PEF report of vegetable oil and proteinmeal industry products

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This PEF compliant to the PEFCR on vegetable oil and protein meal industry products. The PEFCR is based on the PEFCR template of ANNEX B of the document *Suggestions for updating the Product Environmental Footprint (PEF) method* (Zampori and Pant, 2019). However, at this point it is not possible for FEDIOL to be fully compliant with the PEF method, and the process of developing a PEFCR has not been followed. The PEFCR is thus no official PEFCR. Because of the PEFCR not being fully compliant to PEF, this study, performed according to this PEFCR is not fully compliant either.

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LIST OF ACRONYMS

EF	Environmental Footprint
EU	European Union
FEDIOL	The European vegetable oil and proteinmeal industry
FU	Functional unit
IC	Impact Categories
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standardisation Organisation
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCS	Life cycle Stages
LHV	Lower Heating Value
LULUC	Land Use and Land Use Change
PCR	Product Category Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
WFLDB	World Food Life cycle assessment DataBase

CHAPTER 1 INTRODUCTION

This document reports the PEF of sector average products from the European vegetable oil and proteinmeal industry. The scope of this PEF are products of the vegetable oil and proteinmeal industry. All products listed in Table 1 are included.

Table 1: Overview of products included in the scope of this PEF study

Raw material		Rapeseeds	Soybeans	Sunflower seeds	Maize germs	Palm	Palm kernel	Coconut
Status raw material at reception		uncleaned	uncleaned	uncleaned, including husk	uncleaned	crude oil	palm kernel	crude oil
Products	Crushing	Crude oil Meal Lecithin	Crude oil Meal Lecithin Hulls	Crude oil Meal Lecithin Husks	Crude oil Meal			
	Oil processing	Refined oil Soap stock Acid oil/ deodistillates/ fatty acid distillates	Refined oil Soap stock Acid oil/ deodistillates/ fatty acid distillates	Refined oil Acid oil/ deodistillates/ fatty acid distillates	Refined oil Acid oil/ deodistillates	Refined oil Acid oil/ deodistillates/ fatty acid distillates	Refined oil Fatty acid distillates	Refined oil Acid oil/ deodistillates/ fatty acid distillates
Technology	Main refining technology	Chemical refining and physical refining	Physical and chemical refining	Physical and chemical refining	Chemical refining	Physical and chemical refining	Physical refining	Physical and chemical refining

This PEF has been commissioned by the European vegetable oil and proteinmeal industry association (FEDIOL). Data have been collected by the members of FEDIOL. FEDIOL members represent more than 85% of EU vegetable oil and proteinmeal production. In this study, thirteen FEDIOL member companies were involved, who participated in meetings and provided feedback on the draft documents. FEDIOL member companies, ten in total, also provided data for the life cycle assessment of the sector average products. The provided data are applicable to 33% of the sector. This PEF is based on the Product Category Rules for vegetable oil and protein meal industry products v1.2 (FEDIOL, 2022). This PEF 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). At this point it is not possible for FEDIOL to be fully compliant with the PEF method. This document is thus no official PEF study. This PEF report contains the analysis of sector average products, as mentioned in Table 1. The scope of the analysis made for this report is different from the scope of the analysis made for the PEFCR report.

Here results are presented per product. In the PEFCR, a virtual representative product has been used of which the composition is based on weighted average quantities (mass) of European sales to end user industries. This virtual representative product is used only for the development of the PEFCR and for the identification of the most relevant impact categories, life cycle stages, processes and elementary flows of the sector as a whole and to identify processes subject to cut-off. The analysis of the representative product is available in annex of this document and in Annex I of this document and in the PEFCR.

FEDIOL has commissioned this study in view of their mission to strengthen the competitiveness and sustainability of the EU oilseed industry. The vegetable oil and proteinmeal industry has been working on Life Cycle Assessment (LCA-) related issues since 2010. In 2013, FEDIOL published a life cycle assessment study on EU oilseed crushing and vegetable oil refining. The life cycle inventory was based on data collected from a significant number of crushing and refining plants across the EU. The Life Cycle Inventory data published in this study have been picked up by databases such as the Agri-footprint database, the World Food LCA Database (WFLDB) and the Environmental Footprint (EF) Database. Meanwhile, methodological development in the field of life cycle assessment has continued, for example in the European Commission’s Product Environmental Footprint (PEF) initiative. In addition, new data on e.g. agricultural production, transport, electricity have become available. Furthermore, FEDIOL is confronted with an increasing number of requests to update the 2013 LCA study. This PEF study responds to this request.

CHAPTER 2 GOAL OF THE STUDY

2.1. INTENDED APPLICATIONS

This PEF is intended to compose sector-representative environmental profiles of the vegetable oil and proteinmeal industry products which can be used to communicate to customers and other interested parties. It is also used to base the further development of the PEFCR document of vegetable oil and proteinmeal industry products on. The main report contains the PEF of specific vegetable oil and proteinmeal products and presents their sector-representative environmental profiles. The analysis of the representative product is included in Annex I.

This PEF report follows a PEFCR for intermediate products. Comparative assertions should always be made considering the function of the product. At the level of the declared unit of this PEFCR, only products with the same characteristics can be compared. The results of this PEF study can be used by customers of the vegetable oil and proteinmeal industry products to calculate environmental footprints of their final products, and to make comparisons of final products that fulfil the same function. When used for this purpose it needs to be verified that there are no methodological inconsistencies between the PEF studies that are combined.

2.2. REASONS FOR CARRYING OUT THE STUDY

This complete sector study aims to:

- Generate sector-representative ‘environmental profiles’ for vegetable oil and proteinmeal;
- Contribute proactively, through the knowledge gained in the development of the LCA for vegetable oil and proteinmeal industry, to the development of P(EF)CRs by other stakeholders and the debate on use of LCA with other stakeholders and national/sectors initiatives.

2.3. TARGET AUDIENCE

The intended audience are FEDIOL member 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.

2.4. COMMISSIONER OF THE STUDY

This PEF study has been commissioned by FEDIOL, which represents the European Vegetable Oil and Proteinmeal Industry.

2.5. GEOGRAPHIC VALIDITY

This PEFCR is valid for products in scope sold or consumed in the European Union + EFTA.

In principle, according to the PEFCR on vegetable oil and protein meal industry products PEF studies “*shall identify their geographical validity listing all the countries where the product object of the PEF study is consumed/sold with the relative market share. In case the information on the market for the* *specific product object of the study is not available, Europe + EFTA shall be considered as the default market, with an equal market share for each country*."[1] This study concerns a sector study. FEDIOL member companies provided data and based on these data a sector average life cycle inventory dataset has been calculated. An analysis of the countries where the products are sold has not been carried out in the framework of this study. All secondary data beyond the production stage are EU + EFTA data.

2.6. METHODOLOGICAL LIMITATIONS

A PEF does not represent a complete picture of the environmental impact of a system. It represents a picture of those aspects that can be quantified. Any judgements that are based on the interpretation of PEF results must bear in mind this limitation and, if necessary, obtain additional environmental information from other sources (hygienic aspects, risk assessment, etc.). The PEF results are relative expressions and do not predict exceedance of thresholds, safety margins or risks.

