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LCA of Oatly Barista and comparison with cow's milk

LCA report

Blonk
CONSULTANTS

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Blonk is a leading international expert in food system sustainability, inspiring and enabling the agri-food sector to give shape to sustainability. Blonk's purpose is to create a sustainable and healthy planet for current and future generations. We support organizations in understanding their environmental impact in the agri-food value chain by offering advice and developing tailored software tools based on the latest scientific developments and data.

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Table of contents

Abbreviations

CFF	Circular Footprint Formula
CO_2-eq	Carbon dioxide-equivalents
DC	Distribution centre
DE	Germany
E2E	End-to-End Factory
EF	Environmental Footprint (method developed by the European Commission)
EoL	End of Life
Eq	Equivalent
FI	Finland
HTST	High Temperature Short-Time
ISO	International Organisation for Standardization
kWh	Kilowatt hour
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MJ	Megajoules
NL	The Netherlands
PEFCR	Product Environmental Footprint Category Rules
SE	Sweden
UHT	Ultra High Temperature
UK	United Kingdom
US	United States

Executive Summary

Introduction

A Life Cycle Assessment (LCA) has been performed to compare the environmental performance of Oatly Barista (an oat-based drink), to cow's milk in six key sales markets: Germany, Finland, the Netherlands, Sweden, the United Kingdom, and the United States. In addition, the study has analysed the drivers and opportunities linked to the environmental impact of Oatly Barista. The functional unit considered for this study is 1 liter of Oatly Barista/cow's milk at the point of sale, including packaging manufacturing and packaging end of life. For cow's milk, a country-specific average market mix of skimmed, semi-skimmed, and whole milk was considered, as well as the most common heat treatment type (HTST or UHT) and packaging format (plastic, beverage carton, aseptic/chilled) in each country. The foreground data for Oatly Barista is based on company-specific data from Oatly and refers to production from Oatly's End-to-End (E2E) and hybrid factories[1]. For the cow's milk, data and statistics at a national level were used.

The study was performed and critically reviewed according to ISO 14040/14044 and ISO/TS 14071:2014 standards for comparative assertions that may be disclosed to the public and is in line with LCA guidelines including the European Product Environmental Footprint Category Rules (PEFCR). The analysis was done for 9 key impact categories from the ReCiPe 2016 impact assessment method. The study was conducted between January and November 2022.

Comparison of Oatly Barista with cow's milk

Based on this LCA, all Oatly Barista products in scope have a lower impact than cow's milk for climate change (44% to 76% lower), fine particulate matter formation (52% to 92% lower), terrestrial acidification (63% to 78% lower), freshwater eutrophication (25% to 57% lower), and marine eutrophication (41% to 72% lower). The conclusions for the remaining impact categories (land use, mineral resource scarcity, fossil resource scarcity and water consumption) varied depending on the country and factory. Table 1 presents the differences in detail.

TABLE 1 RELATIVE DIFFERENCES OF OATLY BARISTA COMPARED TO COW'S MILK AT POINT OF SALE. FOR EXAMPLE, -65% INDICATES THAT OATLY BARISTA HAS A 65% LOWER IMPACT COMPARED TO COW'S MILK. THE DIFFERENCES HAVE BEEN COLOR-CODED AS FOLLOWS: RED – MORE THAN 10% DIFFERENCE FAVORING COW'S MILK. GREEN – MORE THAN 10% DIFFERENCE FAVORING OATLY BARISTA. YELLOW: THE DIFFERENCE IS 10% OR LOWER INDICATING SIMILAR PERFORMANCE FOR THE COMPARED PRODUCTS. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES AS LISTED IN THE TABLE. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

Sales country	Factory location Oatly Barista	Climate change kg CO2 eq	Fine particulate matter kg PM2.5 eq	Terrestrial acidify-cation kg SO2 eq	Freshwater eutrophi-cation kg P eq	Marine eutrophi-cation kg N eq	Land use m2a crop eq	Mineral resource scarcity kg Cu eq	Fossil resource scarcity kg oil eq	Water consum-ption m3
Germany (retail)	Vlissingen, NL	-65%	-88%	-75%	-57%	-72%	-25%	-4%	3%	-15%
	Landskrona, SE	-74%	-88%	-75%	-57%	-72%	-30%	2%	-44%	-51%
Finland (retail)	Landskrona, SE	-76%	-68%	-78%	-47%	-67%	-48%	-5%	-49%	-48%
	Vlissingen, NL	-63%	-62%	-75%	-44%	-66%	-45%	-9%	17%	-11%
Netherlands (retail)	Vlissingen, NL	-59%	-92%	-70%	-50%	-60%	7%	43%	-6%	-26%
	Landskrona, SE	-67%	-91%	-67%	-48%	-62%	1%	55%	-43%	-56%
Sweden (retail)	Landskrona, SE	-64%	-60%	-75%	-44%	-61%	-41%	15%	-42%	-46%
	Vlissingen, NL	-44%	-52%	-71%	-40%	-60%	-37%	10%	39%	-6%
UK (retail)	Vlissingen, NL	-58%	-86%	-64%	-45%	-63%	-19%	32%	-3%	-13%
	Landskrona, SE	-69%	-86%	-63%	-46%	-64%	-24%	40%	-48%	-50%
US (food service)	Ogden, Utah, US	-46%	-67%	-75%	-25%	-41%	6%	-14%	29%	-71%
US (retail)	Ogden, Utah, US	-46%	-67%	-75%	-25%	-41%	6%	-14%	27%	-71%

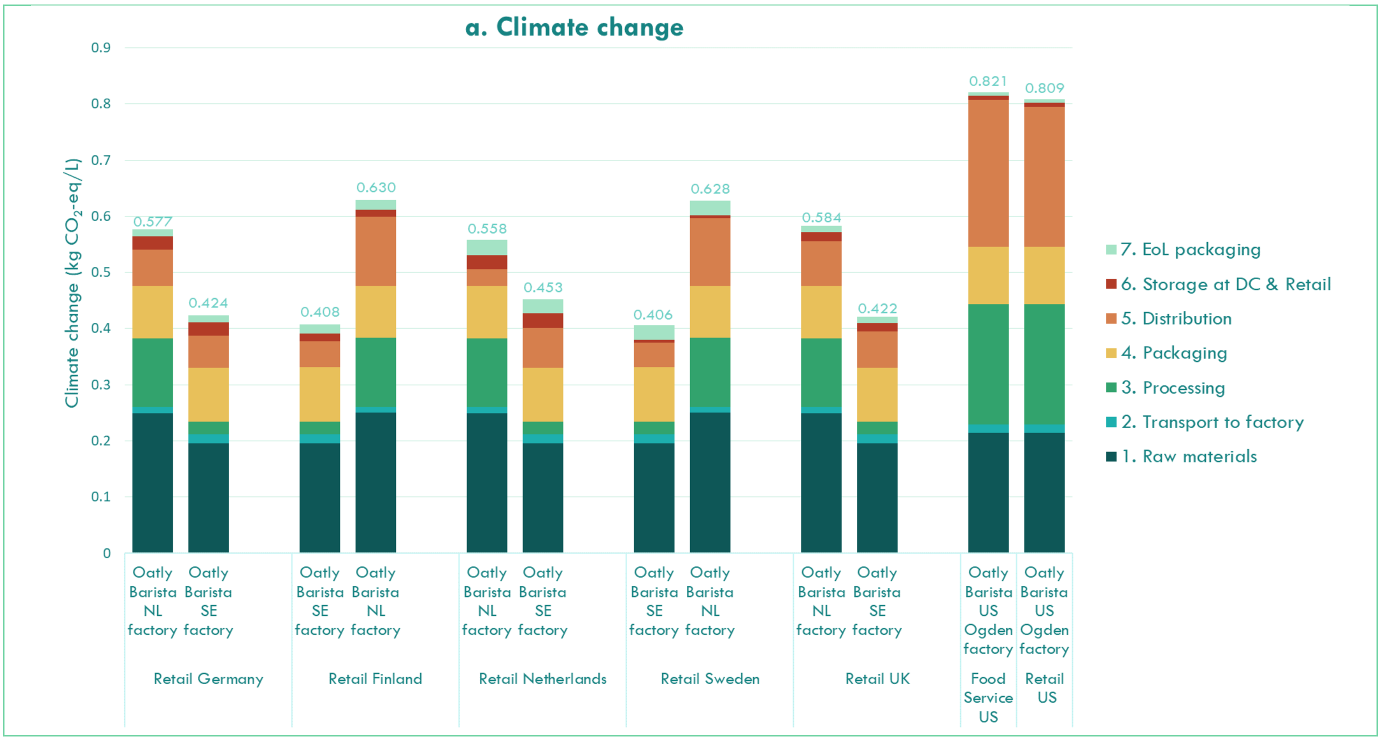
[1] End-to-End (E2E) Factory: The entire production chain happens within Oatly's own factory. From grains to the finished product. At this study those are: "Oatly Landskrona, SE" and "Oatly Ogden, Utah, US".
Hybrid Factory: A Hybrid factory is an Oatly oatbase factory that pumps the oatbase through a pipe to a contract manufacturer next door. The contract manufacturer-neighbour fills and packs the products for Oatly. At this study those are: "Oatly Vlissingen, NL".

When analysing the various life cycle stages (see Chapter 5.1 for detailed graphs), the production of raw cow's milk (i.e. the animal production system itself) is the predominant driver of impact for cow's milk for nearly all environmental impact categories (linked to processes such as enteric fermentation, manure management, and feed cultivation). The impacts of Oatly Barista are distributed between oat cultivation, factory processing, distribution and packaging, and are analysed in detail in the next section of the Executive Summary (Drivers and Opportunities for Oatly Barista).

The influence of assumptions and modelling choices (such as the functional unit, allocation approach, inclusion of use stage, storage conditions, nutrition, and life cycle impact assessment method) were assessed in the sensitivity analysis to evaluate the robustness of the results. Next to the sensitivity analysis, an uncertainty analysis has been performed to determine the range in outcomes when considering uncertainties regarding data quality. All scenarios assessed in the sensitivity analysis uphold the conclusions above, except for the land use and mineral resource scarcity impact categories. Using a different impact assessment method, the European Commission's EF 3.0 method, resulted in different trends for the land use impact category (lower impact of Oatly Barista in all cases), the mineral resource scarcity impact category (reversed trend for some cases), and the water impact category (lower impact of Oatly Barista in all cases). This is because of different underlying metrics[2], indicating a lower robustness of results for these categories.

Drivers and Opportunities for Oatly Barista

Figure 1 shows the environmental performance of Oatly Barista for the key impact categories analysed in this study.



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[2] In the EF 3.0 impact assessment method, the indicator for land considers soil properties in addition to land occupation only, the mineral resource scarcity impact category uses a different model assigning different characterisation factors to different minerals, and the water impact category considers water scarcity in addition to water consumption.

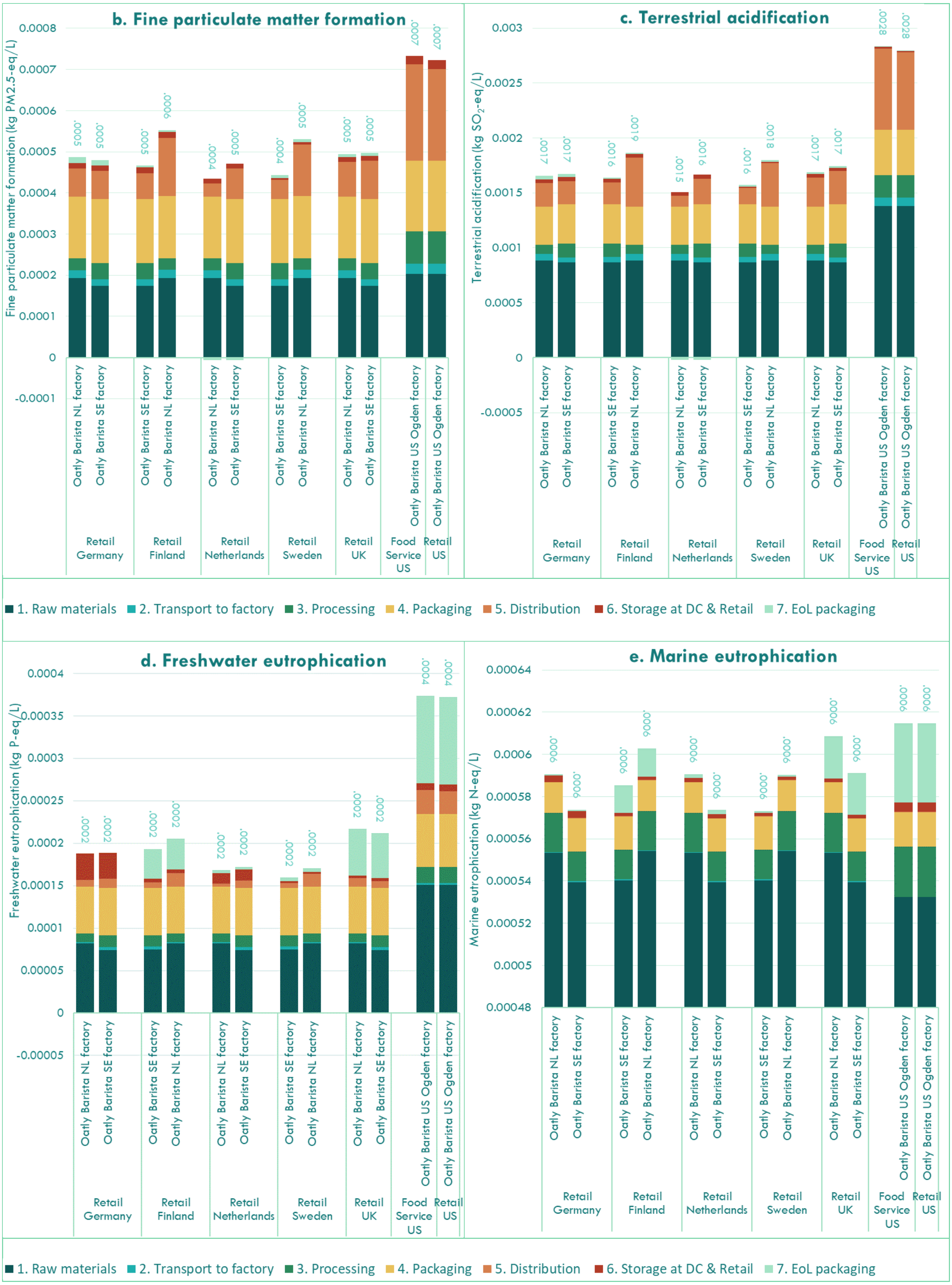
b. Fine particulate matter formation
Fine particulate matter formation (kg PM2.5-eq/L)
c. Terrestrial acidification
Terrestrial acidification (kg SO_2-eq/L)
d. Freshwater eutrophication
Freshwater eutrophication (kg P-eq/L)
e. Marine eutrophication
Marine eutrophication (kg N-eq/L)
Oatly Barista NL factory
Oatly Barista SE factory
Oatly Barista US Ogden factory
Retail Germany
Retail Finland
Retail Netherlands
Retail Sweden
Retail UK
Food Service US
Retail US
1. Raw materials
2. Transport to factory
3. Processing
4. Packaging
5. Distribution
6. Storage at DC & Retail
7. EoL packaging

FIGURE 1: KEY IMPACT CATEGORIES OF OATLY BARISTA AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

Analysing the impact of Oatly Barista across all impact categories in scope (see Figure 1 above), the following main drivers and opportunities have been identified for each stage of the supply chain (for more details see Chapters 4 & 5).

- **Ingredients (raw materials):** For ingredients, cultivation of oats is the primary driver and improvement opportunity for Oatly Barista across most impact categories. Areas of improvement include reducing cultivation on peat soils (peat oxidation is the predominant contributor for climate change for (country-average) oats sourced from Finland and Sweden) and ensuring more efficient fertilizer use. Getting insight into farm-level data could help Oatly to identify most effective and feasible reduction options.
- **Factory (processing):** Water and energy consumption are the main drivers for the factory impact. Identifying alternatives to natural gas in the Ogden and Vlissingen factories could reduce the impact on climate change and fossil resource scarcity considerably. However, renewable electricity sources, as used in the Landskrona factory, have a higher impact for mineral resource scarcity due to the metals used to produce solar panels and wind turbines. With regard to water consumption, options to enhance water efficiency can be considered especially for the US Ogden factory, such as enhanced monitoring of water use, and treatment and reuse of wastewater.
- **Packaging (production & end of life):** Since the aluminum used in ambient packaging is a main contributor to the mineral resource scarcity impact, alternative packaging options that limit the use of aluminum could be considered. For climate change, BioPE is the main contributor (due to sugarcane cultivation and related land use change). Second generation bioplastics (e.g. made from residual streams such as used vegetable oil) could be used to drive reduction in this impact category. The end of life of packaging accounts for only a small fraction of the impact of Oatly Barista in all environmental impact categories apart from freshwater eutrophication (due to long-term leaching to groundwater from landfill).
- **Transportation:** Out of all transportation, the distribution to customers (point of sale) by truck has the biggest impact and is an important contributor for fossil resource scarcity and climate change. This is especially the case for the US market, where the distances are extensive, and the fuels are only fossil-based. The impact is intensified by the use of refrigerated trucks during the cold months to prevent freezing. The use of electric and biofueled trucks in the Finnish and Swedish market is a good example for a reduction opportunity in the distribution stage.
- **Consumer (use phase):** The impact at the consumer stage (refrigeration, food waste, heating) was investigated in in the sensitivity analysis and showed that the primary driver of the use phase is linked to heating the product and to food waste. Due to lack of consumer data, food waste percentages were based on defaults and were considered the same for both cow's milk and Oatly Barista.

Conclusions

The results show that overall:

- Oatly Barista has a lower impact than cow's milk for all production facilities and markets for climate change, fine particular matter, terrestrial acidification, and freshwater and marine eutrophication.
- Oatly Barista has a consistently lower impact than cow's milk for water consumption. The difference is marginal for Oatly Barista produced in the Netherlands sold at retail in Sweden[3].
- For land use, Oatly Barista has a lower impact than cow's milk for all cases analyzed except for the US and the Netherlands, where the impact is comparable. This is attributable to the relatively low yields of oats and rapeseed oil from Canadian origin, and to the use of grass and by-products in the cows' ration[4].
- Oatly Barista has lower, comparable or higher impact for mineral and fossil resource scarcity depending on the case.
- The top drivers for Oatly Barista are oat cultivation, factory processing, distribution, and packaging. However, their contribution varies depending on the environmental impact category and case. While oat cultivation is the top contributing factor for climate change in Europe, the main driver for the US is distribution. For fossil resource scarcity, processing at the Vlissingen and Ogden factories are the main contributors, while this is not the case for the Landskrona factory that uses renewable energy sources. Mineral resource scarcity is driven mostly by packaging while land use is mostly driven by oat cultivation.
- Raw milk production is the main driver for the environmental impact of cow's milk for nearly all impact categories.

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[3] Water consumption for products produced at the Dutch Vlissingen factory is relatively high due to the use of hydropower electricity (ecoinvent dataset), attributed to the evaporation from the water surface of the reservoirs (see also Mekonnen & Hoekstra, 2011).

[4] Grassland has a lower characterization factor in the ReCiPe 2016 method compared to arable land. Without characterization, thus when only considering the land area occupied, Oatly Barista has a consistently lower impact than cow's milk (see also Annex V).

1 Goal & Scope

1.1 Introduction

For over 25 years, Oatly has focused on developing expertise in oats processing which has led to the creation of a broad and increasing portfolio of oat-based products. Oatly's ambition is to play a major role in driving a food system shift[5]. To investigate the environmental sustainability of certain of its products throughout their supply chain, Oatly has commissioned the execution of a life cycle assessment (LCA) in which a selection of Oatly's strategic products, more specifically Oatly Barista, is assessed and in addition compared to cow's milk. This study uses the LCA methodology outlined below to calculate and compare the environmental impacts of the products in scope.

LCA is a standard method that allows the quantitative analysis of the environmental impacts of a product or system throughout all the stages of its life cycle. LCAs provide a holistic approach, allowing to observe how individual life cycle stages contribute to the overall environmental impact of the product in scope, and how substances or emissions contribute to different impact categories. This can result in the identification of opportunities for direct and indirect management actions that may lead to a reduction of environmental impacts throughout the life cycle.

This LCA is conducted according to the iterative, multi-step methodology proposed in ISO 14040 and 14044 LCA methodological standards (ISO 14040, 2006; ISO 14044, 2006), including an external review. In addition, the LCA follows the guidance established by the European Commission in the Product Environmental Footprint (PEF) project (Zampori, 2019) and product specific Product Environmental Footprint Category Rules (PEFCR) when dealing with specific products such as the PEFCR for Dairy Products and the PEFCR on feed for food producing animals (European Commission, 2018b; European Commission, 2018a).

The LCA is conducted according to the following steps, as defined by abovementioned ISO standards.

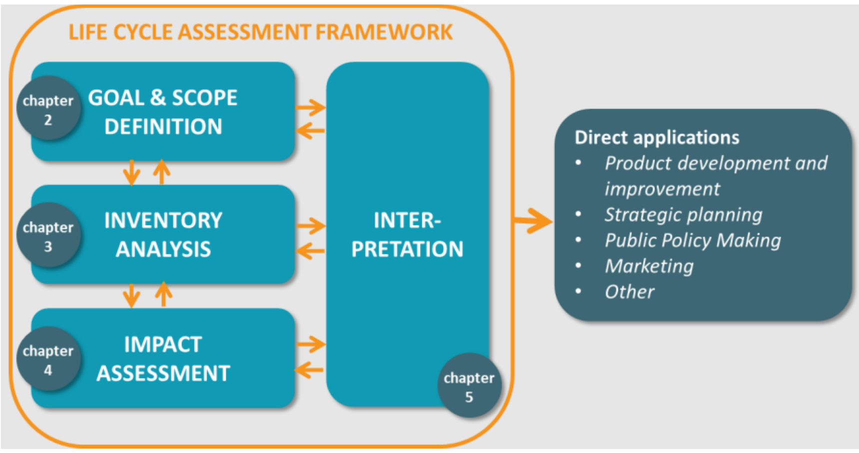

FIGURE 2: METHODOLOGICAL PHASES IN LCA BASED ON ISO 14040

- **Goal & scope definition**: This phase defines the goal of the study and provides a description of the product system in terms of system boundary and functional unit.
- **Life cycle inventory (LCI)**: results in a list with the consumption of resources and the quantities of waste flows and emissions caused by or otherwise attributable to a product's life cycle.
- **Life cycle impact assessment (LCIA)**: provides indicators and the basis for analysing the potential contributions of the resource extractions and emissions in an inventory to a number of potential impacts.
- **Life Cycle Interpretation**: in this phase the results of the analysis and all choices and assumptions made during the analysis are evaluated in terms of soundness and robustness. After this, overall conclusions are drawn.

This report follows the steps as defined above: it describes the goal and scope of the study, the data and methodology used to model the products (i.e. the LCI), after which it provides the results and interpretation for the main analyses and for a number of sensitivity analyses.

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[5] https://www.oatly.com/sustainability/drive-a-food-system-shift

1.2 Goal

The goal of the study is to assess the environmental impact of a selection of Oatly Barista products and in addition compare them to cow's milk in their respective markets. An attributional life cycle assessment was performed to evaluate the environmental impact of these products. Following the ISO 14040/14044 and ISO/TS 14071:2014 standards, the comparative assertion has been validated by an independent external review panel of four experts.

The intended application of the study is twofold. Its aim is primarily to create internal awareness of Oatly's environmental hotspots throughout the production chains and sales markets in scope and identify areas of improvement. Secondly, the results of the comparative assertion with cow's milk may be communicated externally. This external communication might include business-to-business communication, as well as communication to a broader audience, including investors and/or the general public.

Oatly aims to accelerate a transformation of an animal-based diet into a plant-based diet. The study is done to show the environmental impacts of their plant-based products compared to animal-based products. The study does not aim to compare Oatly to other plant-based products, because they are part of the same transition towards a more plant-based diet.

1.3 Scope

1.3.1 Products in scope and their functional units

The function based on which the two systems are compared is defined as follows: the provision of cow's milk or oat-based drinks, to be added to coffee and other food and beverage items for taste and texture, provided in 1 liter (Europe) or 32 fl oz (US) packaging at point of sale.

The functional units associated with both systems are:

- Oat drink: 1 liter of Oatly Barista oat drink, including packaging, at retail or food service (ambient storage)
- Cow's milk: 1 liter of HTST (high temperature short time pasteurization) or UHT (ultra-high temperature pasteurization) whole, and (semi-)skimmed cow's milk (using a country-average mix of these three milk types), including packaging, at retail (chilled or ambient storage)

Table 2 lists the reference flows related to the Oatly products in scope, as well as for their cow's milk equivalents.

Oatly Barista is an oat-based drink that is fortified with calcium, vitamin D, riboflavin, vitamin B12, iodine (only EU markets in scope), and Vitamin A (only US). Next to that, oil is added as a functional ingredient that provides structure and texture to the drink. "Barista" refers to the oat drink's functionality in coffee, for which Oatly Barista's foamability and stability are leading properties. Oatly Barista is known under different market names in the countries in scope (as mentioned in Table 2), but in this report it is consistently referred to as "Oatly Barista" for all countries.

TABLE 2: REFERENCE FLOWS OF THE PRODUCTS IN SCOPE

Oatly Barista…				**…Compared with cow's milk**			
Reference flow	Oatly Barista	Produced in	Sold in	Reference flow	Cow's milk	Produced in	Sold in
1 liter	Oatly Barista (beverage carton) *Local name: Oatly Oatmilk Barista Edition*	Ogden, Utah, United States	United States (under ambient conditions)	1 liter	Mix of HTST-treated whole and (semi-) skimmed cow's milk (HDPE gallon container)	United States	United States (under chilled conditions)
1 liter	Oatly Barista (beverage carton) *Local name: Oatly iKaffe Barista Edition*	Landskrona, Sweden Vlissingen, the Netherlands	Sweden (under ambient conditions)	1 liter	Mix of HTST-treated whole and (semi-) skimmed milk (beverage carton)	Sweden	Sweden (under chilled conditions)
1 liter	Oatly Barista (beverage carton) *Local name: Oatly iKaffe Barista Edition*	Landskrona, Sweden Vlissingen, the Netherlands	Finland (under ambient conditions)	1 liter	Mix of HTST-treated whole and (semi-) skimmed milk (beverage carton)	Finland	Finland (under chilled conditions)
1 liter	Oatly Barista (beverage carton) *Local name: Oatly Haver Barista Edition*	Vlissingen, the Netherlands Landskrona, Sweden	The Netherlands (under ambient conditions)	1 liter	Mix of HTST-treated whole and (semi-) skimmed milk (beverage carton)	The Netherlands	The Netherlands (under chilled conditions)
1 liter	Oatly Barista (beverage carton) *Local name: Oatly Hafer Barista Edition*	Vlissingen, the Netherlands Landskrona, Sweden	Germany (under ambient conditions)	1 liter	Mix of UHT-treated whole and (semi-) skimmed milk (beverage carton)	Germany	Germany (under ambient conditions)
1 liter	Oatly Barista (beverage carton) *Local name: Oatly Oat Drink Barista Edition*	Vlissingen, the Netherlands Landskrona, Sweden	United Kingdom (under ambient conditions)	1 liter	Mix of HTST-treated whole and (semi-) skimmed milk (beverage carton)	United Kingdom	United Kingdom (under chilled conditions)

The comparative assertion of the oat-based and cow's milk-based products requires that all products are compared based on the same function[6]. The main function fulfilled by Oatly Barista and cow's milk is that they are added to coffee and other food and beverage items to provide taste and texture. The study focuses on this functionality of Oatly Barista and cow's milk only, and not on the replacement of any specific macronutrient (e.g. protein or fiber). Nonetheless, due to the ongoing debate on the inclusion of nutritional aspects in food LCAs, a comparison of Oatly Barista and cow's milk on a nutritional basis is presented in the sensitivity analysis (see section 2.7.2). However, it should be stressed that the full diet of a person needs to be considered when meeting dietary needs, and assessing single products might not be sufficient.

Oatly Barista can replace both (semi-)skimmed and whole cow's milk. That is why the country-average mix of (semi-)skimmed and whole cow's milk is selected based on consumption data as elaborated in Table 3 below (the different fat contents are compared separately in the sensitivity analysis, see 5.2.5). The environmental impact of cow's milk is modelled using national data on milk production, so it represents average cow's milk consumed in respective countries. Only cows raised in conventional production systems (thus not organic or other) are taken into consideration, as this is the dominant production system in the countries in scope (Eurostat, 2022; USDA-NASS, 2019). In each country, domestically produced milk accounts for the vast majority of milk consumed, as shown by import and national production data from FAOSTAT trade statistics (FAO, 2021)[7].

[6] Other requirements of a comparative study according to ISO 14044 include an assessment of data quality (including completeness and representativeness of the data used for both systems), equivalence of both systems, sensitivity analysis, uncertainty analysis (including evaluation of significance) and use of relevant and internationally accepted impact indicators. All these elements are tackled in this report.

[7] The exact method used to calculate market mixes can be found in the Agri-footprint methodology (Blonk et al., 2022)

TABLE 3: MARKET MIX FOR COW'S MILK IN TERMS OF FAT CONTENT, HEAT TREATMENT TYPE, AND PACKAGING TYPE

	Sweden	Finland	Germany	Netherlands	United Kingdom	United States
Fat content	(Lindström, 2022)	(LUKE, 2022)	(European Commission, 2018)	(CBS, 2010)	(European Commission, 2018)	(Thoma, Popp, Nutter, et al., 2013)
Skimmed	19%	30%	2%	3%	10%	16%
Semi-skimmed	52%	59%	52%	88%	70%	55%
Whole milk	29%	11%	46%	9%	20%	29%
Thermal treatment	(Rysstad & Kolstad, 2006)	(Rysstad & Kolstad, 2006)	(European Commission, 2018)	(Rysstad & Kolstad, 2006)	(European Commission, 2018)	(IDFA, 2022; Burek et al, 2017)
HTST	97%	90%	31%	80%	95%	Most common
UHT	3%	10%	69%	20%	5%	
Packaging	(Lindström, 2022)	(Leppänen-turkula et al. , 2004)	(European Commission, 2018)	(Velzen & Smeding, 2022)	(European Commission, 2018)	(Burek et al., 2017)*
Multilayer carton 1L	67%	Most common	100%	Most common	11%	
Multilayer carton 1.5 L	33%					8% (0.5 gal)
Plastic bottle 1L			0%		78%	10% (0.5 gal)
Plastic bottle 1 gallon			0%		0%	65%
Glass bottle, returnable 1L			0%		11%	

** For the US, only the main packaging types are included in this table, meaning that the percentages don't add up to a 100%*

Oatly Barista is heat treated using UHT (ultra-high temperature treatment). The most common cow's milk pasteurisation types in the countries under consideration include HTST (high temperature short time treatment) and UHT (ultra-high temperature treatment). For the comparison, the dominant milk type is selected for each country. For the European countries, HTST cow's milk has the highest market share, except for Germany, where UHT cow's milk is more common (European Commission, 2018b). In the United States, HTST cow's milk is most common (IDFA, 2022; Burek et al, 2017).

In Sweden, Finland, the Netherlands, Germany, and the United Kingdom, Oatly Barista is packaged in a 1-liter beverage carton. The oat drink is packaged in a 32 fl oz (approx. 0.946 L) beverage carton in the United States.

For cow's milk, 1 liter/32 fl oz beverage carton was considered for all countries except for the US and the UK. For the US, a HDPE gallon container (Burek et al., 2017; Thoma, Popp, Nutter, et al., 2013; USDA-AMS, 2019), and for the UK a 1 liter HDPE container (European Commission, 2018b) are most common packaging types for cow's milk.

The Oatly Barista products in scope are sold in Sweden, Finland, the United States, the Netherlands, Germany, and the United Kingdom. For each country in which the drink is sold, Oatly Barista is compared with cow's milk produced in that country (see Table 2).

While full demand for Oatly Barista in the countries in scope is partially covered by partner facilities (contract manufacturers not owned by Oatly), the study focused only on Oatly end-to-end (E2E) and hybrid facilities[8]. These facilities were prioritized due to Oatly's better accessibility over the data and control over its operations. The results are representative for a substantial share of products reaching the shelves in Europe and for the food service channel in the US. Products manufactured in Ogden are also sold retail throughout the US in varying amounts based on the state.

[8] End-to-End (E2E) Factory: The entire production chain happens within Oatly's own factory, from grains to the finished product. For this study, this includes the factories "Oatly Landskrona, SE" and "Oatly Ogden, Utah, US".
Hybrid Factory: A hybrid factory is an Oatly oatbase factory that pumps the oatbase through a pipe to a Co-packer next door. The Co-packer-neighbour fills and packs the products for Oatly. For this study, it includes the factory "Oatly Vlissingen, NL".

The production location of Oatly Barista doesn't always match the production country of the cow's milk; the cow's milk that is available to the consumers is usually produced at the country of retail, whereas Oatly Barista is sometimes imported from another country (see Table 2).

1.3.2 System boundaries

The system boundaries for Oatly's Barista products as well as cow's milk are from **cradle-to-point of sale**, as shown in Figure 3 and Figure 4. To adequately reflect the complete impact of packaging, the End of Life (EoL) of the packaging is considered as well.

The system starts at oat cultivation, after which the oats are dehulled and dried at a mill. The dehulled and dried oats are transported to one of Oatly's production facilities, where they are transformed into "oat base", which is a mixture of oats, water, and enzymes. Fiber residues are the by-product of this process. In a subsequent processing step (either at the same or at a different location), the oat base is formulated into the final product with the addition of water, vitamins, minerals, and oil. After formulation, the product is heat-treated and packed, after which the product is distributed to retail stores (supermarkets) or on-premise food service locations. The Barista product from the E2E production location in the United States is distributed primarily through a food service channel and secondarily at retail. Both channels of distribution have been assessed in the analysis.

It should be noted that the consumption life cycle stage is excluded, as it is assumed that this life cycle stage is identical for both systems. However, an estimation of the entire life cycle (cradle-to-grave) is included as sensitivity analysis.

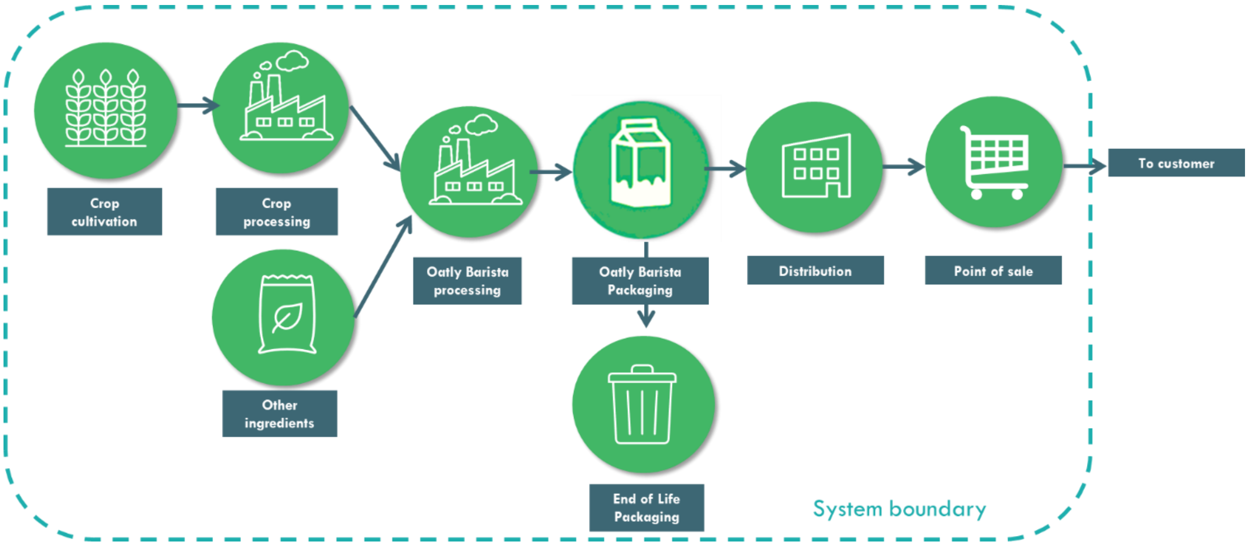

FIGURE 3: SYSTEM BOUNDARIES PACKAGED, OATLY BARISTA. POINT OF SALE REFERS TO RETAIL IN THE EUROPEAN MARKETS AND TO BOTH RETAIL AND FOOD SERVICE IN THE US.

The dairy system follows the same system boundaries, starting at cultivation of feed, followed by feed processing, raw milk production, milk processing, packaging, and distribution to the retail store.

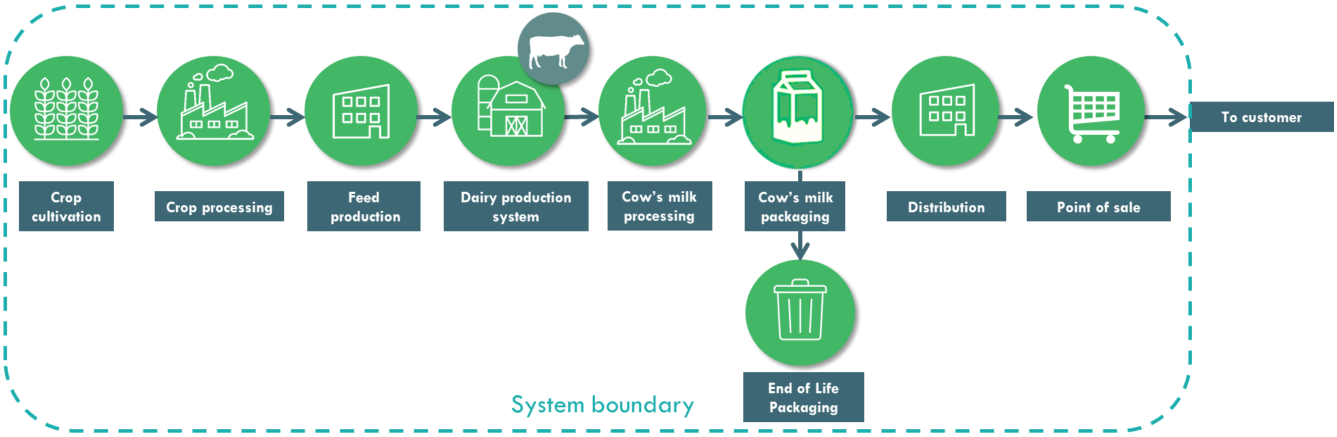

FIGURE 4: SYSTEM BOUNDARIES PACKAGED COW'S MILK. POINT OF SALE REFERS TO RETAIL.

1.3.3 Critical review

A critical review is carried out according to ISO 14040/14044 and ISO/TS 14071:2014 standards (ISO, 2014), in order to assess whether this study is consistent with LCA principles and meets all criteria related to methodology, data, interpretation and reporting. Because of the comparative nature of this LCA, the review is conducted by a panel.

A review panel of four independent and qualified reviewers has been compiled, reflecting a balanced combination of qualifications (LCA, dairy, nutrition) and backgrounds (academic, research institute, non-governmental organisation).

- Jasmina Burek (chair): Assistant Professor at University of Massachusetts Lowell (based in the US)
- Joanna Trewern: Food Systems and Sustainable Diets expert (based in the UK)
- Jens Lansche: LCA expert (based in Switzerland)
- Hayo van der Werf: LCA expert (based in France)

The critical review has been conducted in two phases: in the first phase, the panel has reviewed the Goal & Scope, in order to ensure that the selected methods and data are scientifically and technically appropriate and consistent with the ISO standards.

The second phase of the review took place after the results were captured in this LCA report to ensure that the interpretation of the results is appropriate and reflects the limitations and uncertainties identified. In addition, the panel safeguarded that the results have been presented in a transparent and consistent manner.

The critical review statement and report can be found in Appendix VI.

2 Calculation method

2.1 Methodological standards & approach

Relevant methodological standards and calculation guidelines used for this study are:

- The ISO LCA standards (ISO 14040/14044), which are the leading international LCA standards that describe the overarching principles and framework for LCA, as well as specific requirements and guidelines.
- The latest version of the Product Environmental Footprint Category Rules (PEFCR) from the European Commission (Zampori & Pant, 2019) builds upon these ISO standards, and provides more in-depth guidance on methodological choices, such as how to model specific life cycle stages. It was created as a harmonized approach that ensures consistency and comparability of LCA studies.
- Cow's milk is modelled using Blonk's Animal Production System Footprint (APS Footprint), a tool for computing lifecycle environmental impacts of animal production systems, according to well-defined LCA-standards and guidelines regarding methodology and data (Blonk Consultants, 2020a, 2020b). The methodological framework regarding allocation, functional units, boundary definitions and emission modelling is based on the following published and recognized international guidelines (European Commission, 2018b; European Environment Agency, 2016; IPCC, 2006) :
    - Product Environmental Footprint Category Rules for Dairy Products (European Commission, 2018b) is the leading guideline. This document was developed by the European Commission to standardize the LCA framework for dairy products, in the context of the PEFCR project and is a further concretization of the FAO LEAP guidelines for large ruminants (FAO LEAP, 2016) and the IDF guidelines (IDF, 2010) for calculating GHG emissions.
    - Chapter 3.B of EMEP/EEA air pollutant emission inventory guidebook (European Environment Agency, 2016). This document was published by the European Environment Agency to help government bodies to measure air pollution. It proposes calculation methods for nitrogen volatilization, Non-Methane Volatile Organic Compounds (NMVOC) emissions and Particulate Matters (PM) emissions.
    - Chapter 10 of IPCC (2006b) on emissions from livestock and manure management (IPCC, 2006). The Intergovernmental Panel on Climate Change (IPCC) developed calculation methods and standards to estimate the climate change impact for various industry sectors. This chapter focuses on enteric methane production in animal farms and methane and nitrous oxide emissions from manure management.[9]

[9] The APS tool does not yet include emission factors from the latest IPCC guidelines (it will in a future update). It is estimated that updated emission factors might result in a 1-10% change in methane emissions from manure management and enteric fermentation (the new guidelines provide some minor changes in factors and some more detailed options, e.g., subcategories of certain manure management systems based on different storage times). Variability in emissions from these two sources are covered in the uncertainty analysis.

2.2 Environmental impact assessment method

The environmental impact of the systems under study is evaluated over the following impact categories from ReCiPe 2016 v 1.01 (Huijbregts et al., 2016).

TABLE 4: OVERVIEW OF THE ENVIRONMENTAL IMPACT CATEGORIES AND RELATED INDICATORS FROM RECIPE 2016 (HUIJBREGTS ET AL., 2016).

Midpoint impact category	Characterization Factor	Unit
Climate change	Global warming potential (GWP)	kg CO_2-eq to air
Fine particulate matter formation	Particulate matter formation potential (PMFP)	kg PM2.5-eq to air
Terrestrial acidification	Terrestrial acidification potential (TAP)	kg SO_2-eq to air
Freshwater eutrophication	Freshwater eutrophication potential (FEP)	kg P-eq to freshwater
Marine eutrophication	Marine eutrophication potential (MEP)	Kg N-eq to marine water
Mineral resource scarcity	Surplus ore potential (SOP)	kg Cu-eq
Fossil resource scarcity	Fossil fuel potential (FFP)	kg Oil-eq
Water consumption	Water consumption potential (WCP)	m^3 water-eq consumed
Land use	Agricultural land occupation potential (LOP)	m^2 x yr annual crop land

For the climate change impact category, the GWPs were updated using the most recent ones from the IPCC AR6 2021 (IPCC, 2021). Greenhouse gas emissions caused by land use change (LUC) and peat oxidation are included in the climate change impact category, but are also reported separately in line with the PEFCR guidelines. LUC emissions are calculated according to the PAS 2050:2011 method (BSI, 2011), as defined by the PEFCR.

