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LCA of Oatly Creamy Oats and comparison with dairy cooking cream

LCA report

Blonk
CONSULTANTS

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About us

Blonk, a Mérieux NutriSciences Company 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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Abbreviations

CFF	Circular Footprint Formula
CO_2-eq	Carbon dioxide-equivalents
DC	Distribution centre
E2E	End-to-End Factory
EF	Environmental Footprint (method developed by the European Commission)
EoL	End of Life
Eq	Equivalent
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
PEFCR	Product Environmental Footprint Category Rules
SE	Sweden
UHT	Ultra High Temperature

Executive Summary

Introduction

A Life Cycle Assessment (LCA) has been performed to compare the environmental performance of Oatly Creamy Oat to dairy cooking cream, starting with the Swedish market. In addition, the study has analysed the drivers and opportunities linked to the environmental impact of Oatly Creamy Oat. The functional unit considered for this study is 1 liter of Oatly Creamy Oat/dairy cooking cream at the point of sale, including packaging manufacturing and packaging end of life. For dairy cooking cream, a reference product has been defined based on market research data, that considered the fat content and the most common heat treatment type and packaging format in Sweden. The foreground data for Oatly Creamy Oat is based on company-specific data from Oatly and refers to production from Oatly's End-to-End (E2E) factory in Landskrona[1]. For the dairy cooking cream, 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 10 key impact categories from the ReCiPe 2016 impact assessment method. The study was conducted between November 2023 and January 2024.

Comparison of Oatly Creamy Oat with dairy cooking cream

Based on this LCA, Oatly Creamy Oat has a significantly lower impact than dairy cooking cream for all key impact indicators. The results are similar for both 250 mL and 1 L packaging sizes. Table 1 presents the differences in detail.

TABLE 1: RELATIVE DIFFERENCES OF OATLY CREAMY OAT (0.25L AND 1L) COMPARED TO DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR EXAMPLE, -57% INDICATES THAT OATLY CREAMY OAT HAS A 57% LOWER IMPACT COMPARED TO DAIRY COOKING CREAM. THE COLOUR SCALE USES GREEN TONES TO SHOW WHERE OATLY CREAMY OAT HAS A SIGNIFICANTLY LOWER IMPACT THAN DAIRY COOKING CREAM (MORE THAN 10% DIFFERENCE FAVORING OATLY), AND YELLOW TONES WHERE THE IMPACT DIFFERENCE BETWEEN THE TWO PRODUCTS IS SMALLER (LESS THAN 10% DIFFERENCE FAVORING OATLY).

Product	Climate change	Fine particulate matter	Terrestrial acidify-cation	Freshwater eutrophi-cation	Marine eutrophi-cation	Land use	Land occupation	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*	*m2a*	*kg Cu eq*	*kg oil eq*	*m3*
Oatly Creamy Oat (250mL)	-61%	-59%	-72%	-35%	-54%	-38%	-42%	-20%	-30%	-61%
Oatly Creamy Oat (1L)	-62%	-61%	-73%	-38%	-54%	-38%	-41%	-29%	-36%	-63%

When analysing the various life cycle stages (as shown in Figure 1; see Chapter 5.1 for detailed graphs), the production of raw cow's milk (i.e. the animal production system itself)[2] is the predominant driver of impact for dairy cooking cream for all environmental impact categories (linked to processes such as enteric fermentation, manure management, and feed cultivation). The impacts of Oatly Creamy Oat are distributed between rapeseed cultivation, oat cultivation, packaging, and distribution, and are analysed in detail in the next section of the Executive Summary (Drivers and Opportunities for Oatly Creamy Oat).

The influence of assumptions and modelling choices (such as the functional unit, allocation approach and nutrition) 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.

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

[2] Note that the impact of producing cooking cream out of raw cow's milk is covered in the raw material stage, and therefore the processing stage shows 0.00 climate change impact. More explanation is given in section 5.1.

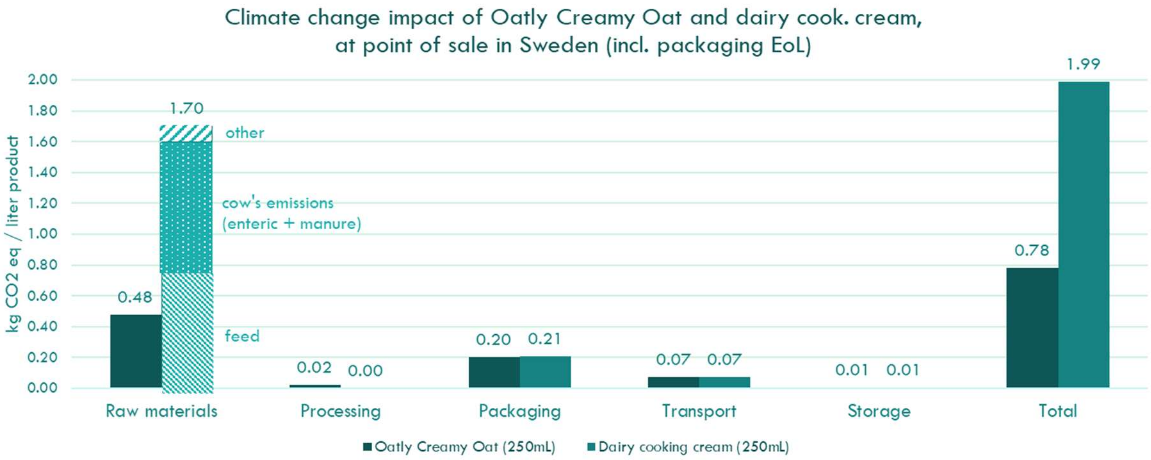

FIGURE 1: CLIMATE CHANGE IMPACTS OF OATLY CREAMY OAT AND DAIRY COOKING CREAM AT POINT OF SALE IN SWEDEN, INCLUDING END-OF-LIFE (EOL) OF PACKAGING.

Drivers and Opportunities for Oatly Creamy Oat

Analysing the impact of Oatly Creamy Oat across all impact categories in scope (see Table 1 and 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:** The cultivation of rapeseed in Sweden is the primary driver and improvement opportunity for Oatly Creamy Oat across most impact categories, followed by oats cultivation. Areas of improvement include reducing cultivation on peat soils (peat oxidation is a predominant contributor for climate change for (country-average) oats sourced from 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):** This life cycle stage is not a major contributor to Oatly Creamy Oat's environmental impacts in any of the impact categories, except for mineral resource scarcity (minerals used in the renewable electricity) and water consumption (water for cleaning and water used in the product).
- **Packaging (production & end of life):** 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 a significant fraction (12%) of the climate change impact of Oatly Creamy Oat, following an update of the background dataset used in the paper recycling fraction of the packaging[3].
- **Transportation:** Out of all transportation, the distribution to retailers by refrigerated truck has the biggest impact and is an important contributor for fossil resource scarcity and climate change. The product losses at this stage (e.g. related to scrapping of products that are not fit for sale anymore)) also impact the results. The use of biofueled trucks is a good example for a reduction opportunity in the distribution stage and has already been implemented by Oatly. However, due to a lack of sufficient quality data on this transportation mode, this reduction is not reflected in the LCA results[4].

Conclusions

The results show that overall:

- Oatly Creamy Oat has a significantly lower impact than dairy cooking cream for all key impact categories.
- The top drivers for Oatly Creamy Oat are rapeseed and oat cultivation, and packaging (production and end of life). However, their contribution varies depending on the environmental impact category. Rapeseed and oat cultivation are the top contributing factor for climate change and most other impact categories. For fine particulate matter formation, rapeseed cultivation and various transport stages are the main

[3] Waste paper sorting was not identified as a major impact in previous LCAs for Oatly products. However, after an update in the background database (ecoinvent 3.9), the impact of this process has increased.
[4] Biofueled trucks used by Oatly have been modelled as diesel trucks, due to a lack of sufficient quality data.

contributors. Fossil resource scarcity is driven mostly by the use of fossil fuels for transport, heat used in the rapeseed oil production, and packaging.

- Raw milk production is the main driver for the environmental impact of dairy cooking cream for all impact categories.

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's product Creamy Oat, is assessed and in addition compared to dairy cooking cream. 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.

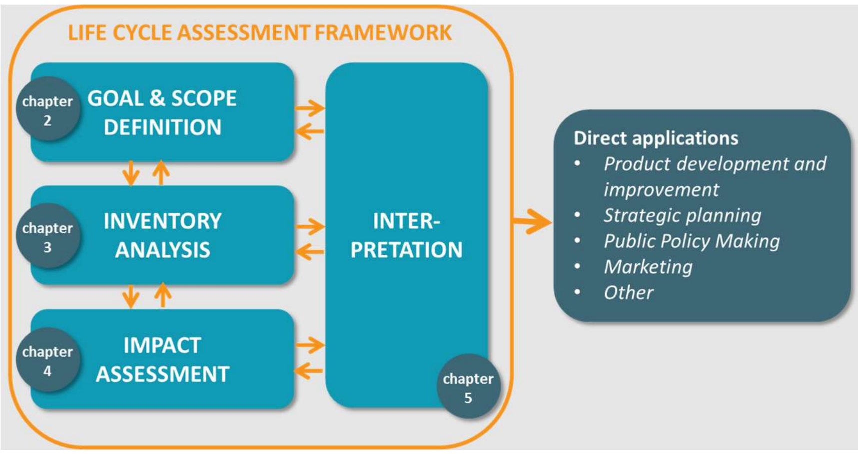

FIGURE 2: METHODOLOGICAL PHASES IN LCA BASED ON ISO 14040

- **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 of 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.

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

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.

1.2 Goal

The goal of the study is to assess the environmental impact of Oatly Creamy Oat product and in addition compare it to dairy (cow milk based) cooking cream in their respective markets, starting with the Swedish market in this report. An attributional life cycle assessment is 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 market in scope and identify areas of improvement. Secondly, the results of the comparative assertion with dairy cooking cream 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 low-fat dairy cream or oat-based cooking product (with a fat content of approximately 13%), to be used in cooking or baking, to provide taste and texture, supplied in 250 and 1000 milliliter packaging at point of sale.

The functional unit associated with both systems is: 1 liter of packed, liquid cooking product with a fat content of approximately 13%, at retail (chilled storage).

Table 2 lists the reference flows related to the Oatly product in scope, as well as for its dairy cooking cream equivalent. Oatly Creamy Oat are oat-based cooking and baking products in which rapeseed oil, emulsifiers, stabilizers, and iodized salts are added as functional ingredients that provide structure and texture to the cream.

TABLE 2: REFERENCE FLOWS OF THE PRODUCTS IN SCOPE

Oatly Creamy Oat cooking products…				…Compared with dairy cooking cream			
Reference flow	Oatly Creamy Oat	Produced in	Sold in	Reference flow	Dairy cooking cream	Produced in	Sold in
250 mL	Oatly Creamy Oat Local name: iMAT RUOKAAN	Landskrona, Sweden	Sweden (under chilled conditions)	250mL	HTST-treated dairy cooking cream with a 13% fat content	Sweden	Sweden (under chilled conditions)
1000mL	Oatly Creamy Oat Local name: iMAT RUOKAAN	Landskrona, Sweden	Sweden (under chilled conditions)	500mL +500mL	HTST-treated dairy cooking cream with a 13% fat content	Sweden	Sweden (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. 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.

The main function fulfilled by Oatly Creamy Oat and the dairy cooking cream is that they are added to dishes to provide taste and texture. The study focuses on this functionality of Oatly Creamy Oat and dairy cooking cream 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 Creamy Oat and dairy cooking cream on a nutritional basis is presented in the sensitivity analysis (see section 2.7). 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 Creamy Oat can replace low-fat dairy cooking creams. Due to the absence of existing literature data on market volumes, an inventory of representative low-fat cooking creams has been established based on retail data as elaborated below and in Appendix II.

For dairy cooking creams, the reference product has been defined using data from ICA Gruppen AB (one of the biggest grocery retailers in Sweden), purchased by Oatly.

According to these data the top sold dairy cream products at ICA in Sweden have the following formats:

- Paper carton with plastic cap, 500 mL, 13% fat;
- Paper carton, 250 mL, 15% fat;
- Paper carton with plastic cap 250 mL, 13% fat.

The heat treatment type for dairy cooking cream described by retailers was limited to non-technical terminology (e.g. "highly pasteurized" or simply "pasteurized"). Consequently, it is assumed that this refers to a conventional HTST pasteurization treatment which is the most common technology for preserving dairy cooking cream (Early, 1998).

As the predicted fat content of cream after separation is 42%, it was calculated how much whole milk, skimmed milk or water would be required to achieve a comparable fat content as reported by the retailers. This is the dilution ratio. For 13% fat containing cooking cream the dilution ratio is calculated as 3.3 with whole milk or 2.2 with skimmed milk.[6] For 15% fat containing cooking cream the dilution ratio is calculated as 2.5 with whole milk or 1.8 with skimmed milk[6]

Data about the fat content, ingredients, packaging and presence of stabilizers for each product. and are presented in Appendix II.

The environmental impact of cow's milk as input for cream production is modelled using national data on milk production. 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 country in scope (Eurostat, 2022). 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].

Oatly Creamy Oat is heat treated using UHT (ultra-high temperature treatment). The most common dairy cooking cream pasteurisation type in the country under consideration is HTST cream, which was also the case for the cow's milk in the Oatly Barista study (te Pas & Westbroek, 2022).

In Sweden, Oatly Creamy Oat product is packaged in a 250 or 1000 mL aseptic carton. For dairy cooking cream, 250 mL or 500 mL cartons are most occurring. In order to have a most clear and fair comparison, 250 mL and 500 mL cartons are considered.

The Oatly Creamy Oat in scope is produced and sold in Sweden. It is compared with dairy cooking cream produced and sold in that same country.

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[6] The dilution ratio and ingredient were calculated based on the assumptions presented in appendix II.
[7] The exact method used to calculate market mixes can be found in the Agri-footprint methodology (Blonk et al., 2022)

1.3.2 System boundaries

The system boundaries for Oatly Creamy Oat as well as dairy cooking cream 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, including all upstream impacts e.g. from fertilizer production, after which the oats are dehulled and dried at a mill. The dehulled and dried oats are transported to Oatly's production facility in Sweden, 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, the oat base is formulated into the final product with the addition of water, oil, emulsifiers, stabilizers and iodized salts. After formulation, the product is heat-treated and packed, after which the product is distributed to retail stores (supermarkets).

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, and due to a lack of specific data on the product use (losses, heating etc.). Including the consumption life cycle stage is expected only marginally (1-2%) increase the relative difference in impact between the two products as was illustrated in Oatly Barista's study.

