LCA study for pea products:
Summary report

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Study accomplished under the authority of Cosucra, Emsland and Roquette
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This report is based on the PEF report template of ANNEX E of the document *Suggestions for updating the Product Environmental Footprint (PEF) method* (Zampori and Pant, 2019). However, at this point it is not possible to be fully compliant with the PEF method. This document is thus no official PEF study. Therefore, the current study is referred to as LCA study, not PEF study. We aim to be as much PEF compliant as possible, indicate where there are deviations from the PEF method and justify why.

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ACRONYMS

CTUe	Comparative Toxic Units - ecotoxicity
CTUh	Comparative Toxic Units - human toxicity
DQR	Data quality rating/ Data quality requirements
DS	dry substance
EC	European Commission
EF	Environmental Footprint
EI	environmental impact
EoL	End of life
EPD	Environmental Product Declaration
FU	functional unit
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
LCA	Life Cycle Assessment
LCDN	Life Cycle Data Network
LCI	life cycle inventory
LCIA	life cycle impact assessment
LCT	life cycle thinking
LULUC	Land use and land use change
NMVOC	non-methane volatile compounds
PCR	Product Category Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PM	Particulate matter

CHAPTER 1 INTRODUCTION

Recently, an up-to-date life cycle assessment of the starch industry products from wheat, maize and potatoes as raw materials was carried out as commissioned by Starch Europe, the European starch industry association. In parallel with this LCA, an update of the product category rules (PCR) for starch industry products was performed. The updated PCR is based on the LCA, and the LCA complies to the updated PCR.

Being member companies of Starch Europe but not fitting the general starch industry product portfolio, a specific LCA for pea starch products was commissioned by pea-processing companies Cosucra, Emsland and Roquette. Production of pea products logically only involves peas in the agricultural stage instead of wheat, maize and potatoes and the manufacturing processes differ significantly, explaining the requirement for a specific LCA for pea products. However, the many similarities between pea products and the general starch industry products justify the alignment of this LCA with the PCR for starch industry products.

In this project, a life cycle assessment of the four main pea starch industry products is carried out. This document describes the LCA, which is as much as possible compliant with the most recent PEF methodology report (Zampori and Pant, 2019). This LCA is based on the Product Category Rules for Starch Industry Products v2.1 (Starch Europe, 2021). This report is based on the PEF report template of ANNEX E of the document Suggestions for updating the Product Environmental Footprint (PEF) method (Zampori and Pant, 2019). However, as for the general starch industry, it is not possible for the pea starch industry to be fully compliant with the PEF method at this point. This document is thus not an official PEF study.

The commissioning pea-processing companies can use the results of this LCA study for the following purposes:

- to focus improvement activities on the most important impact-generating process phases;
- for communication with various stakeholders and to exchange, with national and sector initiatives, the knowledge gained through having done the exercise;
- to anticipate future legislation regarding environment and certification (product development);
- to participate in the stakeholder consultation process of the European Commission's "Products Environmental Footprint (PEF)" pilots;
- to compose an EPD (Environmental Product Declaration), as described in ISO TR 14025 (ISO, 2006);

The methodology used to determine the environmental impacts of the pea products conforms to the LCA methodology, as prescribed in ISO standards 14040 and 14044 (ISO, 2006). According to these ISO standards, an LCA is carried out in 4 phases:

1. Goal and scope definition of the study;
2. Life cycle data inventory (LCI);
3. Life cycle impact assessment (LCIA);
4. Interpretation.

The design of this report complies with these 4 phases of the LCA, whereby the various chapters describe each phase of the LCA.

CHAPTER 2 DEFINITION OF GOAL AND SCOPE

This LCA has been commissioned by pea-processing companies Cosucra, Emsland and Roquette. Data collection has been carried out by these companies as well. This document presents sector-representative environmental profiles of pea starch industry products in the EU 27 for the year 2019.

The LCA is based on the Product Category Rules for Starch Industry Products v2.1 (Starch Europe, 2021). This report is based on the PEF report template of ANNEX E of the document Suggestions for updating the Product Environmental Footprint (PEF) method (Zampori and Pant, 2019).

2.1. GOAL DEFINITION

This LCA is intended to compose sector-representative 'environmental profiles' of four pea starch industry products to communicate to customers and other interested parties. The LCA follows the product category rules as determined in the PCR document of starch industry products.

This sector study aims to:

- Generate sector-representative 'environmental profiles' for pea starch products;
- Communicate these environmental profiles about pea starch products as a sector;
- Contribute proactively, through the knowledge gained in the development of the (general and pea-specific) starch sector LCA, to stakeholders and other national/sectors initiatives (e.g. the European Commission's Single Market for Green Products Initiative).

The intended audience are the pea starch companies, customers and other stakeholders. For communication to stakeholders and customers, a third-party report will be published that summarizes the methodology and results of this study.

2.2. SCOPE DEFINITION

The scope of this LCA are products of the pea starch industry, which are listed in Table 1. Only pea starch, pea protein isolate and dry pea fibres are reported in this document (marked in bold).

Table 1: Products included in the scope of this LCA and their application

Pea product	Application
Pea starch	*food, pet food, industrial*
Pea protein isolate (> 80% protein)	*food*
Wet pea fibres	*feed*
Dry pea fibres	*food*

Pea starch industry products are used in a wide range of applications. Common food applications include meat and dairy alternatives, pasta, (protein-enriched) baked goods, protein powder mixes, sauces,… Pea products are also used in feed (e.g. cattle feed, aquafeed) and pet food, as well as in other industries such as paper, textiles, cosmetics and pharmaceuticals. The performance depends on the specific product and application.

The products of the pea starch industry fulfill multiple functions (Table 1). The functional unit should be considered as a declared unit and does not aim to quantify the performance of a product. The functional unit (FU) is defined as *"1 tonne DS (dry substance) of pea product delivered at the customers' entry gate".*

The life cycle stages and processes included in the system boundary are listed in *Table* 2. The table also indicates which of the three situations described in the PEF method generally applies:

1. Situation 1: the process is run by the company performing the PEF study.
2. Situation 2: the process is not run by the company performing the PEF study, but the company has access to (company-)specific information.
3. Situation 3: the process is not run by the company performing the PEF study and this company does not have access to (company-)specific information.

Table 2: Life cycle stages

Life cycle stage	Short description of the processes included	Situation
Raw material acquisition and pre-processing: agriculture	The agricultural processes include soil cultivation, sowing, weed control, fertilisation, pest and pathogen control, harvest and drying. Growing peas requires energy, water and materials such as fertilisers, pesticides and seeds. It may also result in land transformation. Inputs of auxiliary materials lead to emissions to air, water and soil.	3
Raw material acquisition and pre-processing: transportation	Transport of raw material (peas) from the field to the pea starch production plants.	2
Manufacturing	All relevant processes, starting with the reception of raw materials need to be included. Depending on the pea product these processes may be: grinding, separation, slurry drying, separation/precipitation, juice drying, fibres drying. These processes require energy, and possibly also water and auxiliary materials and may produce waste and emissions to air and water. The manufacturing stage is subdivided into the processes shown in the system boundary diagrams above. This allows to allocate environmental impacts of a process only to the products coming out of this process and to better identify environmental hotspots.	1
Distribution	Transportation from the starch production facility to starch industry customers.	1 or 2

In accordance with the PCR, the following processes are excluded based on the cut-off rule: capital goods for the manufacturing processes of the starch industry, packaging of starch industry products, packaging of incoming auxiliary materials, storage at warehouses, resources and tools for logistic operations at the pea starch plants and process waste.