Since the products in scope originate both from Europe and North America, it was deemed appropriate to use the ReCiPe2016 impact assessment method as it is globally applicable (as opposed to e.g. the TRACI impact assessment method).

The impact categories listed above were selected as they are considered the most relevant environmental impact categories for food products, based on similar impact categories mentioned in the available PEFCRs for food and beverage products (Technical Secretariat of the PEF pilot on pasta, 2018; Technical Secretariat of the PEF pilot on Wine, n.d.; The Brewers of Europe, 2015; The European Dairy Association, 2018).[10]

Even though the interpretation focusses on abovementioned nine impact categories, the full results are provided for all 18 ReCiPe midpoint impact categories, as well as its 3 endpoint impact categories (Appendix V). It should be noted that the conversion and aggregation of midpoint indicators into endpoint indicators is accompanied by multiple assumptions which adds uncertainty to the resulting endpoint indicators[11]. However, they do give a generic and easy-to-understand indication of the impact of both production systems on human health, ecosystems, and resources.

As a sensitivity analysis (see also section 2.7), the results are calculated using the EF 3.0 impact assessment method (European Commission, 2019), to determine whether the main conclusions are also valid using a different impact assessment method.

More details on impact assessment and the above impact categories can be found in Appendix I.

2.3 Allocation

When a process in the life cycle has more than one function related to it, it is necessary to allocate all inputs and outputs associated with the process to each of the relevant functions (such as co-products). According to ISO 14044, wherever possible, allocation should be avoided through subdividing a process into sub-processes, or through system

[10] Note that ecotoxicity is excluded in the most relevant impact categories and in calculating the single score of these PEFCRs as the methodology was under development. In the new EF impact assessment method (EF 3), it has been refined. Nevertheless, this impact category is not investigated in detail in this report as ecotoxicity impact is very much dependent on the type of active ingredient used in e.g. pesticides and is hence most relevant and representative if based on primary data instead of background datasets for cultivation.

[11] However, the uncertainty of endpoint factors has not yet been broadly implemented, and therefore cannot be assessed.

expansion. If this is not possible, allocation should be based on underlying physical relationships of the different products or functions, or alternatively, on other relationships, such as their economic value.

The tables below indicate at which production steps co-products are generated, and what allocation choices are made.

For both production systems, economic allocation is applied at the cultivation stage, in line with the PEFCR on feed for food producing animals (European Commission, 2018a). The same approach applies to allocation at crop processing. The by-products at the mill and oat drink processing stage (oat middling and fiber residue) are largely used as animal feed and/or as feedstock in energy production through anaerobic digestion. Due to the very low economic value of both co-products, it is decided to allocate all impact to the main product at both stages (conservative approach).

Following the PEFCR on Dairy Products, biophysical allocation is applied at the dairy farm (for raw milk and meat) and dry matter allocation at dairy processing (skimmed milk and cream). A sensitivity analysis is carried out to compare both products using economic allocation only, for consistency of the allocation method (see Table 5 and Table 6).

TABLE 5: IMPACT ALLOCATION FOR OAT DRINK PRODUCTION

Production step	Co-products	Allocation type	Remark
Oat cultivation	Raw oats and oat straw	Economic	Allocation based on Agri-footprint (86% to oats, 14% to oats straw)
Oat mill	Dehulled, dried oats and oat middlings	Economic	100% allocation to dried oats
Oat drink processing	Oat base and fiber residue	Economic	100% allocation to oat base

TABLE 6: IMPACT ALLOCATION FOR COW'S MILK PRODUCTION

Production step	Co-products	Allocation type	Remark
Crop cultivation for feed	Main crop and crop residue (e.g. straw)	Economic	Allocation based on Agri-footprint (86%-97% to main crop, remainder to crop residue)
Crop processing	Grain and hulls	Economic	Allocation based on Agri-footprint
Animal farm	Cow's milk and meat	Biophysical allocation	Sensitivity analysis with economic allocation
Milk processing	(Semi-)skimmed cow's milk and cream	Mass allocation based on dry matter	Sensitivity analysis with economic allocation

2.4 Data sources and data quality

A more detailed overview of the foreground system data and sources used per system is presented in the Life Cycle Inventory (Chapter 3). The primary and secondary data is linked to LCI datasets (background data) derived from the following databases:

- Cultivation data: Agri-footprint 6 (economic)
- Dairy farm data (for NL, DE, UK): Agri-footprint 6
- Energy: ecoinvent 3.6 (cut-off) (also used in Agri-footprint processes)
- Auxiliary materials: ecoinvent 3.6 (cut-off)
- Transport: Agri-footprint 6 is used, as it provides more transport options (e.g. different load factors and empty return), compared to ecoinvent transport processes.

LCA datasets on raw cow's milk from Germany, the UK, and the Netherlands are already available in Agri-footprint 6 and have been reviewed by the European Dairy Association. For Sweden, Finland and the United States, the environmental impact of raw milk was modelled based on literature sources using the APS Footprint tool (consistent with the cow's milk datasets for Germany, the UK and the Netherlands). This is further explained in section 3.2.

2.4.1 Data quality rating

Data quality of both systems (cow's milk and Oatly Barista) is assessed based on the PEFCR's data quality criteria, which include the following four requirements:

- Technological-Representativeness
- Geographical-Representativeness
- Time-Representativeness
- Precision/uncertainty

These data quality criteria are assessed according to the simplified data quality ranking as presented in Table 7 below and are applied to rate key data points in this report.

TABLE 7: DATA QUALITY RANKING

Data quality indicator (SD^2)	Characteristics of data
Poor (>1.4)	• Default data, not necessarily specific for the system in scope (e.g. transport of products from retail to consumer) • Data with high uncertainty/variability
Fair (1.30-1.39)	• Literature data, specific to the system in scope • Less accurate estimates (e.g. transport distance of oat fields to mills)
Good (1.20-1.29)	• Recent data specific to the system in scope, based on qualified estimates or good reviewed literature sources. • Primary data, that is based on qualified estimates, not reviewed (e.g. transport distance in between two locations)
Very good-Excellent (1.00-1.19)	• Recent data (<6 years), primary company data based on measurements, reviewed

The benchmarks for each rating are based on SimaPro's pedigree uncertainty calculator. This calculator computes the combined uncertainty value based on the rating for each of five criteria (the four listed above and additionally considering completeness, see Table 8 below. The pedigree uncertainty calculator is used to define the SD^2 (square of the geometric standard deviation) for each data point in SimaPro, which is used for the uncertainty analyses. A basic uncertainty factor of 1.1 is applied (somewhat higher than recommended basic of 1.05). For critical parameters in the animal production system model, such as methane emissions and feed composition, relatively high uncertainty factors are applied, as further explained in the sensitivity analysis.

The pedigree matrix functionality combines the uncertainty factors into an overall uncertainty factor (SD^2) with the following formula (Goedkoop, Oele, Leijting, Ponsioen, & Meijer, 2013):

$$SD^2 = \sum_{n=1}^{6} = SD_n^2$$

Where SD^2 is the total uncertainty expressed as square of the geometric standard deviation, SD_1 is the basic uncertainty factor and SD_2 to SD_6 the additional uncertainty factors based on the criteria.

TABLE 8: DETAILED DATA QUALITY RANKING, BASED ON SIMAPRO'S PEDIGREE UNCERTAINTY CALCULATOR

	Excellent	Very good	Good	Fair	Poor
Precision	Verified based on measurements	Non-verified measurements/verified assumptions	non-verified data based on qualified estimate	qualified estimate	non-qualified estimate
Temporal	<3 years	<6 years	<10 years	<15 years	>15 years
Geographical	From area under study	Larger area in which area under study is included	Area with similar production conditions	Area with slightly similar production conditions	Unknown/distinctly different area
Technological	Data from processes under study	Data from processes under study, but	Data from processes under study, but	Data on related processes	Data on related processes from

		different enterprise	different technology		different technology
Completeness	Representative data from all relevant sites	Representative data from >50% relevant sites	Representative data from only some sites	Representative data from only one site	Representative-ness unknown

2.4.2 Data consistency and completeness

Consistency check

Assumptions, methods, and models in the completion of this LCA are as much as possible in line with the goal and scope formulated. To showcase important aspects to be considered regarding the consistency in this report, the data of both systems has been checked based on the following criteria:

TABLE 9: CONSISTENCY CHECK

Criteria	Oatly Barista	Cow's milk
Data quality:	Data quality is very good. Most recent available and verified scope 1 and scope 2 primary data (which is used for Oatly's other sustainability reporting activities) is used. Only for some data points estimates are used (such as for storage at DC and retail). No primary data was collected for the oat cultivation stage, but this is derived from Agri-footprint, which ensures consistency with the cultivation of feed ingredients (for the cow's milk).	Data quality is good. Since the aim of the study is to compare Oatly's Barista to average cow's milk in respective countries, national average data is used to model cow's milk, derived from peer-reviewed journals or the national inventory report. For some datapoints, such as for the housing system of calves < 1 year in Sweden/Finland, no data was available and it was modelled based on Denmark (nearby country). The housing system of calves has only a relatively small contribution to the overall impact of a dairy system.
Geographical representativeness:	Oatly Barista is produced in multiple locations in the countries in scope. For each country in Europe, data is used for the most representative production locations which are responsible for a substantial share of supply to the countries in scope. This means that data used represents (the largest share of) Oatly Barista which is found on the shelves. In the US, the data used refers to Oatly's end-to-end production at Ogden, Utah, which represents a substantial share of the food service supply in the country and varying amounts at retail throughout the US depending on the state. For storage at DC and retail defaults were used.	Data represents country-average data, so adequately represents the average milk consumed in each country. In case some data points were not available (e.g. for housing system of calves as mentioned above), data from a nearby country is taken as proxy. For storage at DC and retail defaults were used.
Temporal representativeness:	The Oatly supply chain and processing data for the factories in the Netherlands and Sweden was derived from the entire year of 2021. The data for the United States was derived from approximately six months of 2021, as full-scale production did not commence at the Ogden facility until mid-year.	Most essential data points, milk output and quantity of feed consumed, are based on recent reports (from 2017-2021), such as national inventory reports. Other data points, which are not reported in the NIR, such as rations or resource use, are based on other literature sources. The most recent sources were used, however, in some cases data originates from 2009.
Allocation rules:	Consistent application of economic allocation throughout all life cycle stages.	Economic allocation is applied throughout all life cycle stages in general, except for the application of biophysical allocation at the farm level and dry matter allocation at the milk processing level, which is in line with the Dairy PEFCR. This provides the most conservative choice when comparing cow's milk to oat drink. As a sensitivity analysis, economic allocation is applied throughout.
System boundaries:	All life cycle stages are considered from cradle to point of sale, including cultivation, milling, processing, distribution and sale, whether retail or food service channels (including transport in between these stages).	In line with Oatly Barista system boundaries, all life cycle stages are considered from cradle to retail, including cultivation, feed processing, animal production, dairy processing, distribution, and retail (including transport in between these stages).
Impact assessment methodology:	All impact categories of the ReCiPe 2016 impact assessment methodology are applied.	All impact categories of the ReCiPe 2016 impact assessment methodology are applied.

Completeness check

Table 10 provides an overview of the data that is included and excluded for each of the life cycle stages for the two systems. Whenever data is excluded, a justification if provided. Capital goods (such as buildings, machines, other basic infrastructure) are excluded in line with the latest PEFCR guidelines.

TABLE 10: COMPLETENESS CHECK

	Complete?	Included	Excluded
Oatly Barista			
Oat cultivation	Yes	• Cultivation data from all sourcing countries is derived from Agri-footprint • All necessary data and emissions as indicated by the PEFCR, including peat emissions and land use change	n/a
Oat milling	Yes	• All material, water and energy inputs • Co-products and waste streams are considered	• Capital goods
Transport	Yes	• Mode and load of transport, transport distances	• Capital goods
Processing step 1: oat base production	Yes	• All material and energy inputs • All water consumption (in recipe and for cleaning) • Waste streams (fiber residues) are considered	• Capital goods
Processing step 2: finished oat product	Yes	• All material and energy inputs • All water consumption (in recipe and for cleaning) • Waste streams (5% losses i.e. loss in production) are considered	• Capital goods
Packaging	Yes	• Packaging raw materials type and mass • Energy for assembling packaging materials • Transport of packaging materials • Recycled content of packaging materials • End-of-life of packaging materials	• Capital goods
Distribution	Yes	• Energy and water consumption, based on PEFCR	• Capital goods
Point of sale	Yes	• Energy and water consumption, based on PEFCR • Losses in distribution	• Capital goods
Cow's milk			
Feed cultivation	Yes	• Cultivation data from all sourcing countries derived from Agri-footprint • All necessary data and emissions as indicated by the PEFCR, including peat emissions and land use change	n/a
Feed processing	Yes	• All material (feed crops and other ingredients) and energy inputs for compound feed processing and silage production	• Capital goods
Transport	Yes	• Mode and load of transport, transport distances	• Capital goods
Dairy farm	Yes	• Feed ration per animal type • Housing system (energy, material and water inputs) • Manure management emissions • Emissions from enteric fermentation	• Capital goods
Milk processing	Yes	• Energy and material inputs for milk processing • Dry matter content/price for allocation	• Capital goods
Packaging	Yes	• Packaging raw materials type and mass, based on PEFCR dairy • Energy for assembling packaging materials • Transport of packaging material • Recycled content of packaging material • End-of-life of packaging materials	• Capital goods
Distribution	Yes	• Energy and water consumption, based on PEFCR	• Capital goods
Point of sale	Yes	• Energy and water consumption, based on PEFCR • Losses from farm to retail, based on PEFCR	• Capital goods

2.5 General assumptions and limitations

- The comparative assertions are made between products, of which data is based on different sources. The impact of Oatly Barista products is calculated using mainly primary data, whereas the impact of cow's milk is calculated using secondary data, based on different sources. To overcome this, multiple sensitivity analyses are carried out, which are discussed in chapter 2.7.2. It should be noted that for the cow's milk, national statistics and data are used, which is the most suitable way to model country-average conditions of milk production. Data is collected for all datapoints that would also be required to model a farm level footprint based on primary data, ensuring the same level of detail is applied at national level as at farm level.

- It is intended to compare the Oatly Barista and cow's milk based on their main functional application, which is to add taste and texture to food and beverages. Its main function is not to provide a certain quantity of nutrients, like protein or fiber. Therefore, no conclusions on the effect on nutrient intake are intended to be drawn from this study. However, as a sensitivity analysis, a functional unit that considers nutritional quality is considered.

Assumptions and limitations related to the specific products in scope are elaborated in Chapter 3.

2.6 Cut-offs

Capital goods (such as machines and infrastructure used in dairy/Oatly factories) are not considered in modelling the foreground processes. As suggested by the latest PEFCR guidelines, capital goods can be excluded unless there is evidence from previous studies that they are relevant.

When it comes to animal feed for the dairy system, those ingredients are included that represent 90% of the total mass of feed ingredients and are extrapolated to represent 100% of the feed intake.

2.7 Sensitivity and uncertainty analyses

Several sensitivity and uncertainty analyses are performed to assess the robustness of the results, specifically the sensitivity to assumptions made and uncertainties present in input data and models.

2.7.1 Uncertainty analyses

Two types of uncertainty analyses are included:

1. A general uncertainty analysis, showing the range of uncertainty for each of the products in scope.
2. A paired Monte Carlo uncertainty analysis for two products (Oatly Barista and cow's milk for each country), which helps to determine whether the differences between the two products are significant or not.

Both analyses are carried out in SimaPro. As in many cases uncertainty ranges of foreground data are not known, they are estimated with SimaPro's Pedigree Uncertainty Calculation (see also section 2.4.1). For certain parameters that are critical to the animal production system (such as emissions from enteric fermentation and manure management), relatively high uncertainty factors have been selected as described under sensitivity analysis below.

2.7.2 Sensitivity analyses

Below a differentiation is made between sensitivity analyses that apply to both Oatly Barista and cow's milk, and that apply to the two individual systems.

General sensitivity analyses

- A sensitivity analysis that considers the nutritional properties of Oatly Barista and cow's milk was performed, given that health impacts, and among them nutrition, are increasingly considered in food LCAs (Jolliet, 2022; Ridoutt, 2021). There is currently no consensus on a single nutrition-related indicator to use as functional unit for LCA purposes (Bianchi et al., 2020; McLaren & Chaudhary, 2021). However, there are various examples of methodologies that assess the nutrient density of products. In this study the NDU (Nutrient Density Unit) was selected (Dooren, 2018). It is based on the SNRF (Sustainable Nutrient Rich Foods) index (van Dooren, Douma, Aiking, & Vellinga, 2017), which is a variation to the commonly used NRF (Nutrient Rich Foods) index (Drewnowski & Fulgoni, 2008), and was selected for this comparison considering the following aspects:
    - Weidema & Stylianou (2020) suggest that a functional unit based on nutrients should aim to differentiate foods, which is also supported by Jolliet (2022), who recommends that nutrients that are equal across alternatives can be excluded from the functional unit. Oatly Barista is fortified with calcium, vitamin D, riboflavin, vitamin B12, iodine (only EU markets in scope), and Vitamin A (only US) at comparable levels with milk in the markets in scope, as can be seen in Appendix IV.

  - Apart from energy, three key nutrients differ between cow's milk and Oatly Barista: protein, essential fatty acids, and dietary fiber. These macronutrients are considered in the NDU.
  - Dis-qualitative nutrients (nutrients that should be limited, such as saturated fatty acids), as used in the NRF, are problematic for LCA purposes because they can result in a functional unit with negative values (Hallström, Davis, Woodhouse, & Sonesson, 2018; Heller, Keoleian, & Willett, 2013; Saarinen, Fogelholm, Tahvonen, & Kurppa, 2017) and there is no consensus on how negative nutrient density values should be handled (Strid et al., 2021). To make it suitable as functional unit for LCA purposes, the NDU excludes dis-qualitative nutrients.
  - The advantage of the NDU as a functional unit as opposed to more extensive nutrient indices lies in its simplicity whilst maintaining much of the nutritional differentiation achieved by the abovementioned indices (Weidema & Stylianou, 2020).

  As developments with regard to these nutrition indices evolve, a more complex indicator might be applied in the future.
- A sensitivity analysis on the ReCiPe2016 LCIA method is performed to test the robustness of the results calculated with this method. EF3.0 is used as an alternative impact assessment method.
- A sensitivity analysis is executed to calculate the results using the 20-year timeframe for global warming (ReCiPe, Individualist) to account for the different residence time of greenhouse gases, next to the prevalent 100-year timeframe (ReCiPe, Hierarchist). GWPs are updated in line with the most recent IPCC report (IPCC, 2021).
- A sensitivity analysis is performed to consider the entire life cycle (cradle-to-grave) of both systems. The consumer (or use) phase, which is not included in the main analyses, is modelled as follows:
  - Transport from point of sale to consumer is derived from PEFCR defaults for European countries, and from Burek et al. (2017) for the US.
  - It is assumed that both Oatly's Barista and cow's milk have the same share of losses during consumption[12]. Losses at consumption stage are derived from the Dairy PEFCR for European countries, and from Burek et al. (2017) for the US.
  - It is assumed that both Oatly's Barista and cow's milk is stored in the fridge, assuming default refrigeration duration from the Dairy PEFCR for European countries, and from Burek et al. (2017) for the US.
  - As a conservative approach, it is assumed that both drinks are heated (even though it can also be added to drinks without heating), using 50% of the PEFCR default for energy needed to boil water as a proxy. This is because milk is not boiled but heated to 50-60 degrees Celsius (Borcherding, Lorenzen, Hoffmann, & Schrader, 2008; Kamath, Huppertz, Houlihan, & Deeth, 2008). Energy use for foaming is left out as this is assumed negligible compared to boiling and is not applied in all use cases.

Oatly Barista

- Oatly Barista also has a "chilled" version which entails different production and storage requirements. More specifically, it uses a different packaging concept which does not contain aluminum and it is transported and stored chilled. The factory process is identical for chilled and ambient products, yet the ambient version is cooled down to 25 degrees Celsius whilst the chilled product requires cooling to about 5 degrees Celsius. The energy demand for this additional step is estimated to be very small compared to the overall process, so the average energy consumption was used for both versions. The chilled version of Oatly Barista is modelled in a sensitivity scenario. All other sensitivity analyses consider the ambient version.
- A perturbation analysis is carried out for Oatly Barista. This analysis is performed by changing each data point in the model by +10% or -10% at a One-At-Time (OAT) basis while recording the change in the total impact (for each impact category). The perturbation analysis serves to identify the parameters that are the most sensitive i.e. the data points that affect the total impact of Barista the most. For example, if we were to increase the energy consumption by 10% and record a 50% increase in the climate change impact category, while on the other hand an equal increase in the vitamin content would show a 1% change in the total climate change impact, we could deduct that energy consumption is a more sensitive data point (parameter) than vitamins. By repeating the exercise for all data points, we can identify those parameters

[12] Ambient (shelf stable) Barista can be preserved longer (months) while fresh milk best before date is much shorter. Therefore, Oatly Barista might probably have fewer losses at a consumer level and the gap between milk and Oatly Barista could be even higher. Given the absence of qualitative data, we assume losses to the same level as milk as a conservative approach.

that matter the most for each impact category. Results are provided for the climate change impact category.

Cow's milk

- The sensitivity of key parameters in dairy systems is assessed, which include emissions from manure management, enteric fermentation, and feed intake. This has been assessed through selection of high uncertainty factors (SD^2) for these parameters in the uncertainty analysis (see 2.4.1 for further explanation of uncertainty factors).
  - Methane emissions from manure management and enteric fermentation were given an uncertainty factor 1.5 (somewhat higher than the uncertainty factor recommended for methane and N_2O for agriculture (1.2 and 1.4) in the GHG Protocol (2011).
  - Feed rations were also given a high uncertainty factor (1.5) because some assumptions were made on feed composition.
  - For other data points the uncertainty factors are applied as described in section 2.4.1.
- A sensitivity analysis is carried out on the allocation type used for the dairy system. According to the PEFCR for Dairy Products, biophysical and mass allocation should be applied at farm and dairy processing level. Another option is to apply economic allocation to ensure consistency with other datasets. Therefore, impact at the dairy farm and for milk processing is calculated using economic allocation.
- Differences in the impact of skimmed, semi-skimmed and whole milk are investigated.
- A sensitivity analysis is applied to investigate the impact of UHT milk, which like Oatly's Barista, does not require cooling at distribution and retail.

3 Life Cycle Inventory (LCI)

This chapter describes the production chain of Oatly Barista and cow's milk in more detail, as well as the data used for the different stages of each production chain. The quality of these data is assessed using the quality indicators presented in section 2.4. A detailed life cycle inventory can be found in Appendix II and III.

3.1 Oatly Barista

3.1.1 Description of production process

In this work we assessed three Oatly end-to-end and hybrid factories operating in Europe and the US at the time of the study[13]. The three factories produce a substantial part of Oatly Barista supplied to the six markets in question and concern the following locations: a) *Landskrona, Sweden*, b) *Vlissingen the Netherlands*, and c) *Ogden, Utah, United States*. Oatly Barista sold in the Nordics (which includes Sweden and Finland) is mainly produced end-to-end in *Landskrona Sweden*; Oatly sold in the DACH, BENELUX and UK markets[14] (which includes Germany, Netherlands, and United Kingdom) is mainly produced in *Vlissingen the Netherlands* (hybrid factory); Oatly Barista produced end-to-end in *Ogden Utah United States* is sold in the United States. While Oatly Landskrona is the primary production facility for the Nordics, it is at some instances producing Oatly Barista for DACH, BENELUX, and UK (exception based to fulfil demand), and vice versa the factory in Vlissingen is sometimes supplying the Nordic market. These scenarios were assessed too, though the primary locations are considered to be the most representative ones. The Oatly Ogden facility is primarily distributing its Oatly Barista through a food service channel, while a smaller part is distributed through retail. In this section, a short description per production chain is provided.

Production in Landskrona, Sweden

All oat cultivation takes place at multiple locations throughout Sweden. Then, oats are brought to various mills. Oatly is connected to a mill in Järna (Sweden), a mill in Vejle (Denmark), and a mill in Slöinge (Sweden). When the oats are dehulled and dried, they are brought to Oatly's Landskrona production facility in Sweden. In Landskrona, oat base and finished Oatly Barista are produced (end-to-end). Oatly Barista is prepared by first adding water, vitamins and minerals to the oat base, and the product is finished by heat-treatment. Finished Oatly Barista is packaged onsite. A packaging production site in Limburg (Germany) is providing the primary packaging, and the secondary packaging material is provided by a packaging production site in in Eslöv (Sweden). The product is stored at the warehouse in Helsingborg (Sweden) under ambient conditions.

Production in Vlissingen, the Netherlands

Oat cultivation takes place in Finland, Sweden, and Estonia. The oats are dehulled and dried at a mill in Roeselare, Belgium. Then, the dehulled and dried oats are brought to Oatly Vlissingen in the Netherlands, where they are converted into oat base. The oat base is transported via a pipeline to an Oatly partner facility (contract manufacturer) next door (hybrid production). At this contract manufacturer the oat base is converted into finished Oatly Barista. The primary packaging is supplied by a packaging production site Limburg, Germany, and the secondary packaging is supplied primarily by a packaging site in Gent, Belgium. Depending on their final market, the product is stored at an ambient temperature, at a warehouse in Bochum, Germany (for the German market); a warehouse in Raalte, the Netherlands (for the Dutch market); or a warehouse in Manchester, United Kingdom (for the UK market).

Production in Ogden, Utah, United States

Oat cultivation takes place in Canada. The oats are dehulled and dried at a mill in Saskatchewan, Yorkton, Canada. The processed oats are then transported to the Ogden, Utah production facility in the US. In Ogden, oat base as well as the finished Oatly Barista is produced (end-to-end production). The primary packaging is supplied by a packaging production site in Limburg Germany and the cap is supplied by a packaging production site in Mexicali,

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[13] End-to-End (E2E) Factory: The entire production chain happens within Oatly's own factory. From grains to the finished product. Hybrid Factory: A Hybrid factory is an Oatly oatbase factory that pumps the oatbase through a pipe to a Co-packer next door

[14] Nordics = Sweden, Finland, Iceland, Denmark, Norway. DACH = Germany, Switzerland, Austria. BENELUX= Belgium, Netherlands, Luxemburg.

Mexico. The secondary packaging is supplied by a packaging production site in Salt Lake City, Utah, United States. The finished Oatly Barista is then transported to a warehouse in Utah for distribution throughout the United States. The main distribution channel from the Ogden production is through a food service channel, while a small part is distribution for retail. From November to April, the finished Oatly Barista is transported with temperature-controlled conditions to prevent it from freezing.

3.1.2 Inventory of data used

Table 11 provides an overview of the data used to model the environmental footprint of Oatly Barista. Data with regard to the processing stage is verified by an external party. This concerns Scope 1 & 2 data which has been audited by Ernst and Young (EY). Oatly has purchased renewable energy attribute certificates (EACs) for the factories in scope (renewable electricity certificates for all factories, renewable thermal energy certificates only for Landskrona). A detailed life cycle inventory can be found in Appendix III (excluded from the online report due to confidential data).

TABLE 11: INVENTORY DATA LIFE CYCLE STAGES OATLY BARISTA

Life cycle stage	Description of data	Data quality
1a. Oat cultivation	Modelled using oat cultivation datasets from Agri-Footprint 6. Agri-footprint datasets consider cultivation-related inputs and resources (yield, water consumption, land occupation/ transformation, input of manure, fertilizers, lime, pesticides, start material, energy and transport of inputs), as well as emissions related to the use of these inputs and resources (nitrous oxide, ammonia, nitrate, nitric oxide, carbon dioxide, phosphorus, pesticide, heavy metals). Emissions from land use change and peat oxidation are included as well. • Landskrona factory SE: oats from Sweden • Vlissingen factory NL: oats from Finland, Sweden, and Estonia • Ogden factory US: oats from Canada	*Good*
1b. Other ingredient production	The quantity of other ingredients used during processing or added to the final product are provided by Oatly. These include enzymes, calcium carbonate, vitamins, salt, and rapeseed oil. Rapeseed oil and a proxy for vitamins was derived from the Agri-footprint database, whereas the other ingredients were modelled using datasets from ecoinvent 3.8.	*Good*
2. Oats transport to mill	To account for transport from oat cultivation to mills, estimates are provided by Oatly (as location of farmers is not available). • An estimate of 300km is assumed for the transportation between the Swedish, Finnish, and Estonian oat fields to Stockholm, Helsinki, and Tallinn port respectively. We assume diesel trucks from the oat fields to the port, and a consecutive transportation from the port to the mill in Belgium by sea and diesel trucks. • An estimate of 300km is assumed for the transportation between the Swedish oat fields to the mills in Sweden using diesel trucks. • An estimate of 500km is assumed for the transportation between the Canadian oat fields to the mill in Canada diesel trucks, based on the radius of the area that the supplier has indicated to be sourcing their oats from (largest distance). All trucks are modelled with a capacity >20t, a load factor of 80% and an empty return.	*Fair*
3. Oats milling	Primary data was provided by Oatly on energy use (electricity and heat), and water consumption for the 2 mills in Sweden, 1 mill in Denmark, 1 mill in Belgium and 1 mill in Canada. The oat hulls are going to either animal feed or biogas production. In two Swedish mills, they are used to generate heat for the milling process.	*Good*

	For one of the Swedish mills, no information on energy use was available. An estimate was made by assuming the same energy requirements as for the other Swedish mill, but assuming fossil-based energy sources as a conservative assumption for heat. Public information was available for the electricity source in their sustainability report.	
4a. Transport of oats to factory	Distance based on locations of the mills and the Oatly factory. Transport was modelled using diesel trucks for Europe, and using diesel trains for Canada	*Very good*
5. Processing – oat base	The input use (energy, heat, water) to generate oat base and finished product was provided by Oatly based on data from the production facilities in scope. Water use includes both water in the recipe (final product), and water used for processing (mainly cleaning). The quantity of water going to wastewater treatment is also recorded.	*Very good*
6. processing – Oatly Barista	The input use (energy, heat, water) to generate oat base and finished product was provided by Oatly based on data from the production facilities in scope. Water use includes both water in the recipe (final product), and water used for processing (mainly cleaning). The quantity of water going to wastewater treatment is also recorded. To account for losses during processing, an estimation was provided by Oatly of 5% losses during the production. This concerns a maximum and is based on an interview with Oatly's factory controller (Veljanovski, 2022).	*Very good*
7a. packaging	Primary data on packaging composition is supplied by the packaging manufacturer. Next to the materials used (such as LDPE, aluminum, paperboard), energy was accounted for processing these materials based on ecoinvent datasets (sheet rolling for aluminum, injection moulding for the HDPE cap etc). BioPE is used in all beverage cartons used by Oatly. It is generated with sugarcane cultivated in Brazil. A BioPE dataset has been calculated by Quantis (Quantis, 2022) and its climate change impact is slightly higher than regular PE (excl LUC). Land use change was added from Blonk's LUC database to account for the risk of deforestation attributed to sugar cane cultivation in Brazil. Secondary packaging (corrugated board) is also included.	*Very good*
7b. Transport of packaging material	Upstream data for packaging (e.g. of raw materials) is already included in the ecoinvent datasets used. Transport (assuming diesel trucks) was added from the packaging manufacturing facilities to Oatly's corresponding factories based on their locations.	*Very good*
8a. Distribution to DC	The transport from the factory to the distribution center is provided by Oatly. Oatly uses trucks with a capacity of 21.5-36 tons (Månsson, 2022) (modelled as >20ton trucks with a load factor of 80%). In the US, the transport of Oatly Barista is assumed to be 50% ambient transportation and 50% chilled transportation. The latter is to avoid freezing of the product when it is transported between November-April. Refrigerated transport was modelled based on ecoinvent datasets for refrigerated transport. Since ecoinvent only included a small refrigerated transport option (truck < 16 ton), transport for a >20 ton truck was modelled using the same assumptions as for the smaller trucks: 20% higher fuel use for the refrigeration machine, and the use and emission of 1.71E-5 kg R134/tkm. Transport to the warehouse connected to the SE factory concerned electric trucks, and to warehouses connected to the US and NL factories concerned diesel trucks.	*Good*
8b. Distribution to Retail	For the US, Oatly has provided data on the transport distance from DC to retail and food service points of sale. As such data was not available for Europe, the distance was assumed from the warehouse to the capital and additional 50 km of last mile distribution.	*Fair*
9. Storage at DC and retail	For European countries, this is based on defaults for ambient storage provided by the PEFCR, with storage duration provided by the Dairy PEFCR (section 6.4): • 1 week of storage at DC (assuming 3x storage volume)	*Fair-Poor*

	• 3 days chilled storage at retail (HTST) • 14 days ambient storage at retail (UHT) Loss rates at retail were provided by Oatly. For the US, storage at DC and retail/food service points of sale was modelled using data from Burek et al. (2017). Storage at food service locations was assumed to be similar to storage at retail.	
10. Use (only for sensitivity analysis)	The use stage was modelled as follows: • Transport from point of sale to customer: 62% 5km by car with allocation factor of 0.005, 5%: 5km transport by lorry (remaining 33%: no impact), which are PEFCR defaults. • Refrigeration at home: 5 days for HTST milk, 2 days for UHT milk, assuming 3 times product volume and electricity use of 1350kwh/m3/y (Dairy PEFCR default) • Heating: assuming 50% of boiling energy (=0.5*0.18kWh/L), as milk is not boiled but heated to 50-60 degrees Celsius (Borcherding et al., 2008; Kamath et al., 2008). • Losses at consumer: 7% (Dairy PEFCR default) For the US, use was modelled as follows (based Burek et al. (2017)): • Transport from retail to customer: 0.195km/kg milk (same assumed for transport of customer to food service). • Electricity fridge: 0.109 kWh/kg milk for HTST, 2/5 assumed for UHT • Heating: same as above • Losses at consumer: 20%	*Poor*
11. End of Life of Packaging	The EoL of the packaging material is calculated using the Circular Footprint Formula (CFF) from the PEFCR. The CFF is only applied for primary packaging materials, using country-specific parameters as provided in Annex C of the PEFCR. For the US, recycling rates are derived from Thoma, Popp, Nutter, et al., (2013). The CFF annex provides recycling rates for liquid packaging board as a whole. It is assumed that only the paper part of the beverage carton can be recycled (into pulp). All of the plastic and aluminum is assumed to be incinerated and/or landfilled (Kremser et al., 2022; Thoden van Velzen & Smeding, 2022), using country-specific incineration/landfill rates. For secondary packaging material (corrugated board) no CFF was applied, and dataset was selected that already includes recycled material.	*Fair*

3.1.3 Assumptions and limitations

- For one of the Swedish mills data was limited, so it was modelled based on data from the other mill in Sweden, though using fossil-based energy sources as a conservative assumption.
- The impact at the mill is allocated 100% to the production of dehulled, dried oats (conservative assumption).
- At end-to-end factories[15], namely Landskrona (production in Sweden) and Ogden (production in the US) the energy and water were divided between the two processes based on the following logic: the energy and water consumption from all Oatly and partner factories that produce either only oatbase or only finished product (oatbase is delivered to the factory in this case) were analyzed and ranges for the two separate processes were extracted. By analyzing the available data, it has been possible to define the approximate energy/water consumption ranges for producing oatbase only and producing finished product only. As a consequence, the appropriate allocation shares between oatbase and finished product could be estimated for the factories where both outputs are produced.

[15] End-to-End (E2E) Factory: The entire production chain happens within Oatly's own factory. From grains to the finished product.

- Information on the type and quantity of packaging material is provided by packaging producers. Energy consumption required to assemble the primary packaging is based on data from ecoinvent.
- The circular footprint formula (CFF) is only applied to the main packaging type, not to secondary packaging. For secondary packaging, a corrugated board dataset was used that already includes recycled material.
- Some transport distances concern (conservative) estimates, such as the transport of oat fields to the mills and from DCs to point of sale.
- Energy and water consumption at DCs and retail is based on PEFCR defaults, or on literature for the US. Since for the US no information was available on storage at food service locations, it was modelled in the same way as for retail locations.

3.2 Cow's Milk

Secondary data is used to model the dairy production chain for the six countries in scope. The most important element of the footprint of cow's milk at retail, is raw cow's milk from dairy farms. All raw cow's milk from the dairy systems (three of which were already available in Agri-footprint 6) were modeled with country-average data using the APS footprint tool (Blonk Consultants, 2020b), which ensures consistency between countries.

Animal Production System Footprint (APS Footprint) is a tool for computing LCA impacts of animal production systems, according to well-defined LCA-standards and guidelines regarding methodology and data (Blonk Consultants, 2020a, 2020b). The methodological framework regarding allocation, functional units, boundary definitions and emission modelling is based on published and recognized international guidelines (European Commission, 2018b; European Environment Agency, 2016; IPCC, 2006).

LCA datasets on raw cow's milk from Germany, the UK, and Netherlands are already available in Agri-footprint 6 (modelled with APS Footprint) and have been reviewed by the European Dairy Association. For Sweden, Finland and the United States, the environmental impact of raw cow's milk was modelled using literature sources and the APS Footprint tool.

A full account of the methodology and data sources that were used to model raw cow's milk for Sweden, Finland and the US is provided in Appendix II.

3.2.1 Inventory of data used

TABLE 12: INVENTORY DATA COW'S MILK

Life cycle stage	Description of data	Data quality
1. Raw milk	A brief overview of the data used to model raw milk is provided below. A detailed overview of all datapoints used, as well as the APS methodology, is provided in Appendix II. The following data were collected to calculate the environmental footprint of cow's milk using the APS Footprint tool: • Milk output per cow and fat and protein content • Herd characteristics • Feed ration and characteristics • Energy input • Water input • Bedding material Based on these parameters, the footprint is calculated per kg of milk output. The footprint consists of: • Emissions from manure management and enteric fermentation: o Methane (CH_4) from enteric fermentation (calculated with IPCC Tier 2) o CH_4 from manure (calculated with IPCC Tier 2) o Direct dinitrogen monoxide (also called nitrous oxide) (N_2O) from manure (calculated with IPCC Tier 2) o Indirect N_2O from leaching of manure (calculated with IPCC Tier 2)	*Good*

	○ Indirect N_2O from volatilization of ammonia (NH_3) and nitrogen oxides (NOx); (calculated with IPCC Tier 2) ○ Non-methane volatile organic compounds (NMVOC) from manure (calculated with EMEP/EEA Tier 2) ○ Particulate matter (PM2.5 and PM10) from manure (calculated with EMEP/EEA Tier 1) • Emissions from the cultivation and processing of feed crops (modelled with Agri-footprint 6.0 data). Agri-footprint datasets consider cultivation-related inputs and resources (yield, water consumption, land occupation/ transformation, input of manure, fertilizers, lime, pesticides, start material, energy and transport of inputs), as well as emissions related to the use of these inputs and resources (nitrous oxide, ammonia, nitrate, nitric oxide, carbon dioxide, phosphorus, pesticide, heavy metals). Emissions from land use change and peat oxidation are covered as well. Further processing of the crops into feed ingredients, as well as country-specific market mixes, are also included. • Emissions related to energy use and bedding material (modelled with ecoinvent energy data and Agri-footprint for bedding material).	
2. Transport of milk to factory	For all European countries, distances have been derived from Blonk's transport dataset, based on national distances (assumed all truck transport). For the US, the transport distance is derived from literature. This resulted in the following distances: • Germany: 106km • Finland: 81km • Netherlands: 77km • Sweden: 131 km • United Kingdom: 95km • United states: 425 km (Burek et al., 2017) Transport in a refrigerated truck of >20 tons with empty return.	*Fair-Poor*
3. Milk processing	For European countries, the energy, water, and refrigerant use for milk processing has been derived from the Dairy PEFCR (section 6.2.6). For the US, energy and water consumption was derived from (Burek et al., 2017), with refrigerants based on the Dairy PEFCR. Mass allocation was applied based on dry matter values provided in the dairy PEFCR. This resulted in the following mass allocation of milk and cream: • Whole milk: 97.7% milk, 2.3% cream • Semi-skimmed milk: 80.7% milk, 19.3% cream • Skimmed milk: 65.3% milk, 34.7% cream For the US, the dry matter content was derived from (Thoma, Popp, Nutter, et al., 2013), leading to the following allocation factors: • Whole milk: 93% milk, 7% cream • Semi-skimmed milk:81.6% milk, 18.4% cream • Skimmed milk: 65.8% milk, 34.2% cream With regard to losses, the PEFCR default is applied encompassing losses from farm to retail (applied at retail level).	*Fair*
4. Milk packaging	The composition of packaging was based on default data from the Dairy PEFCR (section 6.3) Transport of packaging material was included using default transport distances and modes as mentioned in the Dairy PEFCR (section 6.3). For the US, data was based on Burek et al. (2017) (0.015kg HDPE/L cow's milk) Secondary packaging was modelled using default data from the PEFCR (section 6.3).	*Good-Fair*

5. Distribution to DC and retail	For distribution to DCs and supermarkets, the same national distances have been applied as for the transport of raw milk. Transport in a refrigerated truck >20t is assumed for HTST milk, and non-refrigerated transport for UHT milk.	*Fair-Poor*
6. Storage at DC and supermarkets	For European countries, this is based on defaults for refrigerated storage provided by the PEFCR, with storage duration provided by the Dairy PEFCR (section 6.4): • 1 week of storage at DC (assuming 3x storage volume) • 3 days chilled storage at retail (HTST) • 14 days ambient storage at retail (UHT) For the US, storage at DC and retail was modelled using data from Burek et al. (2017). Default loss rate was assumed of 5% from farm to retail for European countries (Dairy PEFCR section 6.6), and 12% for the US (Burek et al, 2017).	*Fair-Poor*
7. Use (only included in sensitivity analysis)	The use phase was modelled identical to that of Oatly Barista, using the following data (based on section 6.5 from dairy PEFCR, with the exception of heating): • Transport from retail to client: 62% 5km by car with allocation factor of 0.005, 5%: 5km transport by lorry (remaining 33%: no impact) • Refrigeration at home: 5 days for HTST milk, 2 days for UHT milk, assuming 3 times product volume and electricity use of 1350kwh/m3/y • Heating: assuming 50% of boiling energy (=0.5*0.18kWh/L), as milk is not boiled but heated to about 50-60 degrees (Borcherding et al., 2008; Kamath et al., 2008). • Losses at consumer: 7% (Dairy PEFCR 6.6) For the US, use was modelled as follows (based Burek et al. (2017)): • Transport from retail to client: 0.195km/kg milk • Electricity fridge products: 0.109 kWh/kg milk • Heating: same as above • Losses at consumer: 20%	*Poor*
8. End of Life of packaging	End of Life of packaging material has been modelled using CFF parameters for the respective countries For the US, the CFF was applied as well, with the necessary data on recycling rates derived from (Thoma, Popp, Nutter, et al., 2013).	*Fair*

3.2.2 Assumptions and limitations

- Milk is modelled based on literature. However, since national-average data is used, the systems are deemed representative for the countries in scope. Processing energy, packaging composition and storage at DC & Retail is based on defaults from the Dairy PEFCR.
- For certain data points, estimates had to be made, such as for transport distances from dairy farm to factory, from factory to DC and from DC to retail. These were consistently based on national transport distances from Blonk's transport model.
- In some cases, assumptions had to be made in case data on feed ration composition was absent (e.g. for calves <1 year) or aggregated. These are described in Appendix II.
- The APS tool does not yet include updated emission factors for manure management and enteric fermentation from the latest IPCC guidelines (it will in a future update). It is estimated that updated emission factors might result in a 1-10% change (positive or negative) in methane emissions from manure management and enteric fermentation. Variability in emissions from these two sources are covered in the uncertainty analysis.

4 Life Cycle Impact Assessment (LCIA)

The Life Cycle Impact Assessment provides the main results for all products in scope, whereas the next chapter (Life Cycle Interpretation) provides a more detailed account of the stages and processes contributing the most to the impact, as well as how assumptions in data and modelling choices influence the outcomes (section 5.2). The uncertainty present in the data is analyzed in section 5.3.