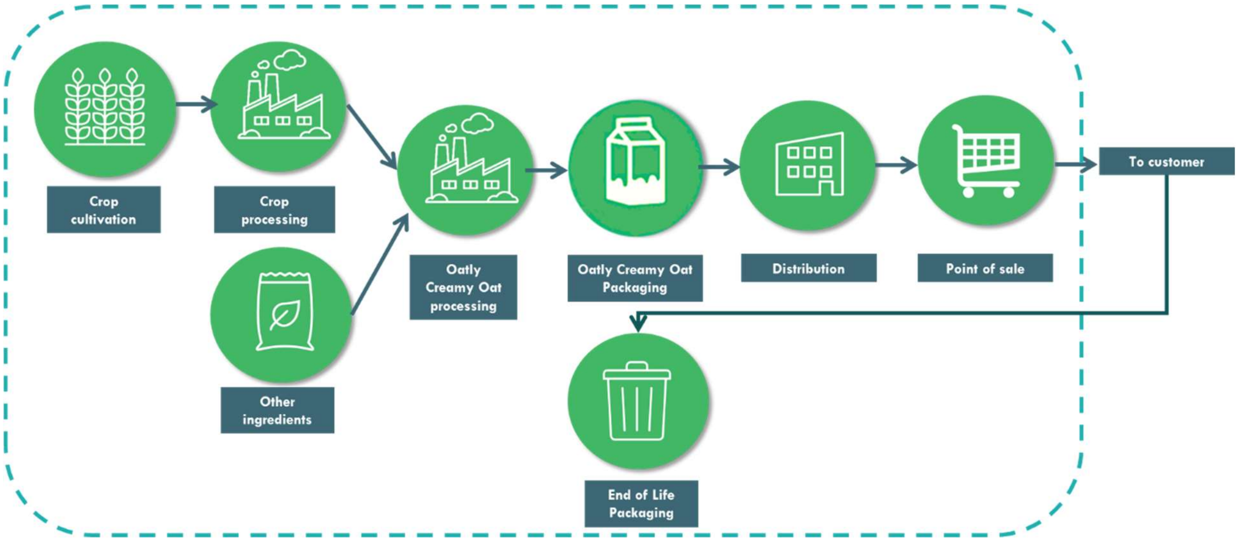

FIGURE 3: SYSTEM BOUNDARIES FOR PACKAGED OATLY CREAMY OAT. POINT OF SALE REFERS TO RETAIL IN SWEDEN.

The dairy system follows the same system boundaries, starting at cultivation of feed, including all upstream impacts e.g. from fertilizer production, followed by feed processing, raw milk production, milk processing & cream production, packaging, and distribution to the retail store.

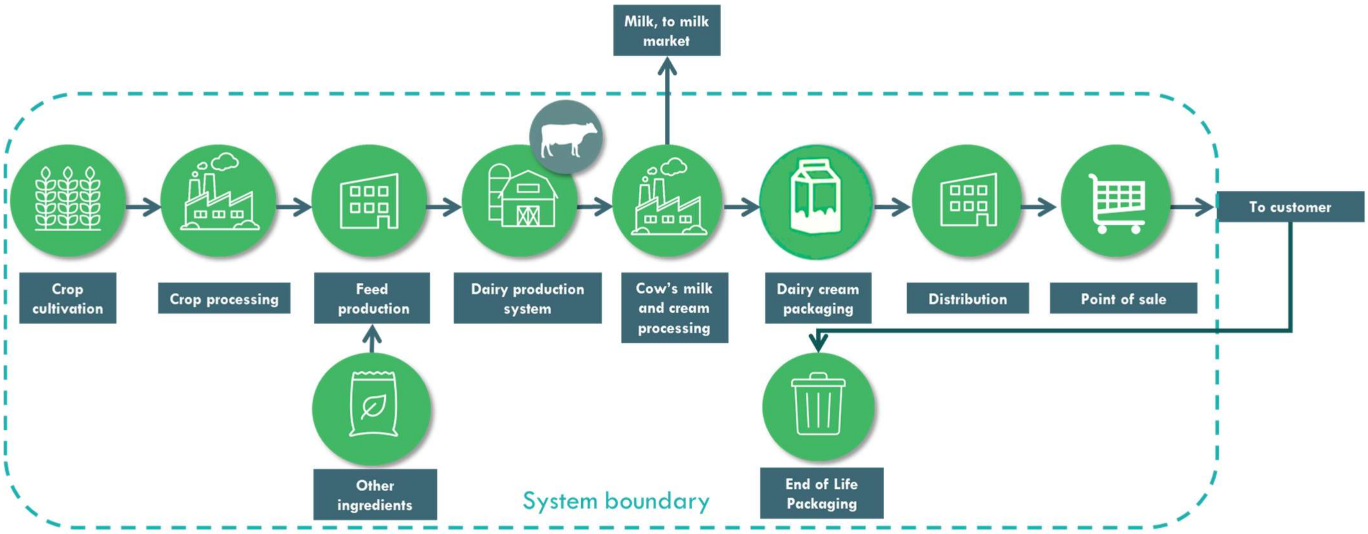

FIGURE 4: SYSTEM BOUNDARIES FOR PACKAGED DAIRY COOKING CREAM. POINT OF SALE REFERS TO RETAIL IN SWEDEN MARKET.

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 will be 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.[8]
- Emulsifiers and stabilizers for which no primary data could be collected and for which no LCI (Life Cycle Inventory) dataset exist at the time of the study were modelled based on scientific literature and/or SuperPro Designer.[9]

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). In addition to the Barista report (te Pas & Westbroek, 2022) and in line with the Oatly No Sugars report (Pas, 2023), land occupation (uncharacterized) was added to this collection in order to exclude the uncertainties involved with geographic representation and validity of the characterized land use method, due to the use of global biodiversity factors which are not regionalised.

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[8] 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.

[9] SuperPro Designer is a software solution developed by Intelligen Inc. (US) to model, evaluate and optimize integrated batch and continuous processes in a wide range of industries, including food processing. Upon completion of the simulation model, data related to the use of utilities (electricity, heating and cooling agents demand) and input materials required by the process are extracted to create an LCI with process specific data.

TABLE 3: 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
Land occupation	None	m^2 x yr

For the climate change impact category, the GWPs were updated using the most recent ones from the IPCC AR6 2023 update (IPCC, 2023). Greenhouse gas emissions caused by land use change (LUC) and peat oxidation are included in the climate change impact category but 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 from Europe, 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 ten impact categories, the full results are provided for all 18 ReCiPe midpoint impact categories.

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 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 base 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

[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.

compare both products using economic allocation only, for consistency of the allocation method (see Table 4 and Table 5).

TABLE 4: IMPACT ALLOCATION FOR OATLY CREAMY OAT 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
Rapeseed cultivation	Rapeseed and rapeseed straw	Economic	Allocation based on Agri-footprint (95.01% rapeseed, 4.99% to rapeseed straw)
Rapeseed crude oil production	Rapeseed crude oil and rapeseed meal	Economic	Allocation based on Agri-footprint (75.19% to crude oil, 24.81% to rapeseed meal)
Rapeseed refined oil production	Rapeseed refined oil and soap stock	Economic	Allocation based on Agri-footprint (99.53% to refined oil, 0.47% to soap stock)
Oatbase production	Oat base and fiber residue	Economic	100% allocation to oat base

TABLE 5: 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 6.3 [11] (economic)
- Energy: ecoinvent 3.9 (cut-off)
- Non agricultural ingredients: ecoinvent 3.9 (cut-off)
- Transport: Agri-footprint 6.3 [11] is used, as it provides more transport options (e.g. different load factors and empty return), compared to ecoinvent transport processes.

For Sweden, the environmental impact of raw milk was modelled based on literature sources using the APS Footprint tool). This is further explained in section 3.2. The average cream and skim milk composition were estimated based on the average chemical characterization of Swedish milk with the aid of the simulation software SuperPro Designer

[11] The current Agri-footprint database has been created using ecoinvent v3.8 secondary datasets for some background processes. By using ecoinvent 3.9 for all other processes we ensure that the model is created using the most up to date data, however this will possibly lead to an inconsistent use of ecoinvent versions.

(see Appendix II for details). SuperPro Designer has also been used to derive the Life Cycle Inventory of Xanthan gum production (ingredient in Oatly Creamy Oat).

2.4.1 Data quality rating

Data quality of both systems (dairy cooking cream and Oatly Creamy Oat) 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 6 below and are applied to rate key data points in this report.

TABLE 6: 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 7 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 7: 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

	Excellent	Very good	Good	Fair	Poor
Technological	Data from processes under study	Data from processes under study, but different enterprise	Data from processes under study, but different technology	Data on related processes	Data on related processes from 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 8: CONSISTENCY CHECK

Criteria	Oatly Creamy Oat	Dairy cooking cream
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 is collected for the oat cultivation and rapeseed cultivation stages, 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 Creamy Oat to a reference dairy cooking cream in Sweden, national average data is used to model cow's milk, derived from peer-reviewed journals or the national inventory report. For consistency and comparability reasons, the dairy data has not been updated since the previous Oatly Barista study (te Pas & Westbroek, 2022), but it is still considered good quality data. The cream produced from the cow's milk is diluted to reach a lower fat content for the cooking cream. The data used to calculate this dilution is of fair quality since it is not modelled with primary data but with the help of a simulation software.
Geographical representativeness:	Oatly Creamy Oat is produced in one location in the country in scope. Primary data has been collected at this exact location. For storage at DC and retail defaults are used.	Data represents country-average data, so adequately represents the average milk used in the representative cream consumed in Sweden. For storage at DC and retail defaults are used.
Temporal representativeness:	The Oatly supply chain and processing data for the factory in Sweden is derived from the complete year of 2022.	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 are 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. 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 at retail (including transport in between these stages).	In line with Oatly' Creamy Oat 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 9 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 9: COMPLETENESS CHECK

	Complete?	Included	Excluded
Oatly Creamy Oat			
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
Rapeseed cultivation	Yes	• Cultivation data from the sourcing country is derived from Agri-footprint • All necessary data and emissions as indicated by the PEFCR, including peat emissions and land use change	• Capital goods
Rapeseed processing	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 product	Yes	• All material and energy inputs • All water consumption (in recipe and for cleaning) • Additional ingredients (oil, emulsifiers, stabilizers, saly) • 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
Dairy cooking cream			
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
Cream processing	Yes	• Energy and material inputs for cream processing • Dry matter content/price for allocation • Dilution to achieve desired fat content (water/milk) • Additional ingredients (e.g. stabilizers)	• 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 Creamy Oat 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. 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 Creamy Oat and cow's milk based on their main functional application, which is to add taste and texture to food. Its main function is not to provide a certain quantity of nutrients, like protein or fibre. 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

One type of uncertainty analysis is included: a pairwise Monte Carlo uncertainty comparison for two products (Oatly Creamy Oat and dairy cooking cream), which helps to determine whether the differences between the two products are significant or not.

The 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). 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 applied to both Oatly Creamy Oat and dairy cooking cream, and those applied to dairy cooking cream only. No sensitivity analyses were applied only to Oatly Creamy Oat as higher quality data was gathered and the calculation methodology is more straightforward.

General sensitivity analysis

- A sensitivity analysis that considers the nutritional properties of Oatly Creamy Oat and dairy cooking cream 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. Apart from energy, three key nutrients differ between dairy cooking cream and Oatly Creamy Oat: 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.

Cow's milk cooking cream

- The sensitivity of key parameters in dairy systems was assessed in the pairwise Monte Carlo analysis, similar to the Oatly Barista study (te Pas & Westbroek, 2022), 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 0 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.
- A sensitivity analysis was 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 at processing level. It is investigated what the consequence is of the selected allocation method.

3. Life Cycle Inventory (LCI)

This chapter describes the production chain of Oatly Creamy Oat and dairy cooking cream 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 Creamy Oat

3.1.1 Description of production process

In this work we assess the Oatly end-to-end factory operating in Sweden at the time of the study[12]. The factory, located in Landskrona, Sweden, produces all of Oatly Creamy Oat product supplied to the Swedish market. In this section, a short description per production chain is provided.

The majority of the data is based on the previous LCA performed for Oatly Barista (te Pas & Westbroek, 2022). This concerns the following life cycle stages:

- Milling
- Transport of oats to factory
- Oatbase manufacturing (*with updated energy & water consumption for the year 2022)*
- Storage at DC and retail (chilled)

For the following life cycle stages, new data is collected:

- Production of Oatly Creamy Oat cooking products, including additional ingredients (e.g. oil, stabilizer, etc.)
- Packaging
- Distribution to DC (refrigerated transport)
- Distribution to retail (refrigerated transport)
- EoL Packaging (based on standard waste scenarios, no primary data from Oatly)

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). The split between the mills has been updated with 2022 data. When the oats are dehulled and dried, they are brought to Oatly's Landskrona production facility in Sweden.

Rapeseed cultivation takes place at multiple locations in Sweden and processing into refined rapeseed oil takes place at Karlshamn, Sweden. From there, it is transported to Oatly Landskrona's factory to be incorporated into the final product.

In Landskrona, oat base and finished Oatly Creamy Oat are produced (end-to-end). Oatly Creamy Oat is produced by mixing the previously produced oatbase with water and other ingredients (e.g. oils, salt, etc.). After the ingredients are mixed and processed the finished product is heat-treated (UHT). Finished Oatly Creamy Oat is packaged onsite. A packaging production site in Gornji Milanovac (Serbia) is providing the primary packaging for the 250mL Oatly Creamy Oat, and the 1L primary packaging is provided by a supplier located in Limburg (Germany).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 chilled conditions.

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

3.1.2 Inventory of data used

Table 10 provides an overview of the data used to model the environmental footprint of Oatly Creamy Oat. Data with regard to the processing stage is verified by an external party. This concerns Scope 1 & 2 data which undergo a limited Assurance Audit by Ernst and Young (EY). Oatly has purchased renewable energy attribute certificates (EACs) for the factory in scope for both heat and power. A detailed life cycle inventory can be found in Appendix III (excluded from the online report due to confidential data).