The environmental profiles are calculated according to the Environmental Footprint method (EF) and include all EF impact categories listed in Table 3.

Table 3: List of the impact categories to be used to calculate the environmental profile

EF impact category	Impact Category indicator	Unit	Characterization model
Climate change **Climate change -biogenic** **Climate change - land use and land use change**	Radiative forcing as Global Warming Potential (GWP100)	*kg CO2 eq*	Baseline model of 100 years of the IPCC (based on IPCC 2013)
Ozone depletion	Ozone Depletion Potential (ODP)	*kg CFC-11 eq*	Steady-state ODPs as in (WMO 2014 + integrations)

EF impact category	Impact Category indicator	Unit	Characterization model
Human toxicity, cancer	Comparative Toxic Unit for humans (CTUh)	*CTUh*	USEtox model 2.1 (Fankte et al, 2017)
Human toxicity, non-cancer	Comparative Toxic Unit for humans (CTUh)	*CTUh*	USEtox model 2.1 (Fankte et al, 2017)
Particulate matter	Impact on human health	*disease incidence*	PM method recommended by UNEP (UNEP 2016)
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	*kBq* U^{235} *eq*	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	*kg NMVOC eq*	LOTOS-EUROS model (Van Zelm et al, 2008) as implemented in ReCiPe 2008
Acidification	Accumulated Exceedance (AE)	*mol H+ eq*	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)
Eutrophication, terrestrial	Accumulated Exceedance (AE)	*mol N eq*	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	*kg P eq*	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	*kg N eq*	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	*CTUe*	USEtox model 2.1 (Fankte et al, 2017)
Land use	• Soil quality index • Biotic production • Erosion resistance • Mechanical filtration • Groundwater replenishment	• *Dimensionless (pt)* • *kg biotic production* • *kg soil* • m^3 *water* • m^3 *groundwater*	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)
Water use	User deprivation potential (deprivation- weighted water consumption)	m^3 *world eq*	Available WAter REmaining (AWARE) as recommended by UNEP, 2016
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	*kg Sb eq*	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002.
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	*MJ*	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002

CHAPTER 3 LIFE CYCLE INVENTORY ANALYSIS

3.1. HANDLING MULTIFUNCTIONAL PROCESSES

Multi-functional processes are handled according to the prescriptions of the PCR. For the agricultural processes economic allocation has been applied, for the pea starch industry processes physical allocation based on dry substance mass has been applied. Mass allocation was chosen because:

- Mass allocation offers the clearest picture throughout the process tree, it relates directly to the functional unit, and is based on the best available data.
- The impact of the main production process is caused mainly by electricity use, waste water treatment and the use of auxiliary materials. As the impact of electricity use for cleaning, grinding,… and waste water treatment is directly related to the mass of the process inputs, it is logical to distribute these impacts to the outputs by mass allocation.
- In theory, allocation should be done based on a physical property that is relevant to the function of the provided co-products. The physical characteristics that are relevant for the function of the different co-products differ per product and as such it is not possible to set one single characteristic which is relevant for all the different output products other than mass.

In the economic allocation of the pea crop, straw is included as a by-product.

3.2. DATA COLLECTION

In the inventory phase all data needed to analyse the environmental impacts associated with the reference and co-products are gathered. In summary this means that all input flows (materials, energy, water, …) and all output flows (emissions, waste, ….) are described and quantified. This is done for all life cycle phases within the system boundaries.

The inventory phase is performed according to the ISO 14040 and ISO 14044 (data inventory) standards (ISO, 2006). The data inventory process is focused on the following life cycle phases:

1. Growing of peas (agriculture);
2. Main production process, yielding pea starch slurry, protein juice, wet pea fibres, other co-products and hull, which is roughly subdivided in:
    a. Production of auxiliary materials and water;
    b. Production of electricity and heat;
    c. Transport steps;
    d. Emissions to water and air
3. Additional processes, i.e. slurry drying, juice drying and fibre drying, to produce the final products;
4. Distribution of finished products to (pea) starch industry customers.

The background data on **agriculture**, i.e. growing of peas, that was used in this study was obtained from the Agri-footprint database (Agri-footprint 5 – economic allocation). Company-specific data on purchased amounts of peas and their countries of origin were provided by the pea-processing companies. This data was combined into an averaged and weighted dataset.

For **transport of raw materials** (peas) **to the starch factories**, company-specific information on transport loads, distances and transport modes was provided by all sites. This data was combined into an averaged and weighted dataset.

For the phases that refer directly to the activities of the three pea-processing companies, i.e. **production process of pea starch products**, specific data are gathered by these companies, representing four production sites. Per reference product, VITO converted the company-specific datasets into one aggregated dataset which is used for the analysis. Aggregation is based on a weighted average, according to the annual production volumes.

For the **distribution** of products to customer’s entry gate, no company-specific information was available. Distribution is included in the LCA study (according to the PCR) by using default values from the PEF-method in combination with Eurostat trade data. However, since the extent to which these default values reflect reality is questionable, distribution is not included in this summary report.

A Data Quality Rating (DQR) according to the PEF requirements was performed. Since this concerns a sector study including different products, the overall DQR entails different values (one for every product). The overall data quality level is shown to be “excellent” (DQR ≤ 1.5).

CHAPTER 4 LIFE CYCLE IMPACT ASSESSMENT RESULTS

4.1. LCA RESULTS

Usually, the inventory process generates a long list of data, which may be difficult to interpret. The life cycle impact assessment (LCIA) relates the large number of inventory values to a smaller number of environmental themes (environmental impact categories) so that the outcome of the assessment is more convenient.

LCAs do not represent a complete picture of the environmental impacts of a system. They represent a picture of those aspects that can be quantified. Any judgments that are based on the interpretation of LCI data must bear in mind this limitation and, if necessary, obtain additional environmental information from other sources (hygienic aspects, risk assessment, etc.). The LCIA results are relative expressions and do not predict any exceeding of thresholds, safety margins or risks.

As defined in the goal and scope, the Environmental Footprint method is used to calculate the impacts for each category. This report includes:

- Individual environmental profiles for the three selected products, covering all impact categories defined in the EF method;
- Normalised environmental profiles for the three selected products, covering all impact categories defined in the EF method;
- A comparative carbon footprint environmental profile, showing the climate change impact of the three selected pea products.

VITO used the LCA software package "SimaPro" for performing the Life Cycle Impact Assessment (LCIA) and generating the environmental profiles of the different pea starch products.

4.2. INDIVIDUAL ENVIRONMENTAL PROFILES OF PEA STARCH PRODUCTS

This paragraph discusses the individual environmental profiles of three studied pea starch products. Individual environmental profiles allow to get a clear insight in those life cycle stages that contribute the most to the environmental burden of each product.

The result of the impact assessment is a table and/or figure in which the environmental themes (impact categories) are presented, describing the environmental profile of "1 tonne dry substance of reference product" (functional unit). For the environmental profile of the pea starch products, the cradle-to-gate cycle is subdivided into different life cycle phases (Raw material acquisition and pre-processing: agriculture and transportation, manufacturing). For the life cycle phases which occur at the pea-processing plants, contribution to the environmental impact is attributed to different process elements, i.e. the use of auxiliary materials, energy or water, water treatment and transportation.

The pea industry's manufacturing processes are shown schematically in Figure 1. The main production process yields pea starch slurry, pea protein juice, wet pea fibres, other co-products and hull. The latter two are not in scope of this study. Pea starch, pea protein isolate and dry pea fibres are produced from respectively pea starch slurry, protein juice and wet pea fibres after an additional drying step.