Figure 5 shows the climate change impact results for Oatly Barista and cow's milk at point of sale (incl. packaging EoL) for all six countries in scope. The results for all key impact categories are listed in Table 13, and for all other impact categories can be found in the Appendix V.

For Europe, two versions of Oatly Barista are included for each country; the Oatly Barista originating from the main production location is listed first, followed by the Oatly Barista from the secondary production location. For the US, the two versions include Oatly Barista distributed through a food service channel and the same product distributed to retail. The percentages indicate how the environmental impact of Oatly Barista compares to cow's milk (e.g. -50% indicates a 50% lower footprint of Oatly Barista compared to cow's milk on a liter basis).

Table 13 and Table 14 show that for all countries Oatly Barista has a lower environmental impact than cow's milk when it comes to the environmental impact categories climate change, fine particulate matter formation, terrestrial acidification, freshwater eutrophication, marine eutrophication, and water consumption. Some of the Oatly Barista produced in the Netherlands and in the US have a higher impact for fossil resource scarcity, because of the relatively high use of fossil resources for heat generation at the factories in the Netherlands and the US. Mineral resource scarcity is higher for some Oatly Barista's due to the use of aluminum in ambient (UHT) packaging. Differences between the products are explained in more detail in the next chapter (life cycle interpretation).

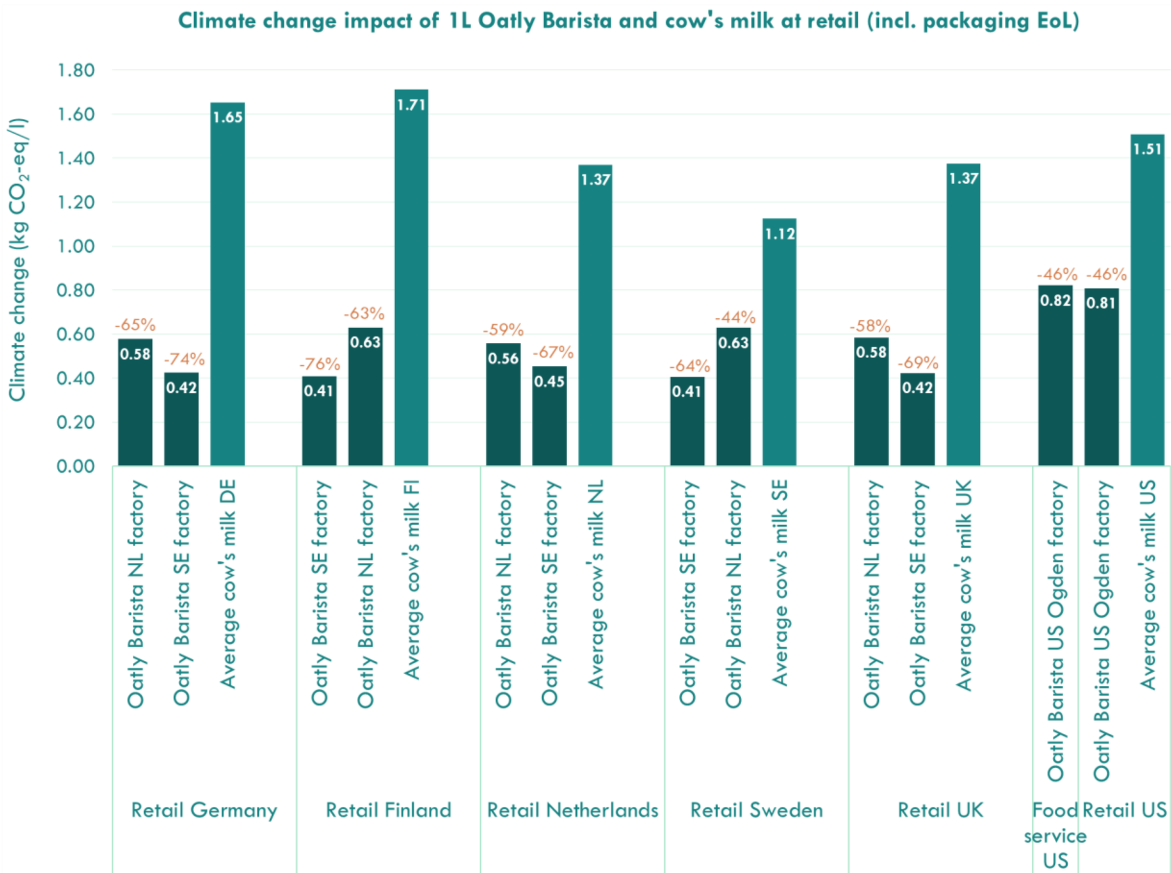

FIGURE 5: CLIMATE CHANGE IMPACT OF 1L OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

TABLE 13: RESULTS FOR KEY IMPACT CATEGORIES FOR OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

Retail Germany						
Impact category	**Unit**	**Oatly Barista NL factory**		**Oatly Barista SE factory**		**Cow's milk DE**
Climate change – incl LUC and peat ox	kg CO_2 eq	0.577	*-65%*	0.424	*-74%*	1.652
Climate change – excl LUC and peat ox	kg CO_2 eq	0.448	*-64%*	0.321	*-74%*	1.247
Climate change – only LUC	kg CO_2 eq	0.018		0.022		0.096
Climate change – only peat ox	kg CO_2 eq	0.112		0.082		0.309
Fine particulate matter formation	kg PM2.5 eq	4.87E-04	*-88%*	4.80E-04	*-88%*	4.01E-03
Terrestrial acidification	kg SO_2 eq	1.65E-03	*-75%*	1.67E-03	*-75%*	6.64E-03
Freshwater eutrophication	kg P eq	1.87E-04	*-57%*	1.88E-04	*-57%*	4.33E-04
Marine eutrophication	kg N eq	5.91E-04	*-72%*	5.74E-04	*-72%*	2.09E-03
Land use	m^2a crop eq	0.683	*-25%*	0.642	*-30%*	0.912
Mineral resource scarcity	kg Cu eq	1.08E-03	*-4%*	1.15E-03	*2%*	1.13E-03
Fossil resource scarcity	kg oil eq	0.126	*3%*	0.069	*-44%*	0.122
Water consumption	m^3	7.72E-03	*-15%*	4.43E-03	*-51%*	9.11E-03
Retail Finland						
Impact category	**Unit**	**Oatly Barista SE factory**		**Oatly Barista NL factory**		**Cow's milk FI**
Climate change – incl LUC and peat ox	kg CO_2 eq	0.408	*-76%*	0.630	*-63%*	1.711
Climate change – excl LUC and peat ox	kg CO_2 eq	0.304	*-74%*	0.500	*-57%*	1.163
Climate change – only LUC	kg CO_2 eq	0.022		0.018		0.035
Climate change – only peat ox	kg CO_2 eq	0.082		0.112		0.513
Fine particulate matter formation	kg PM2.5 eq	4.67E-04	*-68%*	5.53E-04	*-62%*	1.45E-03
Terrestrial acidification	kg SO_2 eq	1.64E-03	*-78%*	1.86E-03	*-75%*	7.37E-03
Freshwater eutrophication	kg P eq	1.93E-04	*-47%*	2.05E-04	*-44%*	3.65E-04
Marine eutrophication	kg N eq	5.85E-04	*-67%*	6.03E-04	*-66%*	1.77E-03
Land use	m^2a crop eq	0.653	*-48%*	0.695	*-45%*	1.259
Mineral resource scarcity	kg Cu eq	1.07E-03	*-5%*	1.03E-03	*-9%*	1.13E-03
Fossil resource scarcity	kg oil eq	0.060	*-49%*	0.139	*17%*	0.119
Water consumption	m^3	4.69E-03	*-48%*	8.07E-03	*-11%*	9.07E-03
Retail Netherlands						
Impact category	**Unit**	**Oatly Barista NL factory**		**Oatly Barista SE factory**		**Cow's milk NL**
Climate change – incl LUC and peat ox	kg CO_2 eq	0.558	*-59%*	0.453	*-67%*	1.369
Climate change – excl LUC and peat ox	kg CO_2 eq	0.428	*-61%*	0.349	*-68%*	1.093
Climate change – only LUC	kg CO_2 eq	0.018		0.022		0.088
Climate change – only peat ox	kg CO_2 eq	0.112		0.082		0.189
Fine particulate matter formation	kg PM2.5 eq	4.29E-04	*-92%*	4.65E-04	*-91%*	5.20E-03
Terrestrial acidification	kg SO_2 eq	1.49E-03	*-70%*	1.65E-03	*-67%*	5.00E-03
Freshwater eutrophication	kg P eq	1.69E-04	*-50%*	1.72E-04	*-48%*	3.34E-04
Marine eutrophication	kg N eq	5.91E-04	*-60%*	5.74E-04	*-62%*	1.49E-03
Land use	m^2a crop eq	0.700	*7%*	0.660	*1%*	0.652
Mineral resource scarcity	kg Cu eq	9.31E-04	*43%*	1.01E-03	*55%*	6.51E-04
Fossil resource scarcity	kg oil eq	0.103	*-6%*	0.062	*-43%*	0.109
Water consumption	m^3	8.14E-03	*-26%*	4.81E-03	*-56%*	1.10E-02
Retail Sweden						
Impact category	**Unit**	**Oatly Barista SE factory**		**Oatly Barista NL factory**		**Cow's milk SE factory**
Climate change – incl LUC and peat ox	kg CO_2 eq	0.406	*-64%*	0.628	*-44%*	1.124
Climate change – excl LUC and peat ox	kg CO_2 eq	0.302	*-68%*	0.498	*-47%*	0.945
Climate change – only LUC	kg CO_2 eq	0.022		0.018		0.054
Climate change – only peat ox	kg CO_2 eq	0.082		0.112		0.125
Fine particulate matter formation	kg PM2.5 eq	4.44E-04	*-60%*	5.30E-04	*-52%*	1.11E-03
Terrestrial acidification	kg SO_2 eq	1.57E-03	*-75%*	1.80E-03	*-71%*	6.22E-03
Freshwater eutrophication	kg P eq	1.60E-04	*-44%*	1.71E-04	*-40%*	2.86E-04

Marine eutrophication	kg N eq	5.73E-04	*-61%*	5.90E-04	*-60%*	1.47E-03
Land use	m^2a crop eq	0.652	*-41%*	0.693	*-37%*	1.103
Mineral resource scarcity	kg Cu eq	1.08E-03	*15%*	1.03E-03	*10%*	9.41E-04
Fossil resource scarcity	kg oil eq	0.056	*-42%*	0.135	*39%*	0.097
Water consumption	m^3	4.63E-03	*-46%*	8.00E-03	*-6%*	8.52E-03
Retail United Kingdom						
Impact category	**Unit**	**Oatly Barista NL factory**		**Oatly Barista SE factory**		**Cow's milk UK**
Climate change – incl LUC and peat ox	kg CO_2 eq	0.584	*-58%*	0.422	*-69%*	1.374
Climate change – excl LUC and peat ox	kg CO_2 eq	0.454	-63%	0.318	-74%	1.224
Climate change – only LUC	kg CO_2 eq	0.018		0.022		0.093
Climate change – only peat ox	kg CO_2 eq	0.112		0.082		0.057
Fine particulate matter formation	kg PM2.5 eq	4.95E-04	*-86%*	4.98E-04	*-86%*	3.65E-03
Terrestrial acidification	kg SO_2 eq	1.69E-03	*-64%*	1.74E-03	*-63%*	4.66E-03
Freshwater eutrophication	kg P eq	2.17E-04	*-45%*	2.12E-04	*-46%*	3.93E-04
Marine eutrophication	kg N eq	6.09E-04	*-63%*	5.91E-04	*-64%*	1.66E-03
Land use	m^2a crop eq	0.692	*-19%*	0.652	*-24%*	0.855
Mineral resource scarcity	kg Cu eq	1.02E-03	*32%*	1.08E-03	*40%*	7.72E-04
Fossil resource scarcity	kg oil eq	0.130	*-3%*	0.070	*-48%*	0.134
Water consumption	m^3	7.85E-03	*-13%*	4.49E-03	*-50%*	9.07E-03
Retail and Food service United States						
Impact category	**Unit**	**Oatly Barista US Ogden factory - food service US**		**Oatly Barista US Ogden factory – retail US**		**Cow's milk US - Retail**
Climate change – incl LUC and peat ox	kg CO_2 eq	0.821	*-46%*	0.809	*-46%*	1.508
Climate change – excl LUC and peat ox	kg CO_2 eq	0.756	-50%	0.744	-49%	1.478
Climate change – only LUC	kg CO_2 eq	0.064		0.064		0.018
Climate change – only peat ox	kg CO_2 eq	0.001		0.001		0.013
Fine particulate matter formation	kg PM2.5 eq	7.31E-04	*-67%*	7.21E-04	*-67%*	2.20E-03
Terrestrial acidification	kg SO_2 eq	2.83E-03	*-75%*	2.79E-03	*-75%*	1.14E-02
Freshwater eutrophication	kg P eq	3.74E-04	*-25%*	3.72E-04	*-25%*	4.99E-04
Marine eutrophication	kg N eq	6.15E-04	*-41%*	6.15E-04	*-41%*	1.04E-03
Land use	m^2a crop eq	0.843	*6%*	0.843	*6%*	0.794
Mineral resource scarcity	kg Cu eq	1.40E-03	*-14%*	1.40E-03	*-14%*	1.64E-03
Fossil resource scarcity	kg oil eq	0.215	*29%*	0.212	*27%*	0.166
Water consumption	m^3	8.26E-03	*-71%*	8.25E-03	*-71%*	2.85E-02

Table 13 shows that similar relative differences between Oatly Barista and cow's milk can be observed when excluding the contribution of land use change and peat oxidation.

TABLE 14: RELATIVE DIFFERENCES OF OATLY BARISTA COMPARED TO COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR EXAMPLE, -65% INDICATES THAT OATLY BARISTA HAS A 65% LOWER IMPACT COMPARED TO COW'S MILK. THE COLOUR SCALE USES GREEN TONES TO SHOW WHERE OATLY BARISTA HAS A LOWER IMPACT THAN COW'S MILK, AND RED TONES WHERE COW'S MILK HAS A LOWER IMPACT THAN OATLY BARISTA. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

		Climate change	Fine particulate matter	Terrestrial acidify-cation	Freshwater eutrophi-cation	Marine eutrophi-cation	Land use	Mineral resource scarcity	Fossil resource scarcity	Water consum-ption
		kg CO2 eq	*kg PM2.5 eq*	*kg SO2 eq*	*kg P eq*	*kg N eq*	*m2a crop eq*	*kg Cu eq*	*kg oil eq*	*m3*
Germany (retail)	Vlissingen, NL	-65%	-88%	-75%	-57%	-72%	-25%	-4%	3%	-15%
	Landskrona, SE	-74%	-88%	-75%	-57%	-72%	-30%	2%	-44%	-51%
Finland (retail)	Landskrona, SE	-76%	-68%	-78%	-47%	-67%	-48%	-5%	-49%	-48%
	Vlissingen, NL	-63%	-62%	-75%	-44%	-66%	-45%	-9%	17%	-11%
Netherlands (retail)	Vlissingen, NL	-59%	-92%	-70%	-50%	-60%	7%	43%	-6%	-26%
	Landskrona, SE	-67%	-91%	-67%	-48%	-62%	1%	55%	-43%	-56%
Sweden (retail)	Landskrona, SE	-64%	-60%	-75%	-44%	-61%	-41%	15%	-42%	-46%
	Vlissingen, NL	-44%	-52%	-71%	-40%	-60%	-37%	10%	39%	-6%
UK (retail)	Vlissingen, NL	-58%	-86%	-64%	-45%	-63%	-19%	32%	-3%	-13%
	Landskrona, SE	-69%	-86%	-63%	-46%	-64%	-24%	40%	-48%	-50%
US (food service)	Ogden, Utah, US	-46%	-67%	-75%	-25%	-41%	6%	-14%	29%	-71%
US (retail)	Ogden, Utah, US	-46%	-67%	-75%	-25%	-41%	6%	-14%	27%	-71%

5 Life Cycle Interpretation

5.1 Contribution analysis

A contribution analysis allows to assess the influence of individual life cycle stages on the impact results. A contribution analysis is provided for all products in scope, after which more detail is provided for Oatly Barista and cow's milk separately. The contribution analyses focus on the climate change impact but are also provided for the other impact categories.

5.1.1 Comparison of Oatly Barista and cow's milk

Figure 6 shows the contribution analysis of the climate change impact category, and Figure 7 shows the same analysis for the other main impact categories.

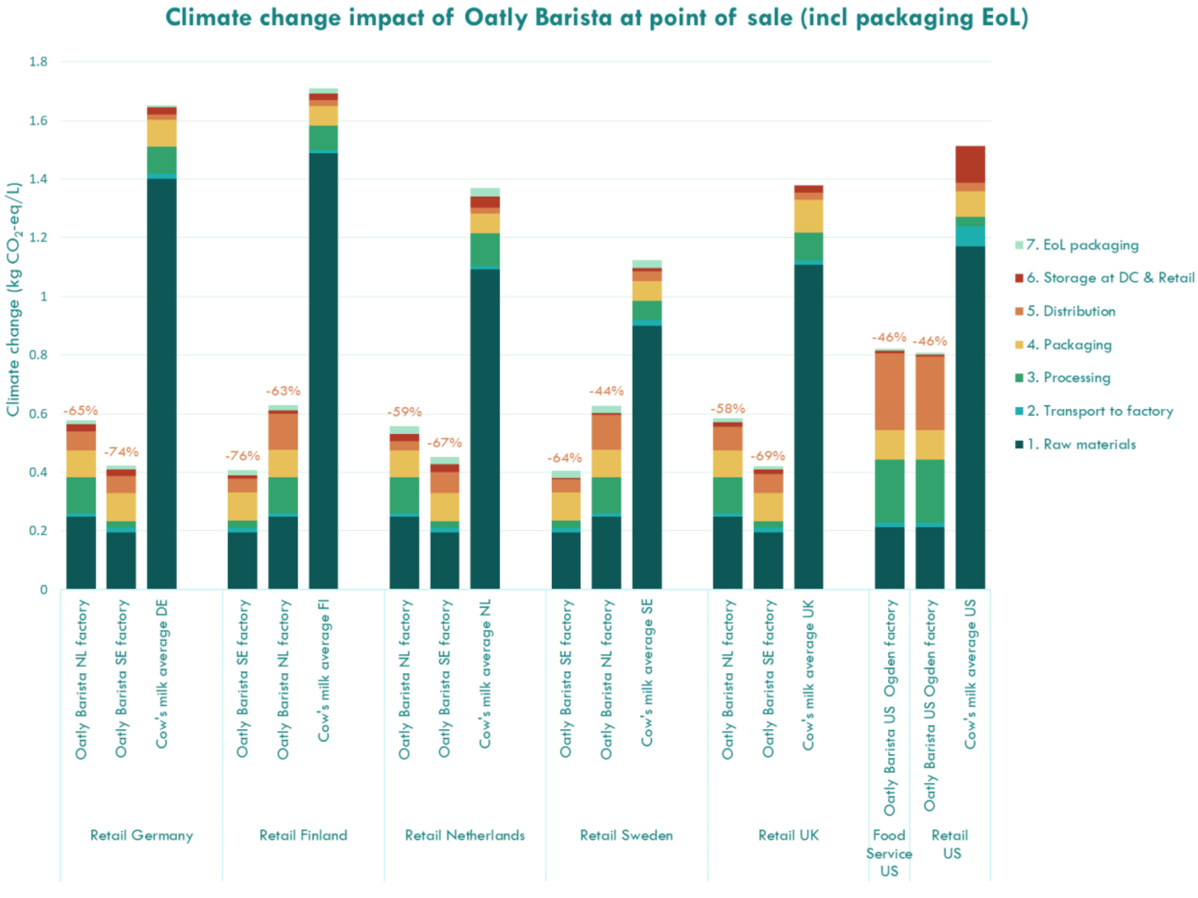

FIGURE 6: CLIMATE CHANGE IMPACT OF 1L OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

These graphs better explain the differences already observed in the previous chapter. A few key processes contributing to the different impact categories are highlighted here:

- **Climate change** is mainly linked to carbon dioxide and nitrous oxide emissions from the cultivation of oats (Oatly Barista) and methane emissions from the production of raw cow's milk, and to a lesser extent to the combustion of fossil fuels during processing and transport of Oatly Barista and cow's milk. In the US, the climate change impact of Oatly Barista is dominated by combustion of fuels for processing and distribution.

- **Fine particulate matter formation** is mainly linked to ammonia emissions from manure (cow's milk), and to a lesser extent to combustion of fuels related to transport and packaging production for both cow's milk and Oatly Barista.
- **Terrestrial acidification** is mainly linked to ammonia emissions from manure (cow's milk), and to a lesser extent to ammonia and nitrogen oxide emissions from the application of fertilizers during cultivation (oats, rapeseed, and cow's feed crops).
- **Marine eutrophication** is linked to nitrate from the application of fertilizers and manure during cultivation of oats, rapeseed, and cow's feed crops.
- **Freshwater eutrophication** is linked to phosphate emissions during cultivation of oats, rapeseed and cow's feed crops, but also to chemical oxygen demand (COD) from processing and waste treatment (long-term leachate from landfill).
- **Land use** is mostly related to cultivation of crops (oats and feed crops). In some cases (for the Netherlands and the US) the land use of Oatly Barista is similar to that of cow's milk. This is related to the feed of the cows; high yielding crops make up the majority of their feed, such as silage and grass with yields of over 40 t/ha (high yields equals low land use per kg)[16]. Part of the cows' ration consists of co-products, which according to allocation principles receive only a fraction of the (land use) impact compared to the main product. This applies for example to straw (by-product of wheat), distillers' grain (by-product of beer), and soybean meal (by-product of soybean oil). The land use of Oatly Barista in the US is higher than in other countries due to the comparatively low yields of oats and rapeseed cultivated in Canada[17].
- **Mineral resource scarcity** is linked to use of mineral fertilizers for crop cultivation (both for the oats and rapeseed used in Oatly Barista, and for the feed consumed by the cows), and the use of aluminum in ambient packaging (mostly relevant for Oatly Barista). Note that in Germany, UHT milk (with ambient packaging that contains aluminum) is most common, hence the higher impact of packaging compared to cow's milk from other countries that use chilled packaging. Using solar and wind electricity at Ogden and Landskrona factories contributes to the mineral resource scarcity impact due to the use of metals in the production of wind turbines and solar panels.
- **Fossil resource scarcity** is linked to the use of fossil fuels for transport, heat, electricity generation, and packaging (material and production) for both systems. Cow's milk in the UK and the US has a relatively high impact because of its HDPE packaging. Negative values at EoL are due to generation of heat during incineration of packaging material, which prevents the use of fossil fuels. Oatly Barista produced in Sweden has a low impact as it uses renewable energy sources for processing. For the US, the relatively high processing energy and long transport distance of the final product to the market contribute to the higher impact of Oatly Barista.
- **Water consumption**[18] is linked to irrigation at cultivation level, and to water used during processing[19] and packaging manufacturing. In the United States more irrigation is applied for the cultivation of feed crops than in other countries. Maize, which makes up a relatively large share of the feed ration, is partly irrigated and contributes most to the water footprint of cow's milk in the US. Water consumption for products produced at the Dutch Vlissingen factory is relatively high due to the use of hydropower electricity (ecoinvent dataset), attributed to the evaporation from the water surface of the reservoirs (see also Mekonnen & Hoekstra, 2011). More specifically, the electricity from hydropower is responsible for the largest share of water consumption for the processing stage in the Vlissingen factory (even though the water is consumed elsewhere). In the other factories, process water (water used e.g. for cleaning) makes up the largest share of the water consumption. It is worth mentioning that process water consumption is relatively higher for the US Ogden factory compared to the other two factories, which means that there is a bigger opportunity for water reduction. Process water accounts for more than half of the water consumption within the factories' four walls, while the remainder is used for the formulation of the product and hence might offer less reduction opportunities.

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[16] Pastures also have a lower characterization factor than arable land in the ReCiPe method, in which land occupation is expressed as intensity of the land use relative to annual crops. See Huijbregts et al. (2016) for more information. Annex V includes a table with land occupation results without characterization.

[17] Yields used in Agri-footprint 6 are derived from FAOSTAT. More information can be found in: https://blonksustainability.nl/tools/agri-footprint#methodology

[18] Water consumption is the fraction of water use that is not returned to its original source. Water consumption at cultivation concerns irrigation water that evaporates or is taken up by the plant. Water consumption at processing concerns tap water use minus water that becomes available again after wastewater treatment.

[19] Water under the processing category includes: 1) Water used within the factory's four walls i.e. water for the formulation of the product and water for processing in the factory (e.g. for cleaning) 2) water consumption that occurs elsewhere but is attributed to the processing at the factory e.g. water consumed for the hydropower production used in the factory.


a. Fine particulate matter formation
Fine particulate matter formation (kg PM2.5-eq/L)
b. Terrestrial acidification
Terrestrial acidification (kg SO2-eq/L)
c. Freshwater eutrophication
Freshwater eutrophication (kg P-eq/L)
d. Marine eutrophication
Marine eutrophication (kg N-eq/L)
Oatly Barista NL factory
Oatly Barista SE factory
Cow's milk DE average
Cow's milk FI average
Cow's milk NL average
Cow's milk SE average
Cow's milk UK average
Oatly Barista US Ogden factory
Cow's milk US average
Retail Germany
Retail Finland
Retail Netherlands
Retail Sweden
Retail UK
Food Service US
Retail US
1. Raw materials
2. Transport to factory
3. Processing
4. Packaging
5. Distribution
6. Storage at DC & Retail
7. EoL packaging

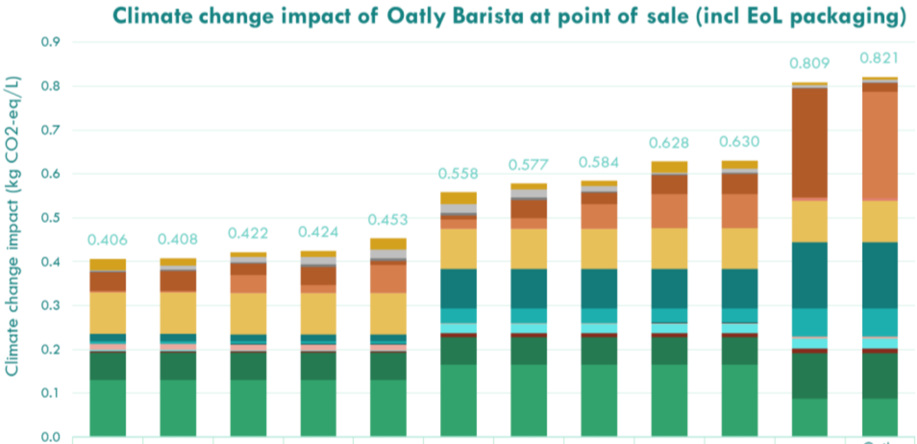
FIGURE 7: KEY IMPACT CATEGORIES OF 1L OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

5.1.2 Oatly Barista

Figure 8 shows the contribution analysis for the climate change impact results for all Oatly Barista products sorted from low to high climate change impact.

Oatly Barista produced in the Swedish Landskrona factory has the lowest climate change impact, which is mainly attributed to the use of renewable electricity and renewable thermal energy sources at the factory. Even when transported to the UK, Germany and Netherlands, Oatly Barista from Sweden still has a lower impact. Despite the longer distance, distribution of Oatly Barista from Sweden to the UK has a lower impact than distribution from NL to the UK because a high share of transport by ship and train. Below some highlights for the main production stages are described.

- **Raw materials**: The oats used in the Dutch Vlissingen factory originate partly from Finland. The comparative high climate change impact associated with oat cultivation in Finland (mainly due to peat oxidation) results in a higher footprint of the oat cultivation stage of Oatly Barista produced in the Netherlands, as can also be seen in Figure 9A. Oats from Sweden also have a significant contribution from peat oxidation. For the Oatly Barista from the US Ogden factory, the rapeseed oil has a high impact due to its relative low yields.
- **Processing**: Figure 9B and Figure 9C shows that heat makes up the largest share of the two processing stages. The heat used in the Swedish Landskrona factory is generated by biogas, whereas natural gas is used in the Dutch Vlissingen and US Ogden factories.
- **Packaging**: Despite the small contribution in terms of weight, the BioPE used in packaging has the largest contribution to the packaging climate change impact (Figure 9D). This is mainly attributed to the land use change impact associated with sugarcane cultivation in Brazil.
- **Distribution to retail/DC**: The main contributor to the climate change impact of Oatly Barista in the US is distribution to the customer. In addition to the long transport distance (>2000km), the use of refrigerated trucks during the winter months is also responsible for the high distribution impact (refrigerated trucks are used in the winter months to present freezing of products).
- **Storage at retail/DC**: Even though the same defaults have been used for energy and water consumption for storage at DCs and retail, the impact varies between European countries because of the different national electricity grid mixes. For storage at DC and retail/food service in the US, different data has been used.
- **End of Life** (EoL) varies between different countries depending on country-specific waste treatment characteristics. In the Netherlands for example, only a small share of the beverage carton is recycled.



	Oatly Barista SE factory Retail SE	Oatly Barista SE factory Retail FI	Oatly Barista SE factory Retail UK	Oatly Barista SE factory Retail DE	Oatly Barista SE factory Retail NL	Oatly Barista NL factory Retail NL	Oatly Barista NL factory Retail DE	Oatly Barista NL factory Retail UK	Oatly Barista NL factory Retail SE	Oatly Barista NL factory Retail FI	Oatly Barista US Ogden factory Retail US	Oatly Barista US Ogden factory Food service US
10. Packaging End of Life	0.025	0.017	0.012	0.013	0.026	0.026	0.013	0.012	0.026	0.018	0.007	0.007
09b. Storage at retail	0.002	0.009	0.011	0.018	0.020	0.020	0.018	0.011	0.002	0.009	0.006	0.006
09a. Storage at DC	0.003	0.003	0.004	0.005	0.005	0.005	0.005	0.004	0.003	0.003	0.002	0.002
08b. Distribution to retail	0.043	0.045	0.025	0.042	0.010	0.010	0.042	0.025	0.043	0.045	0.249	0.020
08a. Distribution to DC	0.002	0.002	0.040	0.015	0.061	0.020	0.023	0.056	0.078	0.078	0.000	0.242
07b. Transport of packaging material	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.006	0.006
07a. Packaging	0.094	0.094	0.094	0.094	0.094	0.092	0.092	0.092	0.092	0.092	0.095	0.095
06. Processing - Oatly Barista	0.017	0.017	0.016	0.016	0.016	0.090	0.090	0.090	0.090	0.090	0.151	0.151
05. Processing - Oat base	0.006	0.006	0.006	0.006	0.006	0.033	0.033	0.033	0.033	0.033	0.064	0.064
04b. Transport of other ingredients to factory	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
04a. Transport of oats to factory	0.014	0.014	0.014	0.014	0.014	0.002	0.002	0.002	0.002	0.002	0.005	0.005
03. Oats milling	0.002	0.002	0.002	0.002	0.002	0.022	0.022	0.022	0.022	0.022	0.023	0.023
02. Oats transport to mill	0.003	0.003	0.003	0.003	0.003	0.008	0.008	0.008	0.008	0.008	0.010	0.010
01b. Other ingredient production	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.104	0.104
01a. Oat cultivation	0.130	0.130	0.130	0.130	0.130	0.165	0.165	0.165	0.165	0.165	0.087	0.087
Total	0.406	0.408	0.422	0.424	0.453	0.558	0.577	0.584	0.628	0.630	0.809	0.821

FIGURE 8: CLIMATE CHANGE IMPACT OF AMBIENT OATLY BARISTA AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING, SORTED FROM LOWEST TO HIGHEST IMPACT. THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

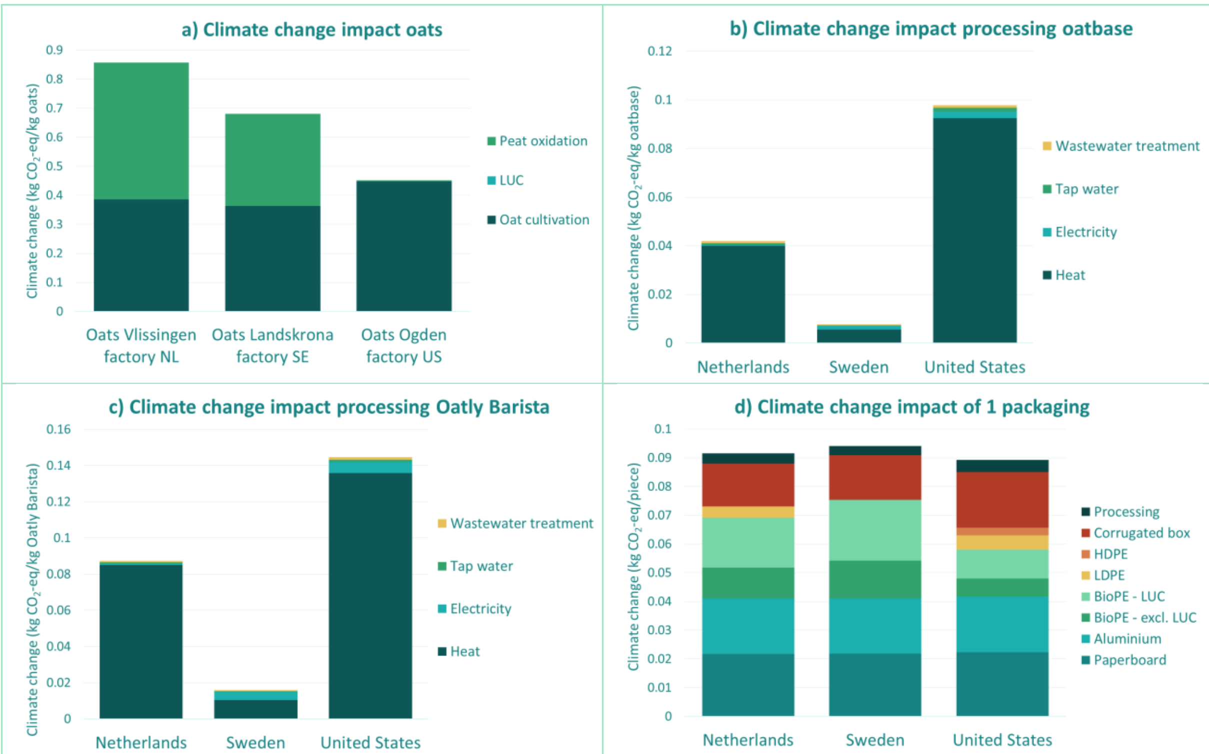


FIGURE 9: CLIMATE CHANGE IMPACT OF A) OATS, B) OATBASE PROCESSING, C) OATLY BARISTA PROCESSING, AND D) 1 PACKAGING

5.1.3 Cow's milk

Figure 10 shows that the raw cow's milk is the main contributor to the climate change impact of cow's milk. Processing energy for European countries is derived from the Dairy PEFCR (using country-specific electricity mixes), which is higher than the processing energy for the United States as reported in Burek et al. (2017). On the other hand, energy for storage at DC and retail is higher in the US compared to the default values for the European countries derived from the PEFCR. The HDPE bottles used in the United Kingdom and the United States have a higher impact than the beverage carton used in the remaining countries, though a larger share can be recycled, leading to a small amount of avoided emissions at end of life.

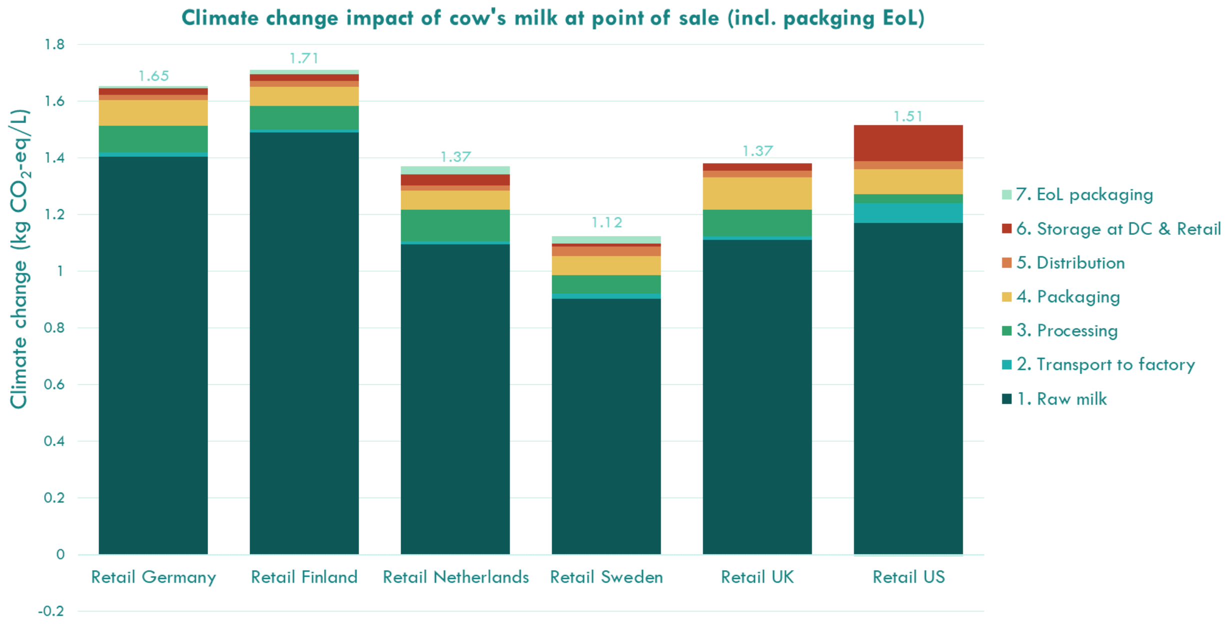


FIGURE 10: CLIMATE CHANGE IMPACT OF 1L COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING

Figure 11 below shows the climate change impact of raw cow's milk, showing that the impact of feed production is relatively similar, however, LUC and peat oxidation linked to feed production result in a high additional impact, particularly for Germany, Finland, and the Netherlands. In these countries, a larger share of the feed is cultivated on peat soils. The land use change (LUC) impact is associated with feed cultivated on land where deforestation has taken place in the last 20 years, such as for soybean cultivation in south America.

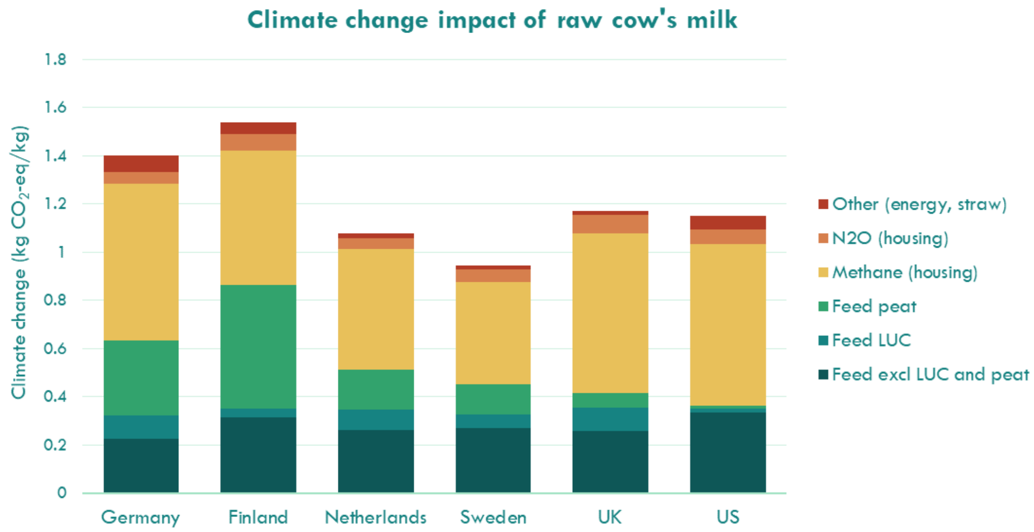


FIGURE 11: CLIMATE CHANGE IMPACT OF RAW COW'S MILK

Methane emissions originate primarily from enteric fermentation and manure management. Manure management systems with liquid storage systems generally lead to higher methane emissions (due to anaerobic conditions). An example of such a system is anaerobic lagoons, which are more frequently used in the US than in Europe.

5.2 Sensitivity analyses

The sensitivity analyses served to evaluate the robustness of the results by assessing the influence of several assumptions and modelling choices that have been made. Sensitivity analyses were performed to evaluate the choice of impact assessment method, the choice of functional unit, the choice of allocation, as well as several choices with regard to characteristics of the systems under study (e.g. inclusion of use stage, comparison to chilled version of Oatly Barista, comparison to ambient version of cow's milk). Next to that, an uncertainty analysis has been performed to determine the range in outcomes when considering uncertainties with regard to data quality and emission factors used in the dairy system.

All sensitivity analyses were performed for ambient Oatly Barista at retail or food service (incl EoL packaging) compared to chilled cow's milk at retail (incl EoL packaging), except for those sensitivity analyses considering chilled Oatly Barista (5.2.4), ambient cow's milk (5.2.7), and inclusion of the use stage (for ambient Oatly Barista) (5.2.2).

The graphs shown in the sensitivity analyses mainly focus on the climate change impact. The results for all impact categories are included in the Appendix V.

Whenever graphs are provided that show the impact of Oatly Barista and cow's milk, for the European countries in scope, first the Oatly Barista of the main production location is shown, followed by the Oatly Barista originating from the secondary production location, and then the cow's milk. In the US both bars represent production at Oatly's end-to-end factory in Ogden, UT, with the first bar reflecting food service and the second reflecting retail. Percentages show the difference of Oatly Barista compared to cow's milk.

5.2.1 Alternative impact assessment methods

Endpoint impact assessment

The endpoint indicators that are part of the ReCiPe impact assessment method are a measure of the damage at the end of the cause-effect chain. They aggregate several midpoint indicators to provide a holistic overview of the impact of products on human health, resources, and ecosystems (see approach in Figure 12 below).

The unit used for human health is disability adjusted life years (DALYs), representing the years that are lost or that a person is disabled due to a disease or accident. The unit for ecosystem quality is the local species loss integrated over time (species year). The unit for resource scarcity is the dollar, which represents the extra costs required for future mineral and fossil resource extraction (Mark Huijbregts et al., 2016).

The results for all endpoint categories are provided in Figure 13. The detailed characterization per midpoint level is provided in Appendix V.

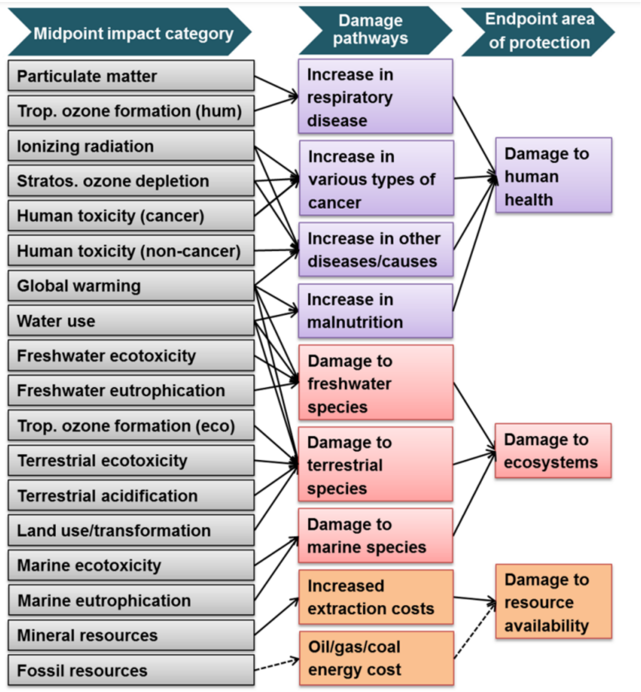


FIGURE 12: OVERVIEW OF THE IMPACT CATEGORIES THAT ARE COVERED IN THE RECIPE 2016 METHODOLOGY AND THEIR RELATION TO THE ENDPOINTS (MARK HUIJBREGTS ET AL., 2016)

For all countries, the impact on ecosystems is lower for Oatly Barista than cow's milk. The difference between Oatly Barista and cow's milk is smaller than when considering the climate change impact only. For the human health endpoint category, Oatly Barista also has lower impacts than cow's milk, whereas for the resource availability endpoint, there's no clear difference between Oatly Barista and cow's milk.