TABLE 10: INVENTORY DATA LIFE CYCLE STAGES OATLY CREAMY OAT

Life cycle stage	Description of data	Data quality
1a. Oat cultivation	Modelled using oat cultivation datasets from Agri-Footprint 6.3. 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	*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 rapeseed oil, emulsifiers, stabilizers, and iodized salt. Rapeseed oil is derived from the Agri-footprint database, whereas the other ingredients are modelled using literature, datasets from other databases (e.g. ecoinvent) and proxies. Rapeseed oil is the main ingredient after the oats and is modelled using the Swedish dataset from Agri-Footprint 6.3. Economic value of the main and co-products are based on market trading prices for feed commodities in the United Kingdom. • Rapeseed cultivation and drying: cultivation-related inputs and resources (water, land occupation and land transformations, fertilizer, lime, pesticides, capital goods and energy use for field management and irrigation) as well as field emissions to the air, water and soil, direct land use change emissions and emissions due to pesticide use, heavy metal emissions and emissions from peat oxidation. Rapeseed straw is produced as a by-product. • Processing to crude oil: rapeseed crushing. The crushing of rapeseed normally occurs in a series of process steps, including mechanical crushing of the seed with partial extraction of the oil, and further extraction of the oil using hexane as a solvent with subsequent hexane recovery steps. These process steps are aggregated into a single rapeseed crushing process in Agri-footprint. Rapeseed meal (solvent) is produced as a by-product. • Processing to refined oil: refined rapeseed oil (solvent) is produced, with soap stock as by-product. In an oil refining process, impurities and fatty acids are separated from the crude oil. This increases the stability and removes undesired flavors, color and odors.	*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 oat fields to the mills in Sweden using diesel trucks. 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 and 1 mill in Denmark.	*Good*

	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. For one of the Swedish mills, no information on energy use is 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.	
4. Transport of oats to factory	Distance based on locations of the mills and the Oatly factory. Transport was modelled using diesel trucks for Europe.	*Very good*
5. Processing – oat base	The input use (electricity, heat, water) to generate oat base is provided by Oatly based on data from the production facility 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 creamy Oat	The input use (electricity, heat, water, additional ingredients) to generate finished product is provided by Oatly based on data from the production facility 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 is 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 that are used. Transport (assuming diesel trucks) is added from the packaging manufacturing facilities to Oatly's factory.	*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%). Refrigerated transport is modelled based on ecoinvent datasets for refrigerated transport. Since ecoinvent only includes a small refrigerated transport option (truck < 10 ton), transport for a >20 ton truck and a 10-20 ton truck are 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 concerns electric trucks.	*Good*
8b. Distribution to Retail	The transport from the distribution center to retail is provided by Oatly. Oatly uses refrigerated biofueled trucks. Since sufficient quality data on the impacts of biofueled trucks is not available at the time of the study, the same ecoinvent dataset for >20ton refrigerated truck as the previous stage is used as a conservative assumption. The last mile distribution is modelled with an additional 50 km using the smaller refrigerated 10-20 ton truck.	*Fair*
9. Storage at DC and retail	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)	*Fair-Poor*

	Loss rates at retail are provided by Oatly.	
10. 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. 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 is applied, and dataset is selected that already includes recycled material.	*Fair*

3.1.3 Assumptions and limitations

- For one of the Swedish mills data was limited, so it has been 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 the end-to-end factory[13] of Landskrona (production in Sweden), the energy and water are 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.
- 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 is used that already includes recycled material.
- Some transport distances concern (conservative) estimates, such as the transport of oat fields to the mills and from DC to point of sale. Due to a lack of sufficient quality data, transportation from DC to point of sale has also been modelled using diesel trucks instead of biofueled trucks.
- Energy and water consumption at DCs and retail are based on PEFCR defaults.
- Due to a lack of data, the inventory of the stabilizer xanthan gum has been derived from the simulation software SuperPro Designer. Another ingredient (emulsifier E472e) has been modelled using a default dataset from the PEFCR for dairy products.

3.2 Dairy cooking cream

A part of the cow's milk data is based on the LCA report on Oatly Barista (te Pas & Westbroek, 2022). This concerns the following life cycle stages:

- Raw milk production in Sweden
- Raw milk transport to processing location
- Storage at DC and retail (chilled)

For the following life cycle stages, new data have been collected:

- Production of cow's milk based cooking cream, including additional ingredients (e.g. stabilizer)
- Packaging (based on the 250mL packaging of the Oatly Creamy Oat product)

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

- Distribution to DC (based on PEFCR for dairy products)
- Distribution to retail (based on PEFCR for dairy products)
- EoL Packaging (presumed equal to Oatly Creamy Oat product, based on standard waste scenarios, no primary data from Oatly)

Secondary data is used to model the dairy production chain in Sweden. The most important element of the footprint of dairy cooking cream at retail, is raw cow's milk from dairy farms. The raw cow's milk from the dairy system is modeled with country-average data using the APS footprint tool (Blonk Consultants, 2020b).

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).

For Sweden, as no datasets are available in Agri-footprint 6.3, the environmental impact of raw cow's milk is modelled using literature sources and the APS Footprint tool (same as for the Oatly Barista report (te Pas & Westbroek, 2022)).

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

3.2.1 Inventory of data used

TABLE 11: INVENTORY DATA DAIRY COOKING CREAM

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) o Indirect N_2O from volatilization of ammonia (NH_3) and nitrogen oxides (NOx); (calculated with IPCC Tier 2) o Non-methane volatile organic compounds (NMVOC) from manure (calculated with EMEP/EEA Tier 2) o 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 6.3 data). Agri-footprint	*Good*

	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 Sweden this is: 131 km 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 is derived from the Dairy PEFCR (section 6.2.6). Mass allocation is 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 The aforementioned values are calculated based on the average dry matter content provided by the PEFCR: raw milk 12.5g/100g, whole milk 12.3g/100g, semi-skimmed milk 10.3g/100g, skimmed milk 9.1g/100g and cream 42g/100g. Since the environmental impacts of cream made respectively with the three different co-products are equal (based on the Oatly Barista study dairy models (te Pas & Westbroek, 2022)), the cream produced with semi-skimmed milk as a by-product is chosen as representative for the market. With regard to losses, the PEFCR default is applied encompassing losses from farm to retail (applied at retail level).	*Fair*
4. Cream processing	The electricity, heat and other input data required to apply heat treatment are derived from Agri-footprint 6.3 and the Dairy PEFCR (section 6.2.6). For additional ingredients (e.g. stabilizers), secondary data are sourced from Agri-footprint or other literature/databases. The dilution of the cream to achieve the intended fat content of 13% is done with skimmed milk or whole milk. Details on the cream dilution can be found in Appendix II.	
5. Cooking cream packaging	Packaging is modelled based on data from the 250mL packaging of Oatly Creamy Oat. The 500mL packaging is modelled using twice the 250mL packaging bill of materials.	*Good-Fair*
6. Distribution to DC and retail	For distribution to DCs and supermarkets, the same national distances are applied as for the transport of raw milk. Transport in a refrigerated truck >20t is assumed for HTST cream.	*Fair-Poor*
7. 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 chilled storage at DC (assuming 3x storage volume) • 3 days chilled storage at retail (HTST) Default loss rate was assumed of 5% from farm to retail for European countries (Dairy PEFCR section 6.6).	*Fair-Poor*
8. End of Life of packaging	End of Life of packaging material is modelled using CFF parameters for Sweden.	*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 country in scope. Processing energy, packaging composition and storage at DC & Retail is based on defaults from the Dairy PEFCR.
- For certain data points, estimates were made, such as for transport distances from dairy farm to factory, from factory to DC and from DC to retail. These are 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.
- The 500mL packaging is modelled using twice the 250mL packaging bill of materials. This probably results in a slight overestimation of the packaging impacts since the 500mL packaging is not expected to be a linear extrapolation of the weights of the 250mL packaging materials.

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 Creamy Oat and dairy cooking cream at point of sale (incl. packaging EoL) for the country 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.

Two versions of Oatly Creamy Oat are included, the 250mL packaging is listed first, followed by the Oatly Creamy Oat 1L packaging. For the dairy cooking cream, the two versions are diluted with skimmed milk and packaged respectively in a 250mL packaging and a 500mL packaging. The dilution of cream with skimmed milk or whole milk to achieve the intended fat content did not result in a significant difference (+0.01% on the carbon footprint of the cooking cream when diluted with whole milk. Additional details can be found in Appendix II). Results will therefore be reported for the cream diluted with skimmed milk as a conservative approach. The percentages indicate how the environmental impact of Oatly Creamy Oat compares to dairy cooking cream (e.g. -50% indicates a 50% lower footprint of Oatly Creamy Oat compared to dairy cooking cream on a liter basis).

Table 12 shows that Oatly Creamy Oat has a lower environmental impact than cow's milk for all key environmental impact categories. The results are similar for both the Oatly Creamy Oat 250mL and 1L packaging sizes in comparison to their most occurring dairy alternatives (250 mL and 500 mL)

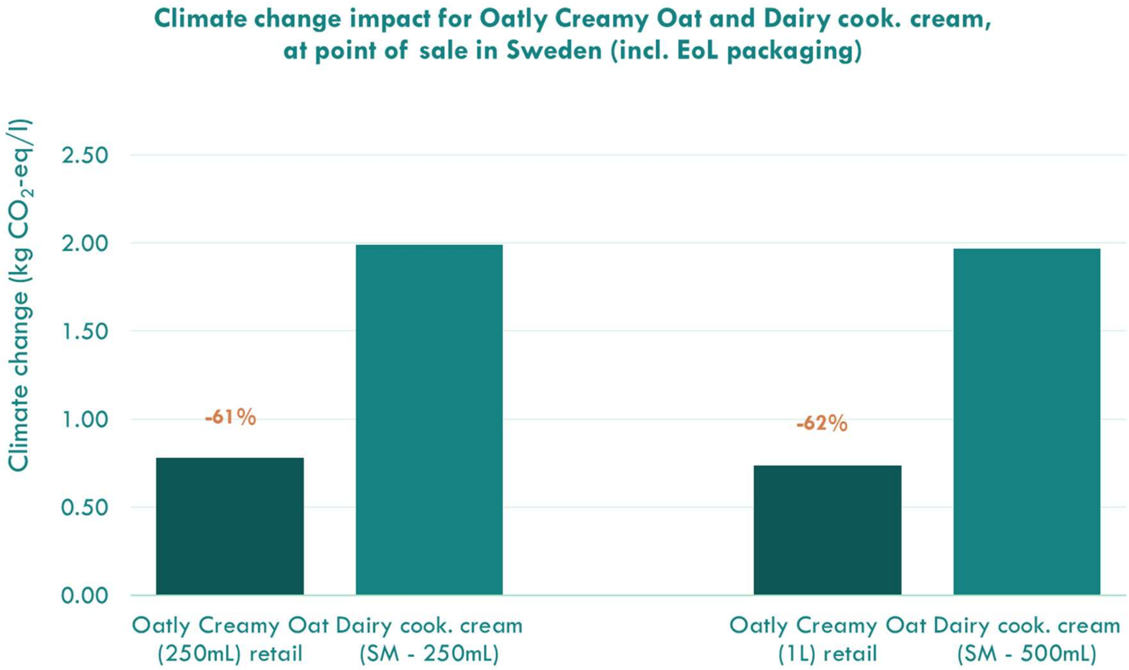


FIGURE 5: CLIMATE CHANGE IMPACT OF OATLY CREAMY OAT AND DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. THE RESULTS REFER ONLY TO OATLY LANDSKRONA END-TO-END FACTORY. DAIRY COOKING CREAM REPRESENTS AN AVERAGE PRODUCT AT RETAIL.

TABLE 12: RELATIVE DIFFERENCES OF OATLY CREAMY OAT (0,25L AND 1L) COMPARED TO DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING. FOR EXAMPLE, -65% INDICATES THAT OATLY CREAMY OAT HAS A 65% LOWER IMPACT COMPARED TO DAIRY COOKING CREAM. THE COLOUR SCALE USES GREEN TONES TO SHOW WHERE OATLY CREAMY OAT HAS A SIGNIFICANTLY LOWER IMPACT THAN DAIRY COOKING CREAM (MORE THAN 10% DIFFERENCE FAVORING OATLY), AND ORANGE TONES WHERE THE IMPACT DIFFERENCE BETWEEN THE TWO PRODUCTS IS SMALLER (LESS THAN 10% DIFFERENCE FAVORING OATLY.

Product	Climate change	Fine particulate matter	Terrestrial acidify-cation	Freshwater eutrophi-cation	Marine eutrophi-cation	Land use	Land occupation	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*	*m2a*	*kg Cu eq*	*kg oil eq*	*m3*
Oatly Creamy Oat (250mL)	-61%	-59%	-72%	-35%	-54%	-38%	-42%	-20%	-30%	-61%
Oatly Creamy Oat (1L)	-62%	-61%	-73%	-38%	-54%	-38%	-41%	-29%	-36%	-63%

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 Oatly Creamy Oat and dairy cooking cream. The contribution analyses focus on the climate change impact but are also provided for the other impact categories.

Graphs in this chapter show only the 250mL packaging versions of the products. Given the limited difference in results for the other packaging sizes (1L Oatly Creamy Oat and 500mL dairy cooking cream), these were omitted from the graphs in order to enhance readability. Full results are reported in Appendix V.

5.1.1 Comparison of Oatly Creamy Oat and dairy cooking cream

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.

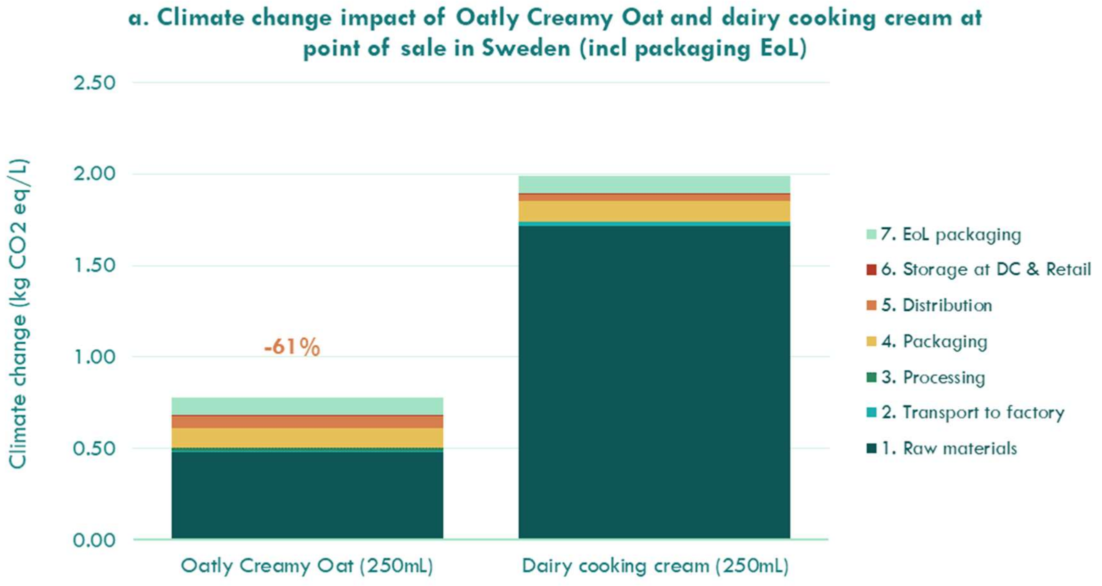
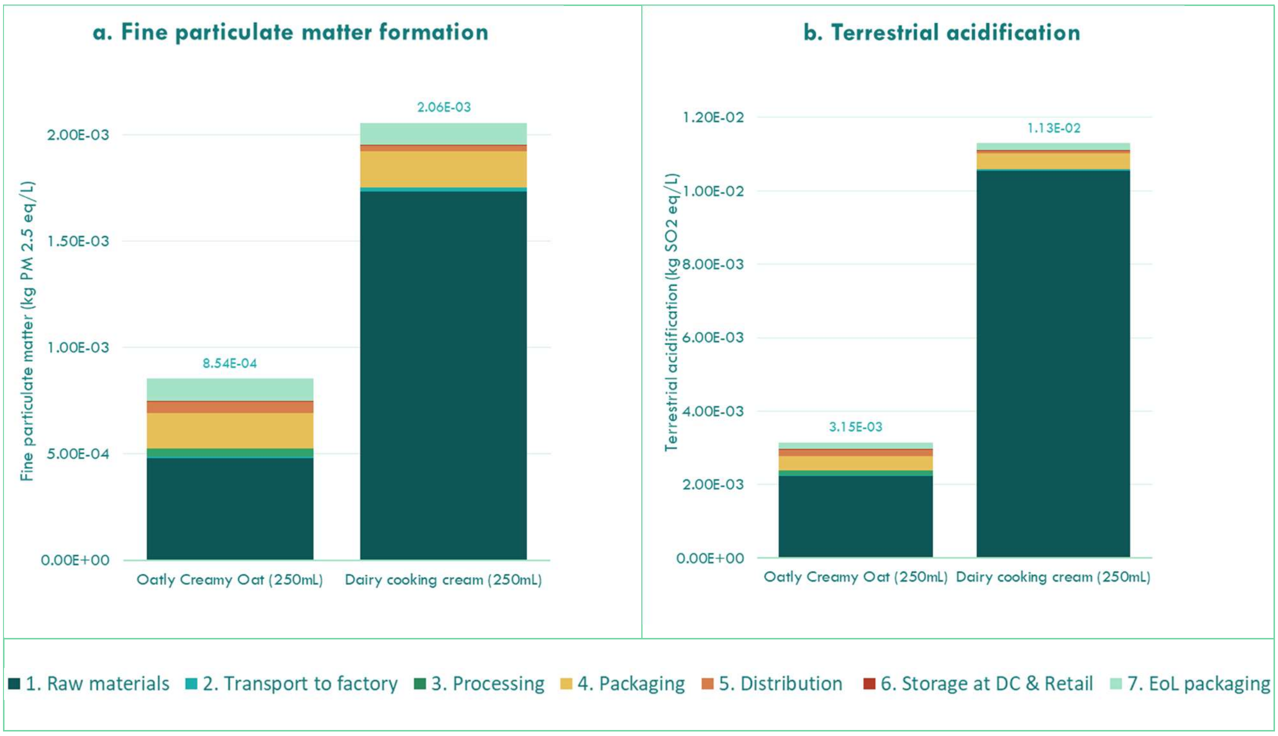


