Report

Climate footprint for average semi-skimmed cow milk, FI

Oatly

CarbonCloud

2020-09-03

CarbonCloud
Stena Center 1 B
412 92 Göteborg

Content

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 (N_2O), methane (CH_4) and carbon dioxide (CO_2).

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 Finnish semi-skimmed milk, chilled in a liquid packaging board, to be sold in Finland with the purpose to serve as a comparison number for oat cream. This study concerns average conditions in Finland. 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

CarbonCloud assesses 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 (CO_2e). The calculation includes emissions to the atmosphere of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O). Sulfur hexafluoride (SF_6) 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 greenhouses gases are weighted with the latest values of GWP_{100} 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 of different fat contents has been done according to the principle of economic allocation. See Table 1 for details.

Impact allocated to	Percentage impact (economic allocation)
Whole milk	84%
Meat and other products	16%

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 payed for the whole 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, and from farm to dairy

- 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)
- **Processing of Ingredients**: (for this product there is no additional processing step before the milk arrives at the dairy)

- **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.
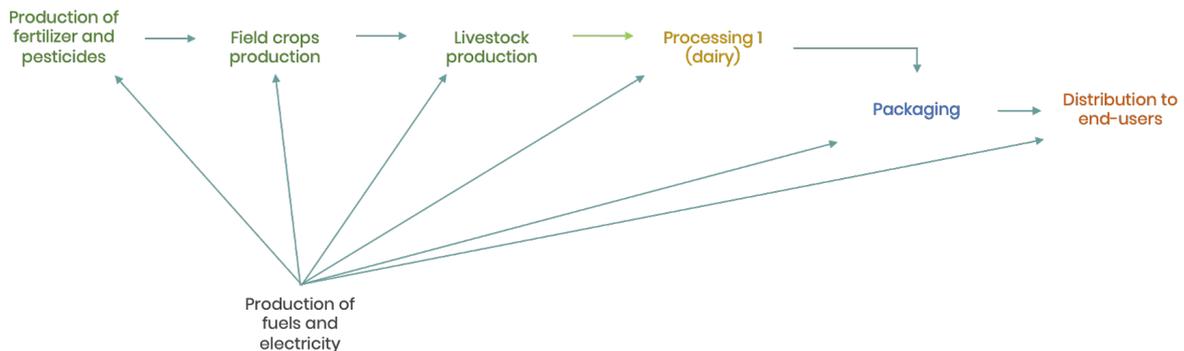

Figure 1. Climate footprint includes emissions from agriculture, processing of ingredients, transport of ingredients factory, packaging and transport

What is not included?

Most importantly the calculations omit

- Product losses after filling
- Manufacture of capital goods (e.g. manufacture of machinery, trucks, infrastructure)
- Corporate activities and services (e.g. research and development, administrative functions, company sales and marketing)
- Travel of employees to and from work

Inventory data

Agriculture

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

Key parameter values for Finnish milk, are	
Whole-milk production per (lactating) cow and year	10032 kg
Weight of cow	650 kg
Number of calves born per cow and year	0.86
Feed ration of cow	cereals and other concentrates: 22% Dry Mass (DM) silage: 56% DM protein concentrates: 17% DM cropland pasture: 4.0% DM grazed forage products (leys): 2%
Feed ration of replacement heifer	cereals and other concentrates: 2% DM silage: 75% DM protein concentrates: 3.0% DM cropland pasture: 0% DM permanent pasture: 7% DM grazed forage products (leys): 13%
Grazing period	3 months
Annual yield per hectare of each crop included in feed ration	cereals: 5.0 tonne DM/ha/yr grass-legumes leys: 4.3 tonne DM/ha/yr permanent pasture: 0.7 tonne DM/ha/yr (grazed intake)
Share of cropland and grazing land that is located on organic soil	cereals: 8.4% grass-legume leys: 8.0% permanent pasture: 29.5%
Type of manure management system	Cows: Slurry 71%, solid-liquid separation 29% Replacement heifer: Slurry 71%, solid-liquid separation 29%
Emission factors of manure management systems	CH_4 slurry: 4.0% of max CH_4-generation potential N_2O slurry: 0% of total N in manure CH_4 solid-liquid: 2.5% of max CH_4-generation potential N_2O solid-liquid: 0.5% of total N in manure CH_4 deep litter: 25% of max CH_4-generation potential N_2O deep litter: 1.2% of total N in manure

Table 2. Agricultural input data for average Finnish milk

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.