FIGURE 13: IMPACT FOR OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING FOR THE THREE ENDPOINT CATEGORIES: A) HUMAN HEALTH, B) ECOSYSTEMS AND C) RESOURCES. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

EF impact assessment

Figure 14 shows the results when applying the environmental impact assessment method EF 3.0 from the European Commission's Product Environmental Footprint (PEF) method. As can also be witnessed by the units, different methods are used to calculate the impact of most categories. Despite different underlying methods, relatively similar differences between Oatly Barista and cow's milk can be observed for all impact categories as for the ReCiPe method (see Table 14). A notable difference is the land use. The EF method uses the LANCA model (Bos, Horn, Beck, Lindner, & Fischer, 2016), which unlike the ReCiPe method, doesn't only quantify the land surface (as annual crop equivalents), but adds a qualitative aspect, based on a combination of soil properties (erosion resistance, mechanical filtration, physicochemical filtration, groundwater replenishment and biotic production). The annual cropland where oat cultivation takes place has a lower LANCA score than the grassland and cropland used for the cultivation of feed. Mineral and metals resource use also show some differences as it uses different characterization factors for metals[20]. EF's water use indicator (based on the AWARE method which uses country-specific water scarcity factors) results on average in higher differences between Oatly Barista and cow's milk (favoring Oatly Barista).

TABLE 15: RELATIVE DIFFERENCES OF OATLY BARISTA COMPARED TO COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING, USING THE EF3.0 IMPACT ASSESSMENT METHOD. FOR EXAMPLE, -68% INDICATES THAT OATLY BARISTA HAS A 68% LOWER IMPACT COMPARED TO COW'S MILK. THE COLOUR SCALE USES GREEN TONES TO SHOW WHERE OATLY BARISTA HAS A LOWER IMPACT THAN COW'S MILK, AND RED TONES WHERE COW'S MILK HAS A LOWER IMPACT THAN OATLY BARISTA. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES.

Sales country	Factory location Oatly Barista	Climate change	Particu-late matter	Acidifi-cation	Eutrophi-cation, freshwater	Eutrophi-cation, terrestrial	Eutrophi-cation, marine	Land use	Resource use, minerals and metals	Resource use, fossils	Water use
		kg CO2 eq	*Disease inc*	*mol H+ eq*	*kg P eq*	*kg N eq*	*mol N eq*	*Pt*	*kg Sb eq*	*MJ*	*m3 depriv*
Germany (retail)	Vlissingen, NL	-68%	-81%	-87%	-54%	-87%	-69%	-74%	3%	3%	-30%
	Landskrona, SE	-76%	-80%	-86%	-55%	-87%	-70%	-75%	13%	-41%	-31%
Finland (retail)	Landskrona, SE	-78%	-74%	-70%	-46%	-83%	-65%	-45%	-25%	-54%	-43%
	Vlissingen, NL	-66%	-73%	-68%	-43%	-79%	-61%	-45%	-32%	0%	-41%
Netherlands (retail)	Vlissingen, NL	-63%	-79%	-87%	-42%	-78%	-59%	-55%	-1%	-2%	-35%
	Landskrona, SE	-69%	-77%	-85%	-45%	-76%	-59%	-55%	15%	-40%	-36%
Sweden (retail)	Landskrona, SE	-67%	-70%	-75%	-29%	-78%	-59%	-55%	-8%	-50%	-47%
	Vlissingen, NL	-49%	-69%	-73%	-25%	-72%	-54%	-55%	-16%	12%	-45%
UK (retail)	Vlissingen, NL	-62%	-81%	-82%	-40%	-57%	-61%	-70%	18%	-9%	-48%
	Landskrona, SE	-72%	-80%	-80%	-44%	-59%	-63%	-70%	30%	-49%	-49%
US (food service)	Ogden, Utah, US	-51%	-73%	-73%	-32%	-74%	-38%	-42%	-51%	21%	-77%
US (retail)	Ogden, Utah, US	-51%	-73%	-72%	-32%	-74%	-38%	-42%	-51%	20%	-77%

This EF 3.0 impact assessment method provides, next to midpoint indicators, a single score based on normalization and weighting of all midpoint categories. The resulting graph shows the single score of each product, and how the impact categories contribute to this score. Climate change is the top driver for the overall impact of the products in scope.

[20] In the EF method, metals are characterized as Sb (antimony)-equivalents and in the ReCiPe method as Cu (copper)-equivalents. The latter assigns for example relatively higher characterization factors to aluminum.

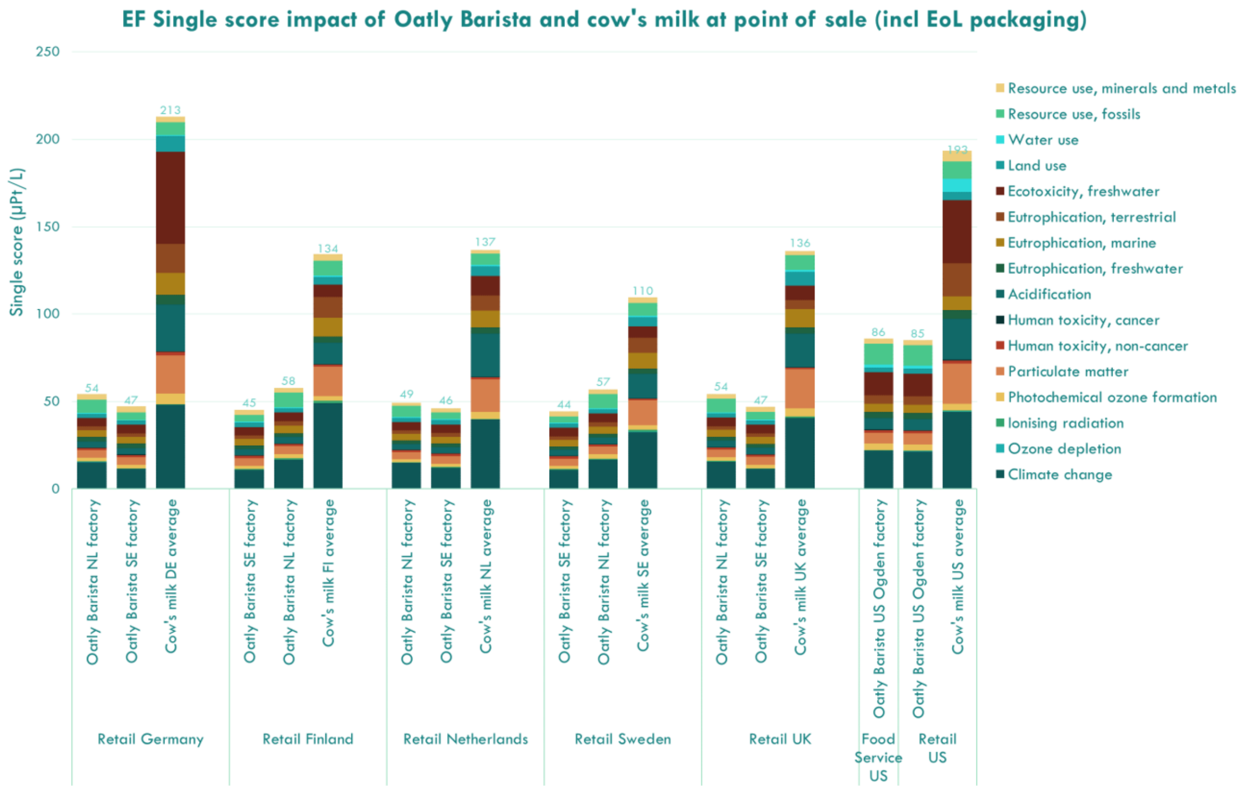


FIGURE 14: EF SINGLE SCORE IMPACT (USING THE EF 3.0 METHOD) OF 1L OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING, SHOWING THE RELATIVE CONTRIBUTION OF THE SEPARATE MIDPOINT IMPACT CATEGORIES TO THE SINGLE SCORE. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

GWP20 instead of GWP100

Usually, GWP100 is used for analyses, which measures the warming potential of greenhouse gases over a 100-year timeframe. Another option is to take a 20-year time frame instead (Figure 15). The resulting GWP20 better reflects the impact of short-lived greenhouse gases. Methane for example, stays in the atmosphere for about 12 years, whilst CO_2 can remain there for over a hundred years. Using GWP20 can help identify measures that reduce GHG emissions in the short term. However, the risk of focusing solely on GWP20 is that less emphasis is put on reducing long-lived GHGs like CO_2 and N_2O, consequently leading to fewer measures that tackle the long-term effects and thus shifting the burden to future generations.

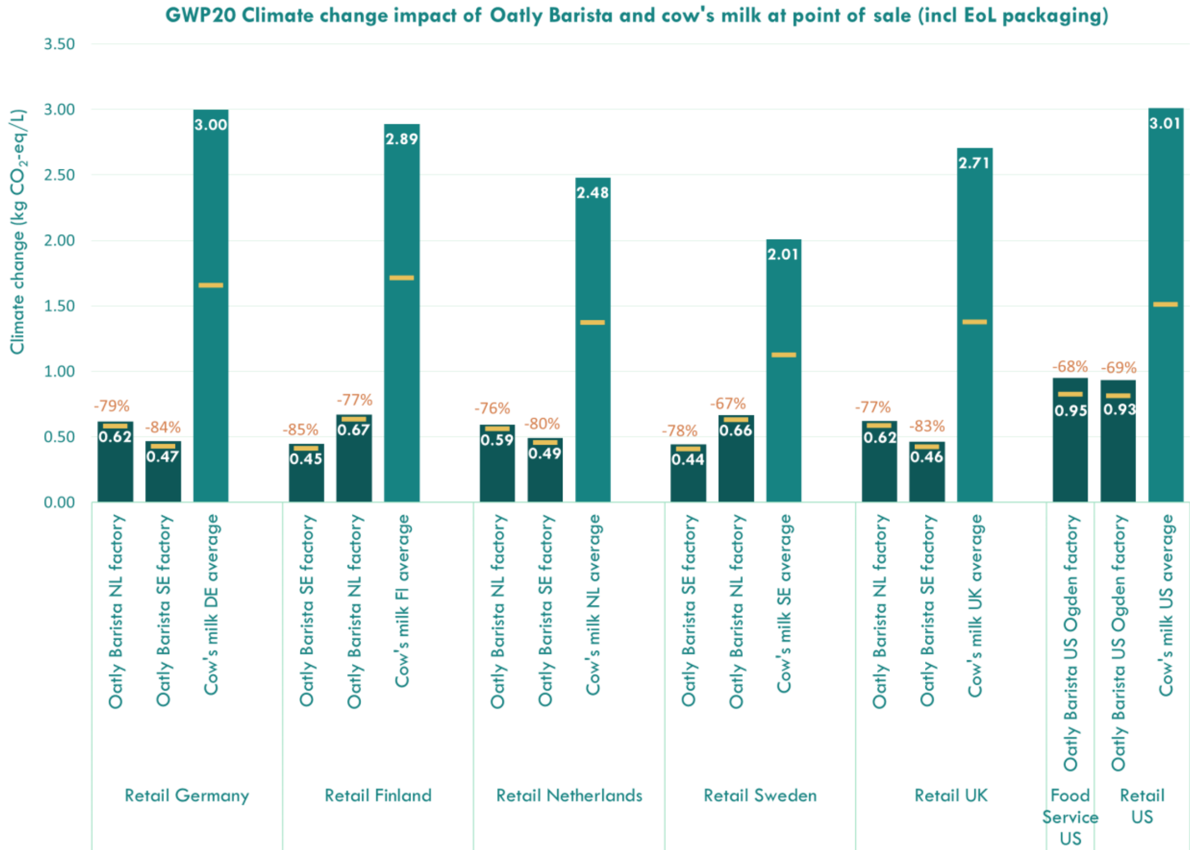


FIGURE 15: GWP20 CLIMATE CHANGE IMPACT OF 1L OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. THE YELLOW LINES INDICATE THE GWP100 RESULTS. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

The climate change impact of cow's milk increases significantly (between 69%-100%) when applying GWP20, whereas the impact of Oatly Barista increased only slightly (between 6%-16%), leading to even bigger differences between the two systems as also indicated by the percentages in Figure 15. This is especially attributed to the methane emissions from manure management and enteric fermentation at the dairy farm.

5.2.2 Inclusion of use stage

The use phase adds between 9%-39% to the climate change impact of the Oatly Barista and cow's milk at retail level, as can be seen in Table 16 and Figure 16. The largest share of this impact is attributed to heating the Oatly Barista and cow's milk, and to losses. The difference is particularly big for the US, where losses at use phase are 20% (same value assumed for cow's milk and Oatly Barista[21]), meaning that 1.25 l of cow's milk/Oatly Barista at retail is necessary to consume 1 liter. Furthermore, the energy use for refrigeration is relatively high in the US compared to European countries.

[21] Ambient (shelf stable) Barista can be preserved longer (months) while fresh milk best before date is much shorter. Therefore, Oatly Barista might probably have fewer losses at a consumer level and the gap between milk and Oatly Barista could be even higher. Given the absence of qualitative data, we assume losses to the same level as milk as a conservative approach.

TABLE 16: CLIMATE CHANGE IMPACT INCL. AND EXCL. USE STAGE (INCL EOL PACKAGING) FOR OATLY BARISTA AND COW'S MILK. THE THIRD COLUMN INDICATES THE DIFFERENCE BETWEEN THE TWO. E.G. 19% MEANS THAT OATLY BARISTAS INCLUDING USE STAGE HAS A 19% HIGHER IMPACT THAN OATLY BARISTA AT RETAIL. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

Product	Climate change impact excl use stage (CO_2-eq)	Climate change impact incl use stage (CO_2-eq)	Difference
Consumer Germany			
Oatly Barista NL factory	0.577	0.688	19%
Oatly Barista SE factory	0.424	0.524	23%
Cow's milk DE average	1.652	1.846	12%
Consumer Finland			
Oatly Barista SE factory	0.408	0.476	17%
Oatly Barista NL factory	0.630	0.714	13%
Cow's milk FI average	1.711	1.886	10%
Consumer Netherlands			
Oatly Barista NL factory	0.558	0.675	21%
Oatly Barista SE factory	0.453	0.562	24%
Cow's milk NL average	1.369	1.568	15%
Consumer Sweden			
Oatly Barista SE factory	0.406	0.448	10%
Oatly Barista NL factory	0.628	0.686	9%
Cow's milk SE average	1.124	1.221	9%
Consumer United Kingdom			
Oatly Barista NL factory	0.584	0.671	15%
Oatly Barista SE factory	0.422	0.497	18%
Cow's milk UK average	1.374	1.532	11%
Consumer United States			
Oatly Barista US factory (through food service)	0.821	1.189	45%
Oatly Barista US Ogden factory (through retail)	0.809	1.174	45%
Cow's milk US average (through retail)	1.540	2.090	39%

The use stage has a relatively higher impact for cow's milk due to longer storage in the fridge at the consumer (except for the UHT milk in Germany).

When comparing the impact of cow's milk to Oatly Barista including use stage, the differences between both products are slightly lower than when considering their impact at the retail stage.

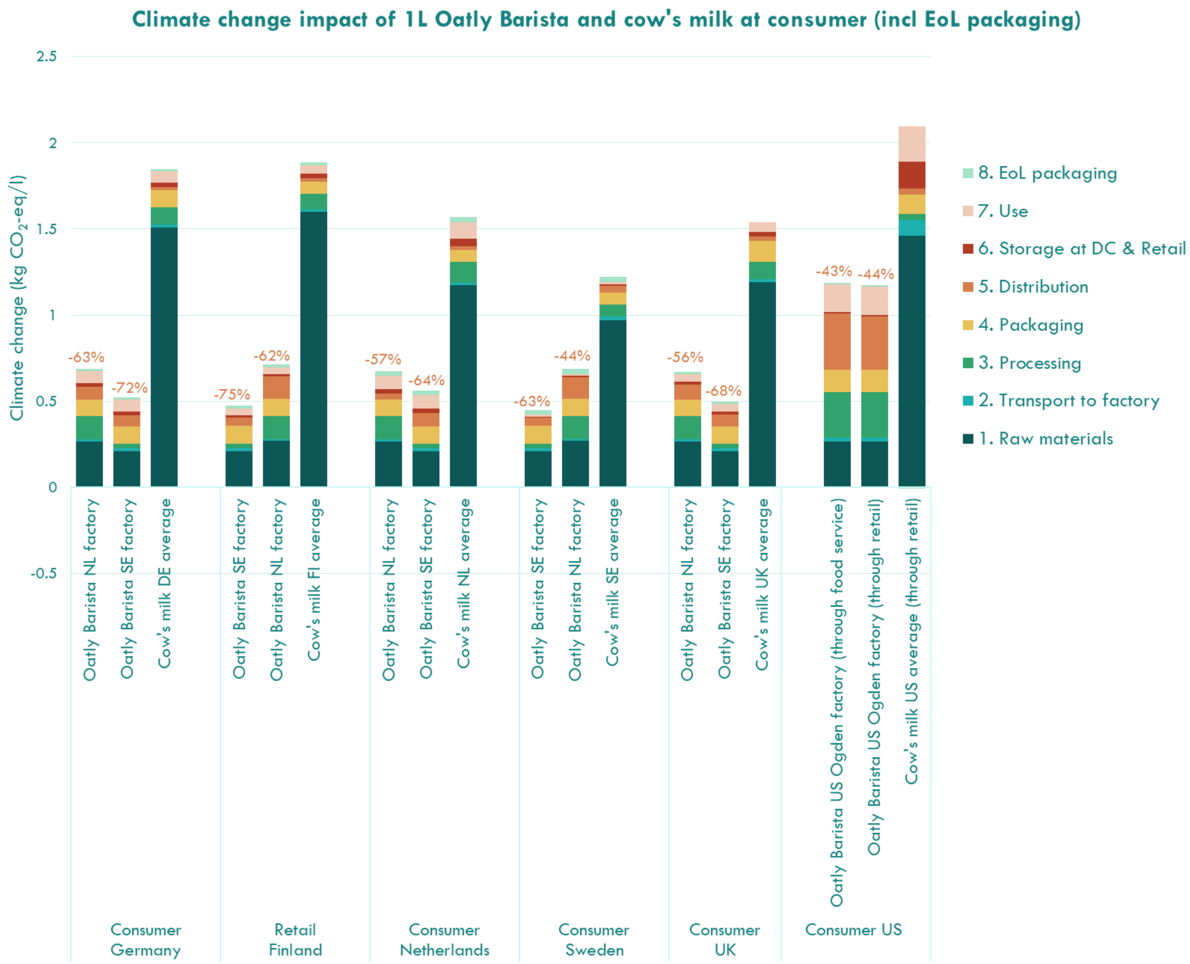


FIGURE 16: CLIMATE CHANGE IMPACT OF 1L OATLY BARISTA AND COW'S MILK AT THE USE STAGE (CONSUMER) INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

5.2.3 Functional unit based on the Nutrient Density Unit (NDU)

This section considers the NDU (Nutrient Density Unit) as functional unit, as explained in section 2.7.2. The NDU considers protein, essential fatty acids, dietary fiber, and energy. It is suitable as functional unit in LCA as it leaves out limiting macronutrients (which can lead to negative values). The NDU is based on the nutrient content per 100 g of product and is calculated as follows (Dooren, 2018):

$$Nutrient\ Density\ Unit = \frac{\left(\frac{\text{g essential fatty acids}}{12.4\ g}\right) + \left(\frac{\text{g protein}}{50\ g}\right) + \left(\frac{\text{g fibre}}{25\ g}\right)}{3\ \times \left(\frac{\text{kcal energy}}{2000\ kcal}\right)}$$

The data as provided in Table 17 has been used to calculate the NDU. For cow's milk, the data sources that have been used are listed in the footnote[22], and concerns primarily recent data derived from national food composition tables. For each of the three milk types, the most conservative values from all countries were selected (thus highest essential fatty acids, protein and fiber content, and lowest energy content). Next, a country-average NDU was calculated based on the country-specific consumption rates of skimmed, semi-skimmed and whole cow's milk, as listed in Table 3. The higher the NDU, the higher amount of encouraged macronutrients the food provides.

TABLE 17: MACRONUTRIENT CONTENT PER 100G OF OATLY BARISTA AND COW'S MILK. FOR EACH OF THE THREE MILK TYPES, THE MOST CONSERVATIVE VALUES FROM ALL COUNTRIES WERE SELECTED.

	Oatly Barista NL factory	Oatly Barista SE factory	Oatly Barista US Ogden factory	Cow's milk skimmed	Cow's milk semi-skimmed	Cow's milk whole
Essential fatty acids (g)	0.8	0.8	0.6	0.005	0.052	0.1
Protein (g)	1.1	1.1	1.2	3.7	3.6	3.5
Fiber (g)	0.8	0.8	0.8	0	0	0
Energy (kcal)	59.1	59.1	56.5	34	45	60
NDU	**1.32**	**1.32**	**1.24**	**1.46**	**1.15**	**0.87**

The resulting climate change impact calculated per NDU is shown in Figure 17. The differences in climate change impact between Oatly Barista and cow's milk are bigger when using a functional unit based on NDU compared to a functional unit based on volume.

As mentioned in section 212.7.2, this method was deemed as appropriate to evaluate the influence of nutritional properties in this sensitivity analysis. A potential follow-up research could take into consideration more complex nutritional indices. Currently there's no consensus on which nutritional index is best fit for LCA purposes.

[22] NL: https://nevo-online.rivm.nl/Home/En
UK: https://milk.co.uk/hcp/wp-content/uploads/sites/2/2017/04/Nutritional-Composition-of-Dairy-2017.pdf
US: https://fdc.nal.usda.gov/index.html
SE: https://www7.slv.se/SokNaringsinnehall/
FI: https://fineli.fi/fineli/en/index
DE: https://milchindustrie.de/milkipedia-register/a/

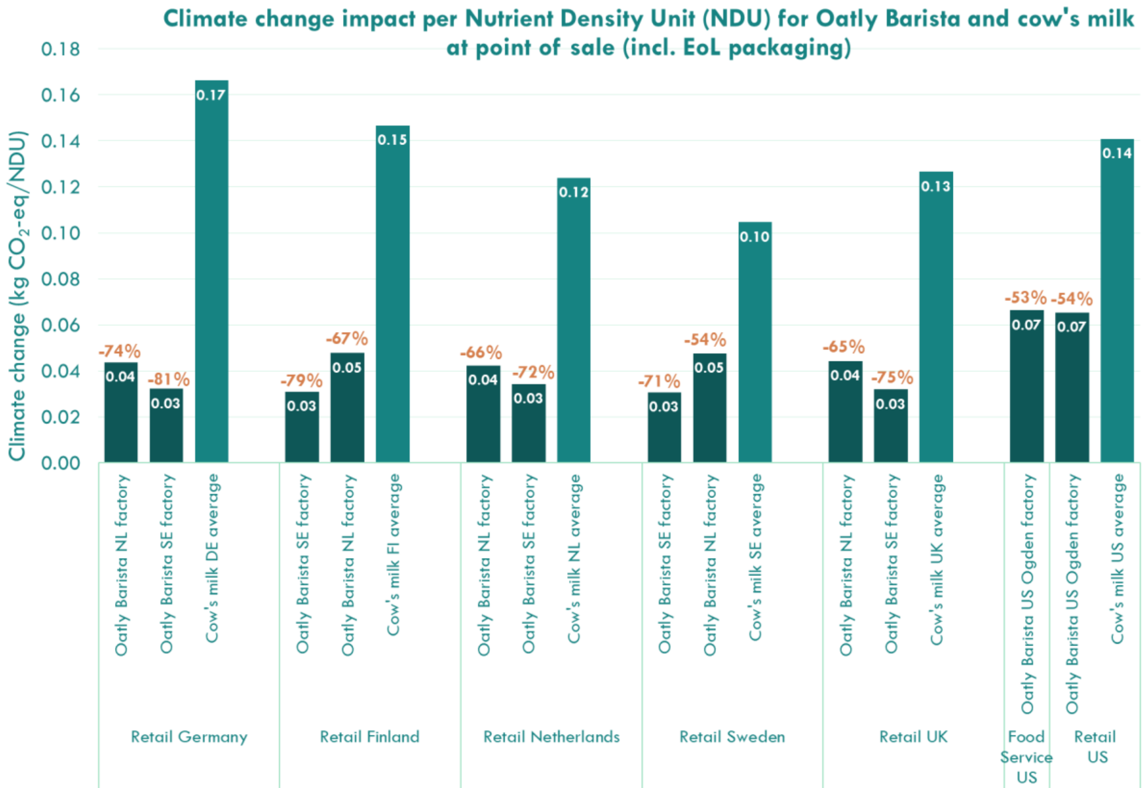


FIGURE 17: CLIMATE CHANGE IMPACT PER NUTRIENT DENSITY UNIT (NDU) FOR OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

5.2.4 Ambient vs chilled Oatly Barista

Figure 18 shows the difference between ambient and chilled Oatly Barista at retail (incl. EoL packaging). The climate change impact of chilled Oatly Barista is 5%-23% higher than of ambient Oatly Barista. A notable exception is chilled packaging in the UK, which has a lower impact because it uses a different DC which requires less transport. Packaging of chilled Oatly Barista has a slightly lower impact, due to the absence of aluminum in the beverage cartons, however, the impact for distribution and storage at retail is higher due to refrigerated transport and storage.

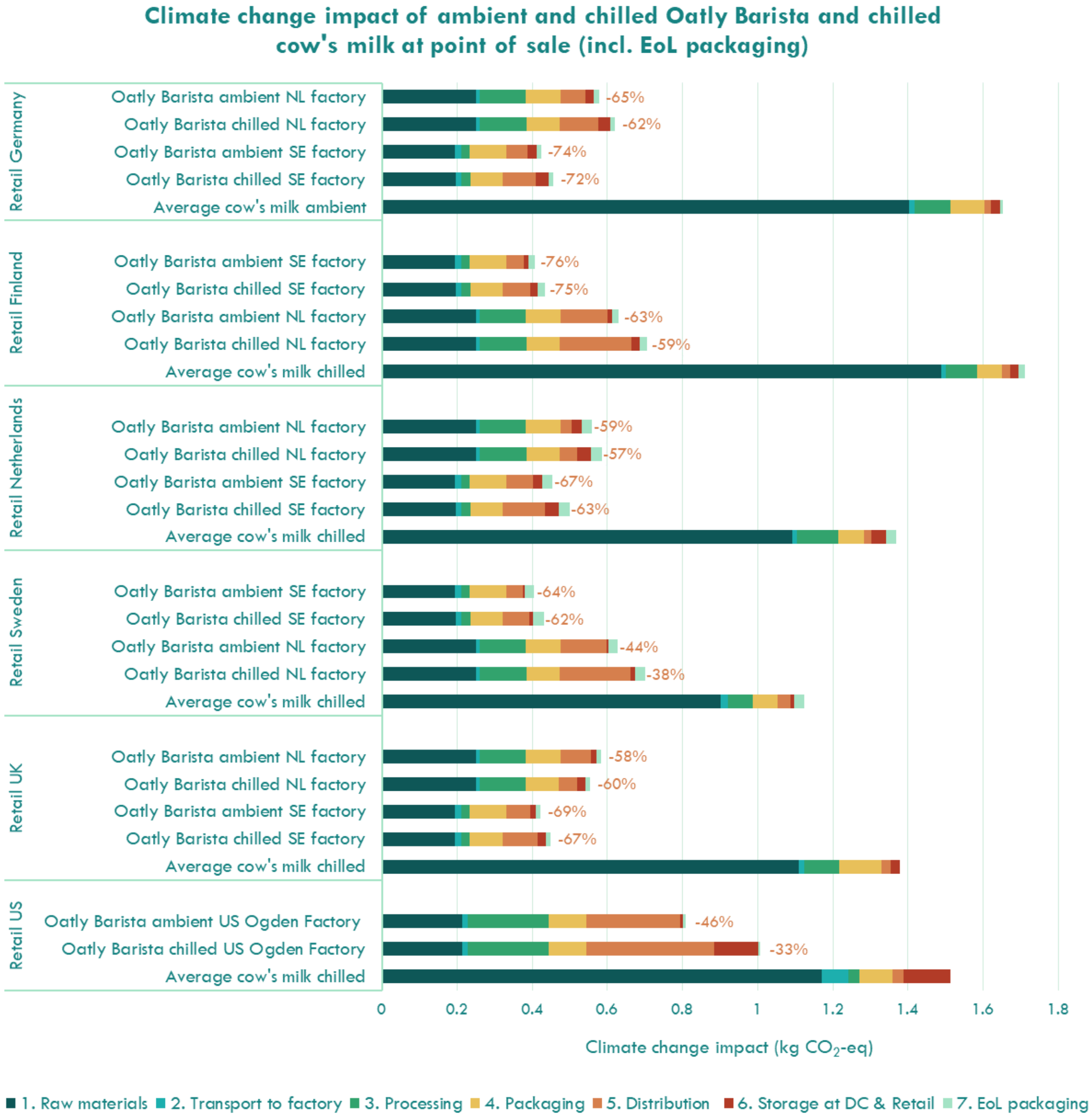


FIGURE 18: CLIMATE CHANGE IMPACT OF AMBIENT AND CHILLED OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE US, A CHILLED VERSION IS ONLY PROVIDED FOR THE OATLY BARISTA AT RETAIL, AS THE OATLY BARISTA PROVIDED TO FOOD SERVICE IS ALWAYS AMBIENT. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

5.2.5 Oatly Barista compared to cow's milk with different fat content

For the main analysis, Oatly Barista was compared to an average mix of skimmed, semi-skimmed and whole milk. This sensitivity analysis investigates how Oatly Barista performs in relation to each of the individual milk types. In line with the main analysis, biophysical allocation (at farm level) and mass allocation (at dairy processing level) is assumed, in line with the dairy PEFCR.

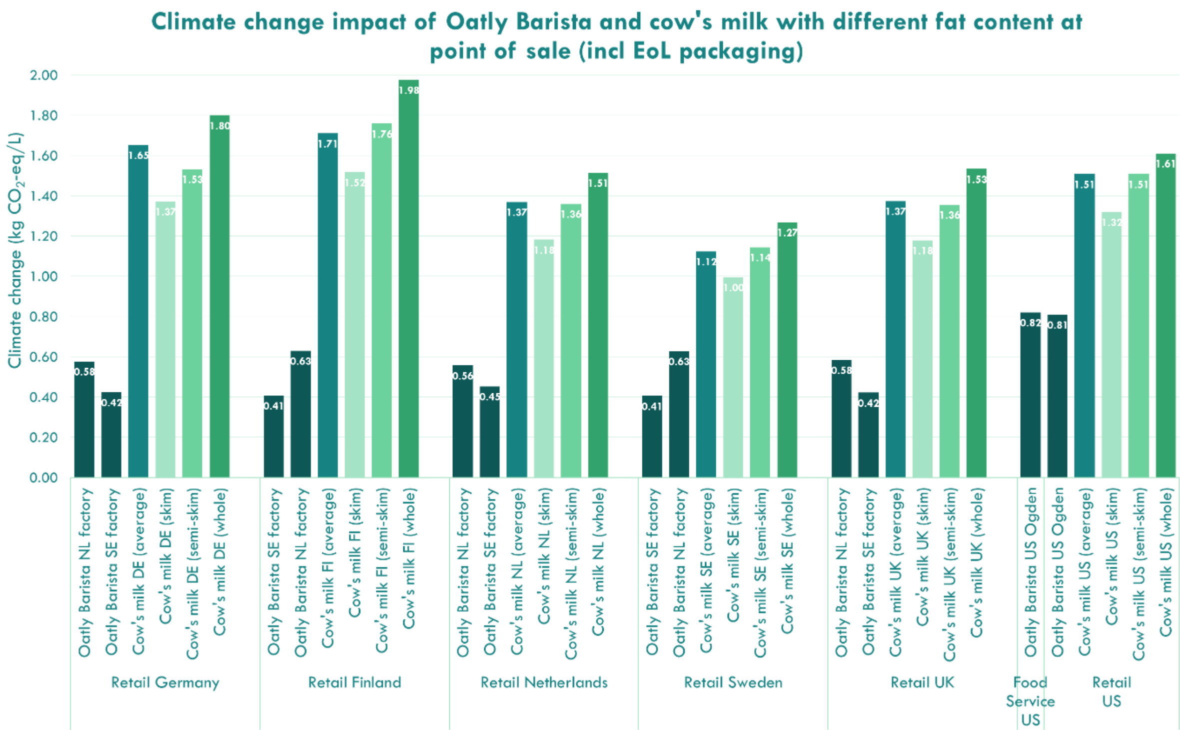


FIGURE 19: CLIMATE CHANGE IMPACT OF 1L OATLY BARISTA AND 1L COW'S MILK WITH DIFFERENT FAT CONTENT AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

Figure 19 shows that skimmed cow's milk has the lowest climate change impact of cow's milk types, because a larger share of the impact at processing is allocated to cream. Whole cow's milk has the highest impact. The climate change impact of Oatly Barista is lower than each of the milk types.

In terms of fat content, Oatly Barista would be most comparable to whole cow's milk. However, in the absence of concrete consumer insights, the average mix was selected to remove the assumption that Oatly drinkers are replacing cow's milk of the same fat content as it is possible that they are switching from semi-skimmed or skimmed milk.

5.2.6 Oatly Barista compared to milk modelled with economic allocation

In line with the Dairy PEFCR, the cow's milk has been modelled using biophysical allocation at farm level and mass allocation at processing level. This sensitivity analysis investigates the impact using economic allocation, consistent with the allocation applied throughout.

The price of raw milk and meat (farm level) and pasteurized milk and cream (processing level) has been derived from the Agri-footprint 6 database and from the Optimeal EU database (Broekema, Blonk, Koukouna, & van Paassen, 2019).

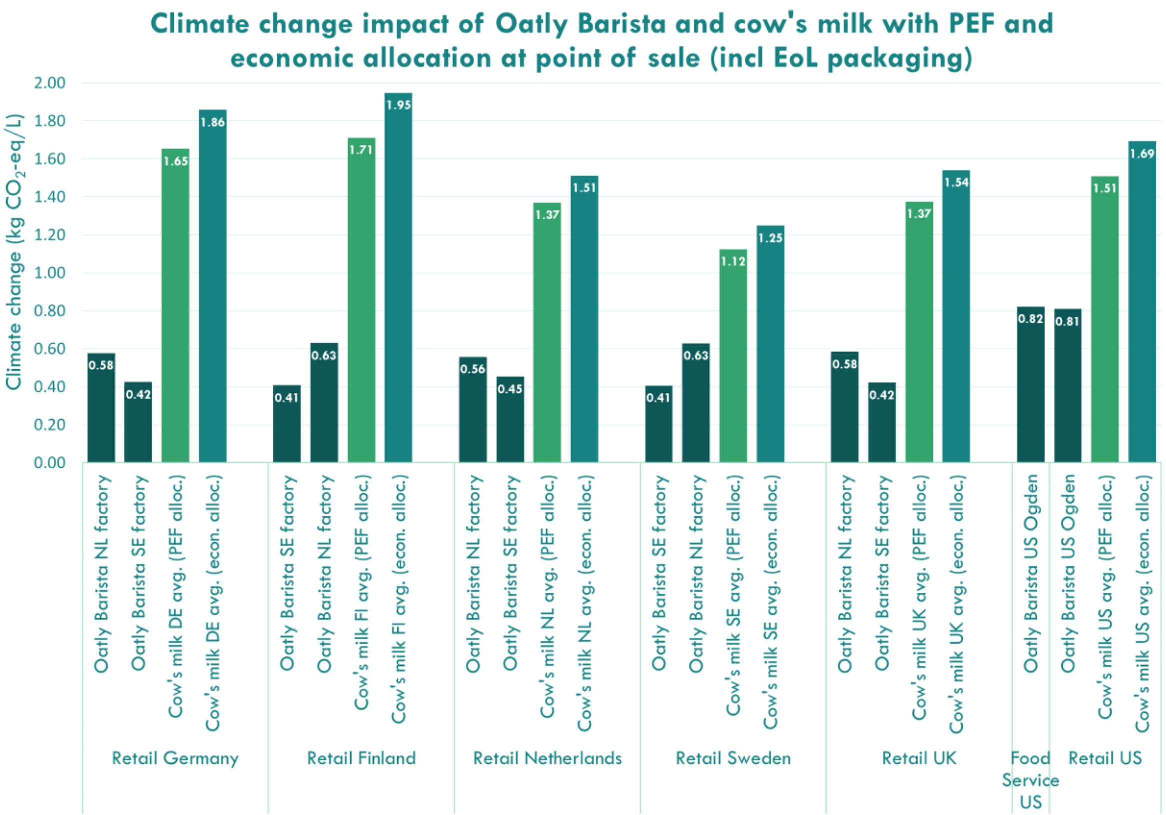


FIGURE 20: CLIMATE CHANGE IMPACT OF 1L OATLY BARISTA COMPARED TO 1L COW'S MILK WITH PEF AND ECONOMIC ALLOCATION, AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) PACKAGING. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

Using economic allocation, the climate change impact of cow's milk is between 10-14% higher than using the allocation methods as described in the PEF (Figure 20). This is because a larger share of the impact at farm and at processing level goes to milk as opposed to meat and cream respectively.

5.2.7 Oatly Barista compared to UHT milk

For the main analysis, Oatly Barista has been compared to cow's milk with the most common heat treatment in that country. In most cases, this was HTST treatment.

In this sensitivity analysis, Oatly Barista is compared to UHT cow's milk which is packed, transported, and stored under ambient conditions, like Oatly Barista.

The analysis has been carried out taking Germany as an example. As can be seen in Figure 20, the change in impact is negligible. Distribution and storage have a lower impact (-36% and -31% respectively) due to ambient instead of refrigerated transport and storage. However, because of the relatively short distribution distances in the dairy value chain, transport has a small contribution to the overall climate change impact. Packaging on the other hand has a higher impact (+37%) because of the use of aluminum in the liquid packaging board. The higher contribution of packaging compensates for the lower impact for transport and distribution, leading to both HTST and UHT cow's milk having the same impact of 1.65 kg CO2-eq/l cow's milk.

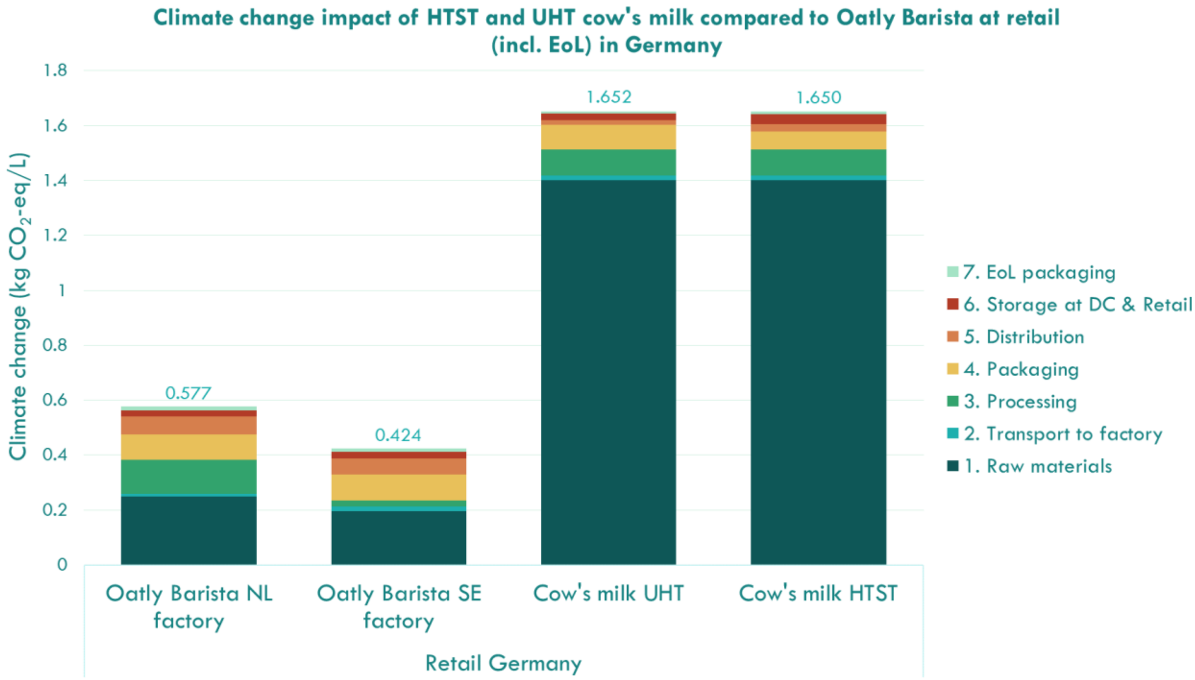


FIGURE 21: CLIMATE CHANGE IMPACT OF HTST (HIGH TEMPERATURE SHORT TIME) AND UHT (ULTRA HIGH TEMPERATURE) COW'S MILK COMPARED TO OATLY BARISTA - GERMANY

5.2.8 Sensitivity of input parameters for Oatly Barista (Perturbation Analysis)

Figure 22 shows which processes are of most influence on the climate change impact of the main products in scope. This analysis has been carried out by increasing each individual parameter by 10% whilst keeping all other parameters fixed and calculating the footprint at retail for each individual scenario.

Note that this is different than a contribution analysis as it includes more interdependencies, e.g. when lowering the quantity of packaging material, this also lowers the transport of those packaging materials, as well as the end of life treatment.

In line with one of the goals of this study, this provides Oatly with additional insight into what processes along its value chain offers potential to improve the environmental performance.

For Oatly Barista produced in the Netherlands, the oat cultivation has the highest contribution to the overall climate change impact, as also reflected in the contribution analysis. For the oatbase produced at Oatly's Dutch Vlissingen factory, it should be noted that the oats originate from three different countries (Sweden, Finland, Estonia). Swedish oats have the highest influence on the final footprint because they make up the largest share even if they have a relatively lower climate change impact than Finnish oats. Thermal energy at the Dutch Vlissingen factory, currently from natural gas, has the second highest influence on the climate change impact of Oatly Barista. Rapeseed oil, which is the main ingredient after oats, has the third highest climate change impact.

For packaging, BioPE (due to its relatively high impact) and cardboard (due to its relatively high weight) have a relatively high contribution. It should be noted that the impact of the packaging is not only linked to packaging material itself, but also to its transport, both transport of packaging to the factory and transport of the packaging to the final consumer. Hence the relatively high impact of packaging materials with a relatively low footprint but high weight (corrugated board, paperboard).

Distribution also has a significant impact, especially when truck transportation is used and distances are long between factory and DC and DC and retail. This especially applies to the US where transport distances between factory and retail are very substantial. The refrigerated transport contributes to this.