LCA and PEF methodology is continuously being developed. Methodological improvements may affect the results even if the underlying LCI data do not change.
Some limitations are especially relevant for agricultural products. For example, quantification of water use and land use in fact requires regionalized inventory data. Data on water use are regionalized in both Agri-footprint and EF database, while land use data are not.
In this project background life cycle inventory data have been taken from the Agri-footprint database and the EF database. The EF database makes use of data from several providers (e.g. ecoinvent, Sphera). All data providers should follow the same modelling approach, yet it is not unconceivable that differences exist between the various providers.

This PEF is a sector study, the presented results are weighted averages based on mass. The environmental performance of individual companies may strongly differ from the average. Being a sector study, some recommendations of the PEFCR are less relevant.

Some data gaps exist, both at the FEDIOL member companies and in the background databases. Therefore, it was necessary to make estimates and use proxies.

2.7. IDENTIFICATION OF THE REVIEWER

Prof. Dr. Matthias Finkbeiner, Chair of Sustainable Engineering, Technische Universität Berlin has validated and reviewed the PEF study. The reviewer acts and was contracted as an independent expert, not as a representative of his affiliated organization.
The review statement is available in Annex IV of this report.

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[1] *"EU +EFTA shall be considered as the default market, with an equal market share for each country" means that no biases are to be introduced in terms of assuming e.g., electricity mixes used in the use stage of products, transport to wholesale/retail/consumer, etc. In other words, all secondary data beyond the production stage must be EU+EFTA and not a selected country with a potentially "better" datasets for whatever the processes may be.*

CHAPTER 3 SCOPE OF THE STUDY

3.1. PRODUCTS SUBJECT TO THE COMPLETE SECTOR STUDY

The scope of this PEF are products of the vegetable oil and proteinmeal industry as listed in Table 1. The vegetable oil and proteinmeal industry products are used in a wide range of applications, including food (ingredient in a vast number of products such as margarines, food dressings, dairy and confectionary products), animal feed and other industries (e.g. cosmetics, detergents, paints, plastics, candles, pharmaceuticals, biofuels). The performance depends on the specific product and application.

In addition to the individual products, a representative product is included to use as a reference for the development of the PEFCR. The representative product is described in Annex I.

3.2. FUNCTIONAL/DECLARED UNIT AND REFERENCE FLOW

The products of the vegetable oil and proteinmeal industry fulfil multiple functions and their whole life cycle is unknown. It is not feasible to include a description of the function, as a vast number of functions exist (e.g. adding nutrients, cooking at high temperature, frying, enhancing flavour, give texture). Even for one specific product, different applications exist. Therefore, the functional unit should be considered as a declared unit (identical to the reference flow[2]) and does not aim to quantify the performance of a product. All quantitative input and output data collected in the study shall be calculated in relation to this reference flow.
The functional unit[3] (FU) is "*the production of 1 tonne of vegetable oil and proteinmeal industry product up to the user's entry gate*".

3.3. SYSTEM BOUNDARY

The system boundaries are split up in various figures due to the large number of products and processes included. The system boundaries for the production of vegetable oil and co-products are presented in Figure 1 for products from rapeseed, in Figure 2 for products from soybean, in Figure 3 for products from sunflower seeds, in Figure 4 for products from maize germs, in Figure 5 for products from palm, in Figure 6 for products from palm kernel and in Figure 7 for products from coconut.
In all these figures, dark grey life cycle steps (further processing by other industries, distribution of the final products, use and end of life) are meant to be beyond the system boundaries.

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[2] The reference flow is the amount of product needed to fulfil the defined functional unit.

[3] This is a declared unit rather than a functional unit, but the term "functional unit" is kept for consistency reasons.

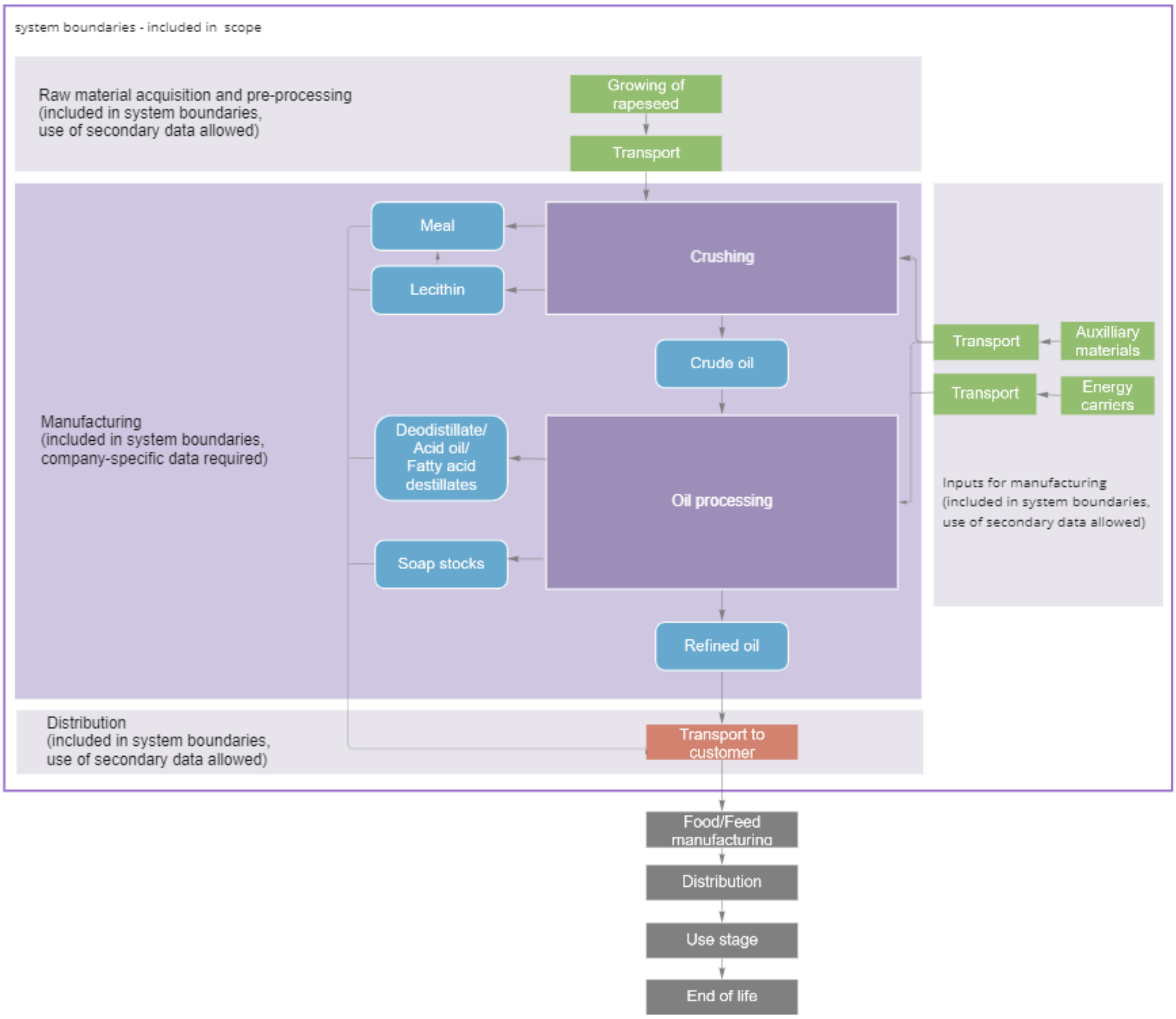

Figure 1: System boundary diagram for vegetable oil and co-products from rapeseeds