Processing of Ingredients

Processing of ingredients is in the case of milk inherent in the agricultural step, since it occurs when feed is digested by the cow. Data for this is to be found under Agriculture.

Transport of Ingredients

Transport occurs between most steps in the production chains of food products. Efficiencies differ between transport modes where some are more efficient than others. Table 3 below specifies transport mode, load factor, fuel type and emission intensity. Conservative assumptions were made based on transport modes typical for each region. The leakage of fluorinated hydrocarbons is assumed to be negligible. A factor of 1.3 is used to calculate the energy consumption for chilled transports[2].

Transport	Mode	Load factor (weight)	Fuel type	Comment	kg CO_2/MJ [3]	km	Fuel use MJ/ton/km	Total kg CO_2e/kg product
Raw milk to dairy	Truck	0.9	Diesel	Chilled	0.089	150	1.5	0.02

Table 3. Transport of Ingredients for average semi-skimmed Finnish milk

Factory – Dairy

Energy consumption is listed in Table 4. For electricity an emission intensity factor representing the Finnish power mix that accounts for upstream emissions and power losses is applied. Energy consumption in the dairy is based on average conditions. In the dairy (factory) the milk undergoes pasteurization and homogenization.

Process	Power use MJ[4]	Reference unit	Type	kg CO2e/MJ[5]	Total kg CO2e
Dairy	0.2	kg milk	Electricity	0.059	0.011

Table 4. Electricity consumption in dairy for average chilled semi-skimmed Finnish milk.

---

[2] NTM, 2008
[3] Edwards et al, 2014
[4] Flysjö et al, 2014; Bosworth et al, 2000
[5] Moro et al, 2018

The gas demand at the dairy is assumed to be met with natural gas (fossil) as it is commonly used by dairies in Finland. Usage level, emission intensity and emission level are specified in Table 5 below.

Process	Energy use MJ[6]	Reference unit	Type	kg CO_2e/MJ[7]	Total kg CO_2e
Milk production	0.6	kg milk	Natural gas	0.069	0.053

Table 5. Fuel consumption for average chilled semi-skimmed Finnish milk

Packaging

The climate impact for 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 6 assumptions for packaging are listed.

Type	Material / kg milk	Emission factor kg CO_2[8]/kg material	Total g CO_2 /kg milk
Primary packaging	Cardboard: 22.45 g/kg milk	1	22.45 g/kg milk
	Polyethene: 7.79 g/kg milk	2.5	19.5 g/kg milk
Secondary packaging	Cardboard: 17.5 g cardboard/kg milk	1	17.5 g/kg milk
Tertiary packaging	Polyethene: 0.54 g/kg milk	2.5	1.35 g/kg milk

Table 6. Packaging for average chilled semi-skimmed Finnish milk

---

[6] Flysjö et al, 2014; Bosworth et al, 2000
[7] Edwards et al, 2014
[8] Hillman et al, 2016

Distribution

Table 7 below specifies transport mode, load factor, fuel type and emission intensity for the distribution. Conservative assumptions were made based on transport modes typical for each region. The leakage of fluorinated hydrocarbons is assumed to be negligible. A factor of 1.3 is used to calculate the energy in chilled transports[9].

Transport	Mode	Load factor (weight)	Fuel type	Comment	kg CO_2/MJ [10]	km	Fuel use MJ/ton/km	Total kg CO_2e/kg product
Dairy to market	Truck	0.9	Diesel	Chilled	0.089	350	1.5	0.05

