g. for tractors and machinery) and electricity at farm and dairy
- Carbon dioxide (CO_2) emissions from transport of inputs to farm, from farm to dairy, and from dairy to market
- Emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O) from production of mineral fertilizers and other inputs

The model represents the flows of carbon (C) and nitrogen (N) through the crop and livestock systems on a mass and energy balance basis. Further model descriptions can be found in Wirsenius (2000, pp. 13-54), Wirsenius (2003a-b) and Bryngelsson (2016).

What is included?

The climate footprint includes emissions from:

- **Agriculture:** The agricultural steps in the production of milk (feed, fertilisers, pesticides, animal management, manure management, use of farm equipment)
- **Transport of Ingredients:** transport from farm to dairy
- **Factory – Dairy:** Greenhouse gas emissions from the production of inputs and the electricity consumption at dairy for all processes at dairy, e.g. separation of milk
- **Packaging:** production and transport of packaging material.
- **Distribution:** The distribution of the final product from factory to market.

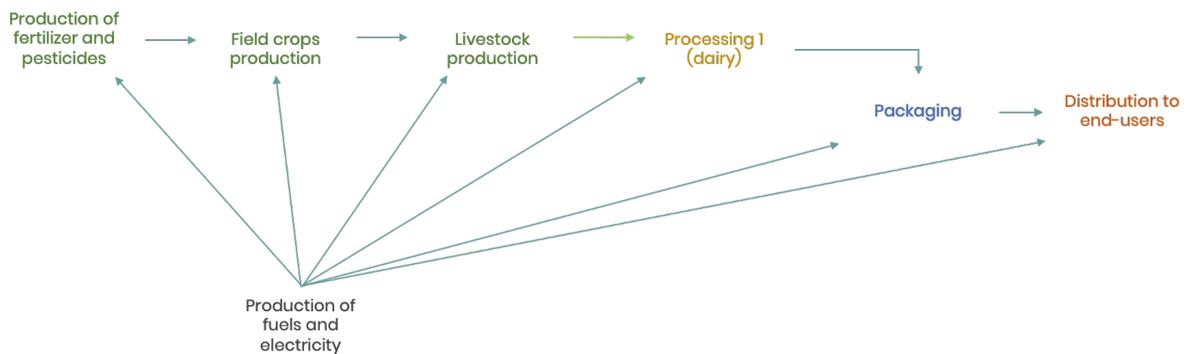


Figure 1. Climate footprint includes emissions from agriculture, processing of ingredients, transport of ingredients factory, packaging and transport

What is not included?

Most importantly the calculations omit

- Product losses after filling
- Manufacture of capital goods (e.g., machinery, trucks, infrastructure)
- Overheat operations (e.g., facility lighting, air conditioning)
- Corporate activities and services (e.g., research and development, administrative functions, company sales and marketing)
- Transport of the product user to the retail location
- Travel of employees to and from work

Inventory data

Agriculture

In the milk calculation the parameters in Table 2 have been used.

Key parameter values for milk UK, are	
Milk yield per lactating cow and year	8968 kg
Weight of cow	650 kg
Number of calves born per cow and year	0.86
Feed ration of cow	cereals and other concentrates: 12% Dry Mass (DM) silage: 42% DM protein concentrates: 10% DM cropland pasture: 36% DM
Feed ration of replacement heifer	cereals and other concentrates: 1% DM silage: 52% DM protein concentrates: 3.0% DM cropland pasture: 29% DM permanent pasture: 15% DM
Grazing period	8 months
Annual yield per hectare of each crop included in feed ration	cereals: 5.9 tonne DM/ha/yr grass-legumes leys: 8.5 tonne DM/ha/yr permanent pasture: 1.8 tonne DM/ha/yr (grazed intake)
Share of cropland and grazing land that is located on organic soil	cereals: 6.3% grass-legume leys: 6.3% permanent pasture: 6.3%
Type of manure management system	Cows: Slurry 70%, solid-liquid separation 30% Replacement heifer: Slurry 70%, solid-liquid separation 30%
Emission factors of manure management systems	CH ₄ slurry: 38.8% of max CH ₄ -generation potential N ₂ O slurry: 0% of total N in manure CH ₄ solid-liquid: 0.0% of max CH ₄ -generation potential N ₂ O solid-liquid: 2.0% of total N in manure CH ₄ deep litter: 25% of max CH ₄ -generation potential N ₂ O deep litter: 1.2% of total N in manure

Table 2. Agricultural input data for average milk UK²

Inputs of fuels and electricity in the cattle sub-systems are covered in the model, including tractor fuel for field operations; and fuel and electricity use for feed processing, ventilation/heating of stables, milking, and manure management. Transport to farm of feed, bedding materials, fertilizers, pesticides and fossil fuels used on farm is included.