Oatly NL retail DE

1	Raw oats from Sweden	-1.56%
2	Heat processing Barista	-1.52%
3	Raw oats from Finland	-1.30%
4	Rapeseed oil	-1.01%
5	transport to retail DE	-0.73%
6	BioPE in pack.	-0.58%
7	Paperboard in pack.	-0.56%
8	Heat processing oatbase	-0.54%
9	transport to DC	-0.40%
10	Aluminium in pack.	-0.36%
11	Electricity retail	-0.31%
12	Corrugated board	-0.28%
13	electricity mill	-0.21%
14	processing losses	-0.21%
15	Raw oats from Estonia	-0.13%
16	electricity gas boiler mill	-0.11%
17	LDPE in pack.	-0.11%
18	enzymes	-0.06%
19	Heat DC	-0.05%
20	Electricity DC	-0.04%

Oatly NL retail FI

Raw oats from Sweden	-1.44%
Heat processing Barista	-1.40%
Transport to DC SE	-1.23%
Raw oats from Finland	-1.20%
Rapeseed oil	-0.92%
Truck transport retail FI	-0.67%
Paperboard in pack.	-0.59%
BioPE in pack.	-0.54%
Heat processing oatbase	-0.50%
Aluminium in pack.	-0.34%
Corrugated board	-0.27%
electricity mill	-0.20%
processing losses	-0.19%
Electricity retail	-0.15%
Raw oats from Estonia	-0.12%
electricity gas boiler mill	-0.10%
LDPE in pack.	-0.10%
enzymes	-0.06%
Transport to retail (sea)	-0.05%
Heat DC	-0.05%

Oatly NL retail NL

Raw oats from Sweden	-1.62%
Heat processing Barista	-1.58%
Raw oats from Finland	-1.35%
Rapeseed oil	-1.04%
Paperboard in pack.	-0.75%
BioPE in pack.	-0.63%
Heat processing oatbase	-0.56%
Aluminium in pack.	-0.38%
Transport to DC	-0.36%
Electricity retail	-0.36%
Corrugated board	-0.28%
electricity mill	-0.22%
processing losses	-0.22%
Transport to retail NL	-0.18%
Raw oats from Estonia	-0.14%
LDPE in pack.	-0.12%
electricity gas boiler mill	-0.12%
enzymes	-0.06%
Heat DC	-0.05%
Electricity DC	-0.05%

Oatly NL retail SE

Raw oats from Sweden	-1.44%
Heat processing Barista	-1.40%
Transport to DC SE	-1.24%
Raw oats from Finland	-1.20%
Rapeseed oil	-0.93%
Transport to retail SE	-0.68%
Paperboard in pack.	-0.68%
BioPE in pack.	-0.57%
Heat processing oatbase	-0.50%
Aluminium in pack.	-0.34%
Corrugated board	-0.27%
electricity mill	-0.20%
processing losses	-0.19%
Raw oats from Estonia	-0.12%
LDPE in pack.	-0.11%
electricity gas boiler mill	-0.10%
enzymes	-0.06%
Heat DC	-0.05%
Transport from mill to fa	-0.03%
Heat mill	-0.03%

Oatly NL retail UK

Raw oats from Sweden	-1.55%
Heat processing Barista	-1.51%
Raw oats from Finland	-1.29%
Rapeseed oil	-1.00%
transport to DC UK	-0.96%
BioPE in pack.	-0.57%
Paperboard in pack.	-0.55%
Heat processing oatbase	-0.53%
transport to retail UK	-0.42%
Aluminium in pack.	-0.36%
Corrugated board	-0.28%
electricity mill	-0.21%
processing losses	-0.21%
Electricity retail	-0.19%
Raw oats from Estonia	-0.13%
electricity gas boiler mill	-0.11%
LDPE in pack.	-0.10%
enzymes	-0.06%
Heat DC	-0.05%
Transport mill to factory	-0.03%

Oatly SE retail DE

1	Raw oats from Sweden	-3.22%
2	Rapeseed oil	-1.37%
3	transport to retail	-0.99%
4	BioPE in packaging	-0.97%
5	Paperboard in packaging	-0.78%
6	Aluminium in packaging	-0.49%
7	Electricity retail	-0.42%
8	Corrugated board	-0.39%
9	Heat proces. Barista	-0.25%
10	Transport (truck) to DC DE	-0.24%
11	processing losses	-0.20%
12	Heat processing oatbase	-0.10%
13	enzymes	-0.08%
14	Transport (train) to DC DE	-0.08%
15	Transport Jarna - Lanskr	-0.08%
16	Heat Sloinge mill	-0.07%
17	Heat DC	-0.07%
18	Electricity proces. Barista	-0.06%
19	Transport raw oats Jarna	-0.06%
20	Electricity DC	-0.06%

Oatly SE retail FI

Raw oats from Sweden	-3.36%
Rapeseed oil	-1.43%
Transport to retail (truck)	-1.03%
BioPE in packaging	-1.02%
Paperboard in packaging	-0.89%
Aluminium in packaging	-0.52%
Corrugated board	-0.40%
Heat proces. Barista	-0.26%
Electricity retail	-0.23%
processing losses	-0.20%
Heat processing oatbase	-0.11%
enzymes	-0.09%
Transport to retail (sea)	-0.08%
Transport Jarna - Lanskr	-0.08%
Heat Sloinge mill	-0.08%
Heat DC	-0.07%
Elect. solar proces. Barista	-0.07%
Transport raw oats Jarna	-0.06%
Transport raw oats Sloinge	-0.06%
Electr. wind proces. Barista	-0.05%

Oatly SE retail NL

Raw oats from Sweden	-3.02%
Transport to DC NL	-1.35%
Rapeseed oil	-1.28%
Paperboard in packaging	-0.96%
BioPE in packaging	-0.95%
Aluminium in packaging	-0.47%
Electricity retail	-0.44%
Corrugated board	-0.37%
Heat proces. Barista	-0.24%
Transport to retail NL	-0.22%
processing losses	-0.18%
Heat processing oatbase	-0.09%
enzymes	-0.08%
Transport Jarna - Lanskr	-0.07%
Heat Sloinge mill	-0.07%
Heat DC	-0.06%
Electr. solar proces. Barista	-0.06%
Electricity DC	-0.06%
Transport raw oats Jarna	-0.06%
Transport raw oats Sloinge	-0.05%

Oatly SE retail SE

Raw oats from Sweden	-3.38%
Rapeseed oil	-1.43%
BioPE in packaging	-1.07%
Transport to retail SE	-1.05%
Paperboard in packaging	-1.04%
Aluminium in packaging	-0.53%
Corrugated board	-0.40%
Heat proces. Barista	-0.27%
processing losses	-0.20%
Heat processing oatbase	-0.11%
enzymes	-0.09%
Transport Jarna - Lanskr	-0.08%
Heat Sloinge mill	-0.08%
Heat DC	-0.07%
Electr. solar proces. Barista	-0.07%
Transport raw oats Jarna	-0.07%
Transport raw oats Sloinge	-0.06%
Electr. wind proces. Barista	-0.05%
Transport to DC	-0.05%
Heat Jarna mill	-0.04%

Oatly SE retail UK

Raw oats from Sweden	-3.24%
Rapeseed oil	-1.38%
BioPE in packaging	-0.96%
Paperboard in packaging	-0.77%
Transport to DC UK (truck)	-0.77%
Transport to retail UK	-0.59%
Aluminium in packaging	-0.49%
Corrugated board	-0.39%
Electricity retail	-0.26%
Heat proces. Barista	-0.26%
processing losses	-0.20%
Transport to DC UK (sea)	-0.17%
Heat processing oatbase	-0.10%
enzymes	-0.09%
Transport Jarna - Lanskr	-0.08%
Heat Sloinge mill	-0.07%
Heat DC	-0.07%
Electr. solar proces. Barista	-0.06%
Transport raw oats Jarna	-0.06%
Transport raw oats Sloinge	-0.05%

Oatly US retail US

1	Transport to retail	-3.99%
2	Raw oats from Canada	-1.26%
3	Rapeseed oil	-1.25%
4	Share refrigerated transport	-1.21%
5	Heat processing Barista	-0.99%
6	Paperboard in packaging	-0.52%
7	Heat processing oatbase	-0.42%
8	Corrugated board	-0.35%
9	Aluminium in packaging	-0.29%
10	BioPE in packaging	-0.27%
11	Electricity mill	-0.24%
12	Transport oats to mill	-0.13%
13	processing losses	-0.11%
14	LDPE in packaging	-0.11%
15	Losses at retail	-0.10%
16	Calcium	-0.08%
17	Electricity processing Barista	-0.07%
18	Electricity retail_Usa	-0.06%
19	Transport mill to factory	-0.06%
20	HDPE	-0.06%

Oatly US food service US

Transport to DC	-3.57%
Raw oats from Canada	-1.29%
Rapeseed oil	-1.28%
Share refrigerated transport	-1.17%
Heat processing Barista	-1.01%
Paperboard in packaging	-0.53%
Heat processing oatbase	-0.43%
Corrugated board	-0.35%
Aluminium in packaging	-0.30%
Transport to food service	-0.29%
BioPE in packaging	-0.28%
Electricity mill	-0.25%
Transport oats to mill	-0.13%
processing losses	-0.11%
LDPE in packaging	-0.11%
Losses at retail	-0.10%
Calcium	-0.08%
Electricity processing Barista	-0.07%
Electricity retail	-0.06%
Transport mill to factory	-0.06%

FIGURE 22: INFLUENCE OF INPUT PARAMETERS ON THE CLIMATE CHANGE IMPACT. EACH INDIVIDUAL INPUT PARAMETER IS LOWERED BY 10%, AND THE RESULTING REDUCTION IN THE OVERALL CLIMATE CHANGE IMPACT IS EXPRESSED AS PERCENTAGE.

For Oatly Barista originating from Sweden, oats and rapeseed oil are the most sensitive factors in most cases, followed by distribution and packaging materials. Processing energy is less relevant as its renewable nature leads to a lower impact.

5.3 Uncertainty analysis

Uncertainty in inventory data has been determined using the pedigree matrix, as described in section 2.4.1. With this data, a Monte Carlo analysis was run in SimaPro to assess the uncertainty range for each product. The Monte Carlo method is a sampling-based method, in which the calculation is repeated multiple times (in this case 1000 runs), in order to estimate the probability distribution of the result based on uncertainty ranges of input data.

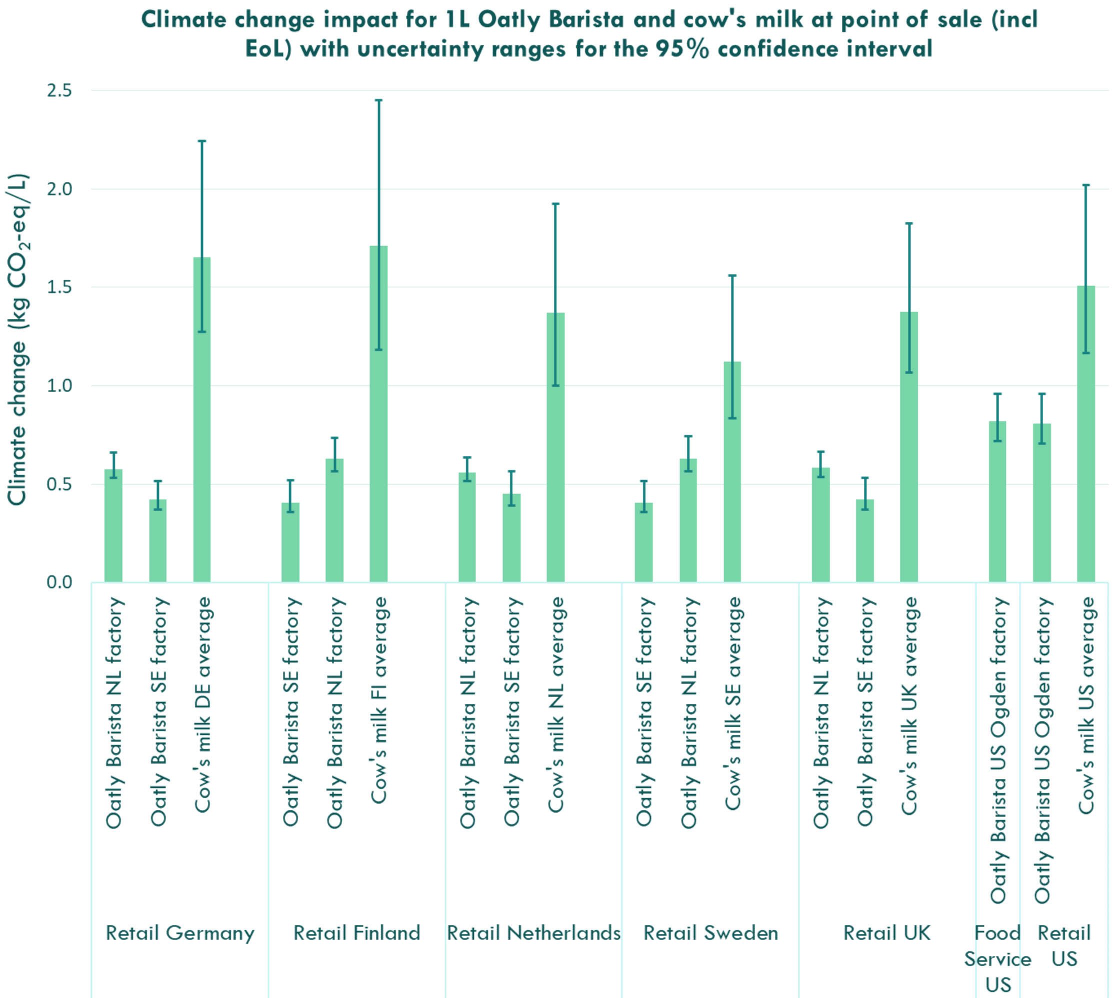


FIGURE 23: CLIMATE CHANGE IMPACT FOR 1L OATLY BARISTA AND COW'S MILK AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) PACKAGING, WITH UNCERTAINTY RANGES FOR THE 95% CONFIDENCE INTERVAL. FOR THE EUROPEAN COUNTRIES, OATLY BARISTA POINT OF SALE IS RETAIL AND THE PRIMARY OATLY PRODUCTION FACILITY IS LISTED FIRST, FOLLOWED BY THE SECONDARY OATLY PRODUCTION FACILITY. FOR THE UNITED STATES, THE PRIMARY SALES CHANNEL IS LISTED FIRST (FOOD SERVICE) FOLLOWED BY THE SECONDARY (RETAIL). THE RESULTS REFER ONLY TO OATLY'S END-TO-END AND HYBRID FACILITIES. SE FACTORY= OATLY LANDSKRONA END-TO-END FACTORY; NL FACTORY= OATLY VLISSINGEN HYBRID FACTORY; OGDEN US FACTORY= OATLY OGDEN, UTAH, US END-TO-END FACTORY. COW'S MILK REPRESENTS AN AVERAGE COW'S MILK PRODUCT AT RETAIL FOR EACH COUNTRY.

Figure 23 shows the climate change impact results including uncertainty ranges for the 95% confidence interval; meaning that 95% of the results lay within this range. The graph shows a higher uncertainty range for cow's milk, which is caused by the higher uncertainty factors attributed to emissions from manure management and enteric fermentation and to feed intake (see section 2.7.1). Oatly Barista has lower uncertainty ranges due to the use of primary (foreground) data.

The graph gives an impression of how Oatly Barista compares to cow's milk when taking these uncertainties into consideration. According to the uncertainty analysis the difference in climate change impact between Oatly Barista and cow's milk consumed in Germany could range from -48% to -83%, for Finland from -38% to -85%, for

Netherlands from -37% to -80%, for Sweden from -11% to -77%, for the UK from -38% to -80%, and for the US from -18% to -65%.

Generally speaking, if the error bars of the 95% uncertainty interval do not overlap, one can assume differences between products are statistically significant (Payton, Greenstone, & Schenker, 2003). It should be noted that this is just an approximation, as uncertainty was estimated for the data.

A more accurate way to compare two products is a paired Monte Carlo analysis, which considers the uncertainty of the difference between two products (thus accounting for correlation in data). The number of runs (from the total of 1000 runs) is counted in which product A has a higher impact than product B. In general it can be assumed that if >90% of the Monte Carlo runs are favourable for one product, the difference can be considered significant (Goedkoop et al., 2013).

The figure below shows the outcome of this paired Monte Carlo analysis for all products in scope, and for all impact categories. It shows that for climate change, fine particulate matter formation, terrestrial acidification, freshwater eutrophication and marine eutrophication, the impact of Oatly Barista is consistently and significantly lower than the impact of cow's milk. For land use, mineral resource scarcity, fossil resource scarcity and water consumption, the differences between Oatly Barista and cow's milk varies between significantly higher, lower or insignificant.

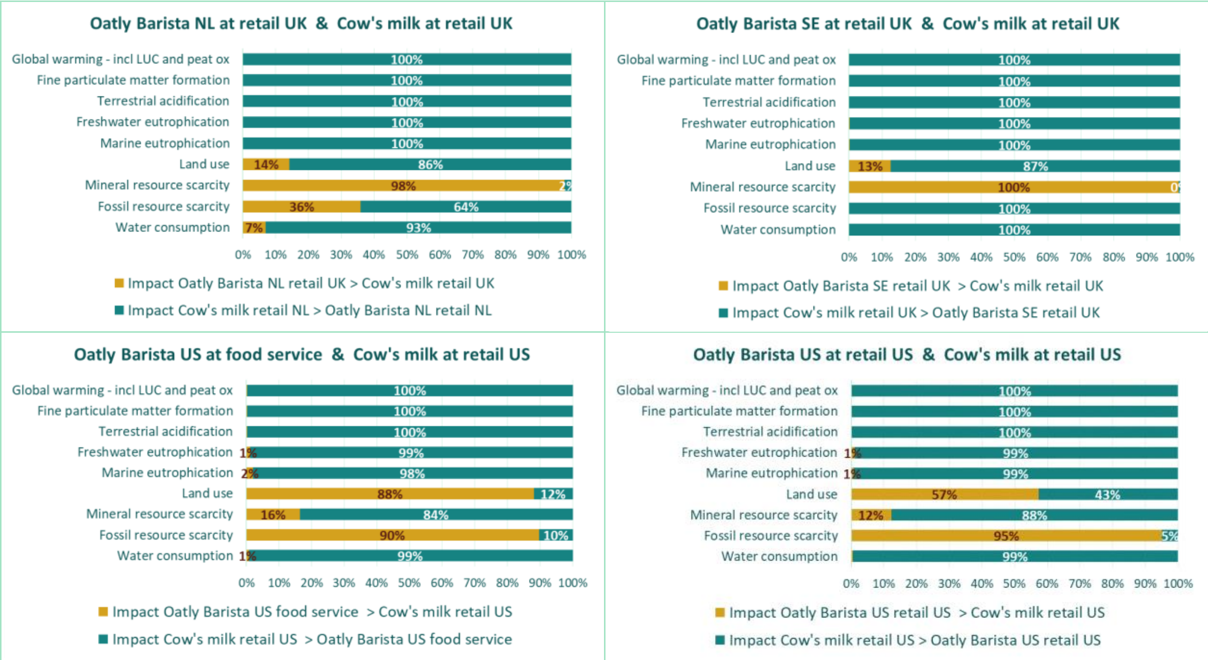


FIGURE 24: PAIRED MONTE CARLO ANALYSIS SHOWING THE PERCENTAGE OF MONTE CARLO RUNS IN WHICH ONE PRODUCT HAS A HIGHER IMPACT THAN THE OTHER. FOR EXAMPLE, FOR CLIMATE CHANGE, OATLY BARISTA AT RETAIL IN GERMANY HAS A LOWER IMPACT THAN COW'S MILK FOR 100% OF THE 1000 MONTECARLO SIMULATIONS PERFORMED.

6 Conclusion

Overall results

A Life Cycle Assessment has been performed to compare the environmental performance of Oatly Barista (oat-based drink), to cow's milk in six key sales markets: Germany, Finland, Netherlands, Sweden, United Kingdom, and the United States. In addition, the study has identified the drivers and opportunities for the environmental impact of Oatly Barista. The study has been performed and critically reviewed according to ISO 14040/14044/14071 standards for comparative assertions to be disclosed to the public and is in line with LCA guidelines including the European Product Environmental Footprint Category Rules (PEFCR).

The results show that for the impact categories climate change, fine particulate matter formation, terrestrial acidification, freshwater eutrophication, and marine eutrophication, Oatly Barista has a lower impact than cow's milk for all six markets. For water consumption, Oatly Barista also has a consistently lower impact, though the difference is marginal for some countries.

For land use, mineral resource scarcity and fossil resource scarcity, the differences between both systems vary depending on the case. Regarding mineral resource scarcity, Oatly Barista has in most cases a higher impact than cow's milk which can be mainly attributed to the use of aluminum in ambient beverage cartons. The Oatly Barista produced in Vlissingen (the Netherlands) and Ogden (United States) has a relatively higher impact for the fossil resource scarcity impact category, because of the use of fossil-based thermal energy during processing and the (higher) use of fuels for distribution. For land use, Oatly Barista has a lower impact than cow's milk except for the US and the Netherlands, where the impact is comparable. This is attributable to the relatively low yields of oats and rapeseed oil from Canadian origin (used in Oatly Barista from the US Ogden factory), and to the use of grass and by-products in the cows' ration (which have a relatively low impact)[23].

Drivers and opportunities for Oatly Barista

For the European countries in scope, the oat cultivation stage is among the highest contributing factors to the climate change, fine particulate matter, terrestrial acidification, freshwater eutrophication, marine eutrophication and land use impact categories. Collecting data at cultivation level, could help Oatly to gain a better understanding of the main opportunities to reduce emissions at this stage, such as through more efficient fertilizer application or minimizing cultivation on peat.

For Oatly Barista produced in the US Ogden factory, transport of the finished product from the factory to the point of sale is the highest contributing factor to the climate change and fine particulate matter impact categories. This is related to the long transport distance as well as the refrigerated transport that is required to prevent the products from freezing during the winter months.

Water and energy consumption at the factory are the main contributing factors to the water consumption and fossil resource scarcity impact in the Ogden and Vlissingen factories. Identifying renewable energy sources (as already used in the Landskrona factory) could reduce the impact on climate change and fossil resource scarcity considerably. However, renewable electricity sources have a higher impact on mineral resource scarcity due to the metals used to produce solar panels and wind turbines. With regard to water consumption, options to enhance water use efficiency and reuse can be considered.

Packaging is the main driver for the impact of mineral resource scarcity, due to the use of aluminium in the ambient beverage carton. The use of bioplastics contributes to the climate change impact category due to the land use change linked to the sugarcane input. The use of second-generation bioplastics, derived from residual streams (e.g. used vegetable oil), could be an opportunity to reduce the impact of packaging.

[23] If land use results are not characterised (the ReCiPe 2016 method uses characterization based on land use intensity, with lower characterization factors for grassland compared to arable land), and only land occupation is considered, Oatly Barista has a lower impact than cow's milk for all sales markets. These land occupation results are shown in Annex V.

Robustness of results

Several sensitivity analyses have been carried out to test the robustness of the results, specifically to evaluate the effect of assumptions made and uncertainties present in input data and models.

The effect of using different characterization methods has been evaluated by performing an endpoint analysis, using a different impact assessment method (EF 3.0) and by considering GWPs for a 20-year timeframe. All analyses confirm the overall higher environmental footprint (considering the endpoint or single score) of cow's milk compared to Oatly Barista for the six countries in scope.

Considering different product characteristics (chilled distribution of Oatly Barista, inclusion of use stage for both systems, cow's milk with different fat contents), does not lead to different conclusions on the environmental footprint of Oatly Barista compared to cow's milk. Choosing economic allocation at the level of the dairy farm and at dairy processing leads to higher impact of the cow's milk compared to the biophysical and mass allocation used in the baseline. The same applies for using a functional unit based on the provision of macronutrients.

Uncertainty in data has been assessed by a paired Monte Carlo analysis, which determines the probability distribution of the results based on uncertainty ranges of input data. The paired uncertainty analysis confirms a significant difference in impact for the environmental impact categories climate change, fine particulate matter formation, terrestrial acidification, freshwater eutrophication, and marine eutrophication. For water consumption, the impact of Oatly Barista was consistently lower than cow's milk, though the difference was not significant for two products (Oatly Barista produced in the Netherlands and retailed in Finland and Sweden), mainly due to the relative high use of water during processing in the Vlissingen factory. For the other impact categories (land use, mineral resource scarcity and fossil resource scarcity), Oatly Barista does not have a consistently lower impact than cow's milk.

Using a different impact assessment method, the European Commission's EF 3.0 method, resulted in different trends for the land use impact category (lower impact of Oatly Barista in all cases), the mineral resource scarcity impact category (reversed trend for some cases), and the water impact category (lower impact of Oatly Barista in all cases). This is because of different underlying metrics[24], indicating a lower robustness of results for these categories.

Conclusions and recommendations presented here are subject to the assumptions and limitations addressed in this report. Any comparative assessment intended to be disclosed to the public, should transparently refer to the conclusions of the study, and be accompanied by the critical review statement.

[24] In the EF 3.0 impact assessment method, the indicator for land considers soil properties in addition to land occupation only, the mineral resource scarcity impact category uses a different model assigning different characterization factors to different minerals, and the water impact category considers water scarcity in addition to water consumption.

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Appendix I Characterisation methods used

TABLE 18: RECIPE2016 IMPACT CATEGORIES

Impact category	Description
Climate Change	All inputs or outputs that result in greenhouse gas emissions. The greatest contributor is generally the combustion of fossil fuels such as coal, oil and natural gas. The consequences include increased average global temperatures and sudden regional climatic changes. Climate change is an impact affecting the environment on a global scale. Unit of measurement: Kilogram of Carbon Dioxide equivalent (kg CO2 eq). During the calculations, the global warming potential of all greenhouse gas emissions are compared to the amount of the global warming potential of 1 kg of CO2
Ozone depletion	The stratospheric Ozone (O3) layer protects us from hazardous ultraviolet radiation (UV-B). Its depletion can have dangerous consequences in the form of increased skin cancer cases in humans and damage to plants. The stratospheric ozone depletion is an impact which affects the environment on a global scale. Unit of measurement: kilogram of CFC-11 equivalent (kg CFC-11 eq). During the calculations, the potential impacts of all relevant substances for ozone depletion are converted to their equivalent of kilograms of Trichlorofluoromethane (also called Freon-11 and R-11).
Particulate matter – respiratory inorganics	The adverse impacts on human health caused by emissions of Particulate Matter (PM) and its precursors (e.g. NOx, SO2). Usually, the smaller the particles are, the more dangerous they are, as they can go deeper into the lungs. Unit of measurement: kilogram of Particulate Matter 2.5 equivalent (kg PM 2.5 eq). The potential impact of respiratory inorganics is converted into the equivalent of a kilogram of particulate matter of a diameter of 2.5 micrometres or less.
Ionising radiation	Ionising radiation is radiation which is released by atoms, which travels as electromagnetic waves or particles. When the atom has sufficient energy it can cause ionisation or remove electrons from an atom. Ionizing radiation can be dangerous. When living cells become ionised they can die or mutates incorrectly and become cancerous. Radioactive substances exist naturally, examples are rocks and soil, however these levels are rather low. Most common source of ionising radiation is the extraction and use of radioactive materials for nuclear power generation. Reference unit for ionising radiation is kBq CO-60 equivalents.
Photochemical ozone formation	While stratospheric ozone protects us, ozone on the ground (in the troposphere) is harmful: it attacks organic compounds in animals and plants, it increases the frequency of respiratory problems when photochemical smog ('summer smog') is present in cities. Photochemical ozone formation is an impact which affects the environment at local and regional scale. Unit of measurement: kilogram NOx eq.
Terrestrial acidification	Changes in acidity of the soil are caused by atmospheric deposition of acidic substances. Serious changes are harmful for specific species. In the ReCiPe 2016 methodology three acidifying emissions are taken into account. These emissions are: NOx, NH3 and SO2. NOx is mainly formed during combustion processes. Agriculture is the main source for NH3. Energy combustion (coal) counts mainly for SO2 emissions. Unit of measurement: kilogram SO2 eq.
Freshwater and marine eutrophication.	Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). These nutrients cause a growth of algae or specific plants and limit growth in the original ecosystem. Eutrophication is an impact which affects the environment at local and regional scale. Unit of measurement: kg N eq for Marine Eutrophication and kg P eq for Freshwater eutrophication.
Land use	Occupation refers to the use of a land cover for a certain period, and it is measured as area-time (m2*yr) crop equivalents.
Water consumption	The withdrawal of water from lakes, rivers or groundwater can contribute to the 'depletion' of available water. Water consumption is the fraction of water use that is not returned to its original source. Unit of measurement: cubic metres (m3).
Mineral resource scarcity	The earth contains a finite amount of non-renewable resources, such as metals and minerals. The basic idea behind this impact category is that extracting a high concentration of resources today will force future generations to extract lower concentration or lower value resources. Unit of measurement: kg Cu eq
Fossil resource scarcity	The earth contains a finite amount of non-renewable resources, such as fossil fuels like coal, oil and gas. The basic idea behind this impact category is that extracting a high

	concentration of resources today will force future generations to extract lower concentration or lower value resources. Unit of measurement: kg oil eq
Human toxicity – carcinogenic	The toxicity potential (TP), expressed in kg 1,4-dichlorobenzeneequivalents (1,4DCB-eq), is used as a characterization factor at the midpoint level for human toxicity, freshwater aquatic ecotoxicity, marine ecotoxicity and terrestrial ecotoxicity. A more elaborate explanation on toxicity can be found in Huijbregts et al.(2016)
Human toxicity – non-carcinogenic	The toxicity potential (TP), expressed in kg 1,4-dichlorobenzeneequivalents (1,4DCB-eq), is used as a characterization factor at the midpoint level for human toxicity, freshwater aquatic ecotoxicity, marine ecotoxicity and terrestrial ecotoxicity. A more elaborate explanation on toxicity can be found in Huijbregts et al.(2016)
Eco-toxicity – fresh water acquatic	The toxicity potential (TP), expressed in kg 1,4-dichlorobenzeneequivalents (1,4DCB-eq), is used as a characterization factor at the midpoint level for human toxicity, freshwater aquatic ecotoxicity, marine ecotoxicity and terrestrial ecotoxicity. A more elaborate explanation on toxicity can be found in Huijbregts et al.(2016)
Ecotoxicity – marine	The toxicity potential (TP), expressed in kg 1,4-dichlorobenzeneequivalents (1,4DCB-eq), is used as a characterization factor at the midpoint level for human toxicity, freshwater aquatic ecotoxicity, marine ecotoxicity and terrestrial ecotoxicity. A more elaborate explanation on toxicity can be found in Huijbregts et al.(2016)
Ecotoxicity – terrestrial	The toxicity potential (TP), expressed in kg 1,4-dichlorobenzeneequivalents (1,4DCB-eq), is used as a characterization factor at the midpoint level for human toxicity, freshwater aquatic ecotoxicity, marine ecotoxicity and terrestrial ecotoxicity. A more elaborate explanation on toxicity can be found in Huijbregts et al.(2016)

TABLE 19: EF3.0 IMPACT CATEGORIES

EF Impact category	Impact category Indicator	Unit
Climate change, total	Radiative forcing as global warming potential (GWP100)	kg CO2 eq
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 $_{eq}$
Human toxicity, cancer	Comparative Toxic Unit for humans (CTUh)	CTUh
Human toxicity, noncancer	Comparative Toxic Unit for humans (CTUh)	CTUh
Particulate matter	Impact on human health	disease incidence
Ionising radiation, human health	Human exposure efficiency relative to U235	kBq U235 eq
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC $_{eq}$
Acidification	Accumulated Exceedance (AE)	mol H+ $_{eq}$
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N $_{eq}$
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P $_{eq}$
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N $_{eq}$
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe
Land use	• Soil quality index • Biotic production • Erosion resistance • Mechanical filtration • Groundwater replenishment	• Dimensionless (pt) • kg biotic production • kg soil • m3 water • m3 groundwater
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 world $_{eq}$
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb $_{eq}$
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ

Appendix II Dairy production modelling

The tables below highlight the data used as well as calculations and assumptions made to model dairy systems in Sweden, Finland and the US.

Further details on the milk modelled for the other three countries in scope (Netherlands, Germany and the UK), can be found in the documentation linked to Agri-footprint 6 (Blonk et al., 2022). The data for these countries has been reviewed by the European Dairy Association (EDA).

System description and data quality

In this section, a short description of the milk production system is provided. A more detailed description on the modelling of dairy systems can be found in the documentation of APS footprint (Blonk Consultants, 2020a).

The APS-footprint framework enables users to perform environmental footprint calculations based on background datasets, parameters defined by the user and modelling of emissions according to specified standards and guidelines. Dairy systems may vary in design and environmental performance due to differences in herd composition, grazing periods, housing types, feeding regimes and manure management systems. The dairy APS module enables a user to model these different characteristics and investigate how they influence environmental impacts. The methodological framework regarding allocation, functional units, boundary definitions and emission modelling are based on published and recognized international guidelines (European Commission, 2018; European Environment Agency, 2016; IPCC, 2006b).

Below are the main parameters used to model the dairy systems in APS are described.

Herd composition

In the APS dairy module, it is necessary to define the animal population (animal type and number) associated with the production system. With APS-footprint, it is also possible to include data based on statistics. This means that the overall population, within a country might be considered as the total herd. The total herd should be presented in a system equilibrium. All inputs should be scaled towards the total herd.

In the dairy module of the APS-footprint tool, four animal types are defined:

Dairy Cow Dairy cows include the milk-producing cattle. Dairy cows start producing milk after giving birth to their first calf, which is usually during their third year of life. Dairy cows are slaughtered at around 4-5 years of age. This animal category includes both dairy cow in lactation and dairy cow in dry period. The weight of dairy cows can vary. Since APS-footprint assumes a system at equilibrium and an average dairy cow weight, it is assumed that there is no weight accumulation of the herd in this stage.

Calves < 1 year Female calves that are not slaughtered are further raised for future replacement of dairy cows. In their first year of life, the weight grows from circa 50 kg to around 300 kg.

Calves 1-2 years In this stage, female calves are raised from 1 year up to 2 years of age. Animals in this stage grow from approximately 300 kg to 600 kg.

Heifers In this stage, female calves are raised from 2 year of age up to calving age. The latter is the age in which it gives birth to calves for the first time, followed by its first lactation period. Calving age varies from 24 up to 26 months in average. This means that heifers are considered as such for a short period of time (few months).

Bulls Sometimes bulls are present on a farm. The average lifespan of bulls varies between 3 to 5 or more years. They usually weigh more than the dairy cows, and their population is very small since one bull can inseminate many cows. In modern systems, bulls might not present since artificial insemination is a common practice. Artificial insemination is not modelled in the dairy APS module. Because of their negligible contribution to the overall impact of the dairy system, bulls are not taken into account.

The number of animals at farm is based on a production period of one year and the average number of present animals is requested as input for APS-footprint. For each animal type, this is called Annual Average Population (AAP).

Feed

Information on feed amount and nutrient content are required as input for the calculations. The feed inputs need to be defined as kg feed (as is) for every AAP for 1 year. Two types of feed are distinguished in the dairy APS module: compound feeds and single ingredients:

- Compound feeds are defined in the compound feed module of the APS-footprint tool. The compound feed formulation can be defined together with inbound (from ingredient production to compounding feed mill) and outbound (from compounding feed mill to farm) transportation and energy use.
- For this project, feed ingredients (crops) are derived from Agri-footprint 6. When a certain region is not covered in APS, the crop (mix) is modelled afterwards in SimaPro.
- The production of single feed ingredients is also based on Agri-footprint 6 (Van Paassen et al., 2019a). This concerns fodder which are directly fed to animals, without the process of including them in a compound feed. This usually happens since they are produced at farm. These include roughages (fresh grass, grass silage, maize silage, straw and hay), wet co-products (spent brewers and distillers' grain) and crops (grains, beets and legumes).

Besides the different types of feed, some feed nutrition related characteristics have to be defined. These characteristics encompass digestibility, overall gross energy (GE) intake, amount of silage and crude protein content in overall diet. Such characteristics should be calculated as a weighted average of the overall diet based on the characteristics at product level. These feed characteristics influence various emissions (such as methane, nitrous oxide, and ammonia) from manure storage and pre-treatment.

Water

There are multiple types of water consumption on the dairy farm. Water is consumed by the animals as drinking water. Water is also used on the farm for management purposes like cleaning the milking area. In practice, water can also be used for irrigation of crops. Irrigation water is already included in the background LCI, such that the total water input on the dairy farm is equal to all water use except the water used for irrigation of crops.

Bedding

Bedding is used in the stable of the dairy cows. Two types of bedding can be selected in APS-footprint: saw dust and straw. These types of bedding are commonly used in typical dairy systems.

Energy

There are several types of energy use on the dairy farm. A main source of energy is electricity (cooling is important), but other fuels, like natural gas and diesel are also used. Electricity use includes all types of farm associated activities. Typical activities are cooling, lighting, ventilation, automated feed and water rationing, automated milking systems, and water recirculation. In APS-footprint, electricity production is based on ecoinvent processes that reflect the national grid. Specific production technologies (e.g. wind or solar electricity) can be altered after exporting the process to SimaPro. Natural gas and diesel are mainly used for the heating system or farm machinery (including the machinery used to store and collect roughage). Diesel used for machines during crop cultivation are not considered here, since this is already included in the cultivation background LCI.

Output

The main output of the dairy APS is raw milk. Required parameters are the yearly farm milk production, the fat content, and the protein content of the milk. Milk losses at farm and milk that is not suitable for consumption (e.g. milk discarded because contaminated by antibiotics or high microbial load) is not accounted in the raw milk output.

The dairy APS module also accounts for live animal leaving the farm. Dairy cows are removed from the herd for various reasons, usually connected to decrease in productivity. These are usually culled. A dairy farm also produces male calves and quite often some surplus female calves which are also co-products of the dairy farm system. These can be slaughtered directly or can be sold for further growth in other production systems. The total amount of liveweight (kg) leaving the dairy APS is required (including both replaced cows and calves).

Mortality output is currently not considered in the dairy APS module, in terms out mortalities (kg) and the fate of mortalities (e.g. rendering, composting, incineration). However, mortality is considered when establishing the steady-state herd size.

Functional unit

The functional unit used in APS is 1 kilogram of Fat-Protein Corrected Milk (FPCM) (corrected to 4% fat and 3.3% protein) as calculated in PEFCR dairy guidelines (European Commission, 2018b):

$$FPCM\ (kg/yr) = Production\ (\ kg/yr)\ x\ (0.1226\ x\ True\ Fat\% + 0.0776\ x\ True\ Protein\% + 0.2534)$$

Where:

- FPCM is the amount of Fat-Protein Corrected Milk (kg/year);
- Production is the amount of milk produced (kg/year);
- True fat is the content of fat present in the produced milk (%);
- True protein in the content if protein in the produced milk (%);

Since this study considers a functional unit of 1 liter of milk "as is" with different fat contents (whole, (semi)skimmed), this FPCM is converted back to milk "as is".

Allocation at farm

Allocation is used to distribute the overall environmental impacts to the different outputs: milk and animal liveweight (aggregate of replaced dairy cows and sold calves). The dairy module of APS-footprint uses biophysical allocation to calculate the environmental impact of the two co-products. This type of allocation is extensively used in the dairy sector. It was developed by the International Dairy Association (IDF, 2010) and was suggested by the dairy PEFCR (European Commission, 2018):

$$AF = 1 - 6.04\ x\ (Mmeat\ /\ Mmilk)$$

Where AF is the Allocation Factor of milk, $Mmeat$ is the mass of live weight of all animal sold including calves and culled mature animals per year, and $Mmilk$ is the mass if FPCM sold per year.

The allocation for Meat can be calculated as 1 - AF. According to the dairy PEFCR, manure can be considered as a residual product, a co-product or waste. In the APS footprint, manure is treated as a residual product. This means that manure is exported from the farm as product with no economic value. There is no allocation: burden is allocated to other products produced at farm, including pre-treatment of manure.

Sweden

The majority of data on Swedish dairy systems is derived from Cederberg (2009). Since this paper is a bit outdated, the two key parameters influencing efficiency of dairy systems were updated with more recent information: milk output and feed intake. The ratio between the two is called feed efficiency (kg feed per kg milk). The milk output (kg milk/animal) is updated based on the latest NIR, and the feed intake is adjusted based on recent feed efficiency from (Tarekegn et al., 2021). For other data points, it was decided for consistency reasons to base the data on one source as much as possible.

More details on the exact data sources used and assumptions made can be found in the table below.

Data point	Value (per year)	Explanation/source
General details		
Farming method	Conventional	
Year	2009	
Geography	Sweden	
Average annual temperature	2.1	
Total herd size	563268	Cederberg, 2009
OUTPUTS		
Milk (total weight) (kg)	3690820180	Milk yield (9385, from NIR) multiplied by number of dairy cows (see below)
Protein content (%)	3.38	Cederberg, 2009
Fat content (%)	4.25	Cederberg, 2009
Total livestock to slaughter (liveweight) (kg)	91725000	NIR2017/2020

		Dairy cows/calves/heifers sent to slaughter multiplied by weight of those animals from NIR 2017
RESOURCE USE		
Electricity use (MJ)	1840494240	Cederberg, 2009 (1300 kWh per dairy cow /year), modelled using Swedish electricity mix
Gas use (MJ)	0	Cederberg, 2009
Diesel use (MJ)	390480000	Cederberg, 2009
Water consumption (kg)	18081075080	From SIK, 2013
HOUSING SYSTEMS		
Housing - Heifers	149000	Dalgaard, 2012 / Cederberg, 2009
Housing - Calves 1-2 year	87000	Dalgaard, 2012 / Cederberg, 2009
Housing - Calves <1 year	194000	Dalgaard, 2012 / Cederberg, 2009
Housing - Dairy cows	393268	Dalgaard, 2012 / Cederberg, 2009
Housing system dairy cows		
RATION		Feed rations are based on a combination of data from Cederberg (2009) and Hendriksson (2013). Ingredients are modelled to represent Swedish conditions, thus using Swedish cultivation data from AFP as well as Swedish market mixes in case of feed from outside the farm. Transport from cultivation country to Sweden, as well as within Sweden, is added.
Concentrate feed	1994	Based on Cederberg. 10 main ingredients were included: rapeseed meal, beet pulp, soymeal, palmkernel exp, grain bran, distiller's dried gr, molasses, fatty acids, grain middlings, peas
Minerals	86	
Grass silage, grown on farm, SE	5350	Adapted N fertilizer input grass based on Cederberg, 2009
Maize silage, grown on farm, SE	294	
Grass for grazing, permanent pasture, SE	1927	Adapted N fertilizer input grass based on Cederberg, 2009
wheat, via feed	133	Swedish market mix
triticale, via feed	114	Swedish market mix
barley, via feed	170	Swedish market mix
oats, via feed	57	Swedish market mix
barley (grain), grown on farm	652	
oats (grain), grown on farm	639	
super pressed pulp	172	sugar beet
straw	66	
Total feed intake (kg/animal)	11654	Total of the above
Gross energy intake (MJ/animal)	112959	Calculated with values from feedipedia
Digestibility (% of GE)	70.2%	Calculated with values from feedipedia
Crude protein in diet (% of DM)	17.9%	Calculated with values from feedipedia
Percentage of silage (% of GE)	41.1%	GE provided by silage/total GE
HOUSING		
Straw for bedding (kg/animal)	44	Based on Danish dairy system, as no Swedish data was available
Saw dust (kg/animal)	6.25	Based on Danish dairy system, as no Swedish data was available
Type (e.g. housed/ free ranging)	housed	
MANURE MANAGEMENT		
Manure management system (select type, e.g. dry lot)	11% solid storage, 79% Liquid/slurry with natural crust cover	From Cederberg (2009) The 2 main manure management systems were modelled, representing 90% of all manure management systems
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	21%	Cederberg, 2009
Time spent in open yard areas (%)	0%	Cederberg, 2009
Time spent in buildings (%)	79%	Cederberg, 2009
Housing system Heifers and Calves 1-2 years		
RATION (in kg as is)		Feed rations are based on a combination of data from Cederberg (2009) and Hendriksson (2013). Ingredients are modelled to represent Swedish conditions, thus using

		Swedish cultivation data from AFP as well as Swedish market mixes in case of feed from outside the farm. Transport from cultivation country to Sweden, as well as within Sweden, is added.
Concentrate feed	366	
Minerals	16	
Grass silage, grown on farm, SE	2592	
Maize silage, grown on farm, SE	0	
Grass for grazing, permanent pasture, SE	934	
wheat, via feed	27	
triticale, via feed	23	
barley, via feed	34	
oats, via feed	11	
barley (grain), grown on farm	130	
oats (grain), grown on farm	128	
super pressed pulp	0	
straw	57	
Total feed intake (kg/animal)	4317	Total of the above
Gross energy intake (MJ/animal)	36738	Calculated with values from feedipedia
Digestibility (% of GE)	69.4%	Calculated with values from feedipedia
Crude protein in diet (% of DM)	16.2%	Calculated with values from feedipedia
Percentage of silage (% of GE)	59.0%	GE provided by silage/total GE
HOUSING		
Straw for bedding (kg/animal)	44	Based on Danish dairy system, as no Swedish data was available
Saw dust (kg/animal)	6.25	Based on Danish dairy system, as no Swedish data was available
Type (e.g. housed/ free ranging)	housed	
MANURE MANAGEMENT		
Manure management system (select type, e.g. dry lot)	liquid/slurry with natural crust cover	The dominant manure management system was modelled
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	46%	Cederberg, 2009
Time spent in open yard areas (%)	0%	Cederberg, 2009
Time spent in buildings (%)	54%	Cederberg, 2009
Housing system calves <1 year		
RATION (kg as is)		The quantity of feed consumed is based on data from Denmark, as Swedish data was not available. This was deemed appropriate as calves don't have a big contribution compared to dairy cows and heifers. Swedish data was used to model the feed ingredients.
Concentrate feed	78	
Grass silage, grown on farm, SE	4281	
Grass for grazing, permanent pasture, SE	40	Grass dataset modelled based on yield and inputs from (Krizsan, Chagas, Pang, & Cabezas-Garcia, 2021) and Cederberg, 2009
Straw	154	
Total feed intake (kg/animal)	4553	Total of the above
Gross energy intake (MJ/animal)	41348	Calculated with values from feedipedia
Digestibility (% of GE)	80.0%	Calculated with values from feedipedia
Crude protein in diet (% of DM)	18.3%	Calculated with values from feedipedia
Percentage of silage (% of GE)	90.5%	GE provided by silage/total GE
HOUSING		
Straw for bedding (kg/animal)	0	
Saw dust (kg/animal)	0	
Type (e.g. housed/ free ranging)	housed	
MANURE MANAGEMENT		
Manure management system	liquid/slurry with natural crust cover	Based on Denmark
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	33%	Based on Denmark
Time spent in open yard areas (%)	0%	Based on Denmark
Time spent in buildings (%)	68%	Based on Denmark

Finland

The National Inventory Report (NIR) of Finland (Statistics Finland, 2021) is taken as the leading source of the data. The reference year listed in this source is 2019. Important parameters, such as the milk output, the protein and fat content of milk, the average liveweight of animals in different age groups, the share of manure management systems, and the share of grazing and non-grazing periods are retrieved from the NIR.