FIGURE 6: CLIMATE CHANGE IMPACT OF OATLY CREAMY OAT AND DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING.

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 attributed to carbon dioxide and nitrous oxide emissions from the cultivation of rapeseed (31%) and oats (15%) for Oatly Creamy Oat and to a lesser extent to the materials used for the packaging (mainly bio-PE) and its end of life. For the dairy cream it is mainly attributed to methane emissions from the production of raw cow's milk.
- **Fine particulate matter formation** is mainly linked to the nitrogen oxide emissions resulting from rapeseed cultivation for Oatly Creamy Oat and to a lesser extent to various transport stages and to the materials used for the packaging (mainly bio-PE) and its end of life. For the dairy cream, it is linked to ammonia emissions from manure in the cow's milk production.
- **Terrestrial acidification** is mainly linked to ammonia emissions from manure (cow's milk) for the dairy cream, and to nitrogen oxide emissions and ammonia emissions during cultivation (cow's feed crops for dairy cream and oats and rapeseed for Oatly Creamy Oat).
- **Marine eutrophication** is linked to nitrate from manure for the dairy cream and to the application of fertilizers during cultivation (cow's feed crops for dairy cream and rapeseed and oats for Oatly Creamy Oat).

- **Freshwater eutrophication** is linked to phosphate emissions during cultivation of rapeseed and oats (Oatly Creamy Oat) and cow's feed crops (dairy cream), but also to a lesser extent to chemical oxygen demand (COD) from waste paper processing for both products.
- **Land use** is mostly related to cultivation of crops (rapeseed, oats, feed crops) and to a lesser extent to the carton used for the packaging for both products.
- **Mineral resource scarcity** is primarily linked to the use of mineral fertilizers for crop cultivation. For Oatly Creamy Oat, this relates to the cultivation of rapeseed and oats. For dairy cooking cream, it relates to production of the feed which is consumed by the cows. Secondly, the mineral resource scarcity impact is related to the aluminum content of packaging. Using solar and wind electricity at the Oatly Landskrona factory 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[14], heat for rapeseed oil production, and packaging (material and production) for both systems.
- **Water consumption**[15] is linked to tap water used at Landskrona factory for processing and to a lesser extent to the production of ascorbic acid, the proxy dataset recommended by the PEFCR to model food additives for the Oatly Creamy Oat product. For dairy cream, the main driver of water consumption is tap water use during raw milk production as well as during the cream production.



[14] Mainly due to the use of diesel trucks instead of biofueled trucks for the modelling of the distribution stage, see chapter 3.1

[15] 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.

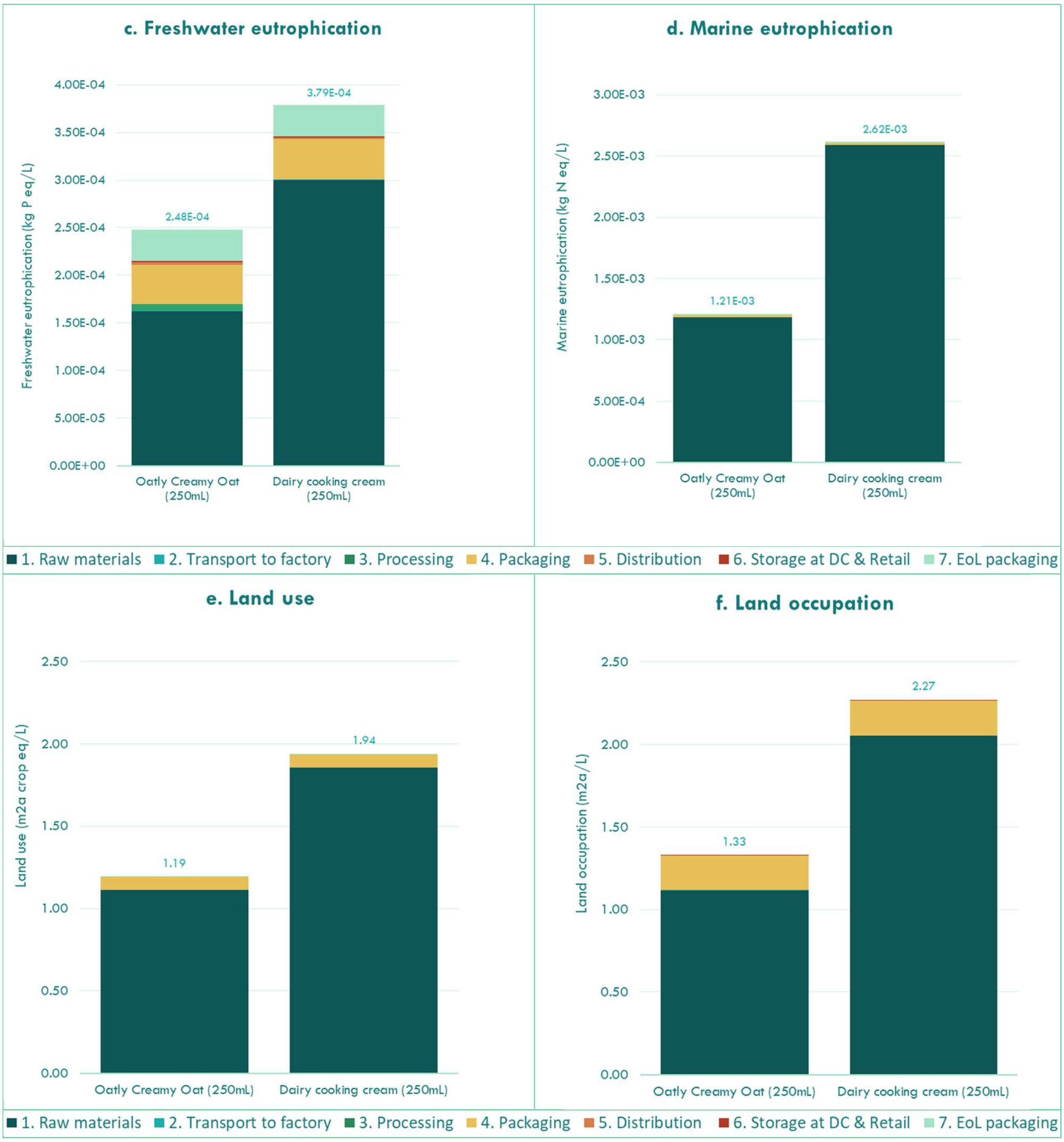

c. Freshwater eutrophication
Freshwater eutrophication (kg P eq/L)
4.00E-04
3.50E-04
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
2.48E-04
3.79E-04
Oatly Creamy Oat (250mL)
Dairy cooking cream (250mL)
d. Marine eutrophication
Marine eutrophication (kg N eq/L)
3.00E-03
2.50E-03
2.00E-03
1.50E-03
1.00E-03
5.00E-04
0.00E+00
1.21E-03
2.62E-03
Oatly Creamy Oat (250mL)
Dairy cooking cream (250mL)
1. Raw materials
2. Transport to factory
3. Processing
4. Packaging
5. Distribution
6. Storage at DC & Retail
7. EoL packaging
e. Land use
Land use (m2a crop eq/L)
2.50
2.00
1.50
1.00
0.50
0.00
1.19
1.94
Oatly Creamy Oat (250mL)
Dairy cooking cream (250mL)
f. Land occupation
Land occupation (m2a/L)
2.50
2.00
1.50
1.00
0.50
0.00
1.33
2.27
Oatly Creamy Oat (250mL)
Dairy cooking cream (250mL)
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 OATLY CREAMY OAT AND DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING.

5.1.2 Oatly Creamy Oat

Figure 8 shows the contribution analysis for the climate change impact results for Oatly Creamy Oat in Sweden.

Below some highlights for the main production stages are described.

- **Raw materials**: In figure 8, the majority of the impacts of "1b. Other ingredients production" is due to the rapeseed oil. As shown by Figure 9A and Figure 9B, the cultivation of rapeseed and oats in Sweden are the main contributors to climate change. Rapeseed oil has a high impact, partially because of the large quantity in the recipe, and partially because of the impacts associated with rapeseed cultivation in Sweden (especially peat oxidation and N_2O emissions as a result from fertilizer application). The main origin of climate change impact from oat cultivation in Sweden comes from peat oxidation.

- **Processing:** Figure 9C and Figure 9D 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.
- **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 9E). This is mainly attributed to the land use change impact associated with sugarcane cultivation in Brazil.
- **Distribution to retail/DC and storage:** The main contributor to the climate change impact of Oatly Creamy Oat in this phase is the transportation by refrigerated trucks from the distribution center (DC) to retail. The product losses at this stage also impacts the results.
- **End of Life** (EoL): wastepaper sorting and incineration of plastics from the packaging are the main contributors to the climate change impact.

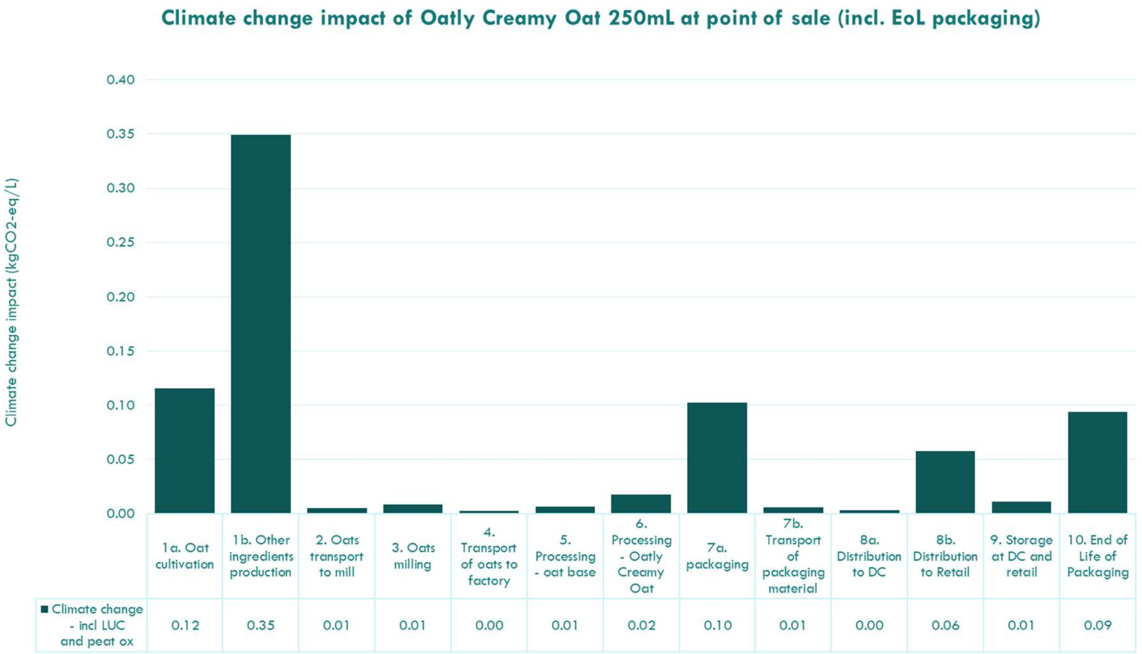
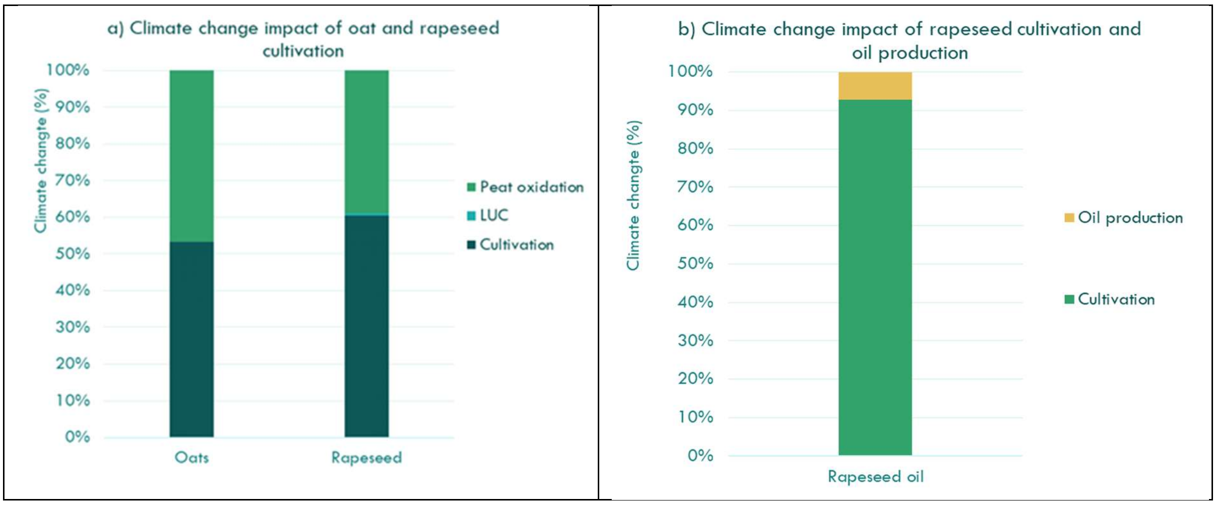


FIGURE 8: CLIMATE CHANGE IMPACT OF OATLY CREAMY OAT AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING.