² Cederberg et al, in prep; Bryngelsson et al, 2016; MacCarthy et al (2020)

Transport of Ingredients

Table 3 specifies transport mode, load factor, fuel type and emission intensity of the raw milk from farm to dairy. The leakage of fluorinated hydrocarbons is assumed to be negligible. A factor of 1.3 is used to calculate the energy in chilled transports³.

Transport	Mode	Load factor (weight)	Fuel type	Comment	kg CO ₂ /MJ ⁴	km	Fuel use MJ/ton/km	Total kg CO ₂ e/kg product
Raw milk to dairy	Truck	0.5	Diesel	Chilled	0.089	500	1.5	0.07

Table 3. Transport of Ingredients for average chilled whole milk, 3.7% fat, UK

Factory – Dairy

In the dairy the milk undergoes pasteurization and homogenization. The energy consumption of the dairy is given in Table 4. For electricity an emission intensity factor representing the power mix of the United Kingdom that accounts for upstream emissions and power losses is applied. Energy consumption in the dairy is based on average conditions.

Energy type	Power use [MJ/kg milk]	Emission factor [kg CO ₂ e/MJ], electricity ⁵ and natural gas ⁶
Electricity	0.2	0.173
Natural gas	0.6	0.063

Table 4. Energy consumption in dairy⁷

³ NTM, 2008

⁴ Edwards et al, 2014

⁵ Moro et al, 2018

⁶ Edwards et al, 2014

⁷ Flysjö et al, 2014; Bosworth et al, 2000

Packaging

The climate impact of packaging depends on the material used, the processes in manufacturing of the material, and the share of recycled material. This study uses average numbers for the recycling of materials. In Table 5 assumptions for packaging are listed.

Type	Material / kg whole milk	Emission factor kg CO ₂ ⁸ /kg material	Total g CO ₂ /kg whole milk
Primary packaging	HDPE: 30 g	2.5	75 g

Table 5. Packaging for average chilled whole milk, 3.7% fat, UK

Distribution

Table 6 below specifies transport mode, load factor, fuel type and emission intensity for the transports in the distribution chain. When no primary data was available, conservative assumptions were made based on transport modes typical for the region. A factor of 1.3 is used to calculate the energy in chilled transports⁹. The leakage of fluorinated hydrocarbons is assumed to be negligible.

Transport	Mode	Load factor (volume)	Fuel type	kg CO ₂ e/MJ ¹⁰	km	Fuel use MJ/ton/km	Total kg CO ₂ e/kg product
Dairy to wholesaler	Truck (chilled)	0.9	Diesel	0.089	350	0.7	0.022
Wholesaler to grocery store	Truck (chilled)	0.5	Diesel	0.089	50	3.7	0.016

Table 6. Distribution transports for average chilled whole milk, 3.7% fat, UK

⁸ Hillman et al, 2016

⁹ NTM, 2008

¹⁰ Edwards et al, 2014

Results

The climate footprint for average whole milk, 3.7% fat, UK is 1.6 kg CO₂e per kg product. The climate footprint is depicted in Figures 2 and 3, separated into the main process steps. The agricultural stage dominates the climate footprint for milk, with the main emission sources being methane from feed digestion, followed by emissions of nitrous oxide and carbon dioxide from soils. Tables 7 shows the climate footprint divided between the stages Agriculture, Transport of Ingredients, Factory (Dairy), Packaging and Distribution.