Various sources are used to complement these data. Data on the herd size- and composition for the year 2019 are retrieved from the Natural Resources Institute Finland database (LUKE, 2019). In addition, LUKE provides data to determine the total amount of livestock (heads) to slaughter (dairy cows and heifers >1 years), which was complemented with data from (Hietala et al., 2021) to determine the share of dairy breed heifers of the total heifers slaughtered (67%).

For the amount and type of bedding material for dairy cows a proxy is retrieved from Hietala et al. (2021), in which the amount and type of bedding material for beef cows is specified. Since this datapoint is expected not to be a key parameter, a proxy is estimated to be appropriate for this purpose.

Moreover, the amount of water consumed (drinking water and cleaning water) is taken from the (confidential) LCA study performed by the Swedish Institute for Food and Biotechnology (SIK) for Oatly. It is assumed that the water used for drinking and cleaning in Sweden is comparable to Finland.

Feed rations for dairy cows and heifers are obtained from ProAgria (ProAgria, 2021). For calves <1 year, no data was available, and hence the feed rations were based on Danish data, which are assumed to be relatively similar to Finland.

Data point	Value (per year)	Explanation / source
General details		
Year		
Geography	Finland	
Average annual temperature	1.7	Wikipedia (2020)
Total herd size	445,985	
All inputs below need to be defined per year		
Outputs		
Milk (total weight) (kg)	2,349,621,560	NIR (2019)
Protein content (%)	3.5%	NIR (2019)
Fat content (%)	4.4%	NIR (2019)
Total livestock to slaughter (liveweight) (kg)	66,306,215	LUKE (2019) and Hietala (2020)
Resource use		
Electricity use (MJ)	1,271,098,137	Valo (2020)
Gas use (MJ)	32,980,010	Valo (2020)
Diesel use (MJ)		No diesel use for animal farm
Fuel oil use (L)	58,563,834	Valo (2020)
Water consumption (kg)	11,312,547,200	Proxy (SIK, 2013)
Housing systems		
Housing - Heifers	15,001	LUKE (2019)
Housing - Calves 1-2 year	85,086	LUKE (2019)
Housing - Calves <1 year	86,958	LUKE (2019) all heifer calves, corrected with replacement ratio
Housing - Dairy cows	258,940	LUKE (2019)
Housing system dairy cows		
RATION (kg as is)		The quantities of main feed ingredients are based on ProAgria (2021). Quantities were converted to kg as is using dry matter percentages from AFP
Silage	9935	84% grass silage, 16% grain silage (assumed maize silage)
Grazed grass	393	Grass dataset modelled based on yields and inputs from (Smit, Metzger, & Ewert, 2008) and Pallière, C. (2011)
Hay & straw	39	
Cereals	1974	Consists of barley and oats. Modelled using barley and oats market mix

Energy compounds	1143	assuming rapeseed meal and sugar beet pulp (common in Swedish compound feed)
Protein compounds	777	assuming soybean meal (common in Swedish compound feed)
By-products	571	assuming distiller's grain
Minerals and additives	105	
Total feed intake (kg/animal)	14938	Total of the above
Gross energy intake (MJ/animal)	166312	Based on GE data per ingredient from feedipedia
Digestibility (% of GE)	74%	Based on digestibility data per ingredient from feedipedia
Crude protein in diet (% of DM)	20%	Based on crude protein data per ingredient from feedipedia
Percentage of silage (% of GE)	53%	Based on GE data per ingredient from feedipedia
HOUSING		
Straw for bedding (kg/animal)	438	Hietala (2020) based on beef breed
Peat for bedding (kg/animal)	803	Hietala (2020) based on beef breed
Saw dust (kg/animal)	0	
Type (e.g. housed/ free ranging)	housed	
MANURE MANAGEMENT		
Manure management system (select type, e.g. dry lot)		NIR: Dairy cows: 51% slurry with natural cover, 23% solid storage, 14% slurry with no cover, 11% pasture
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	32.5%	NIR: length of the pasture season has been estimated to be 125 to 112 days for dairy cows
Time spent in open yard areas (%)	0.0%	
Time spent in buildings (%)	67.5%	
Housing system Heifers and Calves 1-2 years		
RATION		The quantities of main feed ingredients are based on ProAgria (2021). Quantities were converted to kg as is using dry matter percentages from AFP
Silage	6583	84% grass silage, 16% grain silage (assumed maize)
Grazed grass	819	
Hay & straw	455	
Cereals	110	Consists of barley and oats. Modelled using barley and oats market mix
Energy compounds	15	assuming rapeseed meal and sugar beet pulp (common in Swedish compound feed)
Protein compounds	86	assuming soybean meal (common in Swedish compound feed)
By-products	98	assuming distiller's grain
Minerals and additives	64	
Total feed intake (kg/animal)	8229	Total of the above
Gross energy intake (MJ/animal)	73843	Calculated with values from feedipedia
Digestibility (% of GE)	66%	Calculated with values from feedipedia
Crude protein in diet (% of DM)	15%	Calculated with values from feedipedia
Percentage of silage (% of GE)	80%	GE provided by silage/total GE
HOUSING	**DQR: moderate**	
Straw for bedding (kg/animal)	44	Based on Danish dairy system, as no Finnish data was available
Saw dust (kg/animal)	6.25	Based on Danish dairy system, as no Finnish data was available
Type (e.g. housed/ free ranging)	housed	
MANURE MANAGEMENT	**DQR: moderate**	
Manure management system (select type, e.g. dry lot)		NIR: Heifers: 35% slurry with natural cover, 26% solid storage, 23% pasture, 10% slurry with no cover
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	37.0%	NIR: length pasture season 130 to 140 for heifers
Time spent in open yard areas (%)	0.0%	
Time spent in buildings (%)	63.0%	
Housing system calves < 1 year		
RATION (as is)		The quantity of feed consumed is based on data from Denmark, as Finnish nor Swedish data was not available. This was deemed appropriate as calves

		don't have a big contribution compared to dairy cows and heifers.
Concentrate feed	78	
Grass silage, grown on farm	4281	
Grass for grazing, permanent pasture	40	
Straw	154	
Total feed intake (kg/animal)	4553	Total of the above
Gross energy intake (MJ/animal)	41348	Calculated with values from feedipedia
Digestibility (% of GE)	80.0%	Calculated with values from feedipedia
Crude protein in diet (% of DM)	18.3%	Calculated with values from feedipedia
Percentage of silage (% of GE)	90.5%	GE provided by silage/total GE
HOUSING		
Straw for bedding (kg/animal)	0	
Saw dust (kg/animal)	0	
Type (e.g. housed/ free ranging)	housed	
MANURE MANAGEMENT		
Manure management system (select type, e.g. dry lot)		NIR: Calves < 1 year: 37% solid storage, 31% slurry with natural cover, 10% pasture, 9% slurry with no cover
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	31.5%	NIR: 100 to 130 for calves
Time spent in open yard areas (%)		
Time spent in buildings (%)	68.5%	

United States

The National Inventory Report (NIR) of the USA (United States Environmental Protection Agency, 2021) is taken as the leading source of the data. The reference year listed in this source is 2019. Important parameters, such as the milk output, the average liveweight of animals in different age groups, the share of manure management systems, and the share of grazing and non-grazing periods are retrieved from the NIR.

The total livestock to slaughter weight is based on the USDA Quickstat database (2022). Total livestock amounts (heads) include the total amount and average weight of dairy cows and dairy calves sent to slaughter. The total amount of livestock slaughtered does not include heifers sent to slaughter, because the type of heifers (beef breed or dairy breed) could not be distinguished from the source.

The average on-farm resource use is retrieved from "Greenhouse Gas Emissions from Production of Fluid Milk in the US," an unpublished paper by Thoma et al. (2010). The on-farm resource use is a weighted average, based on three archetypical farms as presented in the paper.

Data on feed rations is based on (Thoma, Popp, Shonnard, et al., 2013), as more recent data was not available. Thoma et al. provide detailed feed consumption data per state and per animal type, which was converted to a weighted national average.

Data retrieved from Blonk Consultant's Californian dataset created for APS footprint (Blonk Consultants, 2020a) was used for bedding material, and some components of the feed ration (protein mix and partial mix ration).

More details on the sources used and assumptions made can be found in the table below.

Data point	Value (per year)	Explanation
General details		
Farming method	Conventional	
Year	2019	
Geography	United states	
Average annual temperature	8.55	Wikipedia (2020)
Total herd size	18803000	NIR (2021)
OUTPUTS		
Milk (total weight) (kg)	100726995023.26	total production from NIR (2021)
Protein content (%)	3.42%	based on APS Californian dataset (Blonk Consultants, 2020a)
Fat content (%)	3.92%	based on "Environmental assessment of United States dairy farms" (Rotz et al. 2021) averaged for all regions

Total livestock to slaughter (liveweight) (kg)	2250457129	based on USDA (2022) Quickstat, year 2019
RESOURCE USE		
Electricity use (MJ)	5946555785	from Thoma et al. (2010)
Heat (MJ)	6692629818	from Thoma et al. (2010)
Diesel use (MJ)	20346732702	from Thoma et al. (2010)
Water consumption (kg)	4.03872E+11	Based on APS Californian dataset
HOUSING SYSTEMS		
Housing - Heifers	3270000	Heifers and calves 1-2y
Housing - Calves <1 year	6189000	
Housing - Dairy cows	9344000	
Housing system dairy cows		
RATION (kg as is)		Ration for grazing and non-grazing seasons per region and per animal type obtained from Thoma (2013), corrected for the length of grazing and non-grazing season, then multiplied by number of animals per region (based on NIR) to obtain weighted average diet per animal type per year. Top 15 feed ingredients are included (extrapolated to match total weight), adjusted for higher milk production in 2020.
Pasture	3089	
Corn Silage	3686	
Corn	1503	
Alfalfa Silage	742	
Alfalfa Hay	678	
Partial Mix Ration	704	modelled based on compound feed from Californian dairy
Corn, HM	658	high moisture corn
Grain Mix	525	
Ddg, Dry	454	
Protein Mix	341	modelled based on compound feed from Californian dairy
Cottonseed	305	
Soybean Meal	290	
Supplement	245	
Corn Gluten Feed	221	
Canola Meal	154	
Total feed intake (kg/animal)	13596	Based on Thoma (2013), as is
Gross energy intake (MJ/animal)	153887	NIR
Digestibility (% of GE)	66.70%	NIR
Crude protein in diet (% of DM)	18.65%	Calculated based on ration and feed tables from Thoma (2013)
Percentage of silage (% of GE)	18%	Based on feed from Thoma, on NE instead of GE
HOUSING		
Straw for bedding (kg/animal)	250	Based on APS Californian dataset: 250 kg/dairy cow
Saw dust (kg/animal)	125	Based on APS Californian dataset: 125 kg/dairy cow
Type (e.g. housed/ free ranging)	housed	Based on APS Californian dataset
MANURE MANAGEMENT		
Manure management system (select type, e.g. dry lot)		Three most common types: 38.4% anaerobic lagoon, 24.9% solid storage, 14.6% deep pit (NIR)
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	49.6%	Based on Thoma (2013)
Time spent in open yard areas (%)	30.4%	Based on (USDA, 2016)
Time spent in buildings (%)	20%	Based on (USDA, 2016)
Housing system heifers and calves 1-2 years		
RATION (kg as is)		Ration for grazing and non-grazing seasons per region and per animal type obtained from Thoma (2013), corrected for the length of grazing and non-grazing season, then multiplied by number of animals per region (based on NIR) to obtain weighted average diet per animal type per year. Top 15 feed ingredients are included (extrapolated to match total weight), adjusted for higher milk production in 2020.
Pasture	2210	Based on grass dataset from Californian dataset
Corn Silage	2454	

Alfalfa Hay	407	
Corn	370	
Wheat Straw	280	
Supplement	263	
Grass Hay	265	
Partial Mix Ration	209	modelled based on compound feed from Californian dairy
Alfalfa Silage	148	
Ddg, Dry	163	Maize distillers grains
Soybean Meal	135	
Grain Mix	120	
Protein Mix	81	modelled based on compound feed from Californian dairy (APS Californian dataset)
Corn Gluten Feed	63	
Oat Hay	47	
Total feed intake (kg/animal)	7215	Based on Thoma (2013)
Gross energy intake (MJ/animal)	69411	NIR
Digestibility (% of GE)	63.70%	NIR
Crude protein in diet (% of DM)	18.49%	Calculated based on ration and feed tables from Thoma (2013)
Percentage of silage (% of GE)	21%	Based on feed from Thoma, on NE instead of GE
HOUSING		
Straw for bedding (kg/animal)	0	Based on AFP Californian dataset
Saw dust (kg/animal)	0	Based on AFP Californian dataset
Type (e.g. housed/ free ranging)	housed	Based on AFP Californian dataset
MANURE MANAGEMENT		
Manure management system (select type, e.g. dry lot)		Two most common types: 80% dry lot, 14% daily spread (based on NIR)
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	49.6%	Based on Thoma (2013) (assumed same as dairy cows)
Time spent in open yard areas (%)	30.4%	Based on (USDA, 2016) (assumed same as dairy cows)
Time spent in buildings (%)	20%	Based on (USDA, 2016) (assumed same as dairy cows)
Housing system calves < 1 year		
RATION (kg as is)		Ration for grazing and non-grazing seasons per region and per animal type obtained from Thoma (2013), corrected for the length of grazing and non-grazing season, then multiplied by number of animals per region (based on NIR) to obtain weighted average diet per animal type per year. Top 15 feed ingredients are included (extrapolated to match total weight), adjusted for higher milk production in 2020.
Pasture	1104	
Corn Silage	843	
Alfalfa Hay	297	
Alfalfa Silage	270	
Barley	217	
Partial Mix Ration	194	modelled based on compound feed from APS Californian dataset
Wheat Straw	123	
Grass Hay	120	
Wheat Silage	113	
Corn	107	
Oat Silage	108	
Ddg, Dry	86	
Cotton Gin Trash	88	
Sorghum Silage	91	
Supplement	76	
Total feed intake (kg/animal)	3835	Based on Thoma (2013)
Gross energy intake (MJ/animal)	8598	NIR
Digestibility (% of GE)	63.70%	NIR
Crude protein in diet (% of DM)	18.36%	Calculated based on ration and feed tables from Thoma (2013)
Percentage of silage (% of GE)	23%	Based on feed from Thoma, on NE instead of GE
HOUSING		

Straw for bedding (kg/animal)	0	APS Californian dataset - no straw
Saw dust (kg/animal)	0	APS Californian dataset - no saw dust
Type (e.g. housed/ free ranging)	housed	APS Californian dataset
MANURE MANAGEMENT		
Manure management system (select type, e.g. dry lot)		Two most common types: 80% dry lot, 14% daily spread
TIME SPENT DISTRIBUTION		
Time spent grazing (%)	0%	based on APS Californian dataset
Time spent in open yard areas (%)	*100%*	based on APS Californian dataset
Time spent in buildings (%)	0%	based on APS Californian dataset

Appendix III Oatly production modelling (confidential data)

This appendix is not available in this version of the report due to confidential data.

Appendix IV Nutritional composition of Oatly Barista and cow's milk

For cow's milk a range is provided based on minimum and maximum values for skimmed and whole milk in the six countries in scope. All values are provided per 100 ml.

		Oatly Barista		Cow's milk	
	Unit	EU	US	minimum value	maximum value
Energy	kJ	257.0	244.1	142.0	273.0
	kcal	61.0	58.3	34.0	65.0
Fat	g	3.0	2.9	0.1	3.7
of which saturated	g	0.3	0.2	0.0	2.4
essential fatty acids*	g	0.8	0.6	0.0	0.2
Carbohydrates	g	7.1	6.7	4.5	5.2
of which sugars	g	3.4	2.9	4.5	5.0
Fiber	g	0.8	0.8	0.0	0.0
Protein	g	1.1	1.3	3.0	3.7
Sodium	g	0.0	0.0	0.0	0.1
Vitamin D	µg	1.1	1.5	0.0	1.1
Riboflavin	mg	0.2	0.3	0.1	0.2
Vitamin B12	µg	0.4	0.5	0.4	0.9
Calcium	mg	120.0	145.8	120.0	130.0
Iodine	µg	22.5	0.0	7.5	37.9
Iron	mg	not reported	0.1	0.0	0.1
Potassium	mg	not reported	162.5	150.0	169.0
Vitamin A	µg	not reported	66.7	1.0	58.0
Phosphorus	mg	not reported	112.5	90.0	106.0

* Polysaturates for milk in UK

Appendix V Full LCIA results, ReCiPe 2016 and EF 3.0

Oatly Barista at retail (incl EoL packaging) ambient, per liter

Impact category	Unit	Oatly Barista NL - retail DE	Oatly Barista NL - retail FI	Oatly Barista NL - retail NL	Oatly Barista NL - retail SE	Oatly Barista NL - retail UK	Oatly Barista SE - retail DE	Oatly Barista SE - retail FI	Oatly Barista SE - retail NL	Oatly Barista SE - retail SE	Oatly Barista SE - retail UK	Oatly Barista US - retail US	Oatly Barista US - food service US
Climate change - incl LUC and peat ox	kg CO2 eq	0.577	0.630	0.558	0.628	0.584	0.424	0.408	0.453	0.406	0.422	0.809	0.821
Climate change - excl LUC and peat ox	kg CO2 eq	0.448	0.500	0.428	0.498	0.454	0.321	0.304	0.349	0.302	0.318	0.744	0.756
Climate change - only LUC	kg CO2 eq	0.018	0.018	0.018	0.018	0.018	0.022	0.022	0.022	0.022	0.022	0.064	0.064
Climate change - only peat ox	kg CO2 eq	0.112	0.112	0.112	0.112	0.112	0.082	0.082	0.082	0.082	0.082	0.001	0.001
Stratospheric ozone depletion	kg CFC11 eq	3.02E-06	3.05E-06	3.02E-06	3.05E-06	3.02E-06	2.77E-06	2.77E-06	2.79E-06	2.77E-06	2.77E-06	2.54E-06	2.54E-06
Ionizing radiation	kBq Co-60 eq	3.19E-02	3.69E-02	2.91E-02	3.69E-02	3.60E-02	2.30E-02	2.55E-02	1.88E-02	2.55E-02	2.51E-02	1.57E-02	1.58E-02
Ozone formation, Human health	kg NOx eq	1.37E-03	1.78E-03	1.12E-03	1.71E-03	1.47E-03	1.26E-03	1.23E-03	1.34E-03	1.16E-03	1.39E-03	2.55E-03	2.62E-03
Fine particulate matter formation	kg PM2.5 eq	4.87E-04	5.53E-04	4.29E-04	5.30E-04	4.95E-04	4.80E-04	4.67E-04	4.65E-04	4.44E-04	4.98E-04	7.21E-04	7.31E-04
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.63E-03	2.05E-03	1.38E-03	1.98E-03	1.73E-03	1.55E-03	1.52E-03	1.62E-03	1.45E-03	1.68E-03	3.55E-03	3.62E-03
Terrestrial acidification	kg SO2 eq	1.65E-03	1.86E-03	1.49E-03	1.80E-03	1.69E-03	1.67E-03	1.64E-03	1.65E-03	1.57E-03	1.74E-03	2.79E-03	2.83E-03
Freshwater eutrophication	kg P eq	1.87E-04	2.05E-04	1.69E-04	1.71E-04	2.17E-04	1.88E-04	1.93E-04	1.72E-04	1.60E-04	2.12E-04	3.72E-04	3.74E-04
Marine eutrophication	kg N eq	5.91E-04	6.03E-04	5.91E-04	5.90E-04	6.09E-04	5.74E-04	5.85E-04	5.74E-04	5.73E-04	5.91E-04	6.15E-04	6.15E-04
Terrestrial ecotoxicity	kg 1,4-DCB	0.977	1.052	0.879	1.058	0.973	1.080	1.034	1.066	1.040	1.048	1.504	1.521
Freshwater ecotoxicity	kg 1,4-DCB	2.62E-02	2.66E-02	2.66E-02	2.61E-02	2.66E-02	2.75E-02	2.73E-02	2.75E-02	2.68E-02	2.74E-02	4.60E-02	4.60E-02
Marine ecotoxicity	kg 1,4-DCB	1.78E-02	1.84E-02	1.82E-02	1.76E-02	1.83E-02	1.98E-02	1.96E-02	2.00E-02	1.89E-02	1.98E-02	2.66E-02	2.66E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.58E-02	1.50E-02	1.51E-02	1.50E-02	1.47E-02	1.74E-02	1.60E-02	1.67E-02	1.60E-02	1.60E-02	1.85E-02	1.85E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	5.00E-01	5.10E-01	4.98E-01	4.89E-01	5.14E-01	4.97E-01	4.96E-01	4.93E-01	4.75E-01	5.04E-01	5.05E-01	5.05E-01
Land use	m2a crop eq	6.83E-01	6.95E-01	7.00E-01	6.93E-01	6.92E-01	6.42E-01	6.53E-01	6.60E-01	6.52E-01	6.52E-01	8.43E-01	8.43E-01
Mineral resource scarcity	kg Cu eq	1.08E-03	1.03E-03	9.31E-04	1.03E-03	1.02E-03	1.15E-03	1.07E-03	1.01E-03	1.08E-03	1.08E-03	1.40E-03	1.40E-03
Fossil resource scarcity	kg oil eq	1.26E-01	1.39E-01	1.03E-01	1.35E-01	1.30E-01	6.86E-02	6.05E-02	6.18E-02	5.58E-02	7.03E-02	2.12E-01	2.15E-01
Water consumption	m3	7.72E-03	8.07E-03	8.14E-03	8.00E-03	7.85E-03	4.43E-03	4.69E-03	4.81E-03	4.63E-03	4.49E-03	8.25E-03	8.26E-03

Oatly Barista at retail (incl EoL packaging) ambient, per kg

Density of Oatly Barista SE & NL =1.033 kg/L, density of Oatly Barista US = 1.031 kg/L

Impact category	Unit	Oatly Barista NL - retail DE	Oatly Barista NL - retail FI	Oatly Barista NL - retail NL	Oatly Barista NL - retail SE	Oatly Barista NL - retail UK	Oatly Barista SE - retail DE	Oatly Barista SE - retail FI	Oatly Barista SE - retail NL	Oatly Barista SE - retail SE	Oatly Barista SE - retail UK	Oatly Barista US - retail US	Oatly Barista US - food service US
Climate change - incl LUC and peat ox	kg CO2 eq	0.559	0.610	0.540	0.608	0.565	0.410	0.395	0.439	0.393	0.409	0.785	0.796
Climate change - excl LUC and peat ox	kg CO2 eq	0.434	0.484	0.414	0.482	0.439	0.311	0.294	0.338	0.292	0.308	0.722	0.733
Climate change - only LUC	kg CO2 eq	0.017	0.017	0.017	0.017	0.017	0.021	0.021	0.021	0.021	0.021	0.062	0.062
Climate change - only peat ox	kg CO2 eq	0.108	0.108	0.108	0.108	0.108	0.079	0.079	0.079	0.079	0.079	0.001	0.001
Stratospheric ozone depletion	kg CFC11 eq	2.92E-06	2.95E-06	2.92E-06	2.95E-06	2.92E-06	2.68E-06	2.68E-06	2.70E-06	2.68E-06	2.68E-06	2.46E-06	2.46E-06
Ionizing radiation	kBq Co-60 eq	3.09E-02	3.57E-02	2.82E-02	3.57E-02	3.48E-02	2.23E-02	2.47E-02	1.82E-02	2.47E-02	2.43E-02	1.52E-02	1.53E-02
Ozone formation, Human health	kg NOx eq	1.33E-03	1.72E-03	1.08E-03	1.66E-03	1.42E-03	1.22E-03	1.19E-03	1.30E-03	1.12E-03	1.35E-03	2.47E-03	2.54E-03
Fine particulate matter formation	kg PM2.5 eq	4.71E-04	5.35E-04	4.15E-04	5.13E-04	4.79E-04	4.65E-04	4.52E-04	4.50E-04	4.30E-04	4.82E-04	6.99E-04	7.09E-04
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.58E-03	1.98E-03	1.34E-03	1.92E-03	1.67E-03	1.50E-03	1.47E-03	1.57E-03	1.40E-03	1.63E-03	3.44E-03	3.51E-03
Terrestrial acidification	kg SO2 eq	1.60E-03	1.80E-03	1.44E-03	1.74E-03	1.64E-03	1.62E-03	1.59E-03	1.60E-03	1.52E-03	1.68E-03	2.71E-03	2.74E-03
Freshwater eutrophication	kg P eq	1.81E-04	1.98E-04	1.64E-04	1.66E-04	2.10E-04	1.82E-04	1.87E-04	1.67E-04	1.55E-04	2.05E-04	3.61E-04	3.63E-04
Marine eutrophication	kg N eq	5.72E-04	5.84E-04	5.72E-04	5.71E-04	5.90E-04	5.56E-04	5.66E-04	5.56E-04	5.55E-04	5.72E-04	5.97E-04	5.97E-04
Terrestrial ecotoxicity	kg 1,4-DCB	0.946	1.018	0.851	1.024	0.942	1.045	1.001	1.032	1.007	1.015	1.459	1.475
Freshwater ecotoxicity	kg 1,4-DCB	2.54E-02	2.58E-02	2.58E-02	2.53E-02	2.58E-02	2.66E-02	2.64E-02	2.66E-02	2.59E-02	2.65E-02	4.46E-02	4.46E-02
Marine ecotoxicity	kg 1,4-DCB	1.72E-02	1.78E-02	1.76E-02	1.70E-02	1.77E-02	1.92E-02	1.90E-02	1.94E-02	1.83E-02	1.92E-02	2.58E-02	2.58E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.53E-02	1.45E-02	1.46E-02	1.45E-02	1.42E-02	1.68E-02	1.55E-02	1.62E-02	1.55E-02	1.55E-02	1.79E-02	1.79E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	4.84E-01	4.94E-01	4.82E-01	4.73E-01	4.98E-01	4.81E-01	4.80E-01	4.77E-01	4.60E-01	4.88E-01	4.90E-01	4.90E-01
Land use	m2a crop eq	6.61E-01	6.73E-01	6.78E-01	6.71E-01	6.70E-01	6.21E-01	6.32E-01	6.39E-01	6.31E-01	6.31E-01	8.18E-01	8.18E-01
Mineral resource scarcity	kg Cu eq	1.05E-03	9.97E-04	9.01E-04	9.97E-04	9.87E-04	1.11E-03	1.04E-03	9.78E-04	1.05E-03	1.05E-03	1.36E-03	1.36E-03
Fossil resource scarcity	kg oil eq	1.22E-01	1.35E-01	9.97E-02	1.31E-01	1.26E-01	6.64E-02	5.86E-02	5.98E-02	5.40E-02	6.81E-02	2.06E-01	2.09E-01
Water consumption	m3	7.47E-03	7.81E-03	7.88E-03	7.74E-03	7.60E-03	4.29E-03	4.54E-03	4.66E-03	4.48E-03	4.35E-03	8.00E-03	8.01E-03

Oatly Barista at consumer (incl. EoL packaging) ambient, per liter

Impact category	Unit	Oatly Barista NL - consumer DE	Oatly Barista NL - consumer FI	Oatly Barista NL - consumer NL	Oatly Barista NL - consumer SE	Oatly Barista NL - consumer UK	Oatly Barista SE - consumer DE	Oatly Barista SE - consumer FI	Oatly Barista SE - consumer NL	Oatly Barista SE - consumer SE	Oatly Barista SE - consumer UK	Oatly Barista US - retail US	Oatly Barista US - food service US
Climate change - incl LUC and peat ox	kg CO2 eq	0.688	0.714	0.675	0.686	0.671	0.524	0.476	0.562	0.448	0.497	1.174	1.189
Climate change - excl LUC and peat ox	kg CO2 eq	0.549	0.574	0.535	0.546	0.531	0.412	0.364	0.451	0.336	0.386	1.092	1.108
Climate change - only LUC	kg CO2 eq	0.019	0.020	0.019	0.020	0.019	0.024	0.024	0.024	0.024	0.024	0.080	0.080
Climate change - only peat ox	kg CO2 eq	0.120	0.120	0.120	0.120	0.120	0.088	0.088	0.088	0.088	0.088	1.04E-03	1.04E-03
Stratospheric ozone depletion	kg CFC11 eq	3.28E-06	3.31E-06	3.28E-06	3.29E-06	3.27E-06	3.02E-06	3.01E-06	3.04E-06	2.99E-06	3.00E-06	3.24E-06	3.25E-06
Ionizing radiation	kBq Co-60 eq	4.62E-02	7.43E-02	3.74E-02	7.92E-02	6.38E-02	3.66E-02	6.21E-02	2.63E-02	6.70E-02	5.22E-02	4.72E-02	4.73E-02
Ozone formation, Human health	kg NOx eq	1.55E-03	1.98E-03	1.31E-03	1.87E-03	1.66E-03	1.44E-03	1.39E-03	1.54E-03	1.27E-03	1.58E-03	3.49E-03	3.57E-03
Fine particulate matter formation	kg PM2.5 eq	5.67E-04	6.46E-04	5.02E-04	5.86E-04	5.69E-04	5.60E-04	5.53E-04	5.41E-04	4.94E-04	5.72E-04	1.21E-03	1.22E-03
Ozone formation, Terrestrial ecosyst	kg NOx eq	1.84E-03	2.27E-03	1.59E-03	2.16E-03	1.94E-03	1.75E-03	1.70E-03	1.85E-03	1.58E-03	1.89E-03	4.74E-03	4.83E-03
Terrestrial acidification	kg SO2 eq	1.90E-03	2.12E-03	1.72E-03	1.98E-03	1.92E-03	1.92E-03	1.87E-03	1.89E-03	1.73E-03	1.98E-03	3.91E-03	3.95E-03
Freshwater eutrophication	kg P eq	2.97E-04	2.35E-04	2.20E-04	1.89E-04	2.43E-04	2.98E-04	2.22E-04	2.24E-04	1.77E-04	2.38E-04	5.62E-04	5.63E-04
Marine eutrophication	kg N eq	6.42E-04	6.50E-04	6.38E-04	6.36E-04	6.56E-04	6.23E-04	6.31E-04	6.20E-04	6.18E-04	6.37E-04	7.76E-04	7.76E-04
Terrestrial ecotoxicity	kg 1,4-DCB	1.250	1.291	1.112	1.284	1.218	1.360	1.272	1.313	1.264	1.300	2.50E+0	2.52E+0
Freshwater ecotoxicity	kg 1,4-DCB	3.54E-02	3.34E-02	3.42E-02	3.24E-02	3.33E-02	3.68E-02	3.41E-02	3.52E-02	3.32E-02	3.41E-02	7.15E-02	7.15E-02
Marine ecotoxicity	kg 1,4-DCB	2.83E-02	2.56E-02	2.67E-02	2.43E-02	2.56E-02	3.06E-02	2.70E-02	2.86E-02	2.57E-02	2.72E-02	5.10E-02	5.10E-02
Human carcinogenic toxicity	kg 1,4-DCB	2.31E-02	1.84E-02	1.98E-02	1.78E-02	1.79E-02	2.48E-02	1.94E-02	2.15E-02	1.89E-02	1.93E-02	3.51E-02	3.52E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	6.58E-01	5.91E-01	6.06E-01	5.55E-01	5.91E-01	6.55E-01	5.75E-01	6.00E-01	5.40E-01	5.80E-01	8.06E-01	8.07E-01
Land use	m2a crop eq	7.36E-01	7.50E-01	7.54E-01	7.47E-01	7.48E-01	6.92E-01	7.05E-01	7.11E-01	7.02E-01	7.04E-01	1.06E+0	1.06E+0
Mineral resource scarcity	kg Cu eq	1.31E-03	1.24E-03	1.13E-03	1.25E-03	1.24E-03	1.39E-03	1.29E-03	1.21E-03	1.29E-03	1.30E-03	2.34E-03	2.34E-03
Fossil resource scarcity	kg oil eq	1.52E-01	1.60E-01	1.32E-01	1.48E-01	1.55E-01	9.08E-02	7.47E-02	8.77E-02	6.28E-02	9.05E-02	3.12E-01	3.16E-01
Water consumption	m3	8.67E-03	9.48E-03	9.25E-03	9.29E-03	8.60E-03	5.13E-03	5.85E-03	5.67E-03	5.65E-03	4.99E-03	1.09E-02	1.09E-02

Oatly Barista at retail (incl. EoL packaging) chilled, per liter

Impact category	Unit	Oatly Barista NL - retail DE chilled	Oatly Barista NL - retail FI chilled	Oatly Barista NL - retail NL chilled	Oatly Barista NL - retail SE chilled	Oatly Barista NL - retail UK chilled	Oatly Barista SE - retail DE chilled	Oatly Barista SE - retail FI chilled	Oatly Barista SE - retail NL chilled	Oatly Barista SE - retail SE chilled	Oatly Barista SE - retail UK chilled	Oatly Barista US - retail US chilled
Climate change - incl LUC and peat ox	kg CO2 eq	0.621	0.705	0.586	0.702	0.555	0.456	0.435	0.500	0.431	0.450	1.007
Climate change - excl LUC and peat ox	kg CO2 eq	0.485	0.569	0.451	0.566	0.420	0.351	0.329	0.395	0.326	0.345	0.942
Climate change - only LUC	kg CO2 eq	0.023	0.024	0.023	0.024	0.023	0.024	0.024	0.023	0.024	0.023	0.064
Climate change - only peat ox	kg CO2 eq	0.112	0.112	0.112	0.112	0.112	0.082	0.082	0.082	0.082	0.081	0.001
Stratospheric ozone depletion	kg CFC11 eq	3.07E-06	3.11E-06	3.05E-06	3.10E-06	3.03E-06	2.80E-06	2.80E-06	2.82E-06	2.79E-06	2.79E-06	2.59E-06
Ionizing radiation	kBq Co-60 eq	3.23E-02	3.95E-02	2.95E-02	3.97E-02	3.72E-02	2.42E-02	2.84E-02	1.96E-02	2.85E-02	2.95E-02	1.83E-02
Ozone formation, Human health	kg NOx eq	1.44E-03	1.95E-03	1.16E-03	1.86E-03	1.17E-03	1.31E-03	1.26E-03	1.40E-03	1.18E-03	1.33E-03	2.87E-03
Fine particulate matter formation	kg PM2.5 eq	4.75E-04	5.59E-04	4.14E-04	5.30E-04	4.24E-04	4.62E-04	4.50E-04	4.52E-04	4.21E-04	4.58E-04	8.19E-04
Ozone formation, Terrestrial ecosyst	kg NOx eq	1.71E-03	2.22E-03	1.43E-03	2.13E-03	1.44E-03	1.60E-03	1.55E-03	1.69E-03	1.47E-03	1.62E-03	3.86E-03
Terrestrial acidification	kg SO2 eq	1.65E-03	1.91E-03	1.47E-03	1.83E-03	1.49E-03	1.65E-03	1.62E-03	1.64E-03	1.53E-03	1.65E-03	3.01E-03
Freshwater eutrophication	kg P eq	1.87E-04	2.05E-04	1.66E-04	1.68E-04	2.07E-04	1.88E-04	1.92E-04	1.70E-04	1.55E-04	2.14E-04	3.91E-04
Marine eutrophication	kg N eq	5.94E-04	6.05E-04	5.94E-04	5.94E-04	6.08E-04	5.76E-04	5.87E-04	5.76E-04	5.75E-04	5.91E-04	6.12E-04

Terrestrial ecotoxicity	kg 1,4-DCB	0.997	1.088	0.890	1.092	0.885	1.090	1.033	1.083	1.038	1.056	1.618
Freshwater ecotoxicity	kg 1,4-DCB	2.53E-02	2.55E-02	2.55E-02	2.49E-02	2.52E-02	2.66E-02	2.62E-02	2.65E-02	2.57E-02	2.67E-02	4.76E-02
Marine ecotoxicity	kg 1,4-DCB	1.65E-02	1.70E-02	1.68E-02	1.62E-02	1.65E-02	1.88E-02	1.83E-02	1.88E-02	1.75E-02	1.90E-02	2.86E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.22E-02	1.14E-02	1.14E-02	1.13E-02	1.06E-02	1.39E-02	1.24E-02	1.31E-02	1.23E-02	1.26E-02	1.96E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	4.88E-01	4.95E-01	4.82E-01	4.72E-01	4.90E-01	4.87E-01	4.81E-01	4.79E-01	4.58E-01	4.92E-01	5.27E-01
Land use	m2a crop eq	6.91E-01	7.03E-01	7.09E-01	7.01E-01	6.98E-01	6.46E-01	6.56E-01	6.65E-01	6.54E-01	6.53E-01	8.44E-01
Mineral resource scarcity	kg Cu eq	8.46E-04	8.02E-04	7.07E-04	8.06E-04	7.76E-04	9.16E-04	8.41E-04	7.85E-04	8.45E-04	8.58E-04	1.43E-03
Fossil resource scarcity	kg oil eq	1.26E-01	1.45E-01	1.05E-01	1.40E-01	1.13E-01	7.01E-02	6.23E-02	6.80E-02	5.73E-02	7.14E-02	2.30E-01
Water consumption	m3	7.83E-03	8.07E-03	8.28E-03	7.99E-03	7.92E-03	4.55E-03	4.68E-03	4.94E-03	4.60E-03	4.66E-03	1.05E-02

Cow's milk at retail (incl EoL packaging), per liter

Impact category	Unit	Cow's milk - retail DE	Cow's milk - retail FI	Cow's milk - retail NL	Cow's milk - retail SE	Cow's milk - retail UK	Cow's milk - retail US
Climate change - incl LUC and peat ox	kg CO2 eq	1.652	1.711	1.369	1.124	1.374	1.508
Climate change - excl LUC and peat ox	kg CO2 eq	1.247	1.163	1.093	0.945	1.224	1.478
Climate change - only LUC	kg CO2 eq	0.096	0.035	0.088	0.054	0.093	0.018
Climate change - only peat ox	kg CO2 eq	0.309	0.513	0.189	0.125	0.057	0.013
Stratospheric ozone depletion	kg CFC11 eq	9.41E-06	1.20E-05	7.42E-06	7.58E-06	9.08E-06	6.44E-06
Ionizing radiation	kBq Co-60 eq	2.89E-02	8.24E-02	1.88E-02	8.59E-02	5.49E-02	3.08E-02
Ozone formation, Human health	kg NOx eq	1.82E-03	1.43E-03	9.63E-04	1.55E-03	1.18E-03	2.37E-03
Fine particulate matter formation	kg PM2.5 eq	4.01E-03	1.45E-03	5.20E-03	1.11E-03	3.65E-03	2.20E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	3.79E-03	1.78E-03	1.74E-03	2.19E-03	2.07E-03	2.50E-03
Terrestrial acidification	kg SO2 eq	6.64E-03	7.37E-03	5.00E-03	6.22E-03	4.66E-03	1.14E-02
Freshwater eutrophication	kg P eq	4.33E-04	3.65E-04	3.34E-04	2.86E-04	3.93E-04	4.99E-04
Marine eutrophication	kg N eq	2.09E-03	1.77E-03	1.49E-03	1.47E-03	1.66E-03	1.04E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.844	1.467	1.197	1.314	1.158	2.942
Freshwater ecotoxicity	kg 1,4-DCB	7.90E-02	3.90E-02	3.74E-02	3.82E-02	3.81E-02	8.00E-02
Marine ecotoxicity	kg 1,4-DCB	4.00E-02	2.85E-02	2.34E-02	2.54E-02	2.45E-02	4.56E-02
Human carcinogenic toxicity	kg 1,4-DCB	2.07E-02	1.31E-02	1.21E-02	1.15E-02	1.19E-02	1.81E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	7.95E-01	7.83E-01	6.83E-01	5.88E-01	6.88E-01	8.71E-01
Land use	m2a crop eq	9.12E-01	1.26E+00	6.52E-01	1.10E+00	8.55E-01	7.94E-01
Mineral resource scarcity	kg Cu eq	1.13E-03	1.13E-03	6.51E-04	9.41E-04	7.72E-04	1.64E-03
Fossil resource scarcity	kg oil eq	1.22E-01	1.19E-01	1.09E-01	9.71E-02	1.34E-01	1.66E-01
Water consumption	m3	9.11E-03	9.07E-03	1.10E-02	8.52E-03	9.07E-03	2.85E-02