Figure 9 further breakdowns some of the top contributing processes as identified in Figure 8 in stacked column charts:



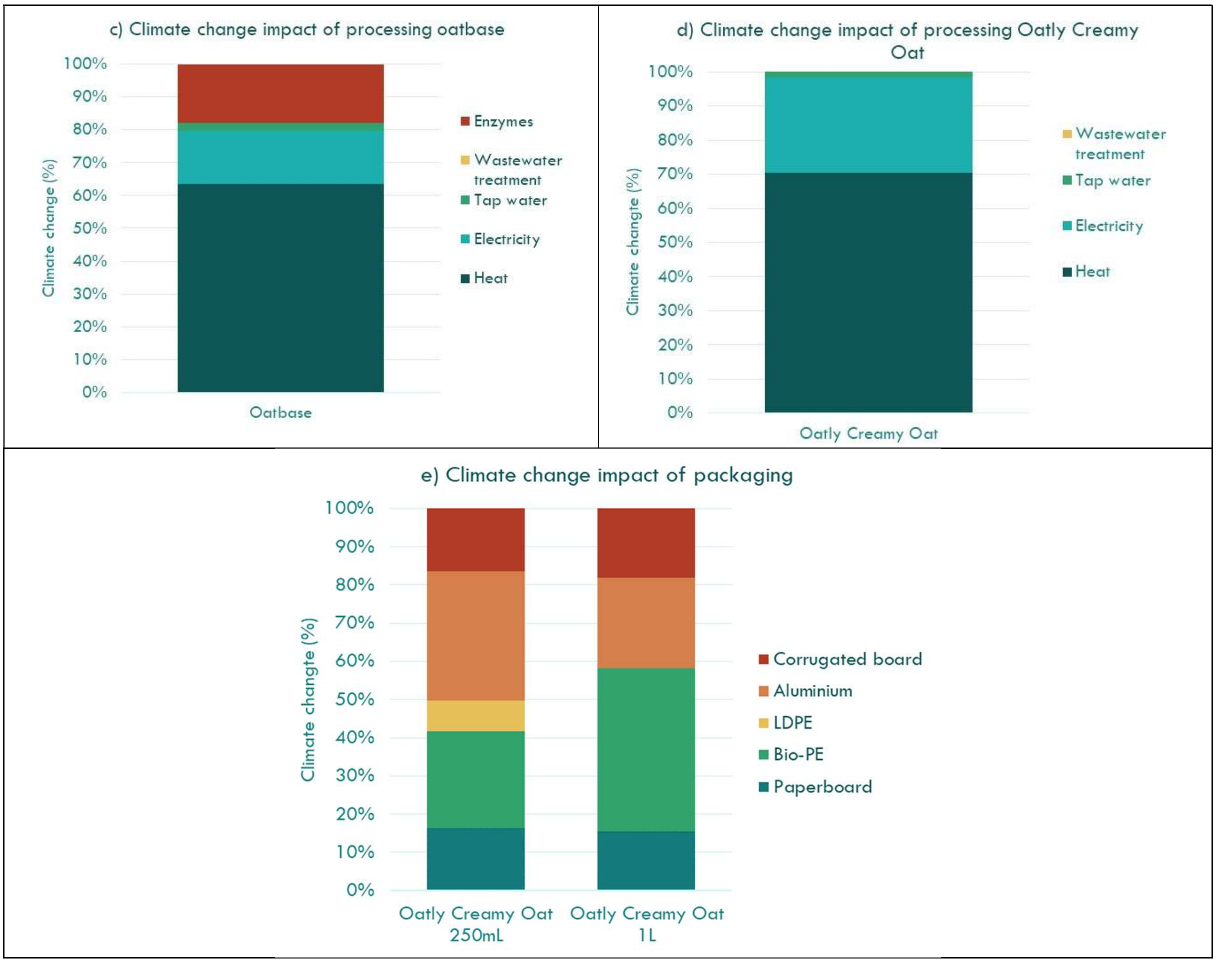


FIGURE 9: CLIMATE CHANGE IMPACT OF A) OAT AND RAPESEED CULTIVATION, B) RAPESEED OIL PRODUCTION, C) OATBASE PROCESSING, C) OATLY CREAMY OAT PROCESSING, D) OATLY CREAMY OAT PRODUCTION AND D) PACKAGING

5.1.3 Dairy cooking cream

Figure 10 shows that the raw milk, used both to produce the 40% fat-containing cream as well as to produce the skimmed milk for cream dilution to a lower fat content (represented below by the step 1.3 cooking cream production), is the main contributor to the climate change impact of dairy cooking cream (87%). All other life cycle stages contribute only with 0 to 6% to the total impact, each. Since the dilution of the cream to achieve the intended fat content of 13% is done with milk, the impact of this dilution (the additional milk needed) is reported in the raw materials production stage. There are no additional processing steps, resulting in zero impact at the processing stage.

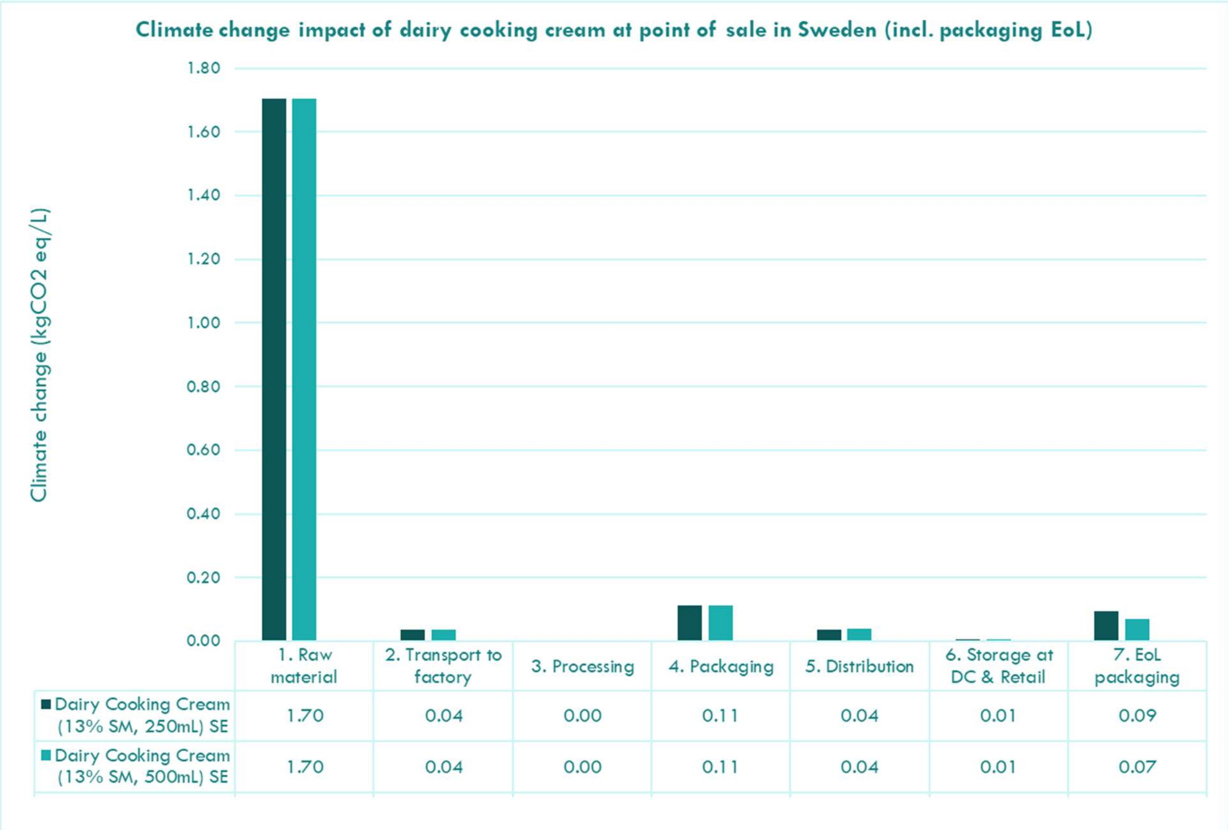


FIGURE 10: CLIMATE CHANGE IMPACT OF 1L DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING

Figure 11 below shows the climate change impact of raw cow's milk in Sweden. It shows that the impact of feed production, as well as the peat oxidation and land use change (LUC) linked to feed production, generate the largest part of the total climate change impact (48%), followed by methane emissions (45%) originating primarily from enteric fermentation and manure management.

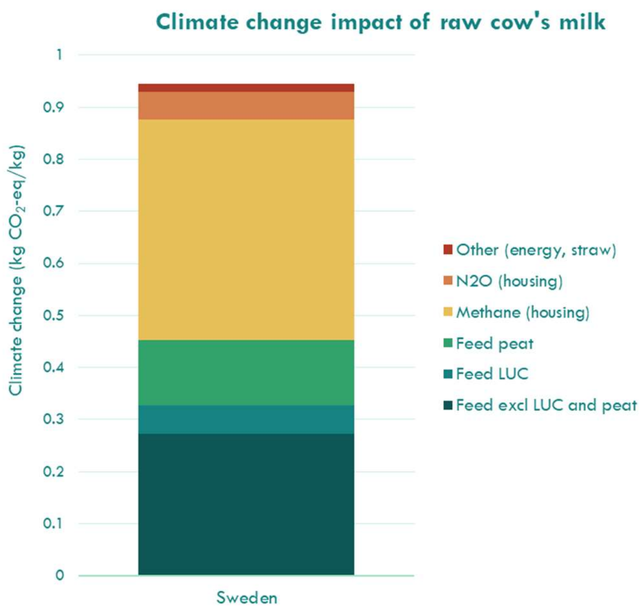


FIGURE 11: CLIMATE CHANGE IMPACT OF RAW COW'S MILK IN SWEDEN

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 functional unit and the choice of allocation method. 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.

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

5.2.1 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 Sensitivity analyses. 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 13 has been used to calculate the NDU. For the dairy cooking cream, the data source that has been used is listed in the footnote[16], and concerns primarily recent data derived from national food composition tables for 15% fat containing cooking creams and scaled down to a 13% fat containing cooking cream. The higher the NDU, the higher the amount of encouraged macronutrients the food provides.

TABLE 13: MACRONUTRIENT CONTENT PER 100G OF OATLY CREAMY OAT AND DAIRY COOKING CREAM.

	Oatly Creamy Oat	Dairy cooking cream (13% fat)
Essential fatty acids (g)	3.45	0.26
Protein (g)	0.88	3.00
Fiber (g)	0.79	0.00
Energy (kcal)	144	162
NDU	**1.52**	**0.33**

The resulting climate change impact calculated per NDU is shown in Figure 12. The difference in climate change impact between Oatly Creamy Oat and dairy cooking cream is larger (91% lower) when using a functional unit based on NDU compared to a functional unit based on volume.

As mentioned in section 2.7, this method was deemed appropriate to evaluate the influence of nutritional properties in this sensitivity analysis. 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.

[16] https://soknaringsinnehall.livsmedelsverket.se/Home/FoodDetails/1717?sokord=Matlagningsgr%C3%A4dde&soktyp=1&kategoriId=#

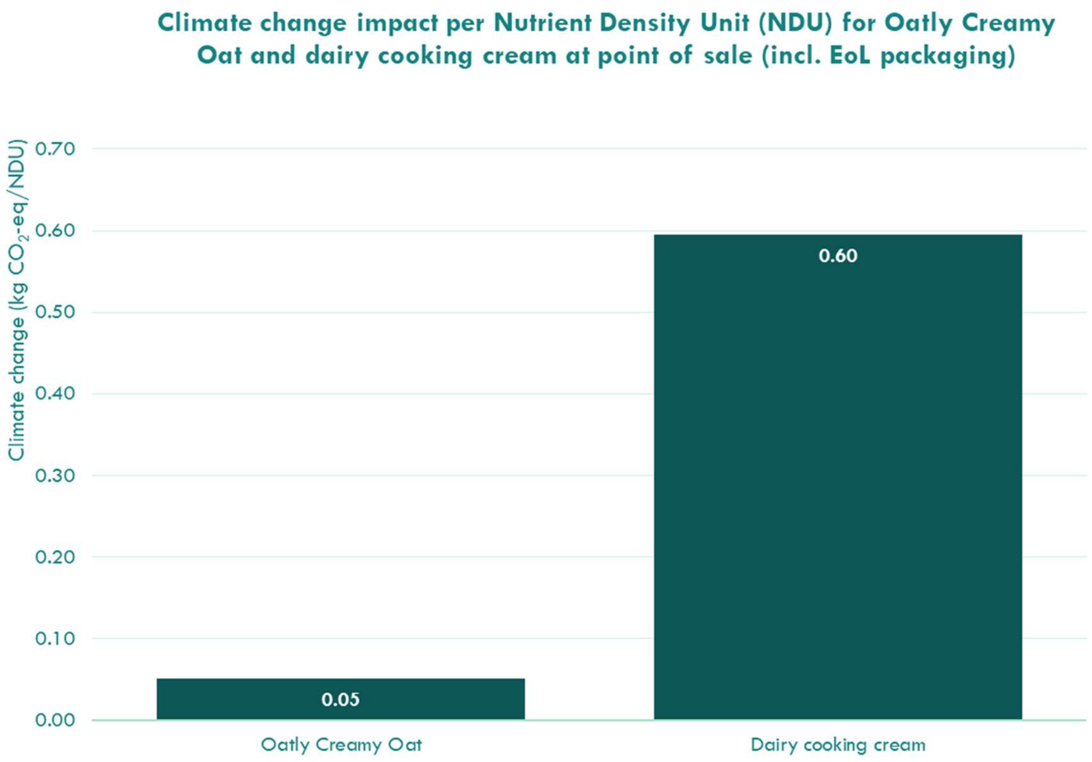


FIGURE 12: CLIMATE CHANGE IMPACT PER NUTRIENT DENSITY UNIT (NDU) FOR OATLY CREAMY OAT AND DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING.