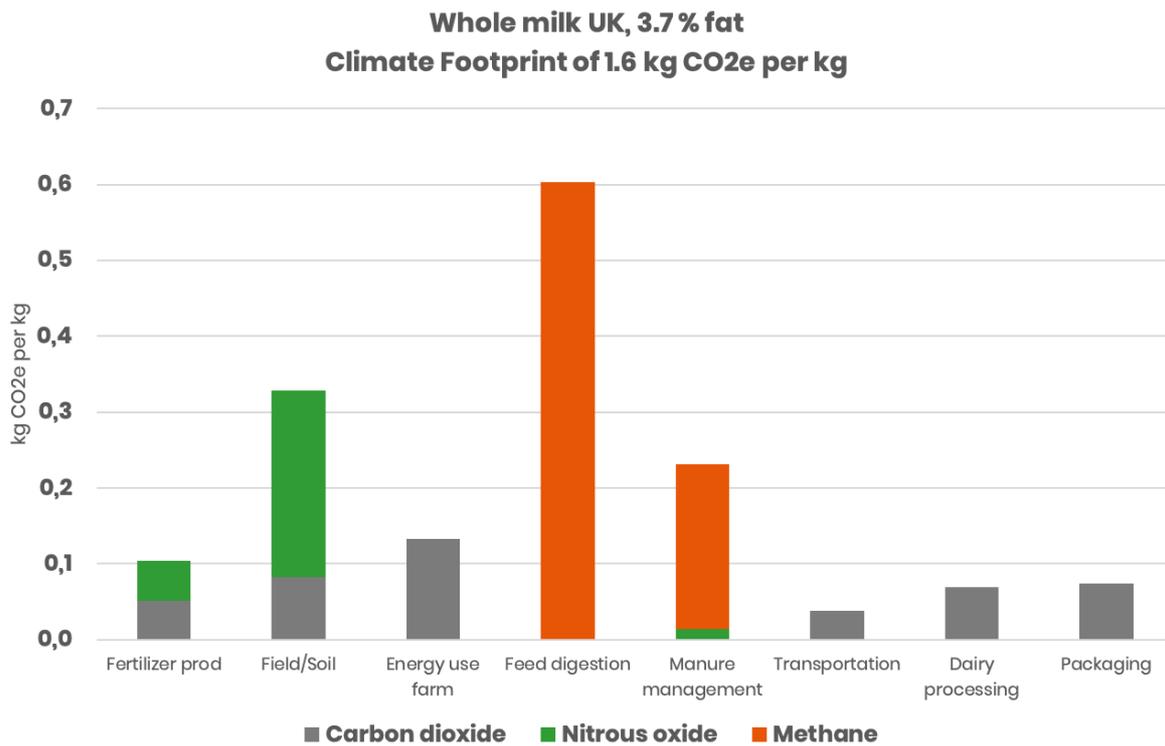


Figure 2. Climate footprint separated into main process steps

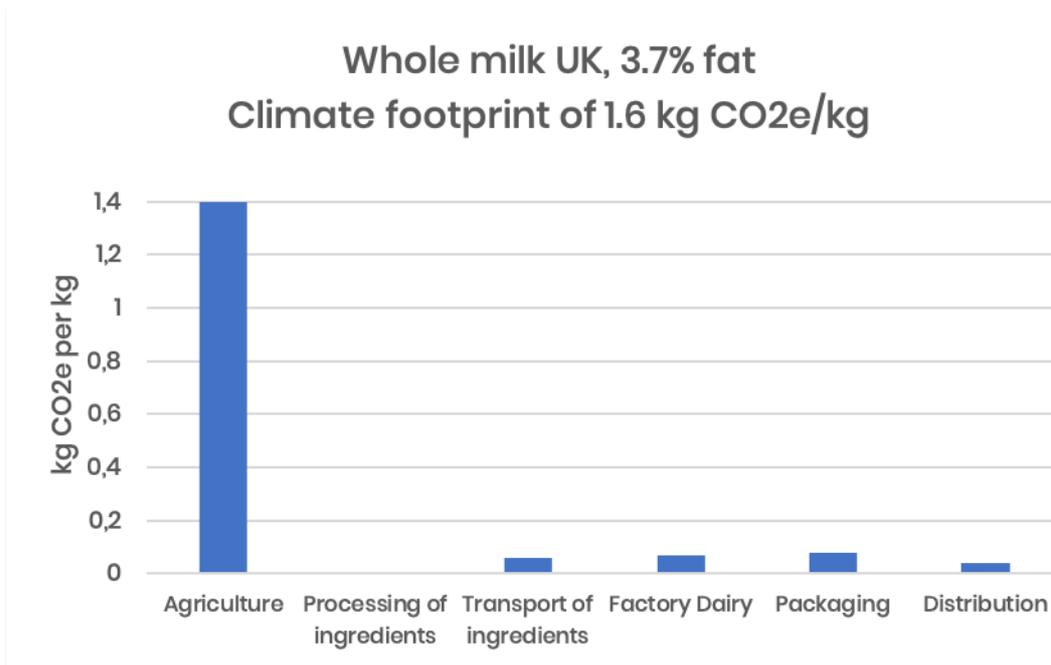


Figure 3. Climate footprint separated into main process steps

	kg CO ₂ e/kg product
Agriculture	1.4
Transport of Ingredients	0.06
Factory Dairy	0.07
Packaging	0.08
Distribution	0.04
Total	1.6

Table 7. Greenhouse gas emissions (climate footprint) per main life cycle stage for average chilled whole milk, 3.7% fat, UK, packaged and delivered to the store. All emissions are expressed in the unit kg CO₂e per kg product.

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