Cow's milk at retail (incl EoL packaging), per kg

Impact category	Unit	Cow's milk - retail DE	Cow's milk - retail FI	Cow's milk - retail NL	Cow's milk - retail SE	Cow's milk - retail UK	Cow's milk - retail US
Climate change - incl LUC and peat ox	kg CO2 eq	1.598	1.653	1.323	1.086	1.328	1.458
Climate change - excl LUC and peat ox	kg CO2 eq	1.206	1.124	1.057	0.913	1.183	1.429
Climate change - only LUC	kg CO2 eq	0.093	0.034	0.085	0.052	0.090	0.017
Climate change - only peat ox	kg CO2 eq	0.299	0.496	0.183	0.121	0.055	0.013
Stratospheric ozone depletion	kg CFC11 eq	9.10E-06	1.16E-05	7.17E-06	7.32E-06	8.78E-06	6.23E-06
Ionizing radiation	kBq Co-60 eq	2.79E-02	7.96E-02	1.82E-02	8.30E-02	5.31E-02	2.98E-02
Ozone formation, Human health	kg NOx eq	1.76E-03	1.38E-03	9.31E-04	1.50E-03	1.14E-03	2.29E-03
Fine particulate matter formation	kg PM2.5 eq	3.88E-03	1.40E-03	5.03E-03	1.07E-03	3.53E-03	2.13E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	3.67E-03	1.72E-03	1.68E-03	2.12E-03	2.00E-03	2.42E-03
Terrestrial acidification	kg SO2 eq	6.42E-03	7.12E-03	4.83E-03	6.01E-03	4.50E-03	1.10E-02
Freshwater eutrophication	kg P eq	4.19E-04	3.53E-04	3.23E-04	2.76E-04	3.80E-04	4.82E-04
Marine eutrophication	kg N eq	2.02E-03	1.71E-03	1.44E-03	1.42E-03	1.60E-03	1.01E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.783	1.417	1.157	1.270	1.119	2.844
Freshwater ecotoxicity	kg 1,4-DCB	7.64E-02	3.77E-02	3.62E-02	3.69E-02	3.68E-02	7.73E-02
Marine ecotoxicity	kg 1,4-DCB	3.87E-02	2.75E-02	2.26E-02	2.45E-02	2.37E-02	4.41E-02
Human carcinogenic toxicity	kg 1,4-DCB	2.00E-02	1.27E-02	1.17E-02	1.11E-02	1.15E-02	1.75E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	7.69E-01	7.57E-01	6.60E-01	5.68E-01	6.65E-01	8.42E-01
Land use	m2a crop eq	8.82E-01	1.22E+00	6.30E-01	1.06E+00	8.26E-01	7.68E-01
Mineral resource scarcity	kg Cu eq	1.09E-03	1.09E-03	6.29E-04	9.09E-04	7.46E-04	1.59E-03
Fossil resource scarcity	kg oil eq	1.18E-01	1.15E-01	1.05E-01	9.38E-02	1.30E-01	1.60E-01
Water consumption	m3	8.81E-03	8.76E-03	1.06E-02	8.23E-03	8.77E-03	2.75E-02

Cow's milk at consumer (incl EoL packaging), per liter

Impact category	Unit	Cow's milk - consumer DE	Cow's milk - consumer FI	Cow's milk - consumer NL	Cow's milk - consumer SE	Cow's milk - consumer UK	Cow's milk - consumer US
Climate change - incl LUC and peat ox	kg CO2 eq	1.846	1.886	1.568	1.221	1.532	2.090
Climate change - excl LUC and peat ox	kg CO2 eq	1.410	1.297	1.271	1.028	1.371	2.051
Climate change - only LUC	kg CO2 eq	0.103	0.038	0.094	0.059	0.100	0.022
Climate change - only peat ox	kg CO2 eq	0.332	0.551	0.203	0.134	0.061	0.016
Stratospheric ozone depletion	kg CFC11 eq	1.02E-05	1.30E-05	8.03E-06	8.17E-06	9.79E-06	8.14E-06
Ionizing radiation	kBq Co-60 eq	4.28E-02	1.34E-01	2.81E-02	1.44E-01	9.16E-02	7.87E-02
Ozone formation, Human health	kg NOx eq	2.04E-03	1.62E-03	1.16E-03	1.71E-03	1.37E-03	3.30E-03
Fine particulate matter formation	kg PM2.5 eq	4.36E-03	1.63E-03	5.64E-03	1.22E-03	3.97E-03	3.16E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	4.16E-03	2.00E-03	2.00E-03	2.39E-03	2.33E-03	3.47E-03
Terrestrial acidification	kg SO2 eq	7.26E-03	8.07E-03	5.53E-03	6.74E-03	5.14E-03	1.47E-02
Freshwater eutrophication	kg P eq	5.61E-04	4.10E-04	4.09E-04	3.15E-04	4.35E-04	7.53E-04
Marine eutrophication	kg N eq	2.25E-03	1.90E-03	1.61E-03	1.58E-03	1.79E-03	1.31E-03
Terrestrial ecotoxicity	kg 1,4-DCB	2.185	1.776	1.493	1.592	1.459	4.374
Freshwater ecotoxicity	kg 1,4-DCB	9.23E-02	4.79E-02	4.73E-02	4.66E-02	4.69E-02	1.17E-01
Marine ecotoxicity	kg 1,4-DCB	5.25E-02	3.81E-02	3.41E-02	3.41E-02	3.38E-02	7.91E-02
Human carcinogenic toxicity	kg 1,4-DCB	2.84E-02	1.68E-02	1.75E-02	1.43E-02	1.54E-02	3.70E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	9.78E-01	8.95E-01	8.23E-01	6.68E-01	7.88E-01	1.31E+00
Land use	m2a crop eq	9.79E-01	1.36E+00	7.03E-01	1.19E+00	9.24E-01	9.98E-01
Mineral resource scarcity	kg Cu eq	1.37E-03	1.38E-03	8.55E-04	1.17E-03	9.96E-04	2.70E-03
Fossil resource scarcity	kg oil eq	1.48E-01	1.40E-01	1.45E-01	1.07E-01	1.63E-01	2.67E-01
Water consumption	m3	1.01E-02	1.08E-02	1.25E-02	1.01E-02	9.98E-03	3.64E-02

ReCiPe Endpoints (H) – results for all products (per liter)

Impact category	Unit	Cow's milk - retail DE	Cow's milk - retail FI	Cow's milk - retail NL	Cow's milk - retail SE	Cow's milk - retail UK	Cow's milk - retail US	Oatly Barista NL – retail DE	Oatly Barista NL – retail FI	Oatly Barista NL – retail NL	Oatly Barista NL – retail SE	Oatly Barista NL – retail UK	Oatly Barista SE – retail DE	Oatly Barista SE – retail FI	Oatly Barista SE – retail NL	Oatly Barista SE – retail SE	Oatly Barista SE – retail UK	Oatly Barista US – retail US	Oatly Barista US – food service US
Climate change, Human health	DALY	1.69E-06	1.73E-06	1.40E-06	1.15E-06	1.43E-06	1.56E-06	5.46E-07	5.95E-07	5.28E-07	5.93E-07	5.52E-07	4.04E-07	3.89E-07	4.30E-07	3.86E-07	4.02E-07	7.63E-07	7.75E-07
Climate change, Terrestrial ecosystems	species.yr	5.11E-09	5.22E-09	4.22E-09	3.46E-09	4.31E-09	4.69E-09	1.65E-09	1.79E-09	1.59E-09	1.79E-09	1.67E-09	1.22E-09	1.17E-09	1.30E-09	1.17E-09	1.21E-09	2.30E-09	2.34E-09
Climate change, Freshwater ecosystems	species.yr	1.39E-13	1.43E-13	1.15E-13	9.45E-14	1.18E-13	1.28E-13	4.50E-14	4.90E-14	4.35E-14	4.89E-14	4.55E-14	3.33E-14	3.20E-14	3.54E-14	3.18E-14	3.31E-14	6.29E-14	6.38E-14
Stratospheric ozone depletion	DALY	5.00E-09	6.39E-09	3.94E-09	4.03E-09	4.82E-09	3.42E-09	1.60E-09	1.62E-09	1.60E-09	1.62E-09	1.60E-09	1.47E-09	1.47E-09	1.48E-09	1.47E-09	1.47E-09	1.35E-09	1.35E-09
Ionizing radiation	DALY	2.45E-10	6.99E-10	1.60E-10	7.29E-10	4.66E-10	2.62E-10	2.71E-10	3.13E-10	2.47E-10	3.13E-10	3.05E-10	1.95E-10	2.16E-10	1.60E-10	2.17E-10	2.13E-10	1.34E-10	1.34E-10
Ozone formation, Human health	DALY	1.60E-09	1.22E-09	1.02E-09	1.23E-09	1.09E-09	2.07E-09	1.17E-09	1.55E-09	9.50E-10	1.49E-09	1.26E-09	1.07E-09	1.04E-09	1.14E-09	9.72E-10	1.19E-09	2.25E-09	2.31E-09
Fine particulate matter formation	DALY	3.03E-06	1.06E-06	3.51E-06	7.51E-07	2.66E-06	1.40E-06	3.30E-07	3.71E-07	2.93E-07	3.57E-07	3.34E-07	3.18E-07	3.09E-07	3.08E-07	2.95E-07	3.29E-07	4.69E-07	4.75E-07
Ozone formation, Terrestrial ecosystems	species.yr	4.06E-10	2.13E-10	2.28E-10	2.65E-10	2.59E-10	3.24E-10	2.03E-10	2.57E-10	1.71E-10	2.48E-10	2.16E-10	1.93E-10	1.88E-10	2.02E-10	1.79E-10	2.10E-10	4.64E-10	4.73E-10
Terrestrial acidification	species.yr	1.16E-09	1.55E-09	8.53E-10	1.23E-09	7.54E-10	2.30E-09	3.30E-10	3.74E-10	2.95E-10	3.60E-10	3.37E-10	3.28E-10	3.20E-10	3.22E-10	3.06E-10	3.43E-10	5.04E-10	5.11E-10
Freshwater eutrophication	species.yr	2.90E-10	2.45E-10	2.24E-10	1.92E-10	2.64E-10	3.35E-10	1.26E-10	1.38E-10	1.13E-10	1.15E-10	1.46E-10	1.26E-10	1.30E-10	1.16E-10	1.07E-10	1.42E-10	2.50E-10	2.51E-10
Marine eutrophication	species.yr	3.54E-12	3.01E-12	2.54E-12	2.49E-12	2.82E-12	1.77E-12	1.00E-12	1.02E-12	1.00E-12	1.00E-12	1.03E-12	9.75E-13	9.94E-13	9.75E-13	9.74E-13	1.00E-12	1.04E-12	1.04E-12
Terrestrial ecotoxicity	species.yr	2.10E-11	1.67E-11	1.37E-11	1.50E-11	1.32E-11	3.36E-11	1.11E-11	1.20E-11	1.00E-11	1.21E-11	1.11E-11	1.23E-11	1.18E-11	1.22E-11	1.19E-11	1.20E-11	1.72E-11	1.73E-11
Freshwater ecotoxicity	species.yr	5.49E-11	2.70E-11	2.60E-11	2.65E-11	2.64E-11	5.55E-11	1.82E-11	1.85E-11	1.85E-11	1.81E-11	1.84E-11	1.90E-11	1.89E-11	1.91E-11	1.86E-11	1.90E-11	3.19E-11	3.19E-11
Marine ecotoxicity	species.yr	4.20E-12	3.00E-12	2.45E-12	2.67E-12	2.57E-12	4.80E-12	1.87E-12	1.93E-12	1.92E-12	1.85E-12	1.92E-12	2.08E-12	2.06E-12	2.10E-12	1.99E-12	2.08E-12	2.80E-12	2.80E-12
Human carcinogenic toxicity	DALY	6.87E-08	4.36E-08	4.02E-08	3.81E-08	3.94E-08	6.00E-08	5.23E-08	4.99E-08	5.00E-08	4.99E-08	4.87E-08	5.77E-08	5.32E-08	5.54E-08	5.32E-08	5.31E-08	6.13E-08	6.14E-08
Human non-carcinogenic toxicity	DALY	1.81E-07	1.79E-07	1.56E-07	1.34E-07	1.57E-07	1.99E-07	1.14E-07	1.16E-07	1.14E-07	1.11E-07	1.17E-07	1.13E-07	1.13E-07	1.12E-07	1.08E-07	1.15E-07	1.15E-07	1.15E-07
Land use	species.yr	8.09E-09	1.12E-08	5.79E-09	9.80E-09	7.59E-09	7.05E-09	6.06E-09	6.17E-09	6.22E-09	6.15E-09	6.15E-09	5.70E-09	5.80E-09	5.86E-09	5.79E-09	5.79E-09	7.48E-09	7.48E-09
Mineral resource scarcity	USD2013	0.000261	0.000261	0.00015	0.000218	0.000179	0.000378	0.00025	0.000238	0.000215	0.000239	0.000237	0.000266	0.000248	0.000233	0.000249	0.00025	0.000323	0.000324
Fossil resource scarcity	USD2013	0.039009	0.041544	0.036485	0.036239	0.04981	0.060735	0.04483	0.052281	0.036437	0.050752	0.047849	0.023617	0.021582	0.022693	0.020071	0.025672	0.080124	0.08166
Water consumption, Human health	DALY	4.03E-09	5.74E-09	4.39E-09	1.72E-08	1.34E-08	3.48E-08	6.40E-09	7.04E-09	7.50E-09	7.21E-09	6.90E-09	7.10E-09	7.69E-09	8.16E-09	7.86E-09	7.56E-09	7.58E-09	7.58E-09
Water consumption, Terrestrial ecosystem	species.yr	3.46E-11	4.35E-11	5.35E-11	4.66E-11	4.06E-11	1.96E-10	2.48E-11	2.87E-11	3.13E-11	2.84E-11	2.72E-11	2.21E-11	2.56E-11	2.84E-11	2.53E-11	2.42E-11	4.57E-11	4.57E-11
Water consumption, Aquatic ecosystems	species.yr	3.33E-15	3.47E-15	3.08E-15	3.92E-15	2.76E-15	6.85E-14	2.84E-15	3.01E-15	3.06E-15	3.00E-15	2.93E-15	3.00E-15	3.12E-15	3.23E-15	3.11E-15	3.07E-15	1.58E-14	1.58E-14

EF 3.0 impact assessment method – results for all products (per liter)

Impact category	Unit	Cow's milk - retail DE	Cow's milk - retail FI	Cow's milk - retail NL	Cow's milk - retail SE	Cow's milk - retail UK	Cow's milk - retail US	Oatly Barista NL - retail DE	Oatly Barista NL - retail FI	Oatly Barista NL - retail NL	Oatly Barista NL - retail SE	Oatly Barista NL - retail UK	Oatly Barista SE - retail DE	Oatly Barista SE - retail FI	Oatly Barista SE - retail NL	Oatly Barista SE - retail SE	Oatly Barista SE - retail UK	Oatly Barista US - retail US	Oatly Barista US - food service US
Climate change	kg CO2 eq	1.845	1.885	1.524	1.250	1.560	1.698	0.590	0.643	0.570	0.641	0.597	0.437	0.421	0.466	0.418	0.435	0.825	0.838
Ozone depletion	kg CFC11 eq	4.20E-08	5.03E-08	4.07E-08	4.88E-08	4.17E-08	8.96E-08	5.32E-08	6.55E-08	4.21E-08	6.37E-08	5.71E-08	3.20E-08	2.96E-08	3.25E-08	2.79E-08	3.46E-08	1.11E-07	1.14E-07
Ionising radiation	kBq U-235 eq	3.55E-02	1.14E-01	2.48E-02	1.21E-01	7.52E-02	4.72E-02	4.09E-02	5.16E-02	3.62E-02	5.16E-02	4.87E-02	3.29E-02	3.76E-02	2.94E-02	3.77E-02	3.83E-02	3.25E-02	3.31E-02
Photochemical ozone formation	kg NMVOC eq	5.05E-03	2.27E-03	3.42E-03	2.07E-03	3.96E-03	3.19E-03	1.68E-03	2.12E-03	1.41E-03	2.04E-03	1.78E-03	1.55E-03	1.50E-03	1.61E-03	1.43E-03	1.68E-03	3.03E-03	3.10E-03
Particulate matter	disease inc.	1.47E-07	1.11E-07	1.25E-07	9.44E-08	1.48E-07	1.54E-07	2.81E-08	2.98E-08	2.65E-08	2.92E-08	2.82E-08	2.96E-08	2.88E-08	2.85E-08	2.82E-08	2.99E-08	4.13E-08	4.16E-08
Human toxicity, non-cancer	CTUh	2.36E-08	1.76E-08	1.33E-08	1.41E-08	1.23E-08	2.05E-08	1.59E-08	1.61E-08	1.57E-08	1.60E-08	1.58E-08	1.70E-08	1.69E-08	1.69E-08	1.68E-08	1.69E-08	1.82E-08	1.83E-08
Human toxicity, cancer	CTUh	3.28E-10	1.61E-10	2.57E-10	1.67E-10	2.52E-10	4.00E-10	2.44E-10	2.49E-10	2.36E-10	2.47E-10	2.42E-10	2.43E-10	2.38E-10	2.38E-10	2.36E-10	2.41E-10	3.44E-10	3.45E-10
Acidification	mol H+ eq	2.40E-02	1.09E-02	2.21E-02	1.25E-02	1.72E-02	2.08E-02	3.10E-03	3.49E-03	2.82E-03	3.38E-03	3.17E-03	3.34E-03	3.28E-03	3.32E-03	3.18E-03	3.47E-03	5.69E-03	5.75E-03
Eutrophication, freshwater	kg P eq	3.10E-04	2.07E-04	2.06E-04	1.56E-04	1.97E-04	2.93E-04	1.43E-04	1.19E-04	1.20E-04	1.17E-04	1.18E-04	1.40E-04	1.12E-04	1.14E-04	1.10E-04	1.11E-04	1.98E-04	1.99E-04
Eutrophication, marine	kg N eq	8.37E-03	7.09E-03	6.18E-03	5.96E-03	6.91E-03	5.09E-03	2.62E-03	2.79E-03	2.52E-03	2.75E-03	2.67E-03	2.51E-03	2.51E-03	2.54E-03	2.47E-03	2.58E-03	3.14E-03	3.16E-03
Eutrophication, terrestrial	mol N eq	7.86E-02	5.64E-02	4.29E-02	4.21E-02	2.52E-02	9.02E-02	1.03E-02	1.21E-02	9.28E-03	1.18E-02	1.07E-02	9.84E-03	9.68E-03	1.01E-02	9.38E-03	1.04E-02	2.33E-02	2.36E-02
Ecotoxicity, freshwater	CTUe	117.492	15.509	24.249	14.167	18.466	80.812	10.945	11.102	10.233	11.077	10.808	11.076	10.722	10.714	10.695	10.857	28.735	28.808
Land use	Pt	91.918	45.195	56.462	54.181	80.672	47.381	23.445	24.749	25.484	24.552	24.542	23.437	24.633	25.584	24.434	24.525	27.325	27.343
Water use	m3 depriv.	9.48E-02	1.34E-01	1.33E-01	1.41E-01	1.43E-01	1.01E+00	6.63E-02	7.85E-02	8.64E-02	7.74E-02	7.39E-02	6.56E-02	7.67E-02	8.54E-02	7.55E-02	7.24E-02	2.36E-01	2.36E-01
Resource use, fossils	MJ	5.673	6.545	4.963	5.675	6.697	7.678	5.869	6.544	4.857	6.346	6.126	3.337	3.040	2.988	2.845	3.442	9.178	9.325
Resource use, minerals and metals	kg Sb eq	2.69E-06	3.21E-06	1.66E-06	2.71E-06	1.90E-06	5.26E-06	2.77E-06	2.19E-06	1.65E-06	2.26E-06	2.24E-06	3.03E-06	2.41E-06	1.91E-06	2.48E-06	2.47E-06	2.59E-06	2.58E-06
Climate change - Fossil	kg CO2 eq	9.36E-01	1.17E+00	7.95E-01	6.76E-01	6.80E-01	8.24E-01	5.68E-01	6.21E-01	5.48E-01	6.19E-01	5.75E-01	4.01E-01	3.85E-01	4.30E-01	3.83E-01	4.00E-01	7.57E-01	7.70E-01
Climate change - Biogenic	kg CO2 eq	8.13E-01	6.80E-01	6.41E-01	5.19E-01	7.88E-01	8.57E-01	4.60E-03	4.06E-03	3.76E-03	4.10E-03	4.08E-03	1.40E-02	1.35E-02	1.32E-02	1.35E-02	1.35E-02	3.96E-03	3.96E-03
Climate change - Land use and LU change	kg CO2 eq	9.60E-02	3.49E-02	8.77E-02	5.41E-02	9.28E-02	1.77E-02	1.79E-02	1.80E-02	1.79E-02	1.80E-02	1.79E-02	2.19E-02	2.19E-02	2.18E-02	2.19E-02	2.18E-02	6.40E-02	6.40E-02
Human toxicity, non-cancer - organics	CTUh	1.01E-08	1.95E-09	2.69E-09	1.62E-09	2.53E-09	7.63E-09	4.51E-10	4.87E-10	4.27E-10	4.66E-10	4.53E-10	4.53E-10	4.55E-10	4.39E-10	4.34E-10	4.84E-10	1.96E-09	1.97E-09
Human toxicity, non-cancer - inorganics	CTUh	7.79E-10	6.76E-10	5.45E-10	6.12E-10	5.73E-10	9.75E-10	5.24E-09	5.28E-09	5.22E-09	5.27E-09	5.24E-09	6.67E-09	6.67E-09	6.68E-09	6.66E-09	6.66E-09	3.74E-09	3.75E-09
Human toxicity, non-cancer - metals	CTUh	1.28E-08	1.50E-08	1.01E-08	1.19E-08	9.26E-09	1.19E-08	1.03E-08	1.03E-08	1.01E-08	1.03E-08	1.02E-08	9.92E-09	9.76E-09	9.85E-09	9.78E-09	9.76E-09	1.26E-08	1.26E-08
Human toxicity, cancer - organics	CTUh	6.71E-11	6.89E-11	5.44E-11	5.82E-11	4.63E-11	8.52E-11	6.72E-11	7.22E-11	6.28E-11	6.94E-11	6.77E-11	6.61E-11	6.58E-11	6.41E-11	6.30E-11	6.81E-11	9.90E-11	9.97E-11
Human toxicity, cancer - inorganics	CTUh	3.38E-20	1.97E-20	3.11E-21	2.23E-20	5.17E-24	1.01E-23	2.25E-19	1.90E-19	1.60E-19	1.95E-19	1.94E-19	2.30E-19	1.96E-19	1.66E-19	2.00E-19	2.00E-19	2.31E-19	2.31E-19
Human toxicity, cancer - metals	CTUh	2.61E-10	9.18E-11	2.03E-10	1.08E-10	2.06E-10	3.15E-10	1.77E-10	1.77E-10	1.73E-10	1.78E-10	1.75E-10	1.77E-10	1.73E-10	1.74E-10	1.73E-10	1.73E-10	2.45E-10	2.45E-10
Ecotoxicity, freshwater - organics	CTUe	111.091	9.130	18.733	8.520	13.933	71.347	4.481	4.539	4.451	4.537	4.495	4.613	4.615	4.629	4.612	4.622	19.853	19.862
Ecotoxicity, freshwater - inorganics	CTUe	1.463	1.372	1.398	1.245	1.327	2.283	0.866	1.014	0.861	1.024	0.893	0.840	0.835	0.950	0.845	0.852	2.018	2.042
Ecotoxicity, freshwater - metals	CTUe	4.939	5.006	4.118	4.402	3.205	7.182	5.598	5.549	4.922	5.516	5.420	5.623	5.272	5.135	5.238	5.383	6.865	6.904

ReCiPe Individualist at Midpoint (with latest GWP20 factors for climate change) – results for all products (per liter)

Impact category	*Unit*	*Cow's milk - retail DE*	*Cow's milk - retail FI*	*Cow's milk - retail NL*	*Cow's milk - retail SE*	*Cow's milk - retail UK*	*Cow's milk - retail US*	*Oatly Barista NL - retail DE*	*Oatly Barista NL - retail FI*	*Oatly Barista NL - retail NL*	*Oatly Barista NL - retail SE*	*Oatly Barista NL - retail UK*	*Oatly Barista SE - retail DE*	*Oatly Barista SE - retail FI*	*Oatly Barista SE - retail NL*	*Oatly Barista SE - retail SE*	*Oatly Barista SE - retail UK*	*Oatly Barista US - retail US*	*Oatly Barista US - food services US*
Climate change	kg CO2 eq	2.999	2.890	2.480	2.010	2.707	3.010	0.616	0.669	0.592	0.665	0.623	0.465	0.447	0.490	0.443	0.463	0.934	0.949
Stratospheric ozone depletion	kg CFC11 eq	6.02E-06	7.69E-06	4.75E-06	4.85E-06	5.80E-06	4.12E-06	1.96E-06	1.98E-06	1.95E-06	1.98E-06	1.96E-06	1.78E-06	1.78E-06	1.78E-06	1.77E-06	1.78E-06	1.64E-06	1.65E-06
Ionizing radiation	kBq Co-60 eq	2.80E-02	7.95E-02	1.82E-02	8.27E-02	5.30E-02	2.94E-02	3.10E-02	3.55E-02	2.83E-02	3.55E-02	3.48E-02	2.21E-02	2.45E-02	1.79E-02	2.45E-02	2.40E-02	1.46E-02	1.46E-02
Ozone formation, Human health	kg NOx eq	1.82E-03	1.43E-03	9.63E-04	1.55E-03	1.18E-03	2.37E-03	1.37E-03	1.78E-03	1.12E-03	1.71E-03	1.47E-03	1.26E-03	1.23E-03	1.34E-03	1.16E-03	1.39E-03	2.55E-03	2.62E-03
Fine particulate matter formation	kg PM2.5 eq	3.70E-03	5.56E-04	4.93E-03	3.99E-04	3.37E-03	6.84E-04	1.85E-04	1.88E-04	1.76E-04	1.84E-04	1.82E-04	1.84E-04	1.82E-04	1.77E-04	1.78E-04	1.80E-04	2.21E-04	2.21E-04
Ozone formation, Terrestrial ecosystems	kg NOx eq	3.79E-03	1.78E-03	1.74E-03	2.19E-03	2.07E-03	2.50E-03	1.63E-03	2.05E-03	1.38E-03	1.98E-03	1.73E-03	1.55E-03	1.52E-03	1.62E-03	1.45E-03	1.68E-03	3.55E-03	3.62E-03
Terrestrial acidification	kg SO2 eq	6.64E-03	7.37E-03	5.00E-03	6.22E-03	4.66E-03	1.14E-02	1.65E-03	1.86E-03	1.49E-03	1.80E-03	1.69E-03	1.67E-03	1.64E-03	1.65E-03	1.57E-03	1.74E-03	2.79E-03	2.83E-03
Freshwater eutrophication	kg P eq	4.33E-04	3.65E-04	3.34E-04	2.86E-04	3.93E-04	4.99E-04	1.87E-04	2.05E-04	1.69E-04	1.71E-04	2.17E-04	1.88E-04	1.93E-04	1.72E-04	1.60E-04	2.12E-04	3.72E-04	3.74E-04
Marine eutrophication	kg N eq	2.09E-03	1.77E-03	1.49E-03	1.47E-03	1.66E-03	1.04E-03	5.91E-04	6.03E-04	5.91E-04	5.90E-04	6.09E-04	5.74E-04	5.85E-04	5.74E-04	5.73E-04	5.91E-04	6.15E-04	6.15E-04
Terrestrial ecotoxicity	kg 1,4-DCB	9.95E-01	6.40E-01	6.02E-01	5.76E-01	5.46E-01	1.37E+00	4.31E-01	4.63E-01	3.88E-01	4.65E-01	4.28E-01	4.77E-01	4.57E-01	4.70E-01	4.60E-01	4.63E-01	6.65E-01	6.73E-01
Freshwater ecotoxicity	kg 1,4-DCB	5.32E-02	2.20E-02	2.16E-02	1.98E-02	2.07E-02	4.83E-02	1.33E-02	1.37E-02	1.36E-02	1.31E-02	1.37E-02	1.50E-02	1.49E-02	1.50E-02	1.43E-02	1.50E-02	2.29E-02	2.29E-02
Marine ecotoxicity	kg 1,4-DCB	1.90E-02	6.48E-03	6.90E-03	5.74E-03	6.79E-03	1.60E-02	3.98E-03	4.13E-03	4.11E-03	3.96E-03	4.13E-03	4.35E-03	4.35E-03	4.43E-03	4.18E-03	4.39E-03	7.21E-03	7.21E-03
Human carcinogenic toxicity	kg 1,4-DCB	1.50E-04	1.33E-04	1.22E-04	1.18E-04	9.44E-05	1.91E-04	1.19E-04	1.39E-04	9.92E-05	1.29E-04	1.18E-04	1.09E-04	1.02E-04	1.01E-04	9.17E-05	1.16E-04	2.09E-04	2.12E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	1.59E-02	8.71E-03	8.22E-03	7.51E-03	7.61E-03	3.95E-02	5.69E-03	6.25E-03	5.35E-03	5.84E-03	5.70E-03	5.98E-03	5.83E-03	5.78E-03	5.43E-03	6.24E-03	1.23E-02	1.24E-02
Land use	m2a crop eq	0.912	1.259	0.652	1.103	0.855	0.794	0.683	0.695	0.700	0.693	0.692	0.642	0.653	0.660	0.652	0.652	0.843	0.843
Mineral resource scarcity	kg Cu eq	8.97E-04	9.64E-04	5.24E-04	8.08E-04	6.35E-04	1.36E-03	8.79E-04	8.15E-04	7.15E-04	8.23E-04	8.13E-04	9.30E-04	8.47E-04	7.74E-04	8.55E-04	8.57E-04	1.09E-03	1.10E-03
Fossil resource scarcity	kg oil eq	1.22E-01	1.19E-01	1.09E-01	9.71E-02	1.34E-01	1.66E-01	1.26E-01	1.39E-01	1.03E-01	1.35E-01	1.30E-01	6.86E-02	6.05E-02	6.18E-02	5.58E-02	7.03E-02	2.12E-01	2.15E-01
Water consumption	m3	9.11E-03	9.07E-03	1.10E-02	8.52E-03	9.07E-03	2.85E-02	7.72E-03	8.07E-03	8.14E-03	8.00E-03	7.85E-03	4.43E-03	4.69E-03	4.81E-03	4.63E-03	4.49E-03	8.25E-03	8.26E-03

Functional unit based on NDU (Oatly)

Impact category	Unit	Oatly Barista NL - retail DE	Oatly Barista NL - retail FI	Oatly Barista NL - retail NL	Oatly Barista NL - retail SE	Oatly Barista NL - retail UK	Oatly Barista SE - retail DE	Oatly Barista SE - retail FI	Oatly Barista SE - retail NL	Oatly Barista SE - retail SE	Oatly Barista SE - retail UK	Oatly Barista US - retail US	Oatly Barista US - food services US
Climate change - incl LUC and peat ox	kg CO2 eq	4.38E-02	4.78E-02	4.23E-02	4.76E-02	4.43E-02	3.22E-02	3.09E-02	3.44E-02	3.08E-02	3.20E-02	6.54E-02	6.63E-02
Climate change - excl LUC and peat ox	kg CO2 eq	3.40E-02	3.79E-02	3.25E-02	3.78E-02	3.44E-02	2.43E-02	2.31E-02	2.65E-02	2.29E-02	2.41E-02	6.01E-02	6.11E-02
Climate change - only LUC	kg CO2 eq	1.37E-03	1.37E-03	1.37E-03	1.37E-03	1.37E-03	1.67E-03	1.67E-03	1.67E-03	1.67E-03	1.67E-03	5.17E-03	5.17E-03
Climate change - only peat ox	kg CO2 eq	8.49E-03	8.49E-03	8.49E-03	8.49E-03	8.49E-03	6.22E-03	6.22E-03	6.22E-03	6.22E-03	6.22E-03	8.08E-05	8.08E-05
Stratospheric ozone depletion	kg CFC11 eq	2.29E-07	2.31E-07	2.29E-07	2.31E-07	2.29E-07	2.10E-07	2.10E-07	2.12E-07	2.10E-07	2.10E-07	2.05E-07	2.05E-07
Ionizing radiation	kBq Co-60 eq	2.42E-03	2.80E-03	2.21E-03	2.80E-03	2.73E-03	1.74E-03	1.93E-03	1.43E-03	1.93E-03	1.90E-03	1.27E-03	1.28E-03
Ozone formation, Human health	kg NOx eq	1.04E-04	1.35E-04	8.49E-05	1.30E-04	1.11E-04	9.56E-05	9.33E-05	1.02E-04	8.80E-05	1.05E-04	2.06E-04	2.12E-04
Fine particulate matter formation	kg PM2.5 eq	3.69E-05	4.19E-05	3.25E-05	4.02E-05	3.75E-05	3.64E-05	3.54E-05	3.53E-05	3.37E-05	3.78E-05	5.82E-05	5.91E-05
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.24E-04	1.55E-04	1.05E-04	1.50E-04	1.31E-04	1.18E-04	1.15E-04	1.23E-04	1.10E-04	1.27E-04	2.87E-04	2.92E-04
Terrestrial acidification	kg SO2 eq	1.25E-04	1.41E-04	1.13E-04	1.37E-04	1.28E-04	1.27E-04	1.24E-04	1.25E-04	1.19E-04	1.32E-04	2.25E-04	2.29E-04
Freshwater eutrophication	kg P eq	1.42E-05	1.55E-05	1.28E-05	1.30E-05	1.65E-05	1.43E-05	1.46E-05	1.30E-05	1.21E-05	1.61E-05	3.01E-05	3.02E-05
Marine eutrophication	kg N eq	4.48E-05	4.57E-05	4.48E-05	4.47E-05	4.62E-05	4.35E-05	4.44E-05	4.35E-05	4.35E-05	4.48E-05	4.97E-05	4.97E-05
Terrestrial ecotoxicity	kg 1,4-DCB	7.41E-02	7.98E-02	6.67E-02	8.02E-02	7.38E-02	8.19E-02	7.84E-02	8.08E-02	7.89E-02	7.95E-02	1.21E-01	1.23E-01
Freshwater ecotoxicity	kg 1,4-DCB	1.99E-03	2.02E-03	2.02E-03	1.98E-03	2.02E-03	2.09E-03	2.07E-03	2.09E-03	2.03E-03	2.08E-03	3.72E-03	3.72E-03
Marine ecotoxicity	kg 1,4-DCB	1.35E-03	1.40E-03	1.38E-03	1.33E-03	1.39E-03	1.50E-03	1.49E-03	1.52E-03	1.43E-03	1.50E-03	2.15E-03	2.15E-03
Human carcinogenic toxicity	kg 1,4-DCB	1.20E-03	1.14E-03	1.15E-03	1.14E-03	1.11E-03	1.32E-03	1.21E-03	1.27E-03	1.21E-03	1.21E-03	1.49E-03	1.49E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	3.79E-02	3.87E-02	3.78E-02	3.71E-02	3.90E-02	3.77E-02	3.76E-02	3.74E-02	3.60E-02	3.82E-02	4.08E-02	4.08E-02
Land use	m2a crop eq	5.18E-02	5.27E-02	5.31E-02	5.26E-02	5.25E-02	4.87E-02	4.95E-02	5.01E-02	4.94E-02	4.94E-02	6.81E-02	6.81E-02
Mineral resource scarcity	kg Cu eq	8.19E-05	7.81E-05	7.06E-05	7.81E-05	7.74E-05	8.72E-05	8.12E-05	7.66E-05	8.19E-05	8.19E-05	1.13E-04	1.13E-04
Fossil resource scarcity	kg oil eq	9.56E-03	1.05E-02	7.81E-03	1.02E-02	9.86E-03	5.20E-03	4.59E-03	4.69E-03	4.23E-03	5.33E-03	1.71E-02	1.74E-02
Water consumption	m3	5.86E-04	6.12E-04	6.17E-04	6.07E-04	5.95E-04	3.36E-04	3.56E-04	3.65E-04	3.51E-04	3.41E-04	6.66E-04	6.67E-04

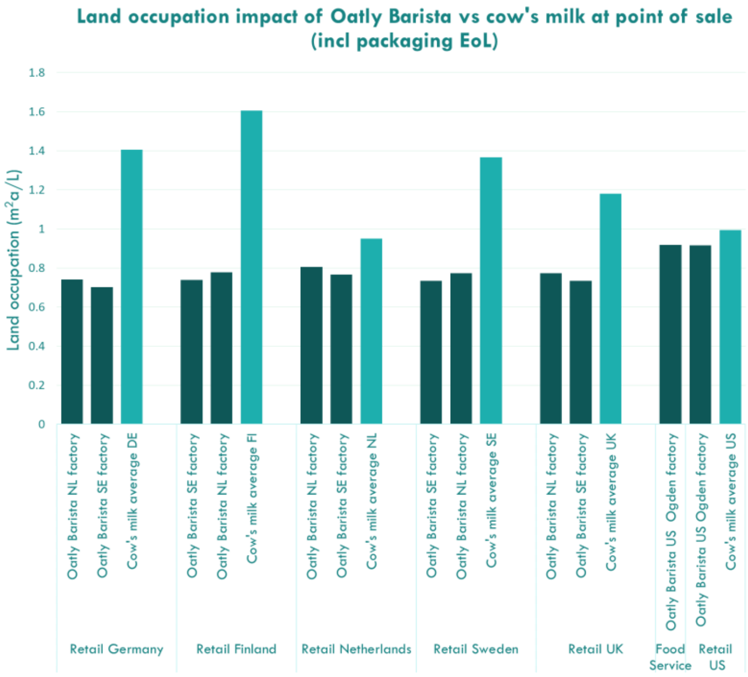
Functional unit based on NDU (cow's milk)

Impact category	Unit	Cow's milk - retail DE	Cow's milk - retail FI	Cow's milk - retail NL	Cow's milk - retail SE	Cow's milk - retail UK	Cow's milk - retail US
Climate change - incl LUC and peat ox	kg CO2 eq	1.66E-01	1.47E-01	1.24E-01	1.05E-01	1.27E-01	1.41E-01
Climate change - excl LUC and peat ox	kg CO2 eq	1.26E-01	9.97E-02	9.89E-02	8.80E-02	1.13E-01	1.38E-01
Climate change - only LUC	kg CO2 eq	9.66E-03	3.00E-03	7.96E-03	5.03E-03	8.56E-03	1.68E-03
Climate change - only peat ox	kg CO2 eq	3.11E-02	4.40E-02	1.71E-02	1.16E-02	5.25E-03	1.21E-03
Stratospheric ozone depletion	kg CFC11 eq	9.47E-07	1.03E-06	6.71E-07	7.06E-07	8.36E-07	6.01E-07
Ionizing radiation	kBq Co-60 eq	2.91E-03	7.06E-03	1.70E-03	8.00E-03	5.06E-03	2.88E-03
Ozone formation, Human health	kg NOx eq	1.83E-04	1.23E-04	8.71E-05	1.44E-04	1.09E-04	2.21E-04
Fine particulate matter formation	kg PM2.5 eq	4.04E-04	1.24E-04	4.70E-04	1.03E-04	3.36E-04	2.05E-04
Ozone formation, Terrestrial ecosystems	kg NOx eq	3.81E-04	1.53E-04	1.57E-04	2.04E-04	1.91E-04	2.33E-04
Terrestrial acidification	kg SO2 eq	6.68E-04	6.32E-04	4.52E-04	5.79E-04	4.29E-04	1.06E-03
Freshwater eutrophication	kg P eq	4.36E-05	3.13E-05	3.02E-05	2.66E-05	3.62E-05	4.66E-05
Marine eutrophication	kg N eq	2.10E-04	1.52E-04	1.35E-04	1.37E-04	1.53E-04	9.71E-05

Terrestrial ecotoxicity	kg 1,4-DCB	1.86E-01	1.26E-01	1.08E-01	1.22E-01	1.07E-01	2.75E-01
Freshwater ecotoxicity	kg 1,4-DCB	7.95E-03	3.34E-03	3.38E-03	3.56E-03	3.51E-03	7.47E-03
Marine ecotoxicity	kg 1,4-DCB	4.03E-03	2.44E-03	2.12E-03	2.37E-03	2.26E-03	4.26E-03
Human carcinogenic toxicity	kg 1,4-DCB	2.08E-03	1.12E-03	1.09E-03	1.07E-03	1.10E-03	1.69E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	8.00E-02	6.71E-02	6.18E-02	5.48E-02	6.34E-02	8.13E-02
Land use	m2a crop eq	9.18E-02	1.08E-01	5.90E-02	1.02E-01	7.87E-02	7.41E-02
Mineral resource scarcity	kg Cu eq	1.14E-04	9.69E-05	5.89E-05	8.76E-05	7.11E-05	1.53E-04
Fossil resource scarcity	kg oil eq	1.23E-02	1.02E-02	9.86E-03	9.04E-03	1.23E-02	1.55E-02
Water consumption	m3	9.17E-04	7.77E-04	9.95E-04	7.93E-04	8.35E-04	2.66E-03

Land occupation without characterization (m^2a/liter)

Product	Land occupation (m^2a)
Cow's milk - retail DE	1.404
Cow's milk - retail FI	1.605
Cow's milk - retail NL	0.950
Cow's milk - retail SE	1.366
Cow's milk - retail UK	1.180
Cow's milk - retail US	0.994
Oatly Barista NL - retail DE	0.740
Oatly Barista NL - retail FI	0.778
Oatly Barista NL - retail NL	0.805
Oatly Barista NL - retail SE	0.772
Oatly Barista NL - retail UK	0.773
Oatly Barista SE - retail DE	0.701
Oatly Barista SE - retail FI	0.739
Oatly Barista SE - retail NL	0.767
Oatly Barista SE - retail SE	0.733
Oatly Barista SE - retail UK	0.734
Oatly Barista US - retail US	0.917
Oatly Barista US - food service US	0.917



Different fat content cow's milk DE (per liter)

Impact category	Unit	Cow's milk - retail DE (skim)	Cow's milk - retail DE (semi-skim)	Cow's milk - retail DE (full)
Climate change - incl LUC and peat ox	kg CO2 eq	1.372	1.532	1.800
Climate change - excl LUC and peat ox	kg CO2 eq	1.042	1.159	1.356
Climate change - only LUC	kg CO2 eq	0.078	0.088	0.105
Climate change - only peat ox	kg CO2 eq	0.252	0.284	0.339
Stratospheric ozone depletion	kg CFC11 eq	7.68E-06	8.67E-06	1.03E-05
Ionizing radiation	kBq Co-60 eq	2.56E-02	2.74E-02	3.06E-02
Ozone formation, Human health	kg NOx eq	1.56E-03	1.71E-03	1.96E-03
Fine particulate matter formation	kg PM2.5 eq	3.30E-03	3.71E-03	4.38E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	3.16E-03	3.52E-03	4.12E-03
Terrestrial acidification	kg SO2 eq	5.49E-03	6.14E-03	7.24E-03
Freshwater eutrophication	kg P eq	3.66E-04	4.04E-04	4.68E-04
Marine eutrophication	kg N eq	1.70E-03	1.92E-03	2.29E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.565	1.724	1.991
Freshwater ecotoxicity	kg 1,4-DCB	6.58E-02	7.33E-02	8.59E-02
Marine ecotoxicity	kg 1,4-DCB	3.45E-02	3.76E-02	4.29E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.86E-02	1.98E-02	2.18E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	6.72E-01	7.42E-01	8.60E-01
Land use	m2a crop eq	0.754	0.844	0.995
Mineral resource scarcity	kg Cu eq	1.01E-03	1.08E-03	1.19E-03
Fossil resource scarcity	kg oil eq	1.07E-01	1.16E-01	1.30E-01
Water consumption	m3	7.01E-03	7.76E-03	1.07E-02

Different fat content cow's milk FI (per liter)

Impact category	Unit	Cow's milk - retail FI (skim)	Cow's milk - retail FI (semi-skim)	Cow's milk - retail FI (full)
Climate change - incl LUC and peat ox	kg CO2 eq	1.518	1.759	1.976
Climate change - excl LUC and peat ox	kg CO2 eq	1.037	1.196	1.329
Climate change - only LUC	kg CO2 eq	0.031	0.036	0.041
Climate change - only peat ox	kg CO2 eq	0.449	0.528	0.606
Stratospheric ozone depletion	kg CFC11 eq	1.06E-05	1.24E-05	1.42E-05
Ionizing radiation	kBq Co-60 eq	7.46E-02	8.43E-02	9.40E-02
Ozone formation, Human health	kg NOx eq	1.29E-03	1.46E-03	1.62E-03
Fine particulate matter formation	kg PM2.5 eq	1.29E-03	1.49E-03	1.69E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.61E-03	1.82E-03	2.04E-03
Terrestrial acidification	kg SO2 eq	6.50E-03	7.58E-03	8.65E-03
Freshwater eutrophication	kg P eq	3.30E-04	3.73E-04	4.16E-04
Marine eutrophication	kg N eq	1.56E-03	1.82E-03	2.08E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.321	1.501	1.682
Freshwater ecotoxicity	kg 1,4-DCB	3.50E-02	3.99E-02	4.48E-02
Marine ecotoxicity	kg 1,4-DCB	2.61E-02	2.91E-02	3.21E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.20E-02	1.34E-02	1.48E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	7.02E-01	8.02E-01	9.03E-01
Land use	m2a crop eq	1.113	1.293	1.474
Mineral resource scarcity	kg Cu eq	1.02E-03	1.15E-03	1.29E-03
Fossil resource scarcity	kg oil eq	1.08E-01	1.22E-01	1.35E-01
Water consumption	m3	8.12E-03	9.29E-03	1.05E-02