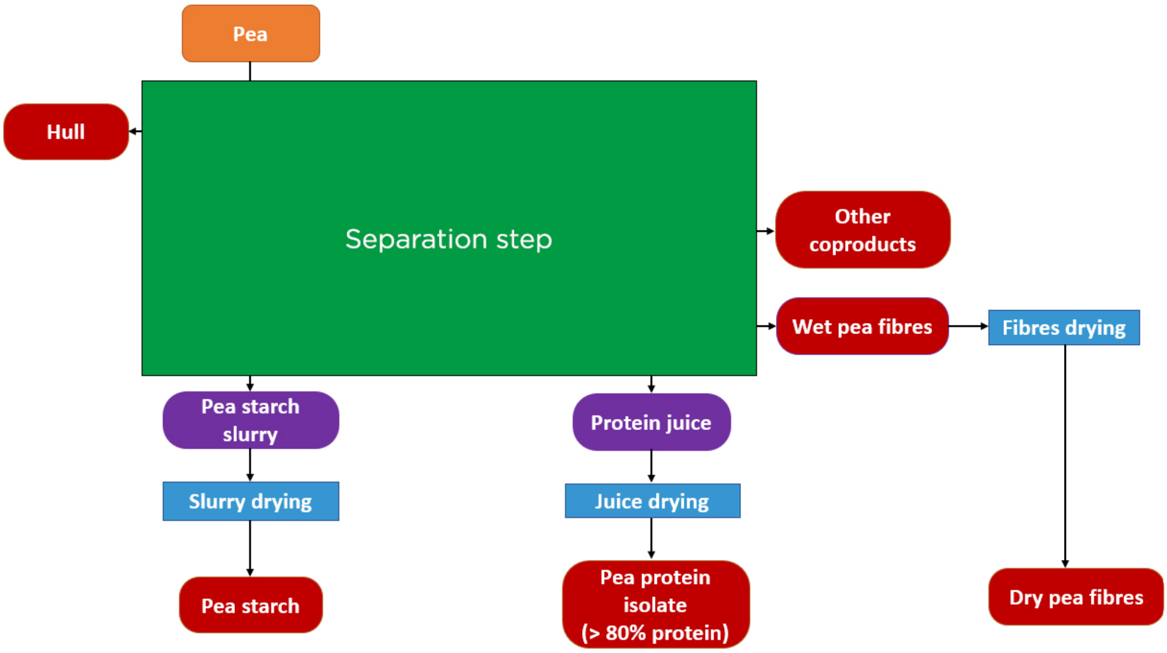

Figure 1: Process chart of the production of pea industry products

4.2.1. PEA STARCH

The environmental profile of 1 tonne DS **pea starch** is shown in Figure 2. The absolute values are given in Table 4. Pea starch is produced by drying the pea starch slurry after it leaves the main production process. Slurry drying is shown in red in the environmental profile.