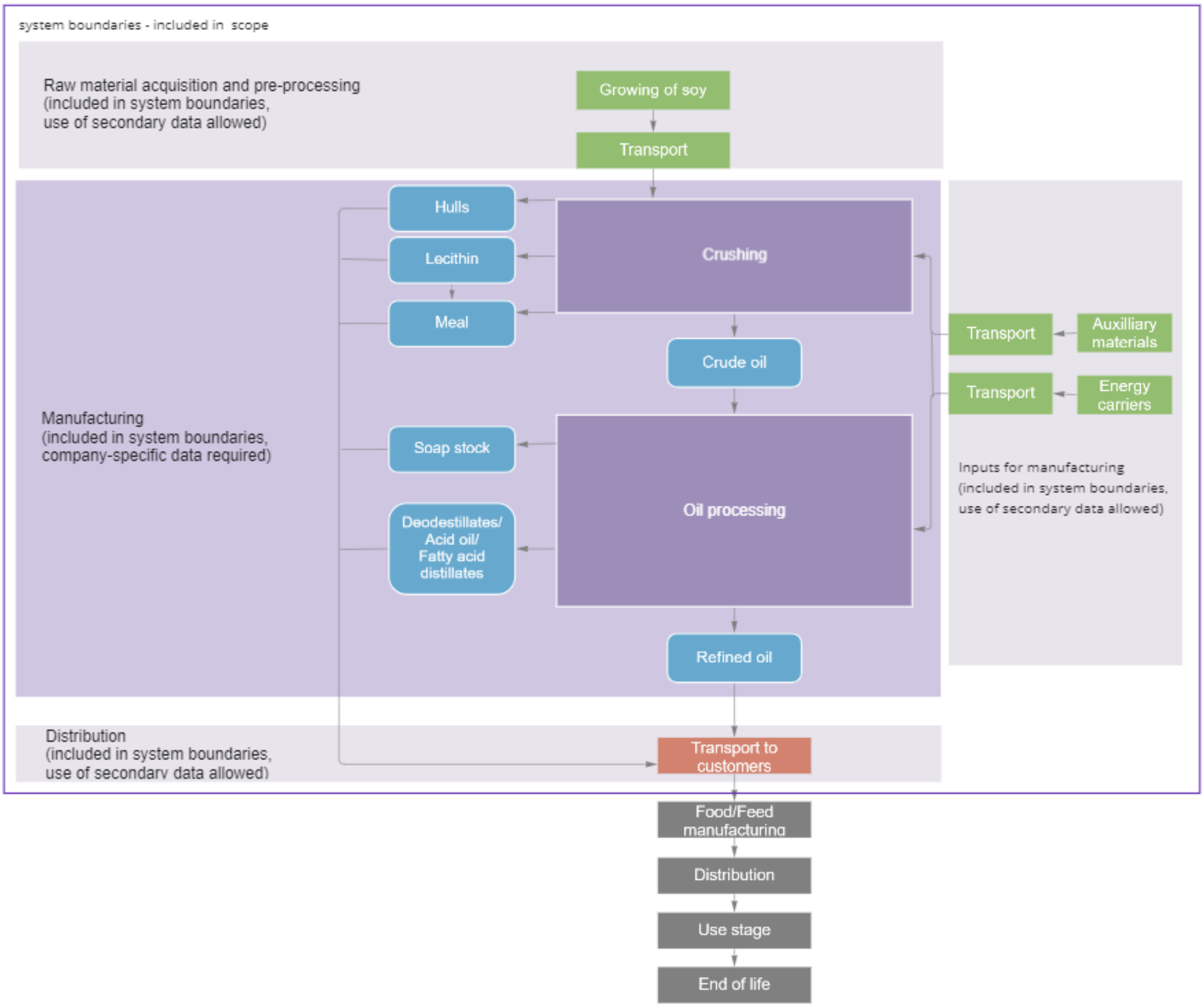

Figure 2: System boundary diagram for vegetable oil and co-products from soybeans

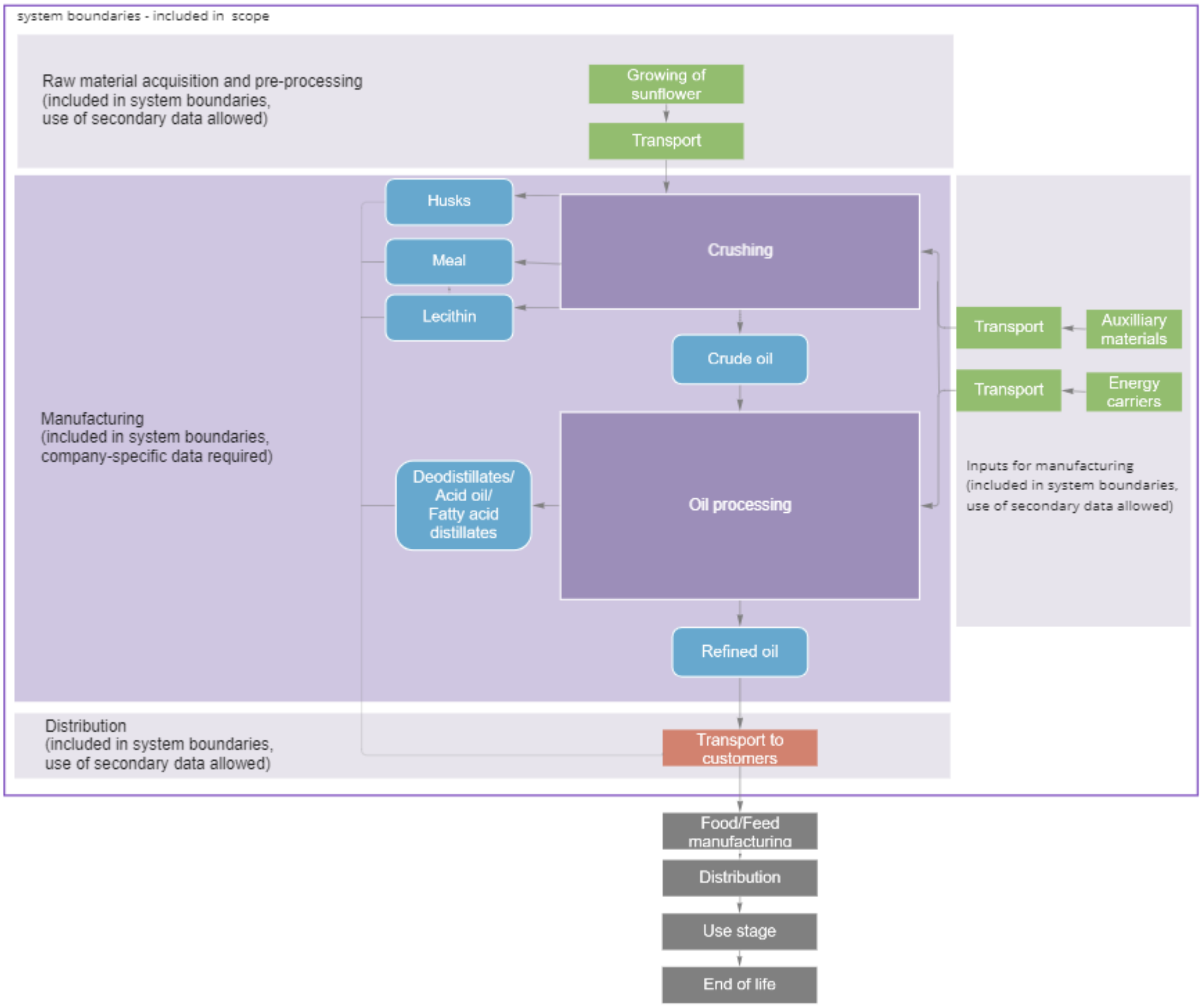

Figure 3: System boundary diagram for vegetable oil and co-products from sunflower seeds