5.2.2 Oatly Creamy Oat compared to dairy cooking cream 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 6.3 database and from the Optimeal EU database (Broekema, Blonk, Koukouna, & van Paassen, 2019).

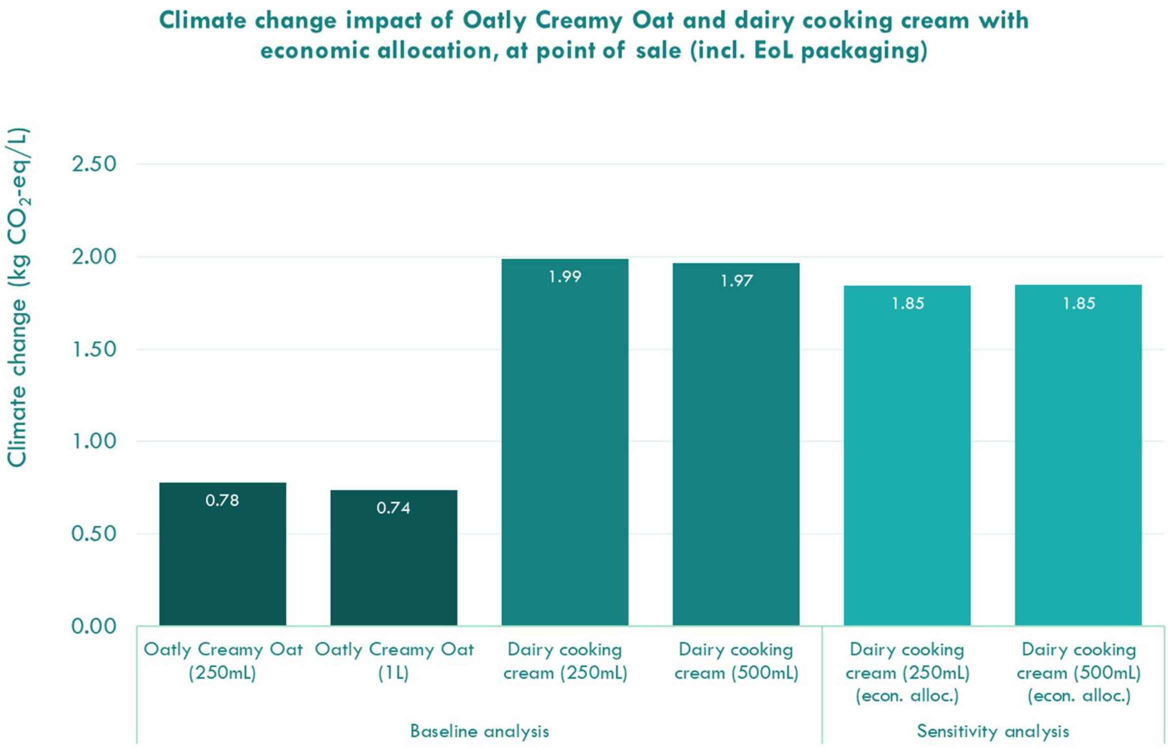


FIGURE 13: CLIMATE CHANGE IMPACT OF OATLY CREAMY OAT COMPARED TO DAIRY COOKING CREAM WITH ECONOMIC ALLOCATION, AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING.

Using economic allocation, the climate change impact of dairy cooking cream is 7% lower than when using the allocation methods as described in the PEF (Figure 13). 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. This means that the climate change impact reduction of Oatly Creamy Oat decreases from 60% to 58% when economic allocation is applied.

5.3 Uncertainty analysis

Uncertainty in inventory data has been determined using the pedigree matrix, as described in section 2.4. 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.

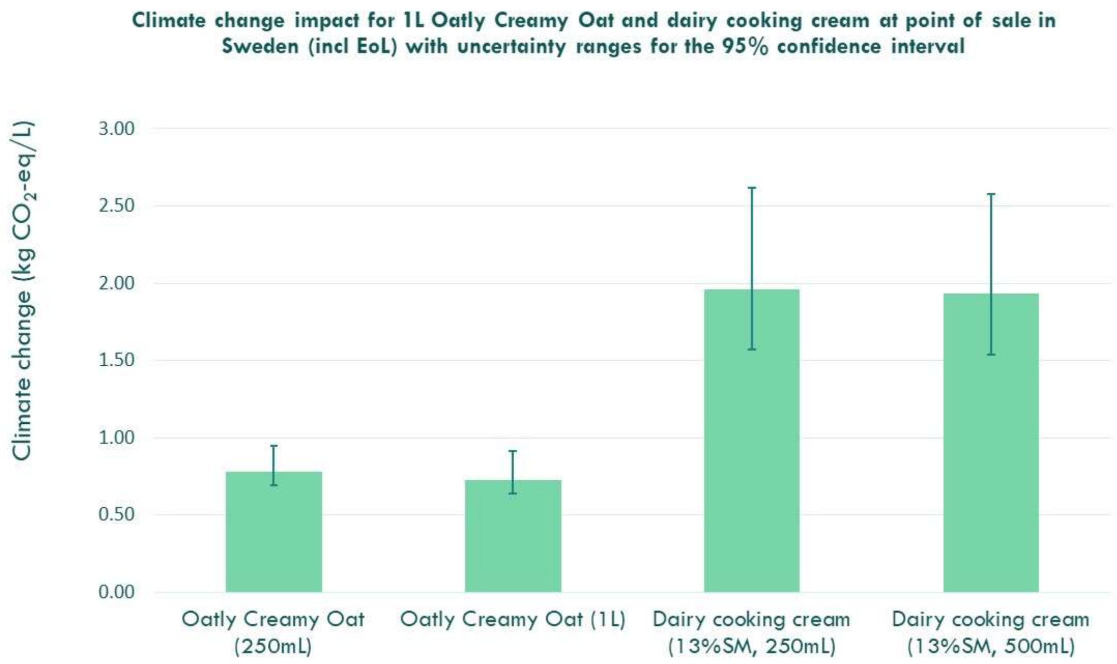


FIGURE 14: CLIMATE CHANGE IMPACT FOR 1L OATLY CREAMY OAT AND DAIRY COOKING CREAM AT POINT OF SALE INCLUDING END-OF-LIFE (EOL) OF PACKAGING, WITH UNCERTAINTY RANGES FOR THE 95% CONFIDENCE INTERVAL.

Figure 14 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 2.4). Oatly Creamy Oat has lower uncertainty ranges due to the use of primary (foreground) data.

The graph presents a comparison of Oatly Creamy Oat and the dairy cooking cream when taking the uncertainties into consideration. According to the uncertainty analysis the difference in climate change impact between Oatly Creamy Oat and dairy cooking cream produced in Sweden could range from -39% to -75%.

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 pairwise 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).

Figure 15 below shows the outcome of this pairwise Monte Carlo analysis for all products in scope, and for all impact categories. It shows that for all impact categories Oatly Creamy Oat is consistently and significantly lower than the impact of dairy cooking cream.

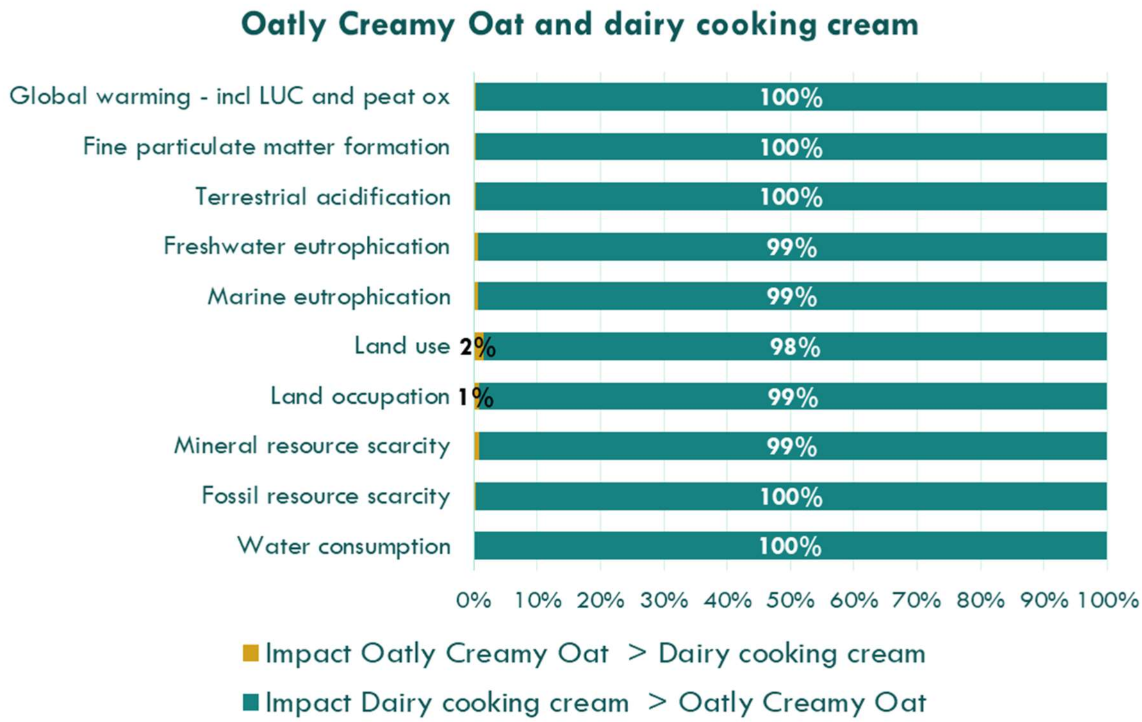


FIGURE 15: PAIRWISE MONTE CARLO ANALYSIS SHOWING THE PERCENTAGE OF MONTE CARLO RUNS IN WHICH ONE PRODUCT HAS A HIGHER IMPACT THAN THE OTHER. FOR EXAMPLE, FOR CLIMATE CHANGE, OATLY CREAMY OAT HAS A LOWER IMPACT THAN DAIRY COOKING CREAM FOR 100% OF THE 1000 MONTECARLO SIMULATIONS PERFORMED. THE FIGURE SHOWS THE RESULTS WITH THE 0,25L PACKAGING VERSIONS OF THE PRODUCTS.

6. Conclusion

Overall results

A Life Cycle Assessment has been performed to compare the environmental performance of Oatly Creamy Oat to dairy cream in the Swedish market. In addition, the study has identified the drivers and opportunities for the environmental impact of Oatly Creamy Oat. The study has been performed and critically reviewed according to ISO 14040 (ISO, 2006a) /14044 (ISO, 2006b) /14071 (ISO, 2014) 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 all of the 10 impact categories Oatly Creamy Oat has a lower impact than dairy cooking cream in the Swedish market.

Drivers and opportunities for Oatly Creamy Oat

The rapeseed and oat cultivation stages are the highest contributing factors to the climate change (respectively 31% and 15% of total carbon footprint) and most other key environmental 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.

Fossil resource scarcity is driven mostly by the use of fossil fuels for transport, heat, electricity generation for rapeseed oil production, and packaging. The use of biofueled trucks, biogas and green electricity are good examples of reduction opportunities that Oatly has already implemented for their own operations.

In the packaging, 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. Increasing the recycling potential of the packaging could be another opportunity since the end-of-life accounts for a significant proportion of the impact.

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.

Choosing economic allocation at the level of the dairy farm and at dairy processing leads to higher impact of the cow's milk and therefore a lower impact of the dairy cooking cream, 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 pairwise 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 all the key environmental impact 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.

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Appendix I Characterisation method used

TABLE 14: 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. Characterization factors are used to express different land use types in the common unit of 'crop equivalent'. The land use category also accounts for impact from land transformation (e.g., deforestation). The impact of transformation is related to the transformed area and the regeneration time.
Land occupation	Occupation refers to the use of a land cover for a certain period but does not include conversion to crop equivalents, so it is measured as area-time (m2*yr).
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)

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.

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 6.3. 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 6.3 (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):

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

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 Agri-footprint 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 Agri-footprint 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

Dairy cooking cream – market insights from ICA (confidential data)

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

Cream dilution

With the aid of the simulation software SuperPro Designer, the average cream and skim milk composition could be estimated based on the average chemical characterization of Swedish milk (see table below). SuperPro Designer is a process simulation tool that allows users to model, evaluate and optimize batch or continuous processes for a wide range of industries. With the help of this tool, it was possible to generate process simulations based on chemical reactions, the laws of thermodynamics, mass and energy transfer and vapor-liquid equilibrium principles.

Main components	Average milk composition Sweden *(Eriksson, 2020)*	Predicted cream composition at milk processing facility (SuperPro Designer)	Predicted skim milk composition at milk processing facility (SuperPro Designer)	Average cream composition for products with 13% fat (retailer data)
Water	87%	53.7%	91.4%	79.5%
Lactose	5%	2.7%	5.3%	4.3%
Protein	3%	1.6%	3.2%	3.1%
Fat	4%	42.0%	0.05%	13.0%
Vitamins and minerals	0.05%	0.03%	0.05%	0.1%

The cream dilution ratio and the potential dilutants (whole milk, skimmed milk or water) were calculated based on the outcomes from the SuperPro model (table above). As the predicted fat content of cream after separation is 42%, it was calculated how much whole milk, skimmed milk or water would be required to achieve a comparable fat content as reported by the retailer. The formula below (based on the Pearson's method) was used to calculate the required dilution.

$$Dilution\ ratio = \frac{(\%\ Cream\ fat\ content - 13\%)}{(13\% - \%\ Dilution\ ingredient\ fat\ content)}$$

Based on this back calculation, it can be concluded that cream at the milk processing factory is likely to be diluted with either whole milk with a 3.27 ratio or with skim milk with a 2.24 ratio to achieve a fat content of 13% and a similar nutritional profile regarding lactose and protein content, as shown in the table below.

Main components	Average cream composition for products with 13% fat (retailer data)	Final cream composition with <u>dilution ratio 3.27 with whole milk</u>	Final cream composition with <u>dilution ratio 2.24 with skimmed milk</u>	Final cream composition with <u>dilution ratio 2.23 with water</u>
Water	79.5%	79.8%	79.8%	85.7%
Lactose	4.3%	4.5%	4.5%	0.8%
Protein	3.1%	2.7%	2.7%	0.5%
Fat	13.0%	13.0%	13.0%	13.0%
Vitamins and minerals	0.1%	0.0%	0.0%	0.0%

The table below shows the relative differences of dairy cooking cream diluted with whole milk (WM) compared to dairy cooking cream diluted with skimmed milk at point of sale, including end-of-life (EOL) of packaging. It shows that the dilution of cream with skimmed milk or whole milk to achieve the intended fat content did not result in a significant difference (0.01% increased impacts for the dilution with whole milk), the cream diluted with skimmed milk being a more conservative approach.

This increase is due to the fact that the impact of whole milk is higher than that of skimmed milk. Additionally, it is also because of a higher amount of whole milk required for the dilution in comparison to skimmed milk.