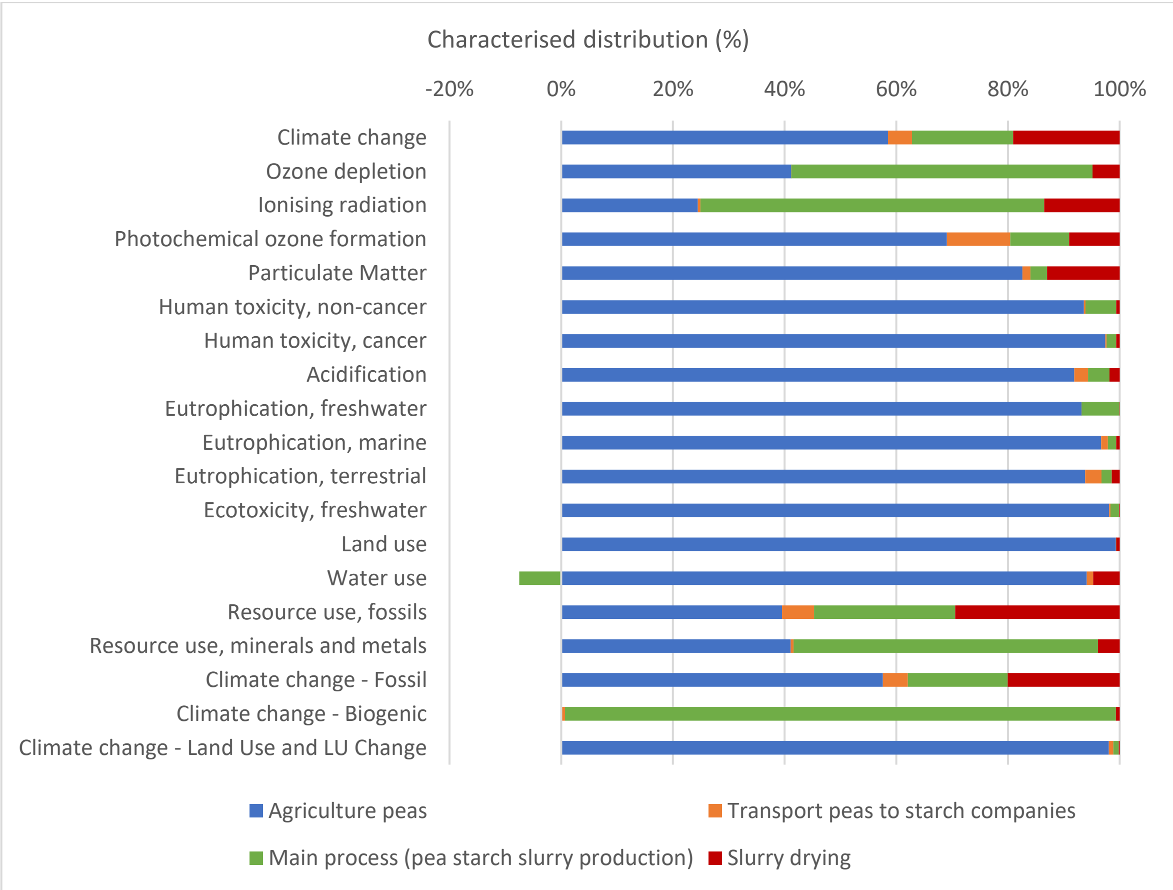

Figure 2: Environmental profile of 1 tonne DS pea starch

Table 4: Characterised results per tonne DS – pea starch

Characterised contribution	Unit	Total excl. distribution	Agriculture peas	Transport peas to starch companies	Main process	Slurry drying
Climate change	*kg CO_2 eq*	8.51E+02	4.98E+02	3.65E+01	1.54E+02	1.62E+02
Ozone depletion	*kg CFC11 eq*	1.26E-05	5.18E-06	1.38E-10	6.78E-06	6.13E-07
Ionising radiation	*kBq U-235 eq*	3.42E+01	8.38E+00	1.56E-01	2.11E+01	4.62E+00
Photochemical ozone formation	*kg NMVOC eq*	1.97E+00	1.36E+00	2.24E-01	2.07E-01	1.78E-01
Particulate matter	*disease inc.*	8.41E-05	6.95E-05	1.22E-06	2.48E-06	1.09E-05
Human toxicity, non-cancer	*CTUh*	8.57E-05	8.02E-05	2.64E-07	4.70E-06	5.40E-07
Human toxicity, cancer	*CTUh*	2.52E-06	2.45E-06	5.78E-09	4.32E-08	1.61E-08
Acidification	*mol H+ eq*	9.80E+00	9.01E+00	2.41E-01	3.77E-01	1.81E-01
Eutrophication, freshwater	*kg P eq*	5.78E-01	5.39E-01	2.28E-04	3.89E-02	3.76E-04
Eutrophication, marine	*kg N eq*	9.59E+00	9.28E+00	1.16E-01	1.38E-01	6.16E-02
Eutrophication, terrestrial	*mol N eq*	4.25E+01	3.99E+01	1.25E+00	7.82E-01	5.98E-01
Ecotoxicity, freshwater	*CTUe*	1.94E+05	1.90E+05	3.61E+02	3.06E+03	1.80E+02
Land use	*Pt*	1.88E+05	1.87E+05	1.49E+02	2.55E+01	1.11E+03
Water use	*m3 depriv.*	1.14E+02	1.16E+02	1.41E+00	-9.33E+00	5.88E+00
Resource use, fossils	*MJ*	8.63E+03	3.41E+03	4.96E+02	2.18E+03	2.54E+03
Resource use, minerals and metals	*kg Sb eq*	4.80E-04	1.97E-04	2.40E-06	2.62E-04	1.87E-05
Climate change - Fossil	*kg CO_2 eq*	8.09E+02	4.66E+02	3.62E+01	1.45E+02	1.62E+02
Climate change - Biogenic	*kg CO_2 eq*	9.67E+00	0.00E+00	6.42E-02	9.54E+00	6.46E-02
Climate change - LULUC	*kg CO_2 eq*	3.27E+01	3.21E+01	2.60E-01	3.05E-01	6.00E-02

The **cultivation of peas** generally accounts for the highest contribution to most of the impact categories. Exceptions hereto are ozone depletion, ionising radiation, resource use (minerals and metals) and biogenic climate change, where the largest contributors to the impact category is waste water treatment in the main production process.

The impact of the **slurry drying** process is generally smaller than the **main process**' impact. Only on climate change, particulate matter, water use, fossil resource use and fossil climate change, slurry drying is the more impactful manufacturing process of the two. These impact categories (except water use) are typically more affected by energy production, illustrating that slurry drying is more energy-intensive than the main process. The higher (in absolute value) impact of the main process on water use is caused by waste water treatment.

Transport of peas to the production plants has a minor impact on all categories.

With regards to climate change, the impact decreases as follows: agriculture of peas (59%), slurry drying (19%), pea starch slurry production (18%) and transport of peas to manufacturing (4%).

4.2.2. PEA PROTEIN ISOLATE

In order to produce **pea protein isolate**, drying of protein juice is required as an additional processing step following the main process. Juice drying requires input of energy (thermal and electrical) and, to a lesser extent, auxiliary materials. This of course results in an additional impact on top of that of the main process. The environmental profile for pea protein isolate is given in Figure 3, where juice drying is shown in light blue. The absolute values are given in Table 5.

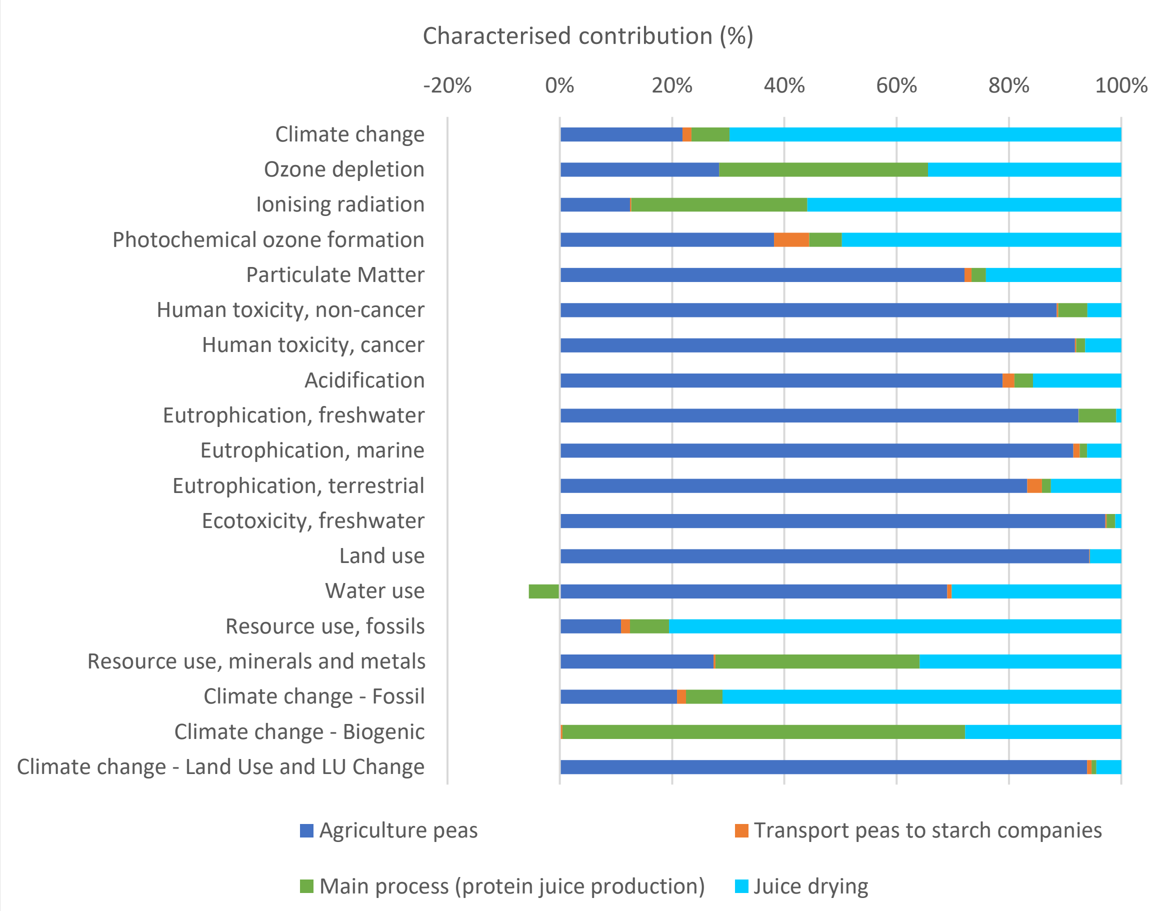

Figure 3: Environmental profile of 1 tonne DS pea protein isolate

Table 5: Characterised results per tonne DS – pea protein isolate

Characterised contribution	Unit	Total excl. distribution	Agriculture peas	Transport peas to starch companies	Main process	Juice drying
Climate change	*kg CO_2 eq*	2.28E+03	4.98E+02	3.64E+01	1.54E+02	1.59E+03
Ozone depletion	*kg CFC11 eq*	1.82E-05	5.18E-06	1.38E-10	6.77E-06	6.27E-06
Ionising radiation	*kBq U-235 eq*	6.71E+01	8.37E+00	1.56E-01	2.10E+01	3.75E+01
Photochemical ozone formation	*kg NMVOC eq*	3.56E+00	1.36E+00	2.24E-01	2.07E-01	1.77E+00
Particulate matter	*disease inc.*	9.63E-05	6.94E-05	1.21E-06	2.48E-06	2.32E-05
Human toxicity, non-cancer	*CTUh*	9.06E-05	8.01E-05	2.64E-07	4.70E-06	5.48E-06
Human toxicity, cancer	*CTUh*	2.67E-06	2.45E-06	5.77E-09	4.32E-08	1.71E-07
Acidification	*mol H^+ eq*	1.14E+01	9.00E+00	2.41E-01	3.77E-01	1.79E+00