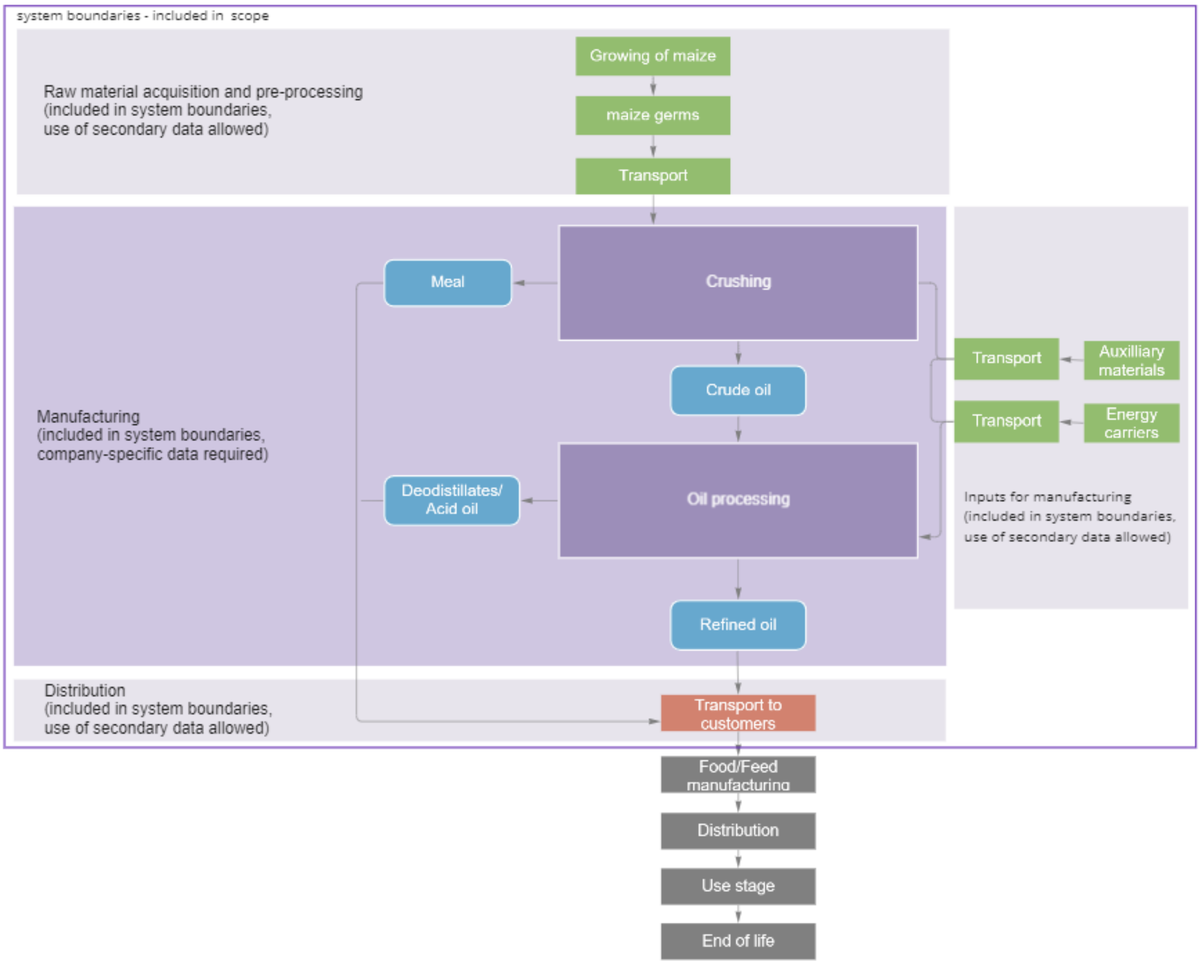

Figure 4: System boundary diagram for vegetable oil and co-products from maize germs