Product	Climate change	Fine parti-culate matter	Terres-trial acidify-cation	Freshw. eutrophi-cation	Marine eutrophi-cation	Land use	Land occu-pation	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*	*m2a*	*kg Cu eq*	*kg oil eq*	*m3*
Dairy Cooking Cream (13% WM, 250mL)	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%
Dairy Cooking Cream (13% WM, 500mL)	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%

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 Creamy Oat and dairy cooking cream

For dairy cooking cream a range is provided based on minimum and maximum values. All values are provided per 100 ml.

	Unit	Oatly Creamy Oat	Dairy cooking cream	
			minimum value	maximum value
Energy	kJ	600	600	700
	kcal	150	150	160
Fat	g	13	13	15
of which saturated	g	1.6	8.3	9.6
Carbohydrates	g	5.8	4.2	4.3
of which sugars	g	3.6	4.2	4.3
Fiber	g	0.8	0	0
Protein	g	0.9	3	3.1
Sodium	g	0.11	0.1	0.1

Appendix V Full LCIA results, ReCiPe 2016

Oatly Creamy Oat and dairy cooking cream at point of sale in Sweden (incl. EoL of packaging), per liter

Impact category	Unit	Oatly creamy Oat (1L)	Oatly creamy Oat (250mL)	Dairy cooking cream (250 mL)	Dairy cooking cream (500 mL)
Global warming - incl LUC and peat ox	kg CO2 eq	7.80E-01	7.38E-01	1.99E+00	1.97E+00
Global warming - excl LUC and peat ox	kg CO2 eq	6.06E-01	5.58E-01	1.65E+00	1.63E+00
Global warming - only LUC	kg CO2 eq	1.90E-02	2.53E-02	1.14E-01	1.13E-01
Global warming - only peat ox	kg CO2 eq	1.55E-01	1.55E-01	2.25E-01	2.25E-01
Stratospheric ozone depletion	kg CFC11 eq	5.76E-06	5.76E-06	1.37E-05	1.36E-05
Ionizing radiation	kBq Co-60 eq	5.17E-02	4.88E-02	1.51E-01	1.46E-01
Ozone formation, Human health	kg NOx eq	1.96E-03	1.87E-03	3.14E-03	3.11E-03
Fine particulate matter formation	kg PM2.5 eq	8.54E-04	7.99E-04	2.06E-03	2.04E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	2.64E-03	2.56E-03	4.54E-03	4.50E-03
Terrestrial acidification	kg SO2 eq	3.15E-03	3.03E-03	1.13E-02	1.13E-02
Freshwater eutrophication	kg P eq	2.48E-04	2.33E-04	3.79E-04	3.75E-04
Marine eutrophication	kg N eq	1.21E-03	1.21E-03	2.62E-03	2.61E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.82E+00	1.75E+00	2.53E+00	2.50E+00
Freshwater ecotoxicity	kg 1,4-DCB	5.59E-02	5.36E-02	6.74E-02	6.72E-02
Marine ecotoxicity	kg 1,4-DCB	3.15E-02	2.85E-02	4.42E-02	4.39E-02
Human carcinogenic toxicity	kg 1,4-DCB	2.62E-02	2.24E-02	2.74E-02	2.66E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	8.50E-01	8.09E-01	1.10E+00	1.10E+00
Land use (Total)	m2a crop eq	1.19E+00	1.19E+00	1.94E+00	1.92E+00
Land use (Transformation)	m2a crop eq	4.61E-04	7.26E-04	1.07E-01	1.07E-01
Mineral resource scarcity	kg Cu eq	1.88E-03	1.65E-03	2.36E-03	2.33E-03
Fossil resource scarcity	kg oil eq	1.19E-01	1.04E-01	1.71E-01	1.63E-01
Water consumption	m3	5.74E-03	5.45E-03	1.49E-02	1.47E-02
Land occupation	m2a	1.33E+00	1.30E+00	2.27E+00	2.22E+00

Oatly Creamy Oat and dairy cooking cream at point of sale in Sweden (incl. EoL of packaging), per kg

Density 1.020 kg/L

Impact category	Unit	Oatly creamy Oat (1L)	Oatly creamy Oat (250mL)	Dairy cooking cream (250 mL)	Dairy cooking cream (500 mL)
Global warming - incl LUC and peat ox	kg CO2 eq	7.64E-01	7.24E-01	1.95E+00	1.93E+00
Global warming - excl LUC and peat ox	kg CO2 eq	5.94E-01	5.47E-01	1.62E+00	1.60E+00
Global warming - only LUC	kg CO2 eq	1.86E-02	2.48E-02	1.11E-01	1.11E-01
Global warming - only peat ox	kg CO2 eq	1.52E-01	1.52E-01	2.20E-01	2.20E-01
Stratospheric ozone depletion	kg CFC11 eq	5.65E-06	5.65E-06	1.34E-05	1.34E-05
Ionizing radiation	kBq Co-60 eq	5.07E-02	4.79E-02	1.48E-01	1.43E-01
Ozone formation, Human health	kg NOx eq	1.92E-03	1.84E-03	3.08E-03	3.04E-03
Fine particulate matter formation	kg PM2.5 eq	8.37E-04	7.83E-04	2.02E-03	2.00E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	2.59E-03	2.51E-03	4.45E-03	4.41E-03
Terrestrial acidification	kg SO2 eq	3.09E-03	2.97E-03	1.11E-02	1.10E-02
Freshwater eutrophication	kg P eq	2.43E-04	2.29E-04	3.71E-04	3.68E-04
Marine eutrophication	kg N eq	1.19E-03	1.18E-03	2.56E-03	2.56E-03
Terrestrial ecotoxicity	kg 1,4-DCB	1.79E+00	1.72E+00	2.49E+00	2.45E+00
Freshwater ecotoxicity	kg 1,4-DCB	5.48E-02	5.25E-02	6.61E-02	6.58E-02
Marine ecotoxicity	kg 1,4-DCB	3.09E-02	2.80E-02	4.34E-02	4.30E-02
Human carcinogenic toxicity	kg 1,4-DCB	2.57E-02	2.20E-02	2.69E-02	2.61E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	8.33E-01	7.93E-01	1.08E+00	1.07E+00
Land use (Total)	m2a crop eq	1.17E+00	1.17E+00	1.90E+00	1.89E+00
Land use (Transformation)	m2a crop eq	4.52E-04	7.12E-04	1.05E-01	1.05E-01
Mineral resource scarcity	kg Cu eq	1.84E-03	1.62E-03	2.31E-03	2.28E-03
Fossil resource scarcity	kg oil eq	1.17E-01	1.02E-01	1.67E-01	1.60E-01
Water consumption	m3	5.63E-03	5.34E-03	1.46E-02	1.44E-02
Land occupation	m2a	1.30E+00	1.27E+00	2.22E+00	2.18E+00

Appendix VI Contribution of additional ingredients (confidential data)

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

Appendix VII Critical Review Statement and Report

Critical Review Statement

The life cycle assessment (LCA) study *LCA of Oatly Creamy Oat and comparison with dairy cooking cream* 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 Creamy Oat and comparison with dairy cooking cream*. The study was critically reviewed by an international panel of experts comprising:

- Jasmina Burek (chair): Assistant Professor, 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 February 13, 2024.

Critical Review Process

The critical review was performed based on ISO 14044:2006 standard, by a 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. Two 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 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 an annex to the report, which is excluded from the published report because of confidentiality.

The critical review panel found the LCA study to be in conformance with ISO 14040 and ISO 14044 standards (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 a draft report 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.

Because the *LCA of Oatly Creamy Oat and comparison with dairy cooking cream* study builds on the foundations of the previous LCA studies study for Oatly, i.e., *LCA of Oatly Barista and comparison with cow's milk,* reviewed by the same external review panel, all reviewers' comments were provided via email including:

- December 21, 2023 – reviewers provided comments on the goal and scope document via email.
- January 04, 2024 - reviewers provided comments on the draft of the final LCA report via email.
- February 12, 2024 - reviewers validated changes from the previous review on the final LCA report 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 (Appendix VII) includes panel review comments and recommendations, and the corresponding responses given by the practitioner of the LCA study.

The review panel concludes based on 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.

February 13, 2024

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 Creamy Oat and comparison with dairy cooking cream
Version of the document submitted on February 13, 2024

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 Creamy Oat and comparison with dairy cooking cream*". The study "*LCA of Oatly Creamy Oat and comparison with dairy cooking cream*" 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 Creamy Oat and comparison with dairy cooking cream*" published on February 13, 2024.

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. In addition, two sets of reviewer comments were provided after LCA practitioners provided the full draft of the LCA report to the critical review panel. The critical review report 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 critical-review process involved the following:

- a review of the goal and scope document
- a review of a draft report 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.

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 Appendix VII.

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 Creamy Oat and dairy cooking cream products produced in Sweden. The sensitivity analysis was performed using an alternative functional unit based on the nutritional density of the Oatly Creamy Oat and dairy cooking cream products. The study is comprehensive in scope and contains a wealth of information and data related to Oatly Creamy Oat 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 performing sensitivity analyses and uncertainty analysis.

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

The authors computed results following the attributional LCA approach. In a baseline scenario, Oatly Creamy Oat was compared to 1 l of dairy cooking cream at the point of sale. 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).

Sensitivity and scenario analyses that were performed for earlier LCA study of Oatly Barista were not included in the study for Oatly Creamy Oat, because the conclusions made there regarding sensitivity and scenario analysis are valid for Oatly Creamy Oat. In this study, sensitivity analyses were performed for (1) nutrient density functional unit of Oatly Creamy Oat and dairy cooking cream and (2) Oatly Creamy Oat comparison to diary cooking cream modelled with economic allocation. Uncertainty analysis has been performed to determine the range in outcomes when considering uncertainties of the input data.

Overall, the methodology and the selection of the 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 Oatly Creamy Oat in Sweden, the study included U.S. dairy cooking cream supply chain LCI data from recent literature and LCI database. The authors of the final report clearly described LCIs and data sources. Also, authors provided information about robustness and limitations of the data used for Oatly Creamy Oat and dairy cooking cream product LCI and assumptions for sensitivity and uncertainty 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. 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 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 goal and scope document and 2 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.

Template for CR comments and commissioner & practitioner responses

Date: February 2024	Document: **LCA of Oatly Creamy Oat and comparison with dairy cooking cream**	Project:

Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner& practitioner	Final reviewer statement
Comments on Goal and Scope report dated December 2023								
HW	283		Table 8	Ed	In the "Data quality" column for Dairy cooking cream we find: *the dairy data has not been updated since the previous Oatly Barista study*	Could you give the name and year of publication of the previous study referred to here?	Oatly Barista study (te Pas & Westbroek, 2022). It will be adjusted in the final report.	OK
HW	290		Table 9	Te	Oatly creamy oat contains 13% fat, 5.8% carbohydrates, 0.8% fiber and 0.9% protein. So probably rapeseed contributes more to its dry matter than oat. Given the important contribution of rapeseed, it would be good to add information on rapeseed cultivation and rapeseed processing to Table 9, in the same way as information is supplied on oat cultivation and oat milling and processing.	Add information on rapeseed as proposed.	Information on rapeseed will be added to the final report (Agri-footprint dataset)	OK
HW	381-408			Te	Given the importance of rapeseed for Oatly creamy oat (see previous comment), it would be good to supply the same type of information for rapeseed as given here for oat (concerning cultivation and processing).	Add information on rapeseed as proposed	Information on rapeseed will be added to the final report (Agri-footprint dataset)	OK
HW	417		Table 10	Te	Given the importance of rapeseed for Oatly creamy oat, it would be good to add information on rapeseed cultivation, transport and processing to Table 10, in the same way as information is supplied on oat.	Add information on rapeseed as proposed	Information on rapeseed will be added to the final report (Agri-footprint dataset)	OK

1 Initials of the **Reviewer**
2 **Type of comment: ge** = general **te** = technical **ed** = editorial

Template for CR comments and commissioner & practitioner responses

Date: February 2024	Document: **LCA of Oatly Creamy Oat and comparison with dairy cooking cream**	Project:

Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner& practitioner	Final reviewer statement
HW	470		Table 11	Te	Line 3. Milk processing, here we find: *Mass allocation is 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* This requires a more detailed explanation.	Could you explain how these mass allocation percentages result from dry matter values provided in the dairy PEFCR?	More details on mass allocation calculation will be provided to the final report	OK
JT	290		Table 9	Ge	Processing for Oatly Creamy Oat – auxiliary materials listed, while for dairy cooking cream – additives listed.	Can language be aligned to better illustrate comparability? And can some further information be added to Oatly Creamy Oat (e.g., emulsifiers)?	Consistency of language will be improved, and additional information will be provided in the final report.	OK
JL	Footer page 11			TE	You refer to the inconsistent use of ecoinvent (ei) database versions.	Could you include an estimate how much uncertainty is introduced with that resp which relevant changes were implemented in ei v3.9 compared to ei v3.8? If that is not possible yet in the goal and scope report, please include it in the final report.	The majority of the impact of Oatly Creamy Oat is coming from the emissions during rapeseed and oats cultivation (from Agri-Footprint methodology). Ecoinvent 3.8. datasets are used to model auxiliary processes (e.g. energy, transport) linked to the production of these raw materials.	OK

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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	Final reviewer statement
							The contribution of these processes is minor, except on the fossil resource scarcity indicator (diesel burned in machinery and heat for rapeseed oil production). The documentation of changes from Ecoinvent regarding the update from 3.8 to 3.9 do not report very significant changes to these sectors, so it seems reasonable that this inconsistency is not going to result in significant changes in the LCA results.	
JL	Several (e.g. line 242, 283ff (Table 8), 464 etc)				Mentioning of Agri-footprint. Agri-footprint is used several times in the report as data-source, method resp. tool used. The usage is a bit inconsistent. Agri-footprint or AFP is used in parallel each with or without version numbers. Version numbers mentioned differ from 6 to 6.0 to 6.3.	Please check if the version numbers are correctly used. Furthermore, is it possible to harmonize a bit more the utilization of the term agri-footprint?	Agri-footprint 6.3 is used. Consistency will be improved in the final report.	OK
JB	Line 34	The results and interpretation for the main analyses and for 34 a number of sensitivity analyses will be provided in a second report		te	This type of review is concurrent critical review in which we review sections of the report, for example in this case, the goal and scope definition; inventory analysis, including data collection and modelling;	it would be better to just mention in the draft LCA report instead of "in the second report"	It will be adjusted in the final report.	OK

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Template for CR comments and commissioner & practitioner responses	Date: February 2024	Document: **LCA of Oatly Creamy Oat and comparison with dairy cooking cream**	Project:

Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner& practitioner	Final reviewer statement
					The milestone where all sections provided is called "draft LCA report"			
JB	249	The current Agri-footprint database has been created using ecoinvent v3.8 secondary datasets for some background processes. By using ecoinvent 3.9 for all other processes we ensure that the model is created using the most up to date data, however this will possibly lead to an inconsistent use of ecoinvent versions.	Footnote	te	I presume that most ecoinvent v3.8 would not be updated.	You may want to check their documentation on the updated version and see if they list processes which were modified or perhaps only new processes were added, which may increase confidence in versions' similarity	More information will be provided in the final report *(see also response to JL's comment on Footer page 11 above)*	OK
JB	Line 283	National average data is used to model cow's milk, derived from peer-reviewed journals or the national inventory report.	Table 8	ge	It seems that the cream processing data quality evaluation is missing	For clarity it would be great to mention cream processing data quality	We will add the cream processing data quality evaluation in the final report. The processing of cream into cooking cream is a dilution process with (skimmed or whole) milk. The dilution has been simulated using SuperPro Designer to derive the dilution parameters.	OK
JB	Line 283		Table 8	ge	Missing data quality of auxiliary processes (Superpro Designer)	In case the auxiliary processes are relevant the recommendation is to evaluate their data quality	According to the preliminary results, the only additive that is expected to have a significant contribution is the rapeseed oil.	OK

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Template for CR comments and commissioner & practitioner responses

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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	Final reviewer statement
							Data quality information will be provided in the final report.	
JB	Line 292		General assumptions and limitations	ge	Eearlier the authors mentioned auxiliary data and SuperPro Designer	Proposed change is to document those processes if they are contributing to limitations	This will be added in chapter 3.1.3	OK
JB	Line 319	a paired Monte Carlo uncertainty		ed	More often in literature it would be called pairwise Monte Carlo uncertainty comparison	Align language with literature	The sentence will be adjusted in the final report.	OK
JB	Line 464	Agri-footprint 6.0,		te	Is it Agri-footprint 6.3 or 6.0	Check consistency of database versions across the document	Consistency will be improved in the final report.	OK
JB	Line 793	With the aid of the simulation software SuperPro Designer, the average cream and skim milk composition could be 793 estimated based on the average chemical characterization of Swedish milk.		ed	It becomes clear now what was the role of SuperPro Designer	It would be good to mention earlier what is the role of the SuperPro Designer so the reader does not wonder if more processes were modelled using SuperPro Designer.	More information about the role of SuperPro Designer will be provided in chapter 2.4 of the final report.	OK
Comments on full report dated January 2024								
HW	48			ed		Change “apredominant” to “a predominant”	It has been adjusted in the final report.	OK
HW	67			te	“Oatly Creamy Oat has a lower impact than dairy cooking cream for all key impact categories”. This is not true, because for the 250 ml packaging mineral resource scarcity	Can you modify the formulation accordingly?	The text has been changed to reflect that the impact on mineral resource scarcity is comparable (3% lower	OK

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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	Final reviewer statement
					is not significantly different for the two products.		impact for Oatly Creamy Oat). Line 20 was also adjusted	
HW	71			ed		Change “stagesare” to “stages are”	It has been adjusted in the final report.	OK
HW	104			ed		Change “with” to “of”	It has been adjusted in the final report.	OK
HW			Table 2	te	The table indicates that for Oatly creamy oat the reference flows are 250 and 1000 ml, for dairy cooking cream the reference flows are 250 and 500 ml. In fact for dairy cooking cream the reference flows are 250 and 500 + 500 ml. because you want to compare 1000 ml of the two products, and for dairy cooking cream this takes two 500 ml packages.	I think this should be clarified to help the reader understand what was compared.	The table has been adjusted (the reference flows have been split in two rows to clarify).	OK
HW	158			ed	The meaning of ICA is not given.	Can you clarify?	It is the name of one of the biggest grocery retailers in Sweden. The text has been adjusted.	OK
HW	161			ed	The end of the sentence seems to be missing.	Can you correct?	The sentence has been deleted.	OK
HW	166			ed	“Paper carton with plastic cap 250 mL, 13% fat” Is this a third item that should be listed as the two items in lines 164 and 165 ?	Can you clarify?	Yes, it has been listed with the other two items in the final report.	OK
HW	174			ed	“Error! Bookmark not defined”	Can you correct?	It has been adjusted in the final report.	OK

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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	Final reviewer statement
HW			Figure 3	ed		Change "System boundaries packaged" to "System boundaries for packaged"	It has been adjusted in the final report.	OK
HW			Figure 4	ed		Change "System boundaries packaged" to "System boundaries for packaged"	It has been adjusted in the final report.	OK
HW	275-276			ed	Table caption and table are not on the same page.	Please correct this.	It has been adjusted in the final report.	OK
HW	300-305			te	Information is given for allocation at oat processing.	Could you give similar information on rapeseed processing?	Table 4 has been adjusted to include this information	OK
HW			Table 4	te	This table presents allocation types for oat cultivation, oat mill and oatbase production.	Could you include a similar table for rapeseed cultivation and processing?	Table 4 has been adjusted to include this information	OK
HW	328			ed		Change "ingredientin" to "ingredient in".	It has been adjusted in the final report.	OK
HW			Table 8	ed	Headings Oatly creamy oat and Dairy cooking cream are hard to read.	Can you correct.	The font was changed to white for better readability.	OK
HW	484			ed		Change "ingredients(e.g." to "ingredients (e.g."	It has been adjusted in the final report.	OK
HW	521			ed		Change "ingredient(emulsifier" to "ingredient (emulsifier"	It has been adjusted in the final report.	OK
HW			Table 12	ed	Table caption and table are not on the same page.	To be corrected.	It has been adjusted in the final report.	OK
HW	605			ed		Delete "all products in scope, after which more detail is provided for"	It has been adjusted in the final report.	OK
HW	606			ed		Delete "separately".	It has been adjusted in the final report.	OK

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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	Final reviewer statement
HW	621			ed		Change "(for" to "for".	It has been adjusted in the final report.	OK
HW	632			ed		Change "andoats" to "and oats".	It has been adjusted in the final report.	OK
HW	645			ed		Delete ",".	It has been adjusted in the final report.	OK
HW			Figure 8	ed	Histogram bar 1b probably is mainly due to rapeseed cultivation and processing and to a minor degree to "other ingredients".	It would be helpful to split this up in three bars: rapeseed cultivation, rapeseed processing, other ingredients.	Due to the sensitivity of the product's recipe, the bars cannot be further split in the report. More details are provided in the confidential appendix VI	OK
HW	677-678				The table here seems superfluous, figure 9 can be understood without this table.	Delete table.	The table has been deleted in the final report.	OK
HW			Figure 9		I think it would be good to merge 9a and 9b, and show both oat cultivation and rapeseed cultivation and rapeseed processing. Like this the reader can know the relative importance of oat and rapeseed cultivation. The current way of presenting suggests that peat oxidation is only due to oat cultivation, which probably is not true.	Modify figure.	Figures 9a and 9b have been updated accordingly	OK
HW			Figure 15		The figure caption does not say for what packaging size(s) these results are.	Can you clarify?	A sentence has been added: "The figure shows the results with the 0.25 L packaging	OK

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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	Final reviewer statement
							versions of the products"	
HW	785-786				"The results show that for all the 10 impact categories Oatly Creamy Oat has a lower impact than dairy cooking cream in the Swedish market." This is not true, because for the 250 ml packaging mineral resource scarcity is not significantly different for the two products	Can you modify the formulation accordingly?	The text has been changed to: " The results show that for 9 out of the 10 impact categories Oatly Creamy Oat has a lower impact than dairy cooking cream in the Swedish market while the impact on mineral resource scarcity is comparable (3% lower impact for Oatly Creamy Oat 250 mL)."	OK
JT			Fig 1		Figure unclear.	Can you make this figure larger to aid interpretation of the numbers?	The size of the font has been increased in this version	OK
JT	266			Ed	Acronym LCI used throughout this section, but has not been spelled out in report (until new section line 450).	Spell out acronym.	See line 110: Life Cycle Inventory (LCI) It has been repeated on line 273 to facilitate readability	OK
JT			Table 9	Ed		Change "Additional ingredients s" to "Additional ingredients".	It has been adjusted in the final report.	OK
JT	405-407			Ed	Wrong tense used to refer to analyses performed.	Change "apply" to "were applied" throughout this paragraph.	It has been adjusted in the final report.	OK
JT	435, 445			ed	Change to past tense to refer to analyses performed.	Change "is" to "was".	It has been adjusted in the final report.	OK
JT	480-481			ed		Change "is taking place" to "takes place". And "processed into refined rapeseed oil at…" to	It has been adjusted in the final report.	OK

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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	Final reviewer statement
						"processing into refined rapeseed oil takes place at…"		
JT			Table 11	Ed		Change "abovementioned" to "aforementioned"	It has been adjusted in the final report.	OK
JT	621			ed		Remove bracket.	It has been adjusted in the final report.	OK
JT	624					Remove "s" from "nitrous oxides"	It has been adjusted in the final report.	OK
JT	628-633			Ge	This result is a nice illustration of the benefits of producing crops for direct human consumption rather than conversion by livestock - terrestrial and marine acidification are drastically reduced as manure impacts are cut out.	No change proposed.	Thank you!	
JT	801			Ed	Word use doesn't reflect intended meaning – "fraction" means very small amount.	Replace "fraction" with "proportion".	It has been adjusted in the final report.	
JL	Footer from page 4			Ed	2023	Change to "2024"	It has been adjusted in the final report.	Ok
JL	23-24			Ed		Specify how "significantly" is defined resp which is the threshold value used to differentiate between significant and non-significant.	The clarification has been added to the table 1 title. Significant is >10% difference in favor of Oatly and non-significant is <10% difference in favor of Oatly	Ok
JL	71			Ed	"For fine particulate matter formation, rapeseed cultivation and various transport stagesare the main…"	Add space between "stages" and "are"	It has been adjusted in the final report.	Ok

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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	Final reviewer statement
JL	73			Ed	"… rapeseed oil production , and packaging."	Remove space after "production"	It has been adjusted in the final report.	Ok
JL	158, 159, 162			Ed	"ICA"	Introduce the acronym with first mention and avoid following repetitions.	It is the name of one of the biggest grocery retailers in Sweden. The text has been adjusted.	Ok
JL	174			Ed	Error! Bookmark not defined.	Please correct	It has been adjusted in the final report.	Ok
JL	166			Ed	There seems to be a formatting issue.	Please correct	It has been adjusted in the final report.	Ok
JL	328, 406, 407, 521, 640			Ed	Several punctuation errors	Please correct	It has been adjusted in the final report.	Ok
JL	Table 9	Processing step 2: finished product		Ed		Add space between "ingredients" and "("	It has been adjusted in the final report.	Ok
JL	Table 9	Cream processing		Ed		Remove last "s" in "Additional ingredients s"	It has been adjusted in the final report.	Ok
JL	476 Table 10	 2. Oats transport to mill		Te	" All oat cultivation takes place at multiple locations throughout Sweden" "An estimate of 300km is assumed for the transportation between the Swedish, Finnish, and Estonian oat fields to Stockholm, Helsinki, and Tallinn port respectively."	Check production location and correct.	The sentence in table 10 has been deleted, it was incorrectly copied from the Barista report (which included more geographies).	Ok

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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	Final reviewer statement
					Both sentences are in contradiction to each other. Either all oats are produced in Sweden or there are other oat field locations in Finland and Estonia.			
JL	733				"Agri-footprint 6 database"	Does it mean version 6.3?	It has been adjusted in the final report.	Ok
JB	48			ed	apredominant	a predominant. Check spelling	It has been adjusted in the final report.	OK
JB	53			ed	with the exception of	except for	It has been adjusted in the final report.	OK
JB	61			te	The product losses at this stage also impact the results	Specify % of losses and is it due to damage or else?	It has been adjusted in the final report.	OK
JB	71			ed	stagesare	stages are	It has been adjusted in the final report.	OK
JB	17 footnote			te	ecoinvent	specify version, for example ecoinvent 3.9	It has been adjusted in the final report.	OK
JB	73			ed	production ,	Remove extra space	It has been adjusted in the final report.	OK
JB	160	Data about the fat content, ingredients, packaging and presence of stabilizers were collected for each product and are presented in		ed	"Unfinished sentence"		The sentence has been deleted in the final report.	OK
JB	166			ed	fatThe	Add space	It has been adjusted in the final report.	OK

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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	Final reviewer statement
JB	174				Error! Bookmark not defined.	Remove	It has been adjusted in the final report.	OK
JB	266	Ingredients for which no primary data could be collected and for which no LCI dataset exist at the time of the study will be modelled based on scientific literature and/or SuperPro Designer.		te/ed	How many ingredients? Most of the sentences are in the past tense so you could also use the past tense for this one.	Specify ingredients or reference table where they are reported	"Ingredients" have been changed to emulsifiers and stabilizers for more clarity	OK
JB	328			ed	ingredientin	Add space	It has been adjusted in the final report.	OK
JB	Table 9			ed	Additional ingredients(oil, emulsifiers, stabilizers)	Add space	It has been adjusted in the final report.	OK
JB	Table 9			ed	Additional ingredients s	remove s	It has been adjusted in the final report.	OK
JB	406			ed	to dairy cooking cream only .	Remove extra space	It has been adjusted in the final report.	OK
JB	484			ed	ingredients(e.g. oils, salt, etc.).	Add space	It has been adjusted in the final report.	OK
JB	521			ed	ingredient(emulsifier E472e)	Add space	It has been adjusted in the final report.	OK
JB	Figure 5	Caption		te	E N D - TO - E N D F A C T O R Y? Is this cradle-to-processing plant gate or only processing plant? Based on definition in the footnote 1 "End-to-End (E2E) Factory: The entire production chain happens within Oatly's own factory. From grains to the finished product." Are	If cradle-to-processing plant gate than reword.	The footnote text has been adjusted: "[…] from the ***reception of*** grains to the finished product."	OK

1 Initials of the **Reviewer**

2 **Type of comment: ge** = general **te** = technical **ed** = editorial

Reviewer[1]	Line number	Clause/ Subclause	Paragraph/ Figure/ Table/	Type of comment[2]	Comments	Proposed change	Response of the commissioner& practitioner	Final reviewer statement
					grains and all other material impacts included or not? Is end-to-end a new terminology for LCA scope?			
JB	627			ed	production..	Remove extra dot	It has been adjusted in the final report	OK
JB	632			ed	andoats	Add space	It has been adjusted in the final report	OK
JB	645			ed	, and packaging	Remove extra comma	It has been adjusted in the final report	OK
JB	Figure 9 e			te	250mL contains aluminum and 1L does not?	Is pasteurization for Creamy Oats in both cases UHT? Explain why no Aluminum in 1L	The 1L packaging bill of materials has been corrected as it indeed contained aluminium	OK

1 Initials of the **Reviewer**
2 **Type of comment: ge** = general **te** = technical **ed** = editorial

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: February 13, 2024

Name: Jasmina Burek

Signature:

Name: Joanna Trewern

Signature:

Name: Jens Lansche

Signature:

Name: Hayo van der Werf

Signature:

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