Eutrophication, freshwater	*kg P eq*	5.82E-01	5.38E-01	2.28E-04	3.88E-02	5.33E-03
Eutrophication, marine	*kg N eq*	1.01E+01	9.27E+00	1.15E-01	1.38E-01	6.15E-01
Eutrophication, terrestrial	*mol N eq*	4.79E+01	3.98E+01	1.25E+00	7.81E-01	5.99E+00
Ecotoxicity, freshwater	*CTUe*	1.96E+05	1.90E+05	3.61E+02	3.06E+03	2.11E+03
Land use	*Pt*	1.98E+05	1.86E+05	1.49E+02	2.54E+01	1.10E+04
Water use	*m^3 depriv.*	1.59E+02	1.16E+02	1.40E+00	-9.32E+00	5.09E+01
Resource use, fossils	*MJ*	3.13E+04	3.41E+03	4.96E+02	2.18E+03	2.52E+04
Resource use, minerals and metals	*kg Sb eq*	7.19E-04	1.97E-04	2.40E-06	2.62E-04	2.58E-04
Climate change - Fossil	*kg CO_2 eq*	2.23E+03	4.65E+02	3.61E+01	1.44E+02	1.58E+03
Climate change - Biogenic	*kg CO_2 eq*	1.33E+01	0.00E+00	6.41E-02	9.53E+00	3.69E+00
Climate change - LULUC	*kg CO_2 eq*	3.41E+01	3.21E+01	2.60E-01	3.05E-01	1.51E+00

The environmental profile of pea protein isolate reveals that the **agricultural life cycle stage** is the largest contributor to particulate matter, human toxicity (non-carcinogen and carcinogen), acidification, eutrophication (freshwater, marine and terrestrial), freshwater ecotoxicity, land use, water use and climate change due to land use and land use change, with contributions to the impact category of ca. 70% or higher.

The **manufacturing processes** have large contributions to the impact categories that are linked to energy use; indeed, the combined contribution of the main process and juice drying accounts for over 70% to climate change (total and fossil), ionising radiation, resource use (fossil) and climate change (biogenic). The impact on the latter is explained by waste water treatment (for juice production) and the use of boilers or CHPs on biogas (for juice drying). The manufacturing processes also contribute significantly to ozone depletion and mineral and metal resources use, which is caused by the use of auxiliary materials during manufacture. For most impact categories, the impact of protein juice production is lower than that of juice drying. Exceptions hereto are biogenic climate change and ozone depletion, where the impact of protein juice production is higher due to waste water treatment and a higher amount of auxiliary materials or 'environmentally unfriendlier' auxiliaries used in the process, respectively. Again a credit on water use is found, caused by the main process, and specifically by waste water treatment.

Pea transport has a minor contribution to the overall environmental impact (max. 6% of the impact).

Regarding climate change, the impact of the life cycle stages decreases as follows: juice drying (70%), agriculture (22%), protein juice production (7%) and pea transport (2%).

4.2.3. Dry pea fibres

After leaving the main process as an output, wet pea fibres are dried to produce **dry pea fibres**. The environmental profile for 1 tonne DS dry pea fibres is shown in Figure 4, the absolute values in Table 6. The fibre drying process, displayed with yellow bars in the profile, requires mostly energy (electrical as well as thermal) as an input.