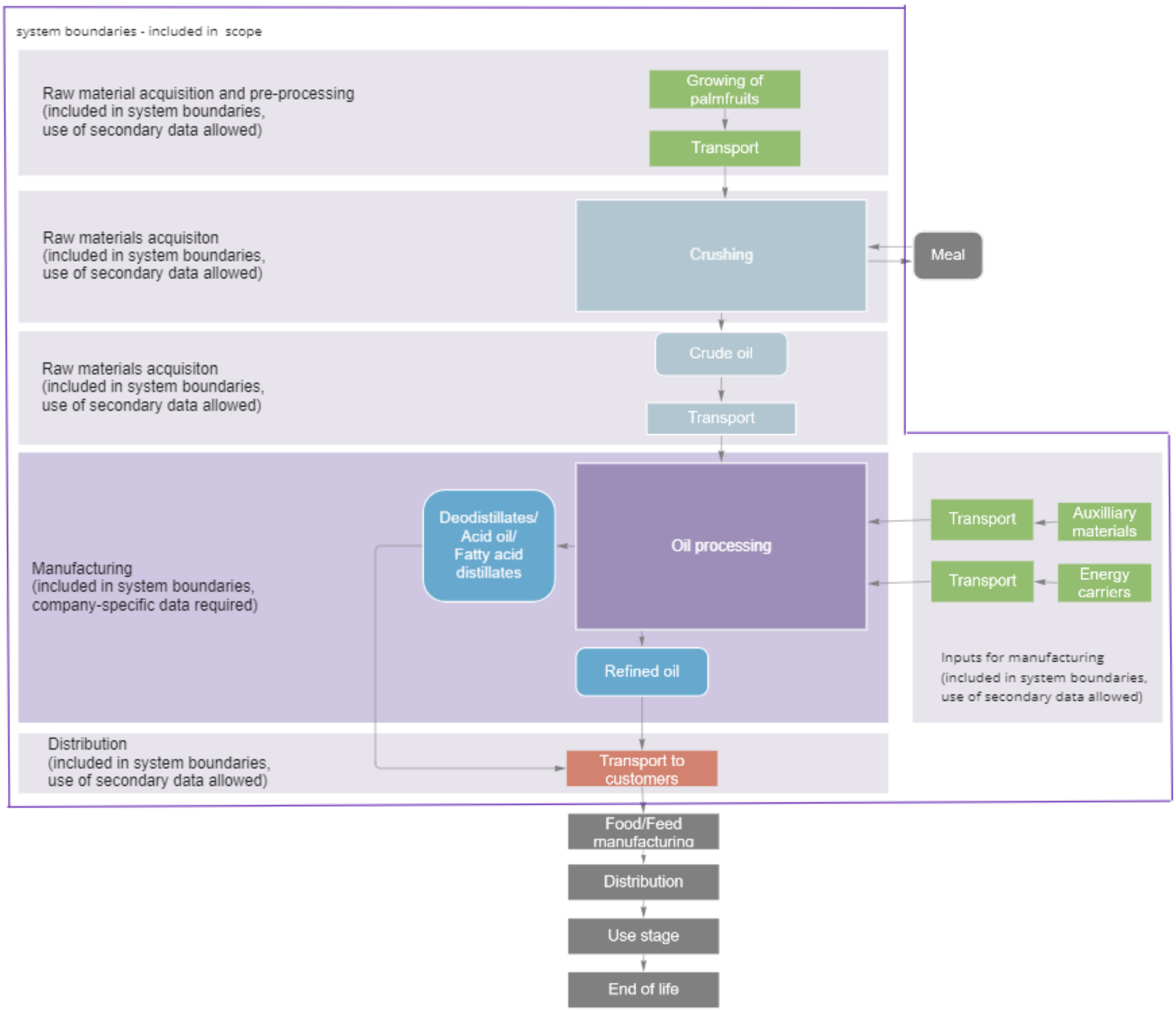

Figure 5: System boundary diagram for vegetable oil and co-products from palm

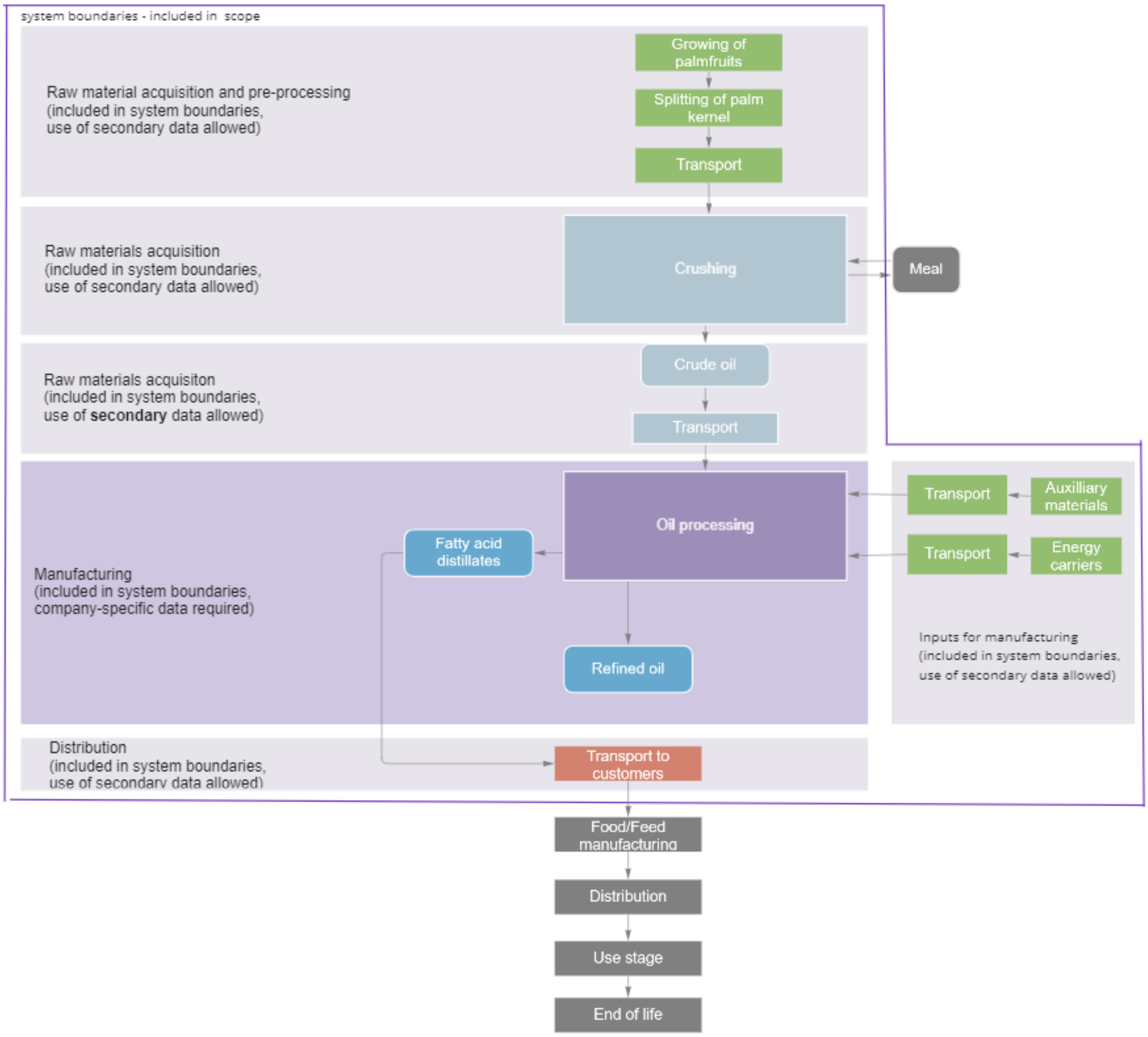

Figure 6: System boundary diagram for vegetable oil and co-products from palm kernel