Table 7. Transport for average chilled semi-skimmed Finnish milk

---

[9] NTM, 2008
[10] Edwards et al, 2014

Results

The climate footprint for average Finnish chilled semi-skimmed milk (1.5% fat) is 1.28 kg CO_2e per kg product. The climate footprint is depicted in Figure 1, separated into the main process steps. The agricultural stage dominates the climate footprint, with the main emission sources being emissions of carbon dioxide and nitrous oxide from soils and methane from feed digestion. A small proportion of the climate impact occurs in the dairy processing.
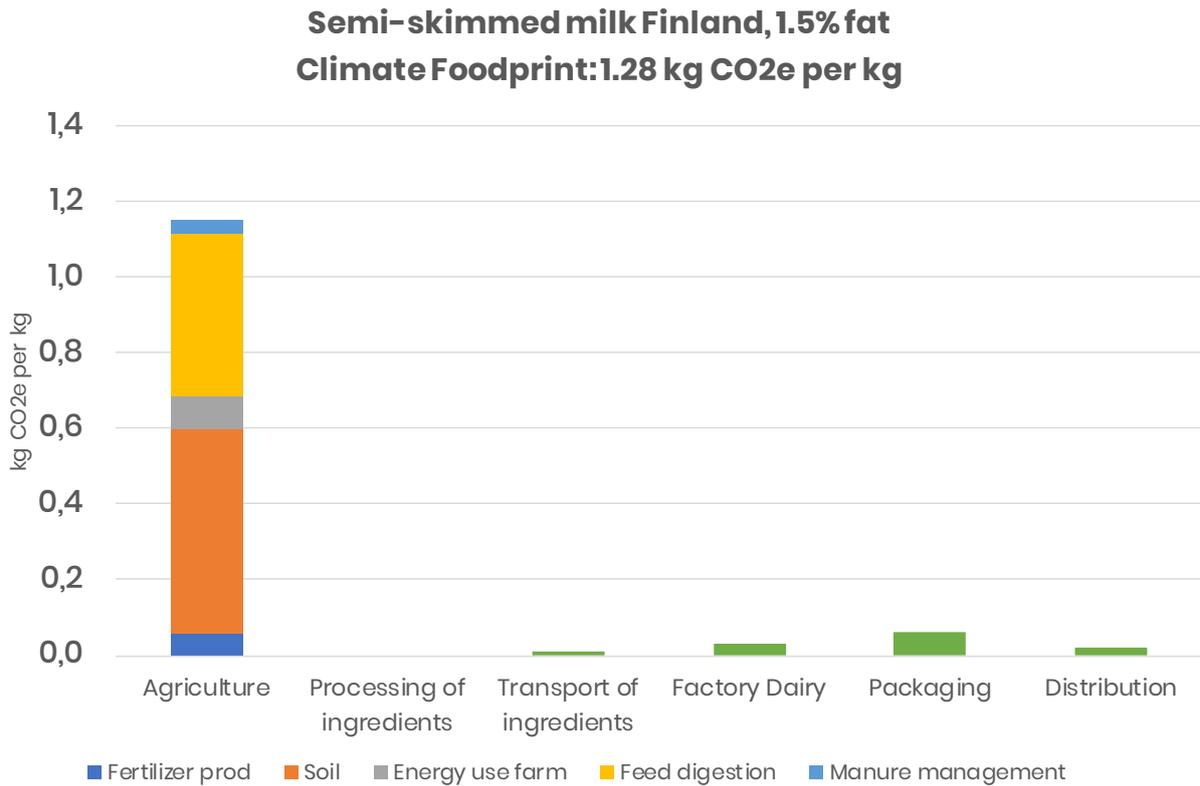
Semi-skimmed milk Finland, 1.5% fat
Climate Foodprint: 1.28 kg CO2e per kg

Figure 2. Climate footprint separated into main process steps

	kg CO$_2$e/kg product
Agriculture	1.15
Processing of Ingredients	0.00
Transport of Ingredients	0.01
Factory Dairy	0.03
Packaging	0.06
Distribution	0.02
Total	**1.28**

Table 8. Greenhouse gas emissions (climate footprint) per main life cycle stage for average semi-skimmed milk in Finland, packaged and delivered to the store. All emissions are expressed in the unit kg CO$_2$e per kg product.

References

Bouwman AF, Lee DS, Asman WAH, et al. (1997). A global high-resolution emission inventory for ammonia. 11:561–587.

Bosworth, M., Hummelsmose, B., & Christiansen, K. (2000). Cleaner production assessment in dairy processing. *COWI Consulting Engineers and Planners AS, Denmark*, 17-21.

Bryngelsson, D., Wirsenius, S., Hedenus, F., & Sonesson, U. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. Food Policy, 59, 152-164.

Cederberg C, Henriksson M, Wirsenius S, Einarsson R, in prep. Combined milk and beef production – implications on climate, land use qualities, pesticide use and nutrient surplus. Working paper