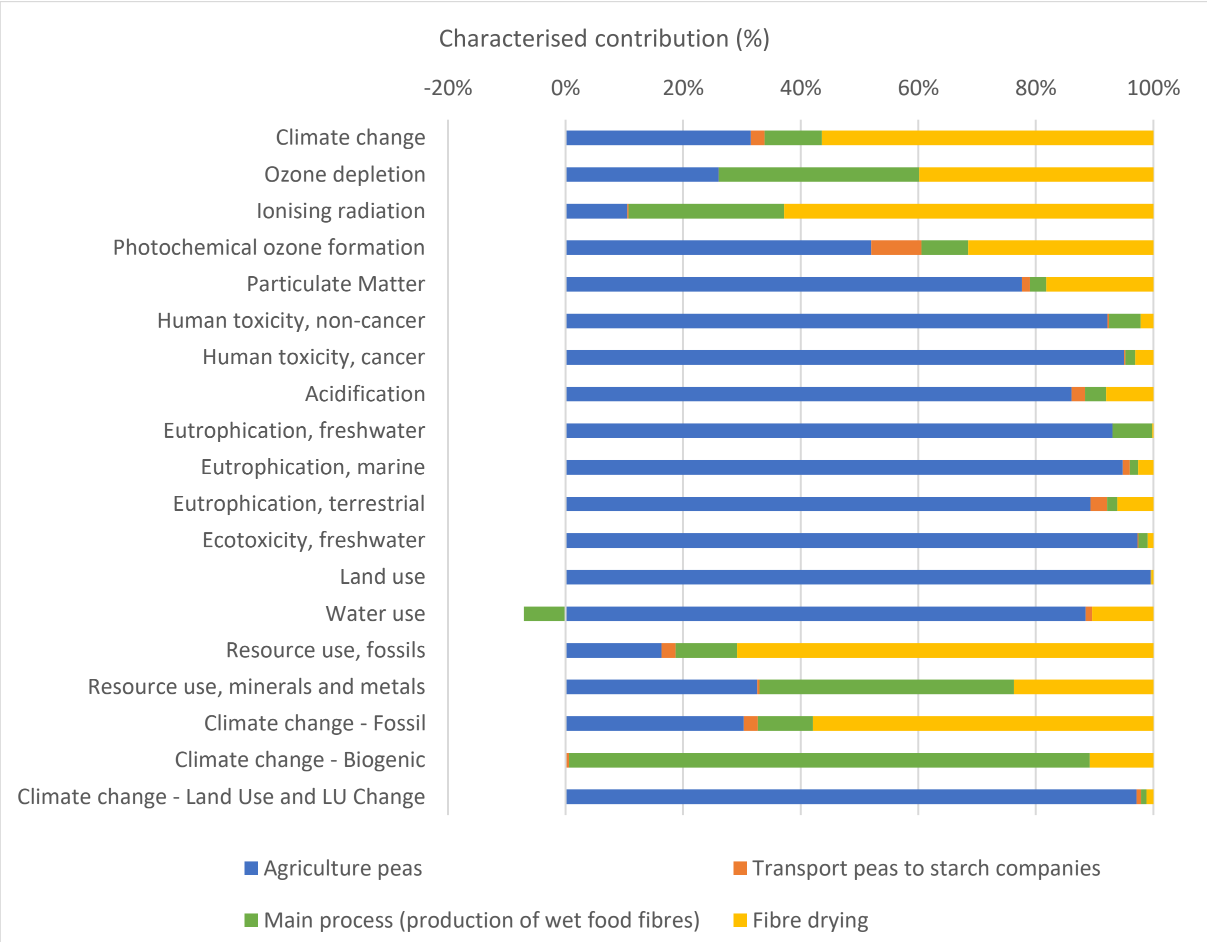

Figure 4: Environmental profile of 1 tonne DS dry pea fibres

Table 6: Characterised results per tonne DS – dry pea fibres

Characterised contribution	Unit	Total excl. distribution	Agriculture peas	Transport peas to starch companies	Main process	Fibre drying
Climate change	*kg CO_2 eq*	1.57E+03	4.97E+02	3.64E+01	1.54E+02	8.88E+02
Ozone depletion	*kg CFC11 eq*	1.98E-05	5.16E-06	1.38E-10	6.75E-06	7.90E-06
Ionising radiation	*kBq U-235 eq*	7.94E+01	8.36E+00	1.56E-01	2.10E+01	4.99E+01
Photochemical ozone formation	*kg NMVOC eq*	2.61E+00	1.36E+00	2.23E-01	2.07E-01	8.22E-01
Particulate Matter	*disease inc.*	8.92E-05	6.93E-05	1.21E-06	2.47E-06	1.62E-05
Human toxicity, non-cancer	*CTUh*	8.68E-05	8.00E-05	2.64E-07	4.69E-06	1.85E-06
Human toxicity, cancer	*CTUh*	2.57E-06	2.45E-06	5.76E-09	4.31E-08	7.90E-08
Acidification	*mol H^+ eq*	1.04E+01	8.98E+00	2.40E-01	3.76E-01	8.37E-01
Eutrophication, freshwater	*kg P eq*	5.77E-01	5.37E-01	2.27E-04	3.88E-02	1.18E-03
Eutrophication, marine	*kg N eq*	9.75E+00	9.25E+00	1.15E-01	1.38E-01	2.53E-01
Eutrophication, terrestrial	*mol N eq*	4.45E+01	3.98E+01	1.25E+00	7.80E-01	2.73E+00

Ecotoxicity, freshwater	*CTUe*	1.95E+05	1.90E+05	3.60E+02	3.05E+03	1.89E+03
Land use	*Pt*	1.87E+05	1.86E+05	1.48E+02	2.54E+01	7.02E+02
Water use	*m^3 depriv.*	1.22E+02	1.16E+02	1.40E+00	-9.30E+00	1.37E+01
Resource use, fossils	*MJ*	2.08E+04	3.40E+03	4.94E+02	2.17E+03	1.47E+04
Resource use, minerals and metals	*kg Sb eq*	6.03E-04	1.97E-04	2.39E-06	2.61E-04	1.43E-04
Climate change - Fossil	*kg CO_2 eq*	1.53E+03	4.65E+02	3.60E+01	1.44E+02	8.86E+02
Climate change - Biogenic	*kg CO_2 eq*	1.07E+01	0.00E+00	6.40E-02	9.51E+00	1.16E+00
Climate change - LULUC	*kg CO_2 eq*	3.29E+01	3.20E+01	2.59E-01	3.04E-01	3.84E-01

Agriculture of peas again affects many impact categories with contributions of 50% and up, i.e. photochemical ozone formation, particulate matter, human toxicity (cancer and non-cancer), acidification, eutrophication (freshwater, marine and terrestrial), freshwater ecotoxicity, land use, water use and climate change due to land use and land use change. On all other impact categories, manufacture (main process and fibre drying) has the highest impact, with combined contributions of ca. 60% or higher.

The impact of **fibre drying** is generally larger (in absolute value) than that of the **main process** (except for non-carcinogenic human toxicity, freshwater eutrophication, minerals and metals resource use and biogenic climate change). Contrary to the main process, fibre drying is not water- or auxiliary materials-intensive, explaining the lower impact of fibre drying on the above mentioned impact categories, which are typically affected by these inputs. The environmental credit to water use is attributed to water treatment of the waste water generated during the main process.

Transport of peas remains a negligible life cycle stage with regard to its environmental impact (max. 4%).

Focusing on climate change, the impact of the process stages involved in the life cycle of dry pea fibres decreases as follows: fibre drying (56%), agriculture (32%), wet fibres production (10%) and pea transport (2%).

4.3. NORMALISED ENVIRONMENTAL PROFILES

The characterised results (absolute values) as shown and discussed in paragraph 4.2 do not provide insights regarding the scale of the different impacts; it is not clear whether an environmental burden is ‘small’ or ‘large’. In normalisation, the life cycle impact assessment results are compared to a ‘baseline’ (normalisation factor), representing the total impact of a reference region for an impact category in a reference year. Normalisation thus provides a better understanding of the *magnitude* of the different impacts because they are now scaled, however it does not reflect the *severity* of the impact. It also serves to identify the most important impact categories and life cycle stages. In the EF method, the global impacts per person are used as normalisation factors, which can be found in the Annex.

The normalised environmental profiles are shown in Figure 5 through Figure 7.