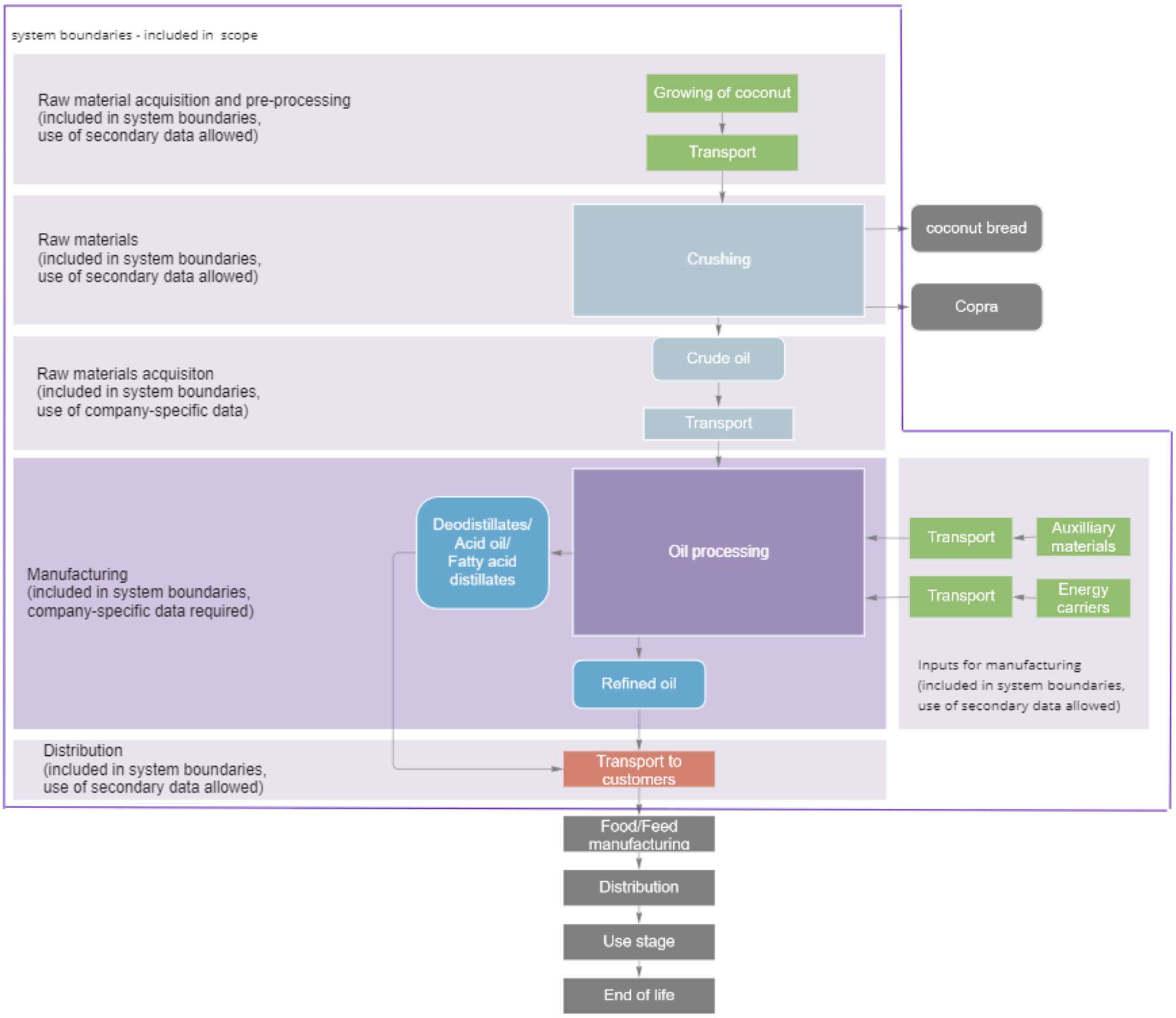

Figure 7: System boundary diagram for vegetable oil and co-products from coconut

The life cycle stages and processes included in the system boundary are listed in Table 2 for products from rapeseed, soybeans, sunflower seeds and maize germs and in Table 3 for products from palm, palm kernel and coconut.

Table 2: Life cycle stages products from rapeseed, soybeans, sunflower seeds and maize germs

Life cycle stage	Short description of the processes included
Raw material acquisition and pre-processing: agriculture	The agricultural processes include soil cultivation, sowing, weed control, fertilisation, pest and pathogen control, harvest and drying (if relevant). Growing rapeseed, soybeans, sunflower and maize requires energy, water and materials such as fertilisers, pesticides and seeds. It may also result in land transformation. Inputs of chemicals lead to emissions to air, water and soil. Land use change emissions shall be included following the methodology described in the PEF method (Zampori and Pant, 2019).
Raw material acquisition and pre-processing: transportation	Transport of raw materials from the field to the crushing plant. Crushing can either take place at FEDIOL member company sites or elsewhere. This life cycle stage takes into account the transportation to either the FEDIOL member companies or the external company doing the crushing.
Manufacturing: crushing	All relevant processes, starting with the reception and storage of the raw materials need to be included. Relevant processes are reception and unloading, storage, cleaning, conditioning, flaking, pressing, solvent extraction, oil distillation, meal desolventising and toasting, meal cooling and drying, meal storage and loading (vessel, truck, train). This life cycle stage includes the production of energy, steam, water and solvent (or other chemicals) needed for crushing. The process may produce waste and emissions to air and water.
Manufacturing: oil processing	All relevant processes, starting with the reception of crushed seeds/fruits/beans need to be included. Relevant processes are reception and unloading, storage, chemical or physical refining, bleaching, desodorisation, special processes like interesterification, winterization, hardening, soap stock splitting (chemical refinery only), storage and loading of vessels, trucks, trains. These processes require energy, and often also water and chemicals (caustic soda, hydrochloric acid etc.) and may produce waste and emissions to air and water. Optional modification steps such as interesterification, fractionation and hardening.
Distribution	Transportation from the vegetable oil and protein meal production facility to the customers.

Table 3: Life cycle stages products from palm, palm kernel and coconut

Life cycle stage	Short description of the processes included
Raw material acquisition and pre-processing: crude oil production	This life cycle stages concerns the production of crude oil. It includes agricultural processes, transport of the crops to the crushing plant and the crushing process. The agricultural processes include soil cultivation, sowing, weed control, fertilisation, pest and pathogen control, harvest and drying (if relevant). Growing palm and coconut requires energy, water and materials such as fertilisers, pesticides and seeds. It may also result in land transformation. Inputs of chemicals lead to emissions to air, water and soil. Land use change emissions shall be included following the methodology described in the PEF method (Zampori and Pant, 2019).
Raw material acquisition and pre-processing: transportation	Transport of raw materials from the crushing plant to the refining plants.

Manufacturing: oil processing	All relevant processes, starting with the reception of crude oil need to be included. These processes require energy, and often also water and chemicals (caustic soda, hydrochloric acid etc.) and may produce waste and emissions to air and water. Optional modification steps such as interesterification, fractionation and hardening
Distribution	Transportation from the oil processing facility to the customers.

In accordance with the PEFCR, the following processes are excluded based on the cut-off rule: capital goods for the manufacturing processes of the vegetable oil and protein meal industry, packaging of incoming auxiliary materials, storage of refining products, resources and tools for logistic operations at the vegetable oil and protein meal plants and process waste (excluding wastewater).

3.4. ENVIRONMENTAL FOOTPRINT IMPACT CATEGORIES

The environmental profile is calculated including all EF impact categories listed in Table 4.

Table 4: List of the impact categories to be used to calculate the environmental profile (Zampori and Pant, 2019)

EF impact category	Impact Category indicator	Unit	Characterization model
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg CO_2 eq	Baseline model of 100 years of the IPCC (based on IPCC 2013)
- Climate change - biogenic			
- Climate change - land use and land use change			
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 eq	Steady-state ODPs as in (WMO 2014 + integrations)
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[4] 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[5], 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

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[4] This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by LANCA model as indicators for land use.

[5] The results of this impact category shall be interpreted with caution, because the results of ADP after normalization may be overestimated. The European Commission intends to develop a new method moving from depletion to dissipation model to better quantify the potential for conservation of resources.

EF reference package 3.0 is used. As the Agri-footprint database is used for agricultural production[6], the EF 3.0 method is made compatible to the nomenclature of this database. The calculation of the environmental profiles of the different products has been done with SimaPro software version 9.3. In SimaPro, such a compatible version is available: EF 3.0 method (adapted). In this adapted method, flow names are aligned with SimaPro nomenclature (and thus also Agri-footprint). Nevertheless, this method does not include all flows of the original EF 3.0 method. Therefore, a combined method is made, containing all flows and characterisation factors of the original as well as the adapted EF 3.0 method to be compatible with both the EF database and the Agri-footprint database.