Edenhofer O., R. Pichs-Madruga, Y. Sokona, S. Kadner, J.C. Minx, S. Brunner, S. Agrawala, G. Baiocchi, I.A. Bashmakov, G. Blanco, J. Broome, T. Bruckner, M. Bustamante, L. Clarke, M. Conte Grand, F. Creutzig, X. Cruz-Núñez, S. Dhakal, N.K. Dubash, P. Eickemeier, E. Farahani, M. Fischedick, M. Fleurbaey, R. Gerlagh, L. Gómez-Echeverri, S. Gupta, J. Harnisch, K. Jiang, F. Jotzo, S. Kartha, S. Klasen, C. Kolstad, V. Krey, H. Kunreuther, O. Lucon, O. Masera, Y. Mulugetta, R.B. Norgaard, A. Patt, N.H. Ravindranath, K. Riahi, J. Roy, A. Sagar, R. Schaeffer, S. Schlömer, K.C. Seto, K. Seyboth, R. Sims, P. Smith, E. Somanathan, R. Stavins, C. von Stechow, T. Sterner, T. Sugiyama, S. Suh, D. Ürge-Vorsatz, K. Urama, A. Venables, D.G. Victor, E. Weber, D. Zhou, J. Zou, and T. Zwickel, 2014: Technical Summary. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Energimyndigheten (2018). Drivmedel 2018. Redovisning av rapporterade uppgifter enligt drivmedelslagen, hållbarhetslagen och reduktionsplikten. ER 2019:14

Flysjö, A., Thrane, M. and Hermansen, J.E., (2014). Method to assess the carbon footprint at product level in the dairy industry. International Dairy Journal, 34(1), pp.86–92.

Flysjö, A., Cederberg, C., & Strid, I. (2008). LCA-databas för konventionella fodermedel: miljöpåverkan i samband med produktion. SIK Institutet för livsmedel och bioteknik.

Gerber PJ, Steinfeld H, Henderson B, et al. (2013) Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome

Herridge DF, Peoples MB, Boddey RM (2008) Global inputs of biological nitrogen fixation in agricultural systems. Plant Soil 311:1–18. doi: 10.1007/s11104-008-9668-3

Hillman, K., Damgaard, A., Eriksson, O., Jonsson, D., & Fluck, L. (2016). *Climate Benefits of Material Recycling*. Nordiska ministerrådet.

IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. IGES, Japan

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

Jordbruksverket (2010) Riktlinjer för gödsling och kalkning 2011. Jönköping, Sweden

Edwards, R., Larivé, J-F., Rickeard, D. & Weindorf, W. (2014). Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context. JRC Technical Reports, Report EUR 2637 EN. ISBN 978-92-79-33888-5

Karlsson S, Rodhe L (2002) Översyn av Statistiska Centralbyråns beräkning av ammoniakavgången i jordbruket – emissionsfaktorer för ammoniak vid lagring och spridning av stallgödsel. Uppsala, Sweden

Network for Transport and Environment (2008). Additional CO2e-factors in goods transport

Moraes LE, Strathe AB, Fadel JG, Casper DP, Kebreab E, (2014) Prediction of enteric methane emissions from cattle. Global Change Biology 20:2140–2148.

Moro, A., & Lonza, L. (2018). Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. *Transportation Research Part D: Transport and Environment*, *64*, 5-14.

NRC (1996) Nutrient Requirements of Beef Cattle, 7th ed. National Academy Press, Washington, D.C

NRC (2001) Nutrient Requirements of Dairy Cattle, 7th ed. National Academy Press, Washington, D.C

Rodhe L, Ascue J, Nordberg Å. (2009). Emissions of greenhouse gases (methane and nitrous oxide) from cattle slurry storage in Northern Europe. IOP Conf Ser Earth Environ Sci 8:012019. doi: 10.1088/1755-1315/8/1/012019

De Ruijter FJ, Huijsmans JFM. (2012). Ammonia emission from crop residues. Wageningen, The Netherlands

Velthof GL, Oudendag D, Witzke HP, et al. (2009). Integrated assessment of nitrogen losses from agriculture in EU-27 using MITERRA-EUROPE. J Environ Qual 38:402–17. doi: 10.2134/jeq2008.0108

Wirsenius S (2000). Human use of land and organic materials: Modeling the turnover of biomass in the global food system. Chalmers University of Technology, Gothenburg

Wirsenius S (2003b). Efficiencies and biomass appropriation of food commodities on global and regional levels. Agric Syst 77:219–255. doi: 10.1016/S0308-521X(02)00188-9

Wirsenius S (2003a). The Biomass Metabolism of the Food System: A Model-Based Survey of the Global and Regional Turnover of Food Biomass. J Ind Ecol 7:47–80. doi: 10.1162/108819803766729195

Wirsenius S, 2019. Utsläpp av växthusgaser från svensk produktion och konsumtion av mat år 2045. Rapport, Chalmers tekniska högskola