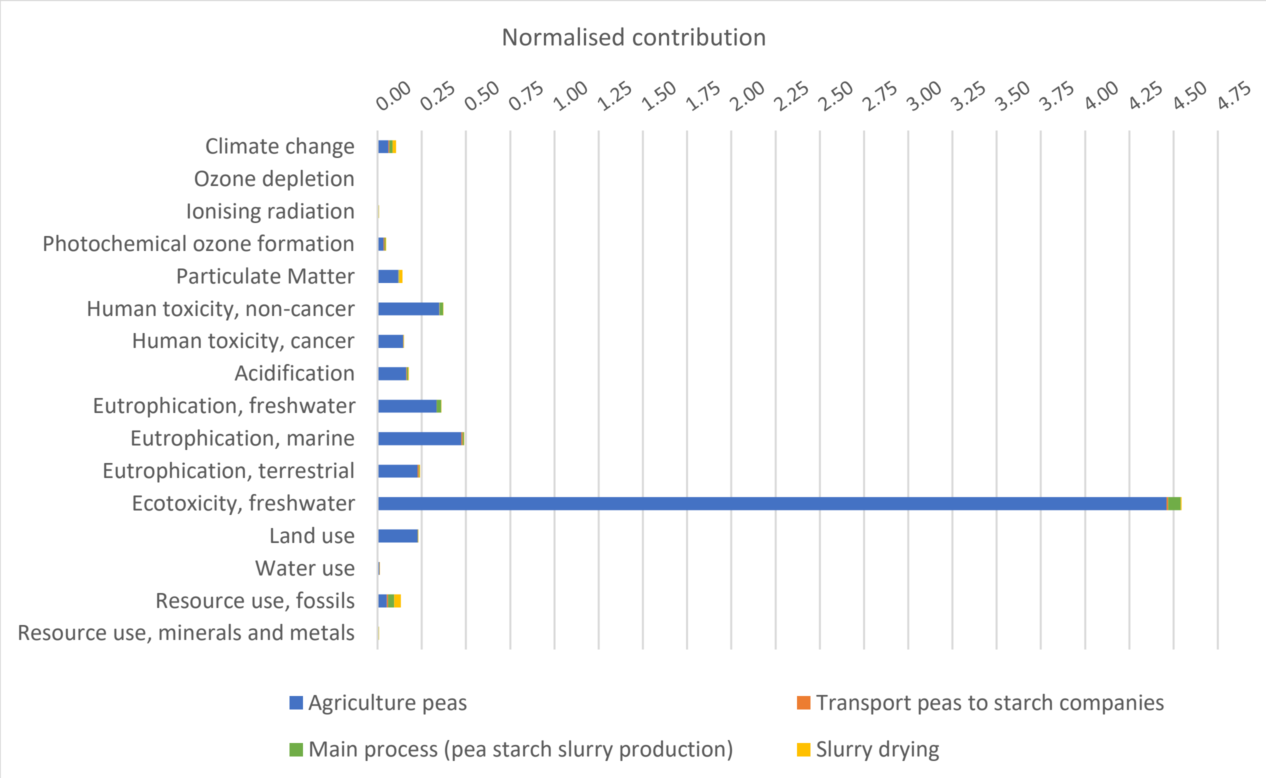

Figure 5: Normalised environmental profile of 1 tonne DS pea starch

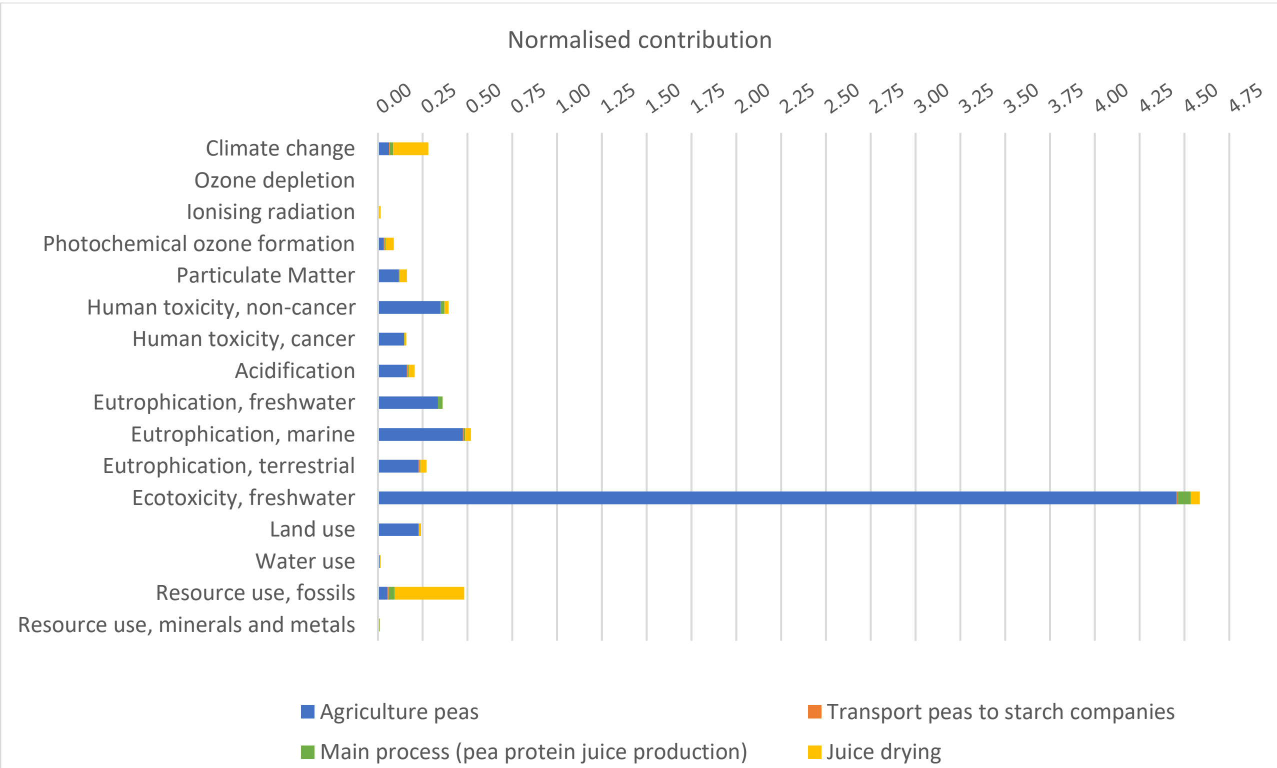

Figure 6: Normalised environmental profile of 1 tonne DS pea protein isolate

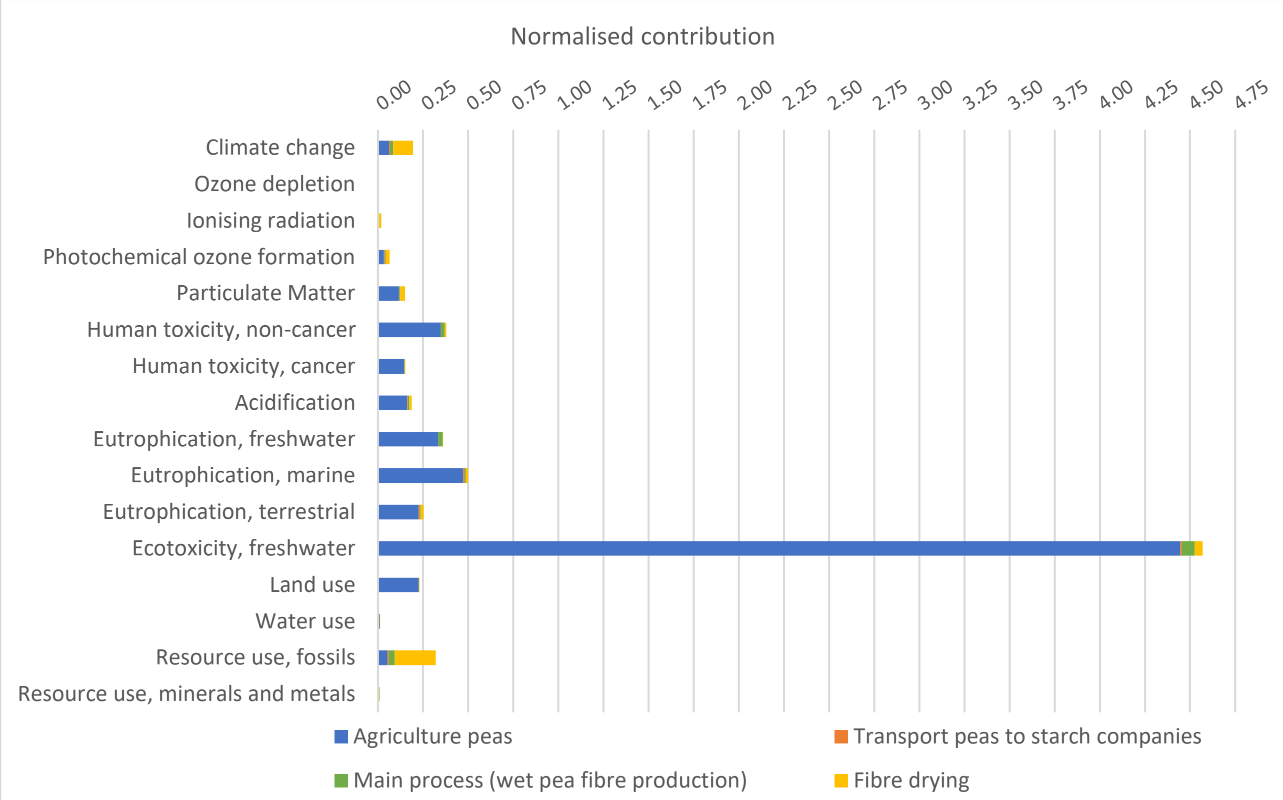

Figure 7: Normalised environmental profile of 1 tonne DS dry pea fibres

The normalised profiles of pea starch, protein isolate and dry fibres are very similar; they show that freshwater ecotoxicity[1] is by far the most relevant impact category. This is related to the large contribution of the agricultural life cycle phase, which contributes most significantly to almost any impact category. The second most relevant environmental theme is marine eutrophication.

Minimal contributions of the main production process are found on all impact categories except freshwater eutrophication, freshwater ecotoxicity and fossil resource use.

The impacts of the drying processes are variable. Juice drying and fibre drying show significant impacts on climate change and fossil resources use, which is much less the case for slurry drying.

The normalised profiles also show that the cumulative impacts on ozone depletion, mineral and metal resources use, ionising radiation and water use are minimal for every product.

[1] One reason for freshwater ecotoxicity to pop up in many LCA/PEF studies as a hot spot impact category after normalisation, is the fact that many emissions contribute to this impact category, but only a limited selection of these emissions were available for calculating the corresponding EF normalization factor.