3.5. ADDITIONAL INFORMATION

The PEFCR requires to report biogenic carbon content at factory gate and recycled content for all products and biodiversity for products from palm, palm kernel and soybeans. The additional information is reported in 5.4.

3.6. ASSUMPTIONS AND LIMITATIONS

The study has been carried out in accordance to the PEFCR on vegetable oil and protein meal industry products (FEDIOL, 2022). Assumptions had to be made during the life cycle inventory and during the selection of appropriate datasets to model a certain flow or process. The proxy datasets are discussed in section 3.6.2.

3.6.1. DATA GAPS

No data gaps are allowed. In case specific data were unavailable, a proxy has been used (see next section).

3.6.2. LIST OF PROXY DATASETS

Life cycle inventory data are provided in the accompanying Excel file ‘PEFCR vegetable oil products – Life cycle inventory’. The file clearly indicates for which processes proxy datasets have been used for all inputs and outputs other than confidential ones. Proxy datasets have mainly been used for the production of auxiliary materials, for electricity production from CHP’s and for heat production. These proxy datasets have been used in situations where no fully matching dataset was available in the database.

→ **Raw material acquisition and pre-processing**

- **Road transport of sunflower seeds, maize germs, rapeseed, soybeans, crude palm oil, crude palm kernel oil, crude coconut oil**: Diesel driven trucks, norm Euro 4, 20 - 26 tons were used to model all road transport as most companies have indicated that these transport steps take place with this type of truck.

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[6] At the time of publication of this PEF report, the use of the EF node on Feed (which contains agricultural production) was not authorized outside the official PEF track. Therefore, the Agri-footprint database is used.

- **Loading rates**: For road transport (trucks), a default loading rate of 50% for bulk transport was used (i.e. 100% loaded outbound and 0% loaded inbound). For non-bulk road transport (trucks) a default loading rate of 64% was used. These values are adopted from Zampori and Pant (2019). The secondary dataset that was used to model transport by freight train includes an average share of empty runnings, while the secondary dataset for bulk transport via barge tanker includes an average utilisation ratio.

- **Agricultural production/crude oil production**: For the agricultural production of rapeseed, sunflower, soyabeans and maize, in exceptional cases there was no dataset available for a specific geographic origin. In these cases, a proxy was used, the proxy chosen being a nearby country (e.g. proxy for Croatia is Italy). For crude palm and crude palm kernel oil production, few geographies were available in the Agri-footprint database (only Indonesia and Malaysia), meaning that often proxies had to be selected. For crude palm oil originating from Columbia, Guatemala, Honduras, Papua New Guinea and other confidential origins, crude palm oil from Indonesia and Malaysia has been used as a proxy. For crude palm kernel oil originating from Colombia, Guatemala, Papua New Guinea and other confidential origins, crude palm kernel oil from Indonesia and Malaysia has been used as a proxy.

→ **Manufacturing**

- **Bulk vs. non-bulk materials**: based on the specific data that were provided on the use of auxiliary materials, it was not clear for every material whether it is used in bulk or not. Auxiliary materials for which one company reported packaging materials were therefore considered as non-bulk materials, auxiliary materials with no packaging reported were considered as non-bulk materials. The only implication of the classification into bulk versus non-bulk is a different loading rate for the transportation with a truck. The impact of packaging materials of auxiliary materials falls below the cut-off of 3% (see PEFCR) and packing of the incoming auxiliary materials is therefore omitted in this study.

- **Auxiliary materials production**: many auxiliary materials which are used during manufacturing of vegetable oil and proteinmeal products are not available from the EF database. Production of these chemicals was therefore modelled using proxies, which are all fully compliant with the EF reference package. For confidentiality reasons, only the proxies for materials used by more than three companies in either the crushing or refining process are disclosed in Table 5 and listed alphabetically for all processes instead of per process.

Table 5: Proxies used for auxiliary material production modelling

Auxiliary material	Proxy dataset Ecoinvent EF 2.0 node	UUID
Hexane	Pentane production {RER} | technology mix | production mix, at plant | 100% active substance | LCI result	18646e52-3f27-43de-81bb-68b82ba1538c
Bleaching earth	Activated bentonite production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result	971bc6e6-237e-4ce0-8c04-f71955c2e6aa

- **Energy production:** The proxies that were used to model energy production are listed in Table 6. All processes are fully compliant with the EF reference package. Since an identical proxy from an aggregated dataset was used to model steam produced by steam boilers and CHP's, it is not opportune to modify the efficiencies to a weighted average efficiency as reported by the member companies. Indeed, a certain error margin is expected due to the proxy and therefore a slightly adjusted efficiency is not expected to produce a gain in accuracy of the impact calculation. It should be noted that water and fuel input for the steam boilers and CHP's is included by default in the EF records. For electricity production, country-specific data were used. The mix of countries was compiled on the basis of the data supplied. For photovoltaic electricity, only data from France are available in the EF database and have been used as a proxy for photovoltaic electricity from other countries as well. For steam and heat production, EU-28+3 datasets were used. Country-specific datasets are not available in the EF database.

Table 6: Proxies used for energy production modelling

Energy input	**Proxy dataset from Sphera EF2.0 node**	**UUID**	**Comment**
Electricity from photovoltaic [country]	Electricity from photovoltaic {FR} | AC, technology mix of CIS, CdTE, mono crystalline and multi crystalline | production mix, at plant | 1kV – 60kV | LCI result	f84ba014-38d8-49ª0-8cdb-3aef6cb7bc5e	Only available for FR
Steam from CHP on natural gas	Process steam from natural gas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 90% efficiency | LCI result	2e8bee44-f13b-4622-9af3-74954af8acea	/
Steam from natural gas boiler	Process steam from natural gas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 90% efficiency | LCI result	2e8bee44-f13b-4622-9af3-74954af8acea	/
Heat from natural gas	Thermal energy from natural gas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 100% efficiency | LCI result	81675341-f1af-44b0-81d3-d108caef5c28	

CHAPTER 4 LIFE CYCLE INVENTORY ANALYSIS

4.1. MODELLING CHOICES

This section summarizes the modelling choices that were made for the applicable aspects listed below. More specific information on these aspects is provided in section 5.3.

Agricultural production: the Agri-footprint® 5.0 economic allocation database (Paassen et al., 2019) has been used for agricultural modelling. This database complies to all modelling guidelines as described in the PEF. This is also stated on the SimaPro website: "The methodologies and data quality in Agri-footprint 5.0 are compliant with the PEF initiative of the European commission, ILCD and ReCiPe, and have been reviewed by RIVM (Dutch national institute for public health and the environment)." Heavy metal uptake by the crop is not modelled, the Agri-footprint 5.0 database is not compatible with the EF 3.0 reference package on this topic (see also PEFCR).