Different fat content cow's milk NL (per liter)

Impact category	Unit	Cow's milk - retail NL (skim)	Cow's milk - retail NL (semi-skim)	Cow's milk - retail NL (full)
Climate change - incl LUC and peat ox	kg CO2 eq	1.182	1.361	1.514
Climate change - excl LUC and peat ox	kg CO2 eq	0.949	1.087	1.200
Climate change - only LUC	kg CO2 eq	0.074	0.087	0.100
Climate change - only peat ox	kg CO2 eq	0.160	0.187	0.215
Stratospheric ozone depletion	kg CFC11 eq	6.28E-06	7.36E-06	8.43E-06
Ionizing radiation	kBq Co-60 eq	1.72E-02	1.87E-02	2.03E-02
Ozone formation, Human health	kg NOx eq	8.66E-04	9.58E-04	1.05E-03
Fine particulate matter formation	kg PM2.5 eq	4.41E-03	5.15E-03	5.89E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.53E-03	1.73E-03	1.94E-03
Terrestrial acidification	kg SO2 eq	4.27E-03	4.96E-03	5.65E-03
Freshwater eutrophication	kg P eq	2.91E-04	3.32E-04	3.72E-04
Marine eutrophication	kg N eq	1.27E-03	1.48E-03	1.70E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.057	1.189	1.322

Freshwater ecotoxicity	kg 1,4-DCB	3.28E-02	3.72E-02	4.16E-02
Marine ecotoxicity	kg 1,4-DCB	2.12E-02	2.32E-02	2.52E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.10E-02	1.20E-02	1.31E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	5.96E-01	6.78E-01	7.60E-01
Land use	m2a crop eq	0.563	0.647	0.731
Mineral resource scarcity	kg Cu eq	5.78E-04	6.46E-04	7.15E-04
Fossil resource scarcity	kg oil eq	9.65E-02	1.09E-01	1.21E-01
Water consumption	m3	9.58E-03	1.09E-02	1.23E-02

Different fat content cow's milk SE (per liter)

Impact category	Unit	Cow's milk - retail SE (skim)	Cow's milk - retail SE (semi-skim)	Cow's milk - retail SE (full)
Climate change - incl LUC and peat ox	kg CO2 eq	0.996	1.145	1.269
Climate change - excl LUC and peat ox	kg CO2 eq	0.841	0.963	1.061
Climate change - only LUC	kg CO2 eq	0.047	0.055	0.063
Climate change - only peat ox	kg CO2 eq	0.108	0.127	0.146
Stratospheric ozone depletion	kg CFC11 eq	6.56E-06	7.69E-06	8.81E-06
Ionizing radiation	kBq Co-60 eq	7.66E-02	8.66E-02	9.75E-02
Ozone formation, Human health	kg NOx eq	1.40E-03	1.57E-03	1.75E-03
Fine particulate matter formation	kg PM2.5 eq	9.81E-04	1.13E-03	1.28E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.95E-03	2.22E-03	2.49E-03
Terrestrial acidification	kg SO2 eq	5.42E-03	6.30E-03	7.19E-03
Freshwater eutrophication	kg P eq	2.53E-04	2.89E-04	3.27E-04
Marine eutrophication	kg N eq	1.27E-03	1.49E-03	1.70E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.161	1.310	1.519
Freshwater ecotoxicity	kg 1,4-DCB	3.32E-02	3.79E-02	4.51E-02
Marine ecotoxicity	kg 1,4-DCB	2.23E-02	2.48E-02	3.02E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.04E-02	1.15E-02	1.29E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	5.19E-01	5.92E-01	6.74E-01
Land use	m2a crop eq	0.963	1.118	1.273
Mineral resource scarcity	kg Cu eq	8.36E-04	9.41E-04	1.08E-03
Fossil resource scarcity	kg oil eq	8.77E-02	9.80E-02	1.08E-01
Water consumption	m3	7.52E-03	8.61E-03	9.72E-03

Different fat content cow's milk UK (per liter)

Impact category	Unit	Cow's milk - retail UK (skim)	Cow's milk - retail UK (semi-skim)	Cow's milk - retail UK (full)
Climate change - incl LUC and peat ox	kg CO2 eq	1.179	1.356	1.534
Climate change - excl LUC and peat ox	kg CO2 eq	1.053	1.209	1.364
Climate change - only LUC	kg CO2 eq	0.078	0.091	0.105
Climate change - only peat ox	kg CO2 eq	0.048	0.056	0.065
Stratospheric ozone depletion	kg CFC11 eq	7.63E-06	8.94E-06	1.03E-05
Ionizing radiation	kBq Co-60 eq	4.99E-02	5.45E-02	5.91E-02
Ozone formation, Human health	kg NOx eq	1.05E-03	1.16E-03	1.28E-03
Fine particulate matter formation	kg PM2.5 eq	3.08E-03	3.60E-03	4.11E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.80E-03	2.05E-03	2.29E-03
Terrestrial acidification	kg SO2 eq	3.97E-03	4.60E-03	5.22E-03
Freshwater eutrophication	kg P eq	3.52E-04	3.89E-04	4.26E-04
Marine eutrophication	kg N eq	1.40E-03	1.64E-03	1.88E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.030	1.146	1.262
Freshwater ecotoxicity	kg 1,4-DCB	3.34E-02	3.76E-02	4.18E-02
Marine ecotoxicity	kg 1,4-DCB	2.26E-02	2.43E-02	2.60E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.09E-02	1.18E-02	1.27E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	6.00E-01	6.80E-01	7.59E-01
Land use	m2a crop eq	0.721	0.843	0.965
Mineral resource scarcity	kg Cu eq	6.87E-04	7.65E-04	8.42E-04
Fossil resource scarcity	kg oil eq	1.23E-01	1.33E-01	1.44E-01
Water consumption	m3	7.94E-03	8.97E-03	1.00E-02

Different fat content cow's milk US (per liter)

Impact category	Unit	Cow's milk - retail US (skim)	Cow's milk - retail US (semi-skim)	Cow's milk - retail US (full)
Climate change - incl LUC and peat ox	kg CO2 eq	1.319	1.510	1.612
Climate change - excl LUC and peat ox	kg CO2 eq	1.293	1.479	1.578
Climate change - only LUC	kg CO2 eq	0.015	0.018	0.019
Climate change - only peat ox	kg CO2 eq	0.011	0.013	0.014
Stratospheric ozone depletion	kg CFC11 eq	5.47E-06	6.41E-06	7.04E-06
Ionizing radiation	kBq Co-60 eq	2.73E-02	3.05E-02	3.34E-02
Ozone formation, Human health	kg NOx eq	2.06E-03	2.36E-03	2.56E-03
Fine particulate matter formation	kg PM2.5 eq	1.89E-03	2.19E-03	2.39E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	2.17E-03	2.49E-03	2.70E-03
Terrestrial acidification	kg SO2 eq	9.70E-03	1.13E-02	1.24E-02
Freshwater eutrophication	kg P eq	4.41E-04	4.97E-04	5.36E-04
Marine eutrophication	kg N eq	8.89E-04	1.04E-03	1.14E-03
Terrestrial ecotoxicity	kg 1,4-DCB	2.536	2.931	3.192
Freshwater ecotoxicity	kg 1,4-DCB	6.89E-02	7.97E-02	8.69E-02
Marine ecotoxicity	kg 1,4-DCB	4.01E-02	4.55E-02	4.91E-02
Human carcinogenic toxicity	kg 1,4-DCB	1.61E-02	1.80E-02	1.93E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	7.57E-01	8.68E-01	9.43E-01
Land use	m2a crop eq	0.675	0.791	0.868
Mineral resource scarcity	kg Cu eq	1.42E-03	1.63E-03	1.77E-03
Fossil resource scarcity	kg oil eq	1.49E-01	1.66E-01	1.78E-01
Water consumption	m3	2.43E-02	2.83E-02	3.10E-02

Economic allocation cow's milk (per liter)

Impact category	Unit	Economic allocation milk DE	Economic allocation milk FI	Economic allocation milk NL	Economic allocation milk SE	Economic allocation milk UK	Economic allocation milk US
Climate change - incl LUC and peat ox	kg CO2 eq	1.857	1.947	1.512	1.248	1.540	1.688
Climate change - excl LUC and peat ox	kg CO2 eq	1.395	1.315	1.201	1.046	1.369	1.652
Climate change - only LUC	kg CO2 eq	0.110	0.040	0.099	0.061	0.106	0.020
Climate change - only peat ox	kg CO2 eq	0.353	0.591	0.212	0.142	0.065	0.015
Stratospheric ozone depletion	kg CFC11 eq	1.07E-05	1.39E-05	8.32E-06	8.57E-06	1.04E-05	7.38E-06
Ionizing radiation	kBq Co-60 eq	3.05E-02	9.07E-02	1.99E-02	9.30E-02	5.81E-02	3.39E-02
Ozone formation, Human health	kg NOx eq	2.00E-03	1.59E-03	1.03E-03	1.70E-03	1.28E-03	2.63E-03
Fine particulate matter formation	kg PM2.5 eq	4.55E-03	1.65E-03	5.82E-03	1.24E-03	4.15E-03	2.49E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	4.25E-03	1.99E-03	1.91E-03	2.42E-03	2.30E-03	2.78E-03
Terrestrial acidification	kg SO2 eq	7.51E-03	8.45E-03	5.58E-03	6.99E-03	5.27E-03	1.30E-02
Freshwater eutrophication	kg P eq	4.67E-04	4.01E-04	3.61E-04	3.11E-04	4.21E-04	5.45E-04
Marine eutrophication	kg N eq	2.38E-03	2.03E-03	1.68E-03	1.66E-03	1.90E-03	1.19E-03
Terrestrial ecotoxicity	kg 1,4-DCB	2.054	1.645	1.306	1.441	1.268	3.325
Freshwater ecotoxicity	kg 1,4-DCB	8.89E-02	4.38E-02	4.11E-02	4.23E-02	4.22E-02	9.08E-02
Marine ecotoxicity	kg 1,4-DCB	4.40E-02	3.15E-02	2.49E-02	2.75E-02	2.61E-02	5.09E-02
Human carcinogenic toxicity	kg 1,4-DCB	2.19E-02	1.44E-02	1.28E-02	1.23E-02	1.27E-02	1.99E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	0.882	0.883	0.749	0.651	0.765	0.980
Land use	m2a crop eq	1.033	1.441	0.723	1.240	0.976	0.909
Mineral resource scarcity	kg Cu eq	1.21E-03	1.26E-03	7.04E-04	1.03E-03	8.43E-04	1.84E-03
Fossil resource scarcity	kg oil eq	1.30E-01	1.31E-01	1.17E-01	1.04E-01	1.42E-01	1.81E-01
Water consumption	m3	1.01E-02	1.02E-02	1.21E-02	9.43E-03	1.01E-02	3.24E-02

Appendix VI Critical Review Statement and Report

Critical Review Statement

The life cycle assessment (LCA) study *LCA of Oatly Barista and comparison with cow's milk* was commissioned by Oatly (commissioner of the study) and carried out by Blonk Consultants (practitioner of the LCA study). Blonk Consultants commissioned a panel of external experts to review the study *LCA of Oatly Barista and comparison with cow's milk*. The study was critically reviewed by an international panel of experts comprising:

- Jasmina Burek (chair): Assistant Professor at University of Massachusetts Lowell, United States
- Jens Lansche: LCA expert and project manager, Switzerland
- Joanna Trewern: Food Systems and Sustainable Diets expert, United Kingdom
- Hayo van der Werf: LCA expert, France

All members of the review panel were independent of any party with a commercial interest in the study. The following is a final statement by the external review panel based on the review of the Draft Report, a version of the document submitted on December 7, 2022.

Critical Review Process

The critical review was performed based on ISO 14044:2006, 6.3. by panel of interested parties (ISO 14044, 2006). The critical review panel followed the ISO/TS critical review process guidelines (ISO/TS, 2014). The critical review was performed concurrently with the LCA study. Panel provided recommendations on a draft goal and scope document. All subsequent sets of review comments were performed after LCA practitioners provided the full draft of the LCA report to the critical review panel. The review excluded an assessment of the LCI models developed by Blonk for the purposes of this project and hence all the findings of the critical review are based solely on the LCA report that was made available to the panel during the critical review. However, the LCI was made available to the reviewers as annex to the report, which is excluded from published report due to confidentiality.

The critical review panel found the LCA study to be in conformance with ISO 14040 and ISO 14044 (ISO 14040, 2006; ISO 14044, 2006) including:

- the methods used to carry out the LCA were consistent with the applicable international standards
- the methods used to carry out the LCA were scientifically and technically valid
- the data used were appropriate and reasonable in relation to the goal of the study
- the interpretations reflected the limitations identified and the goal of the study, and
- the study report was transparent and consistent.

The critical review did not verify nor validate the goals that are chosen for an LCA by the commissioner of the LCA study, nor the ways in which the LCA results are used (ISO/TS, 2014). Finally, following the ISO/TS standard (ISO/TS, 2014) this critical review in no way implies an endorsement of any comparative assertion that is based on an LCA study. The panel asserts conformity with the ISO standards followed (ISO 14040, 2006; ISO 14044, 2006; ISO/TS, 2014) and a scientifically and technically valid methodological approach and results interpretation.

The critical-review process involved the following:

- a review of the goal and scope definition at the outset of the project;
- a review of two versions of draft reports according to the above criteria and recommendations for improvements to the study and the report; and
- a review of the final version of the report, in which the authors of the study fully addressed the points as suggested in the draft critical review.

The reviewers' comments were provided via email and discussed in virtual meetings with Oatly (stakeholder) and Blonk Consultants (LCA practitioner) including:

- the virtual meeting with LCA practitioners (Blonk Consultants) and stakeholders (Oatly) on April 21, 2022, following the reviewers' comments on the draft goal and scope document
- the virtual meeting with LCA practitioners (Blonk Consultants) and stakeholders (Oatly) on October 6th, 2022, following the reviewers' comments on the draft of the final LCA report
- additional reviewers' comments on the draft of the final LCA report were provided via email.

After each review, the LCA practitioner responded and/or and documented the adopted changes and implementation in the next version of the draft report. The Critical Review Report (Chapter 4) includes panel review comments and recommendations, and the corresponding responses given by the practitioner of the LCA study.

The review panel concludes on the basis of the goals set forth to review this study, that the study generally conforms to the applicable ISO standards as a comprehensive study that may be disclosed to the public.

The reviewers recognize the tremendous work of the LCA practitioners and stakeholder in completing this study.

January 23, 2023

Dr. Jasmina Burek	Dr. Jens Lansche	Dr. Joanna Trewern	Dr. Hayo van der Werf
Panel Chair	Panel Member	Panel Member	Panel Member

LCA of Oatly Barista and comparison with cow's milk
Version of the document submitted on December 7, 2022

Critical Review Report

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1. Introduction

The **Critical Review Report** is the summary report documenting the critical review process according to the ISO/TS 14071:2014 Standard - Environmental management -- Life cycle assessment -- Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006. The **Critical Review Report** provides details of the complete review process (ISO/TS, 2014) and includes all review comment iterations of the study "*LCA of Oatly Barista and comparison with cow's milk*". The study "*LCA of Oatly Barista and comparison with cow's milk*" was commissioned by Oatly and life cycle assessment (LCA) was performed by Blonk Consultants. The critical review was commissioned by the practitioners of the LCA study. A critical review was carried out by a panel of reviewers, as defined in ISO 14044:2006 (ISO 14044, 2006). The **Critical Review Report** was prepared by the critical review panel. The **Critical Review Report** applies to final version "LCA of Oatly Barista and comparison with cow's milk" published on 7-12-2022.

2. Critical Review Process

The critical review panel followed the ISO/TS critical review process guidelines (ISO/TS, 2014). Because this LCA study includes results which are intended to be used to support a comparative assertion intended to be disclosed to the public, per critical review process guidelines (ISO/TS, 2014), the critical review was conducted by a panel.

The critical review was performed concurrently with the LCA study and thus, a first set of comments by the critical review panel was shared with the practitioners of the LCA study after LCA practitioners provided a draft goal and scope document to the independent panelists. All subsequent sets of review comments (total 3) were performed after LCA practitioners provided the full draft of the LCA report to the critical review panel. The critical review report (Chapter 4) includes panel review comments and recommendations, and the corresponding responses given by the practitioner of the LCA study.

Per critical review process guidelines (ISO/TS, 2014), the goal of this critical review was to verify that:

- the methods used to carry out the LCA study are consistent with the 14040/14044 International Standards (ISO 14040, 2006; ISO 14044, 2006),
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations reflect the limitations identified and the goal of the study,
- the study report is transparent and consistent.

However, critical review can neither verify nor validate the goals that are chosen for an LCA by the commissioner of the LCA study, nor the ways in which the LCA results are used (ISO/TS, 2014). Finally, following the ISO/TS standard (ISO/TS, 2014) this critical review in no way implies an endorsement of any comparative assertion that is based on an LCA study.

The review was performed by an independent expert panel composed of four members. The reviewers participated at:

- the virtual meeting with LCA practitioners (Blonk Consultants) and stakeholders (Oatly) on April 21, 2022, following the reviewers' comments on the draft goal and scope

document
- the virtual meeting with LCA practitioners (Blonk Consultants) and stakeholders (Oatly) on October 6th, 2022, following the reviewers' comments on the draft of the final LCA report
- additional reviewers' comments on the draft of the final LCA report were provided via email.

3. Critical Review Results

This section includes summary of the critical review. A complete list of comments addressing specific statements on the draft LCA report provided by the critical review panelists and subsequent revisions is provided in Chapter 4.

The reviewers recognize the remarkable effort by the LCA practitioners (Blonk Consultants) in conducting the comparative LCA study as well as the stakeholder (Oatly) that provided primary data as well as critical comments.

The critical review panel pointed out both the strengths as well as key areas of improvement necessary to conform to the 14040/14044 International Standards (ISO 14040, 2006; ISO 14044, 2006).

3.1. Consistency with 14040/14044 International Standards

The final LCA report is consistent with the 14040 and 14044 International Standards (ISO 14040, 2006; ISO 14044, 2006) and the European Product Environmental Footprint Category Rules (PEFCR) (European Commission, 2017). The authors appropriately defined the goal of the study and functional unit for comparison of one-liter Oatly Barista and cow's milk products. The sensitivity analysis was performed using an alternative functional unit based on the nutritional density of the Oatly Barista and cow's milk products. The study is comprehensive in scope and contains a wealth of information and data related to Oatly Barista product supply chains in their respective production countries. The authors provided information why the critical review is being undertaken and what data collection covered and to what level of detail and how comparison with the milk was conducted in addition to testing different scenarios, performing sensitivity analyses and uncertainty analysis.

3.2. Life Cycle Assessment Approach and Life Cycle Impact Assessment Method

The authors computed results following attributional life cycle assessment approach. In a baseline scenario, Oatly Barista was compared to 1 l of cow's milk at the point of sale. Since, the study excluded use phase, additional scenario was performed which assessed inclusion of use stage. Cow's milk average product includes economic allocation for crop cultivation and processing, biophysical allocation at farm, and mass allocation (dry matter) at processing plant. The choice of allocation was tested through sensitivity analysis, e.g., Oatly Barista was compared to milk modelled with economic allocation throughout all life-cycle stages.

The life cycle impact assessment was performed using nine key midpoint environmental impact categories from the ReCiPe 2016 impact assessment method (Huijbregts et al., 2016). The choice of impact assessment method was tested using sensitivity analysis with endpoint environmental impact categories from the ReCiPe 2016 and alternative midpoint environmental impact categories from EF 3.0 (European Commission, 2017).

Finally, sensitivity of input parameters (perturbation analysis) for Oatly Barista and uncertainty analysis has been performed to determine the range in outcomes when considering uncertainties of the input data.

The primary Oatly Barista was compared to average chilled cow's milk product. In addition, authors included several scenario analyses with varying cow's milk options in a comparison: (1) comparing Oatly Barista to cow's milk with different fat content, (2) comparing Oatly Barista to ambient milk.

Overall, the methodology and the selection of the scenario, sensitivity and uncertainty analyses to evaluate the results of the impact assessment and support conclusion are considered appropriate for the goal and scope of the study.

3.3. Data Used for Life Cycle Inventory in Relation to the Goal of the Study

Overall, the data used is considered appropriate and reasonable for the goal and scope of the study. In parallel to proprietary stakeholder life cycle inventory (LCI) data necessary to perform LCA of Barista Oatly in different locations, the study included different cow's milk supply chains from recent literature and LCI databases. The equivalency for comparison was assured by consistency check and additional scenario and sensitivity analyses. Authors of the final report clearly described LCIs and data sources. Also, the authors provided information about robustness and limitations of the data used for Oatly Barista and cow's milk product LCI and assumptions for scenario and sensitivity analyses.

3.4. Interpretation and Limitations within the Goal of the Study

The authors present a large variety of results addressing various aspects of the study. The selected results help to understand study's conclusions and adequately support derived interpretation. Scenario, sensitivity, and uncertainty analyses further provide insights of the methodological and data choices and their influence on results, robustness of the conclusions, and the limitations of the results. Overall, interpretation of results and limitations of the study discussed in the report are considered appropriate for the goal of the study.

3.5. Transparency and Consistency of the Final Report

The authors provided an extensive report following the 14040/14044 International Standards (ISO 14040, 2006; ISO 14044, 2006) and supplemental information with information concerning the data and methodology used. The main report describes LCA framework including goal and scope, LCI, LCIA, results and interpretation, sensitivity and scenario analyses, uncertainty analysis and conclusion. The key aspects of the data used is described in the LCI section and accompanied with the supplemental information, which provides more details on the data sources. Overall, the information given in the documentation is considered appropriate for under-standing the methodology and data basis for most topics.

Literature

European Commission, 2017. Product Environmental Footprint Category Rules Guidance. PEFCR Guid. Doc. - Guid. Dev. Prod. Environ. Footpr. Categ. Rules (PEFCRs), version 6.3, December 2017. 238.

Huijbregts, M.A.J., Steinmann, Z.J.., Elshout, P.M.F., Stam, G., Verones, F., Vieira, M.D.., Zijp, M., van Zelm, R., 2016. ReCiPe 2016: A harmonized life cycle impact assessment method at midpoint and enpoint level - report 1 : characterization, National Institute for Public Health and the Environment.

ISO/TS, 2014. ISO/TS 14071:2014 - Environmental management -- Life cycle assessment -- Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006 [WWW Document]. URL https://www.iso.org/standard/61103.html (accessed 6.21.19).

ISO 14040, 2006. ISO 14040:2006 - Environmental management - life cycle assessment - principles and framework [WWW Document]. ISO. URL https://www.iso.org/standard/37456.html (accessed 2.22.17).

ISO 14044, 2006. Environmental management - Life cycle assessment — Requirements and guidelines (International Organization for Standardization).

4. List of Specific Reviewer Comments Recommendations and Corresponding Responses

Critical Review Panel provided comments on the goal and scope and three iterations of the draft report. These comments were addressed and/or incorporated in the final version of the report by the LCA partitioners. The review statement and review panel report including comments of the experts and any responses to recommendations made by the reviewers or by the panel have been included in the final LCA report.

Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
HW				ge	This is certainly a very detailed, thorough and well-documented LCA study. Among many other points, the contribution analysis of the climate change impacts of the different Oatly Barista products and cow milk products is very interesting, as are the results using protein provide as a functional unit. The results of the perturbation analysis are also of major interest as they may suggest ways to reduce impacts. The paired Monte Carlo analysis has proven particularly appropriate, as it allows a very clear presentation of the impacts differences.		The LCA practitioners appreciate your compliments
HW	78			ed	"for the European countries", USA is not a European country	Rephrase.	This is adjusted in the new version.
HW	108			ed	"USES RED TONES TO SHOW NEGATIVE DIFFERENCES, AND GREEN TONES FOR POSITIVE DIFFERENCES"	Rephrase e.g. : USES GREEN TONES TO SHOW NEGATIVE VLUES, AND RED TONES FOR POSITIVE VALUES"	This is adjusted in the new version.
HW	153			ed	"assertation"	Correct spelling	Changed to "assertion' in the new version.
HW	181			te	"protein substitution may be a relevant aspect for some consumers" A latte contains 88% milk, a cappuccino contains 81% milk, so these drinks are mainly milk. Oatly may be attractive for vegans, who tend to have a lower-than-average protein intake. .	Suggestion to include some additional information regarding the "protein functional unit". For instance: "Nevertheless, given that drinks such as latte and cappuccino contain 80% or more milk, and that Oatly may be attractive for vegans, who tend to have a lower-than-average protein intake, protein substitution may be a relevant aspect for some consumers. Furthermore, the scientific discussion ….etc. "	In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This section was therefore adjusted based on this different focus.
HW	183			te	"a functional unit based on the provision of macronutrients"	Suggestion to modify as: "a functional unit based on the provision of protein"	*(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
							section was therefore adjusted based on this different focus.
HW	193			te	% of milk in the USA is packaged as 1 gallon (3.8 liter)	Is this really true? Difficult to picture a 3.8 l plastic bottle.	 (source: Wikipedia – plastic milk container) Yes, this is the most common milk container in the US, see following references (Burek et al., 2017; Thoma et al., 2013; USDA-AMS, 2019)
HW	244			ed		Indicate for each panel member country of residence	Country of residence added in new version.
HW	283			te	As recommended in the goal and scope review, it should be indicated here that the APS footprint tool has not yet been updated according to IPCC2019 calculation guidelines. In addition, the estimated effect of this difference on emissions and overall results will be described.	It should be indicated that this will in particular affect N2O emissions from fertilizer and manure and thus will affect results. As specified in the practitioners response to expert panel's comments of the Goal and Scope report, the estimated effect of this difference on emissions and overall results should be described.	The N2O emissions from fertilizers and manure used in crop production follow the 2019 IPCC guidelines, as the new version of AFP was used (not yet released at time of goal & scope report). Methane conversion factors related to enteric fermentation and manure management systems still follow the old guidelines. In the new guidelines more detailed options/slight changes are provided for some manure management types. The maximum change in methane emissions is estimated 10%.
HW	334			te		Could you indicate for oat cultivation the allocation percentages for oat and straw? Often economic value of straw is close to zero.	Allocation percentages are added in the new version.
HW	336			te		Could you indicate for crop cultivation the allocation percentages for crop and straw? Often economic value of straw is close to zero	Allocation percentages are added in the new version.

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
HW	363			ed	The category "Excellent", which is present in table 8 is missing in Table 7.	Add "Excellent"to Table 7	Adjusted in new version.
HW	365-371			te	Some additional explanation is needed: how is the combined uncertainty value calculated from the data quality values for each of the four requirements?	Give additional explanation.	Combined uncertainty values are calculated by the pedigree functionality in SimaPro, additional explanation (including formula) is added in the new version.
HW	388		Table 10	te	Not clear why silage production requires water.	Clarification needed.	The mistake in the text was corrected (silage production releases water)
HW	589			te	"emissions from manure management and enteric fermentation"	Reformulate as: "emissions from manure management, enteric fermentation and from application of organic and mineral nitrogen fertilser"	The emission factors from application of organic and mineral nitrogen fertilizers follow the latest IPCC guidelines from 2019, as the latest version of Agri-footprint (version 6) was used.
HW	596			ed		Modify "are" to "a".	Adjusted in new version.
HW	778-779			te		Can you comment not only on the results for Ecosystems, but also on those for Human health (lower impacts for Barista) and Resources (no clear difference) as given in Table 15.	This was added in the new version.
HW	855			te		Proposition to add a sentence here: "However, given that drinks such as latte and cappuccino contain 80% or more milk, and that Oatly may be attractive for vegans, who tend to have a lower-than-average protein intake, protein provision is a relevant functional unit for certain consumers."	*(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This section was therefore adjusted based on this different focus.
HW	925			ed		Change "aluminium" to "aluminum"	Changed in the new version
HW	932			ed	Figure 22 is present twice, on page 49 and on page 51.		Removed in the new version.
HW	1032			ed		Change "aluminium" to "aluminum"	Changed in the new version
HW	1070			ed		Proposition to add a sentence here: "Nevertheless, protein provision is a relevant functional unit for consumers such as vegans, who tend to have lower than average protein intake."	*(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This

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							section was therefore adjusted based on this different focus.
HW	1197			ed		Suggestion to give a title to the appendix, e.g. "Characterisation methods used"	Added in the new version.
HW	1203			ed		Suggestion to give a title to the appendix, e.g. "Dairy production modelling"	Added in the new version.
HW	1376			ed		Suggestion to give a title to the appendix, e.g. "Oatly production modelling"	Added in the new version.
HW	1513			ed		Suggestion to give a title to the appendix, e.g. "Full LCIA results, ReCiPe 2016 and EF 3.0"	Added in the new version.
HW	1515			ed		Suggestion to add a heading: "ReCiPe Midpoints"	Added in the new version.
HW	1526			ed	Not clear why this table is in bold.		Corrected in new version
JL				ge	The study is well-written and comprehensive with a high quantitative and qualitative level of documentation. Both the choice of methods and the modelling (data, models and assumptions) are transparently presented and comprehensible. Reproducibility is given and the robustness of the results is comprehensively demonstrated by the sensitivity analyses, uncertainty analyses and parameter variations.		
JL	98			ed	typo: lower case letter for "land"		Corrected in the new version.
JL	101			ed	"The only scenario where the environmental impact of Oatly Barista is in most cases lower than cow's milk was when considering an alternative functional unit of 1kg of protein provided by the drinks"	Replace "lower" by "higher"	Removed due to different nutritional analyses (see comment above)
JL	109			ed	"THE COLOUR SCALE USES RED TONES TO SHOW NEGATIVE	Misleading. Please rephrase.	The caption was adjusted in the new version.

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					DIFFERENCES, AND GREEN TONES FOR POSITIVE DIFFERENCES"		
JL	120			te	"LCA is a framework that allows the quantitative analysis of the environmental burdens of a product or system" LCA can also show positive environmental impacts, not only burdens.	Replace "burden" by "impact"	Corrected in the new version.
JL	153			ed	Typo: "assertation"	Replace by "assertion"	Corrected in the new version.
JL	199			ed	"1liter"	Insert blank character	Corrected in the new version.
JL	204			ed	Point is missing at end of the sentence		Corrected in the new version.
JL	245			ed		please exclude affiliation	Corrected in the new version.
JL	333			te	"Allocation based on data from AFP"	Please specify further the allocation factors used for raw oats and oat straw	The allocation factors were added in the new version.
JL	335			te	Remark field is empty	Please specify further the allocation factors used for crop and crop residues	Allocation factors are specified in the new version.
JL	400			te	"Therefore, no conclusions on the effect on nutrient intake are intended to be drawn from this study."	it could be added that the digestibility of vegetable and animal proteins differs and this was also not taken into account	*(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This section was therefore adjusted based on this different focus.
JL	528			ed	"This concerns Scope 1 & 2 data which has been audited by EY"	Please introduce abbreviation "EY"	Added in the new version.
JL	532			ed	"Ecoinvent"	Replace by "ecoinvent"	Corrected in the new version.
JL	575			te	"Emissions from the cultivation and processing of feed crops (modelled with Agri-footprint 6.0 data)"	Please specify further which emissions are modelled from crop cultivation and processing.	More clarification was added in the new version. "Agri-footprint datasets consider cultivation-related inputs and resources (yield, water use, land occupation/ transformation, input of manure, fertilizers, lime, pesticides, start material, energy and transport of inputs), as well as emissions related to the use of these inputs and resources (nitrous oxide, ammonia, nitrate, nitric oxide, carbon dioxide,

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
							phosphorus, pesticide, heavy metals). Further processing of the crops into feed ingredients, as well as country-specific market mixes, are also included.”
JL	625			ed	“The colour scale uses Green tones to show negative differences, and Red tones for positive differences.”	Misunderstandable. Please rephrase.	Corrected in the new version.
JL	699			ed	“The United States has a comparative high use of heat and electricity as the factory is in commissioning stage.”	Please rephrase, e.g. “the factory in the United States has a comparative high use of heat and electricity as it is in commissioning stage”	This sentence was removed in the new version.
JL	791			ed	“…doesn’t only quantity the land surface but adds a qualitative aspect…”	Replace “quantity” by “quantify”	Corrected in the new version
JL	851			ed	“It should be noted that considering protein as a functional unit is not in line with the primary function of Oatly Barista, which is not consumed to provide protein, but to provide taste and texture to coffee and other food and beverage items” What is the rationale behind the statement that Oatly Barista is not consumed to provide protein, but only to provide taste and texture? It replaces milk, which provides protein, taste and texture (besides other ingredients). Is there any evidence that Oatly consumers consciously do not want protein intake and therefore choose this product?	Further explanation needed.	*(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This section was therefore adjusted based on this different focus.
JB		General comment s			The reviewers recognized the tremendous effort by the LCA team as well as the participating stakeholders that provided primary data as well as critical comments. The study is comprehensive in scope and contains a wealth of information related to Oatly production systems in different markets as well as comparison with the cow milk.		The LCA practitioners appreciate your compliments.

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
					The authors appeared to have addressed the comments and suggestions from the goal and scope review. The methods used to carry out the LCA were consistent with the applicable international standards. Appropriate allocation method was selected including the sensitivity analysis performed. The LCA team has performed in-depth comprehensive assessment of Oatly product in different markets and conducted comparative Monte Carlo uncertainty analysis, which is in line with the ISO standard. The methods used to carry out the LCA were scientifically and technically valid. . ReCiPe 2016 is appropriate method used in addition results were also assessed using a different method from European Commission, which is also appropriate. The data used were appropriate and reasonable in relation to the goal of the study. Uncertainty and sensitivity analyses contribute to robustness and understanding the results and conclusions of the study. The interpretations reflected the limitations identified and the goal of the study. The study report was transparent and consistent. Finally, this body of work is important to the many stakeholders in the food industry sectors, adding much needed perspectives on aspects of environmental performance as it pertains to oat milk. There are specific comments and editorial changes that follow. The comments submitted are in the spirit of enabling the		

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
					work that has been done to be accessible at its highest value.		
JB	79			ed	Missing location at the end of the Figure 1	FOLLOWED BY OATLY BARISTA PRODUCED AT THE SECONDARY PRODUCTION **LOCATION**	Corrected in the new version
JB	101			ed	Is this statement correct (lower or higher?) "The only scenario where the environmental impact of Oatly Barista is in most cases lower than cow's milk was when considering an alternative functional unit of 1kg of protein provided by the drinks."		This is adjusted in the new version based on the new nutritional analysis.
JB	103			te	"resulted in different trends for the land use and mineral resource scarcity impact categories" Perhaps explain that each method uses different metrics to account for resource use/impacts	Add explanation	Brief explanation was added in the new version.
JB	118			ed	Environmental impact should be plural	Change to environmental impacts	Corrected in the new version.
JB	120			te	It would be better to say LCA is a standard method instead of framework.	rephrase	Corrected in the new version.
JB	122			te	You can add also which substance (emissions) contribute to different impact categories since you also included discussion about it in the report.	Continue sentence with emission/substance contribution	Added in the new version.
JB	135			te	Also goal of the study	Add sentence about goal	Added in the new version, "This phase defines the goal of the study, and provides a description of the product system in terms of system boundary and functional unit"
JB	137			ed	Remove analysis for life cycle inventory or move LCI before analysis so it does not look like twice LCIA		Adjusted in the new version.
JB	148				The goal of the study was to evaluate environmental benefits and LCA is a method used	Rephrase. Also, I suggest adding content from the 2 footnote, which I believe fits into the objective plus goal.	The footnote is transferred to the goal in the new version.
JB	176			te		List all the requirements for comparative assertions	Added as a footnote: "Other requirements of a comparative study according to ISO

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							14044 include an assessment of data quality (including completeness and representativeness of the data used for both systems), equivalence of both systems, sensitivity analysis, uncertainty analysis (including evaluation of significance) and use of relevant and internationally accepted impact indicators. All of these are tackled in this report.”
JB		Footnote 4		te	1-10% change in total GHG emissions or of specific emission such as methane?	Specify if it is increase or decrease as well as if the change is reflected in total GHG or individual greenhouse gas.	This especially concerns methane emissions. In the new guidelines more detailed options/slight changes are provided for methane conversion factors for some manure management types. The maximum change in methane emissions is estimated 10% increase/decrease. This is now now specified in the text.
JB	237		Critical review	te	I would add the more recent standard in addition to mentioned one “according to ISO 14040/ 14044 and ISO/TS 14071:2014 standards”. ISO/TS 14071:2014 provides details of a critical review process, including clarification with regard to ISO 14044:2006; guidelines to deliver the required critical review process, linked to the goal of the life cycle assessment (LCA) and its intended use; content and deliverables of the critical review process; guidelines to improve the consistency, transparency, efficiency and credibility of the critical review process; the required competencies for the reviewer(s) (internal, external and panel member); the required competencies to be represented by the panel as a whole.	Add reference to: ISO/TS. ISO/TS 14071:2014 - Environmental management -- Life cycle assessment -- Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006 https://www.iso.org/standard/61103.html (accessed Jun 21, 2019).	Added the reference in the new version

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
JB	308	Uncertainty to the resulting endpoint indicators		te		You may add that uncertainty of impact factors or endpoint factor has not yet been broadly implemented with methods.	Added in the new version.
JB	341			ed	Agri-footprint 6	Even though Agri-footprint 6 by default is considered economic allocation it may be worth either explaining in the text or add economic.	Adjusted in the new version.
JB	402			te		Add rationale, for example " due to literature or LCA advances/efforts to provide protein based LCA for all food items	*(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This section was therefore adjusted based on this different focus.
JB	529			ed	Are those certificates in all markets?	Specify markets	All markets are specified in the new version.
JB	588			te	Does 1-10% matter for the overall impact increase or decrease	Specify if it is increase or decrease. I think you can also elaborate the finding here so it does not seem like this will have a large impact on final result or conclusions.	Some additional explanation was added in the new version.
JB	646			te	It seems like for US that may not be the case (based on figure)	Perhaps add except the US if true	Adjusted in the new version.
JB	646			te	In other bullets you mention the most relevant substances	You can add what has largest contribution to climate change (CO2 or Methane)	Added in new version.
JB		age 32		te	Processing and Packaging for mineral resources scarcity and fossil resource scarcity in U.S. Oatly vs US much higher. According to line 700 it is because factory is at commissioning stage? What does that mean?		This is adjusted in the new version.
JB	733			te	Is deforestation in Brazil still happening? (such as cane sugar)		Yes, LUC needs to be considered if it has occurred in the last 20 years (PAS 2050/PEFCR). Since origin of the sugarcane is unknown, default LUC data

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
							has been used based on Blonk's LUC tool.
JT				Ge	This is a detailed, clear and useful study, which makes good use of high quality and granular company-specific data detailing Oatly Barista's environmental impacts and makes an appropriate comparison to cow's milk. It is recognised that the previous comments from the reviewers have been taken into account to improve the quality of the study (e.g., on protein as functional unit). It is also interesting to see the environmental hotspots for this product and variation in impact due to production geography (e.g., peat oxidation).		The LCA practitioners appreciate your compliments. *(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This section was therefore adjusted based on this different focus.
JT			Table 1	Te	Some explanation is needed up front to interpret these results – why are the figures so variable for land use? And what does this tell us about the overall environmental impact of this product vs cow's milk? Can some variation be explained by differences in livestock production systems across these different markets?		An explanation is added in the text below the graph. Further explanation on the difference in land use is provided in the life cycle interpretation.
JT	123			Ed	LCA measures environmental impact of a product/system, not just climate impact.	Replace 'emissions' with 'environmental impacts'	This is corrected in the new version.
JT	152-155		Goal	Ge	If the goal is to inform external communications/green claims, care must be taken to communicate the results in a transparent way and avoid making sweeping statements (see verdict on Alpro case with ASA in UK).		This is noted. (The conclusion mentions: any comparative assessment intended to be disclosed to the public, should transparently address the conclusions of the study)
JT	244			Ed	Update job title	Head of Consumption	This is updated according to latest review comments below.
JT	440-441			Te	s assumed that both Oatly's Barista and cow's milk have the same share of losses during consumption. Losses at		This is indeed a conservative assumption, in practice Oatly Barista has likely lower losses. However due to lack of

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
					consumption stage are derived from the Dairy PEFCR." Is this fair and appropriate? My understanding is that Oatly Barista has a longer shelf-life and stays fresher for longer once open when compared to cow's milk, so I am not sure this is a fair comparison. Without data on Oatly losses I imagine it is hard to say for sure.		consumption data, losses are assumed to be the same for Oatly Barista and cow's milk. A footnote was added to explain this.
JT	470-474			Ge	The poor data quality and resulting high uncertainty factors applied for methane and feed in cow's milk analysis need to be noted clearly in the interpretation of the results to ensure transparency.	Note data quality concerns clearly in interpretation of results.	Uncertainty in data is addressed in the interpretation, and also mentioned in the executive summary and conclusions. A reference to the uncertainty analysis is now also added at the start of the impact assessment results.
JT	1066-1069			Ge	It is necessary to state what the outcomes were of the sensitivity analysis with protein as the functional unit.	Include information from the results – that Oatly Barista has a higher climate change impact than cow's milk based on protein content (1kg protein).	*(Repetition)* In the review meeting with the four panellists, it was decided to focus on a broader set of nutrients instead of only protein. The reviewers agreed to the use of the Nutrient Density Unit (NDU) which considers key macronutrients. This section was therefore adjusted based on this different focus.
HW	145			ed	Vegetable oil is not a residual stream	Change "vegetable oil" to "used vegetable oil"	This is changed in the new version.
HW	332-333				I do this review as an individual, not as a representative of INRAE.	Can you delete "at the French National Research Institute for Agriculture, Food, and Environment INRAE"?	This is deleted in the new version
HW			Table 11		In section 3 Oats milling the sentence "For the second Swedish mill, no information on energy use was available." seems to be in contradiction with the previous sentence, in which two Swedish mills are mentioned, so either this is the third Swedish mill, or in the previous sentence it should be one Swedish mill. In the next sentence "as for the other Swedish mills" should probably be "as for the other Swedish mill".	Can you correct this?	This is corrected in the new version.

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Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner & practitioner
JT	140-141			ed	It would be useful to include some examples of options to enhance water efficiency and reuse.	Can you add some examples into the text	Some examples were added. More clarification on the water footprint result was provided in section 5.1.1
JT	149			Ed	Specify transport method – by road/rail	Add information on main transport method	This was added in the new version
JT	348				I have participated in this review panel as an independent expert, not on behalf of WWF. WWF cannot endorse this review or Oatly products.	Revise wording to 'Food Systems and Sustainable Diets expert' and remove 'WWF-UK'	This is revised in the new version

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5. Self-declaration of independence

I, the signatory, hereby declare that:

- I am not a full-time or part-time employee of the commissioner or practitioner of the LCA study
- I have not been involved in defining the scope or carrying out any of the work to conduct the LCA study at hand, i.e. I have not been part of the commissioner's or practitioner's project team(s)
- I do not have vested financial, political, or other interests in the outcome of the study

I declare that the above statements are truthful and complete.

Date: January 23, 2023

Name: Jasmina Burek

Signature:

Name: Jens Lansche

Signature:

Name: Joanna Trewern

Signature:

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