4.4. COMPARATIVE ENVIRONMENTAL PROFILE

The pea products' impact on climate change (i.e. their carbon footprint) is presented in one graph to allow for comparison between them. The corresponding absolute values per life cycle stage are shown in Table 7.

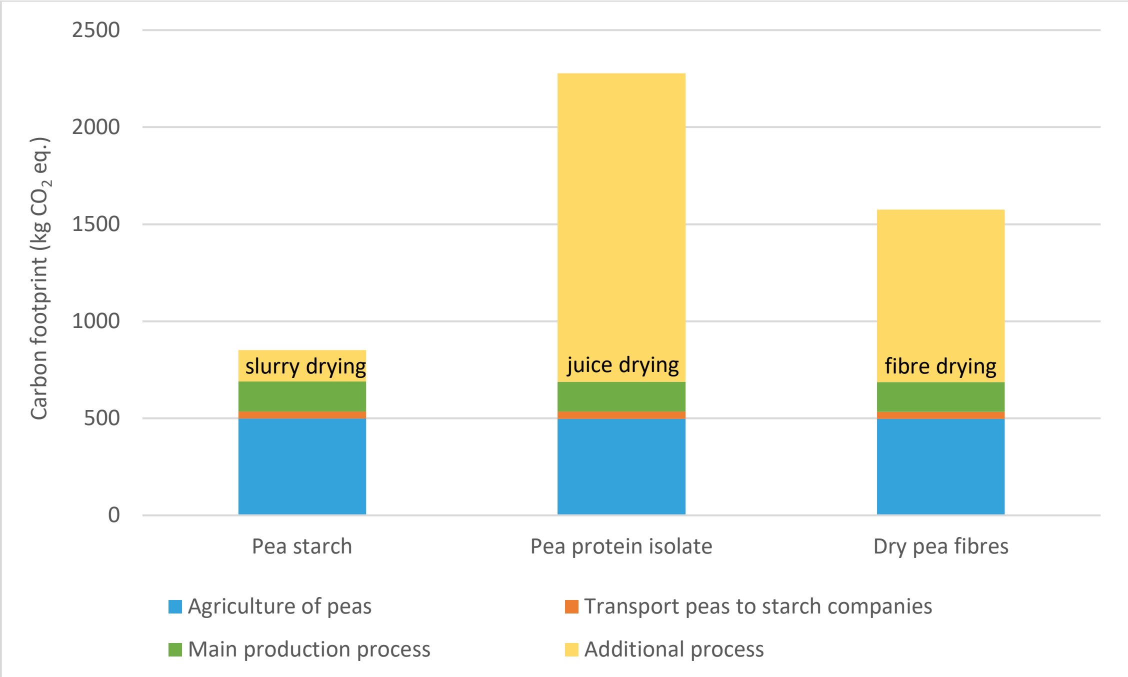

Figure 8: Comparative carbon footprint profile per tonne DS pea product

Table 7: Absolute contributions to the carbon footprint - per tonne DS pea product

Pea product	Total excl. distribution (kg CO_2 eq.)	Agriculture of peas (kg CO_2 eq.)	Transport peas to factories (kg CO_2 eq.)	Main production process (kg CO_2 eq.)	Additional process (kg CO_2 eq.)
Pea starch	851.3	498.1	36.5	154.4	Slurry drying: 162.3
Pea protein isolate	2277.3	497.5	36.4	154.2	Juice drying: 1589.0
Dry pea fibre	1574.8	496.5	36.4	153.9	Fibre drying: 888.0

Cultivation of peas has a more or less equal contribution of ca. 497 kg CO_2 eq. per tonne DS for every pea product. This contribution originates mainly from lime, dolomite and fertiliser emissions at the field and to a smaller extent from the production of fertilizers, energy use from agricultural machinery and drying of the peas.

The products also have **transportation of peas** to the production plants and the **main production process** in common, resulting in consistent contributions of ca. 36 and 154 kg CO_2 eq. per tonne DS, respectively. Energy use in the manufacturing processes (both electricity and heat) has a large impact on climate change. This makes sense since combustion emissions such as carbon dioxide, methane and dinitrogen monoxide contribute greatly to the greenhouse effect.

Pea protein isolate and dry pea fibres have the largest carbon footprint. The **drying processes** which lead to these products, i.e. juice drying and fibre drying, are more energy-intensive than slurry drying, resulting in a larger contribution to the carbon footprint.

The pea starch products' carbon footprints range from 851 to 2777 kg CO_2 equivalents.

CHAPTER 5 SUMMARY CONCLUSIONS

This life cycle assessment has shown that the impact of the **agricultural phase**, i.e. production of the main raw material, has a significant contribution to the general environmental impact of the studied pea products. The impact categories which are strongly affected (60% or higher of the impact) by the agricultural processes are particulate matter, human toxicity (carcinogenic and non-carcinogenic), acidification, eutrophication (freshwater, marine and terrestrial), freshwater ecotoxicity, land use, water use and climate change due to land use and land use change. The impact of agriculture on ozone depletion, ionising radiation, photochemical ozone formation, resource use (fossil and minerals and metals) and climate change due to biogenic emissions on the other hand, is generally limited.

Focussing on the **manufacturing processes**, it became clear that the impact of the main production process is generally a result of the energy consumption (mainly electrical) for the process and the use of auxiliary materials. Also treatment of the generated waste water has a significant impact on some impact categories (freshwater eutrophication and ecotoxicity, human toxicity (non-cancer)) however on other categories its influence may be beneficial (water use, land use, particulate matter and terrestrial eutrophication).
The impacts of the additional drying processes are mainly driven by electricity and heat use. Comparing these processes based on the weighted results shows that juice drying has the highest impact, followed by fibre drying and lastly slurry drying.

Comparing the pea products shows that the overall environmental impact (weighted impact) of pea protein isolate is the highest of the three products, followed by dry pea fibres and finally pea starch.

Overall, the **carbon footprint** of 1 tonne dry substance pea product ranges from 851 to 2777 kg CO_2 equivalents depending on the product. The carbon footprint is mostly affected by CO_2 emission caused by energy use during the drying processes and by CO_2 and N_2O (dinitrogen monoxide) emissions during pea cultivation.

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ANNEX – LIST OF EF NORMALISATION FACTORS

Global normalisation factors are applied within the EF. The normalisation factors as the global impact per person are used in the EF calculations.

The table below lists the normalisation factors that were used to calculate the normalised environmental profiles, as prescribed in the PCR for Starch Industry Products.

Table 8: EF normalisation factors

Impact category	**Unit**	**Normalisation factors** *(unit/person)*
Climate change, total	*kg CO2 eq*	8,10E+03
Ozone depletion	*kg CFC-11 eq*	5,36E-02
Particulate matter	*disease incidence*	5,95E-04
Ionising radiation, human health	*kBq U^{235} eq*	4,22E+03
Photochemical ozone formation, human health	*kg NMVOC eq*	4,06E+01
Acidification	*mol H+ eq*	5,56E+01
Eutrophication, terrestrial	*mol N eq*	1,77E+02
Eutrophication, freshwater	*kg P eq*	1,61E+00
Eutrophication, marine	*kg N eq*	1,95E+01
Human toxicity, cancer	*CTUh*	1,69E-05
Human toxicity, non-cancer	*CTUh*	2,30E-04
Ecotoxicity	*CTUe*	4,27E+04
Land use	*Dimensionless (pt)*	8,19E+05
Water use	*m^3 world eq*	1,15E+04
Resource use, minerals and metals	*kg Sb eq*	6,36E-02
Resource use, fossils	*MJ*	6,50E+04