Transport and logistics: Transportation distances are provided in the life cycle inventory tables in the Excel file 'PEFCR vegetable oil products – Life Cycle Inventory' and are based on weighted average transport distances reported by the companies. Transportation modes for road transports are the transportation modes most often reported by the companies being a 20-26 ton truck. The Euro class is the EUR4 class, which is the default Euro class mentioned in the PEF method. Also, payloads have been taken from the PEF method, with a payload of 50% for bulk transports and a 64% for non-bulk transport.
Transport of crops to vegetable oil and proteinmeal factories (bulk): company-specific data were used (see Excel file 'PEFCR vegetable oil products – Life Cycle Inventory');
Transport of auxiliary materials (bulk and non-bulk) to vegetable oil and proteinmeal factories: company-specific data were used (included in the LCI tables in the accompanying Excel file 'PEFCR vegetable oil products – Life Cycle Inventory');
Distribution of finished products to vegetable oil and proteinmeal customer: distribution of bulk products other than bulk refined oil has been modelled using a default transport distance and mode of 150 km by truck. For transport of bulk refined oil, company specific data have been collected. Few companies were able to provide these data, as a consequence equal weighted average transport distances have been applied to all oil types.

Storage and retail: Storage of harvested crops at farms: included in the Agri-footprint database;
Storage of finished products at vegetable oil and proteinmeal factories: initially included in distribution life cycle phase (meets the 3% cut-off rule and therefore not included in the PEF study);
Retail from FEDIOL customer to end consumer: out of scope.

Electricity use: the Sphera node of the EF 2.0 database was used to model electricity and heat production. Electricity was modelled as described in the PEFCR, section 5.8.

Sampling procedure: A sampling procedure according to a certain protocol was not applied. However, in order to generate a sector-representative environmental profile of the products, life cycle inventory data were collected by 10 companies for in total 28 plants. The site-specific data were averaged and weighted based on production volumes to create an aggregated dataset.

Greenhouse gas emissions and removals: a simplified modelling approach was used to model biogenic carbon emissions. Except biogenic methane emission, no other biogenic emissions or uptakes from the atmosphere are included. Choosing the simplified modelling approach is an option offered by the PEF method. The characterisation factors for carbon dioxide, biogenic are set to zero in the EF method, only biogenic methane has a characterization factor. The records with agricultural production from

Agri-footprint database do not consider uptake of CO_2. In theory the model should give correct results, omitting biogenic carbon emissions, except biogenic methane emissions. However, we cannot be sure that nowhere in the value chain errors have been made and biogenic carbon has been classified as fossil carbon. Checking this is beyond the scope of this project.

Offsets: not applicable.

4.2. HANDLING MULTI-FUNCTIONAL PROCESSES

Multi-functional processes are handled according to the prescriptions of the PEFCR, section 5.7. For the agricultural processes energy allocation has been applied and also for the vegetable oil and proteinmeal industry processes energy allocation has been applied. Energy allocation holds the middle between mass and economic allocation. Energy allocation assigns more environmental impact to the oil than mass allocation does, but also more to the meal than economic allocation does. Basing allocation on prices (economic allocation) is considered too variable, even when average prices over larger time spans (e.g. five years) are taken.

4.3. DATA COLLECTION

In the inventory phase all data that are necessary 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.

Primary data have been collected for:

- Transport distances and mode of raw materials to crushing and/or refining facilities;
- crushing of rapeseed, soybeans, sunflower seeds and maize germs soybeans;
- refining of rapeseed, soybeans, sunflower seeds, maize germs, palm oil, palm kernel oil and coconut oil.

For agricultural production processes and crude oil production from palm, palm kernel and coconut amongst others, average background data have been used.

The inventory phase is performed according to PEF method, with exception of data quality rating which is out of scope for this project. The data inventory process is focused on the life cycle phases mentioned in Table 2.

For the phases that refer directly to the activities of the FEDIOL member companies, specific data are gathered by a selection of companies (10), representing 28 production sites. The provided data are applicable to 33% of the sector.

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 mass. Company-specific data will never be made available for any party.

In case less than three datasets are available for a specific process or product, a weighted average of the available data has been made, however, these data are not listed in the LCI Excel table and a detailed environmental profile could not be provided in this report. It concerns the crushing step of maize germ oil and refining of coconut oil.

Names of auxiliary materials have been included in the LCI's when three or more companies use the same material in that specific process. If not, they are lumped under 'other auxiliary materials'. In case the auxiliary material concerns a chemical substance, the name of the chemical substance has been used, not the brand name.

Cut-off

According to the product category rules for vegetable oil and proteinmeal industry products, capital goods, packaging materials of incoming materials, warehouses, logistic resources and waste can be excluded and are therefore not considered in this study. More information on the excluded process can be found in Annex I.

4.3.1. LIFE CYCLE INVENTORY RAW MATERIALS ACQUISITION AND PRE-PROCESSING: AGRICULTURE AND TRANSPORT

The background data on **agriculture**, i.e. growing of rapeseed, maize, sunflower and soybean, that were used in this study were obtained from the Agri-footprint[7] database (Agri-footprint 5 – energy allocation). Company-specific data on purchased amounts of rapeseed, maize germs, sunflower seeds and soybeans and their countries of origin were provided by all sites. These data were combined into an averaged and weighted dataset. The life cycle inventories are shown in the Excel file 'PEFCR vegetable oil products – Life Cycle Inventory', where the amounts are given per tonne output of the crushing process. Life cycle inventory data on agricultural production have been taken from the Agri-footprint database, but they can differ between different sources. Testing of the influence of different sources of LCI data on agricultural production is outside the scope of this study, but the uncertainty related to the inventory should be kept in mind when interpreting the results.

The Agri-footprint database takes into account land use change.

Rapeseed input:

Modelled with average background data from Agri-footprint database.

Rapeseed drying is included in the Agri-footprint record for rapeseed cultivation, the drying is assumed to take please at the farm.

Rapeseed is purchased in 26 different countries. The largest share (16%) comes from Germany.

Soybean input:

Modelled with average background data from Agri-footprint database.

It is not clear whether drying of soybeans is included in the Agri-footprint record for soybean cultivation. Nevertheless, the dry matter content of the soybeans in Agri-footprint corresponds to the dry matter content reported by the companies. The dry matter content of the soybeans from the Agri-footprint database is 0.89kg/kg. The water content in the soybeans received by the companies is 12 or 11%. This corresponds to the water content in the Agri-footprint record. Most soybeans originate from US or Brazil. A minor part comes from other regions in the world.

Sunflower input:

Modelled with average background data from Agri-footprint.

The dry matter content of the sunflower seeds from the Agri-footprint database is 0.93kg/kg. The weighted average water content in the sunflower seeds received by the companies is 6.6%. This corresponds to the water content in the Agri-footprint record. Most sunflower seeds purchased by the participating companies originate from Hungary, France and Romania.

Maize germ input:

Modelled with average background data from Agri-footprint.

Maize germ oil producing companies purchase maize germs. The Agri-footprint records used to model maize germs with are 'Maise germ dried, at processing/{country}'. The dry matter content of the maize germs, dried, from Agri-footprint database is 0.92kg/kg.

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[7] Note that Agri-footprint 5 is filled in under 'data source', although it is not an official EF node.

The LCI on **transport of these raw materials** (rapeseed, soybean, sunflower seed, maize germ) **to the FEDIOL factories** is given in the Excel file 'PEFCR vegetable oil products – Life Cycle Inventory'. Company-specific information on transport loads, distances and transport modes was provided by (almost) all sites. These data were combined into an averaged and weighted dataset. For road transport, Euro 4, diesel driven trucks (20 - 26t) with an assumed loading rate of 50%. The loading rate and Euro class are the defaults suggested for bulk transport by Zampori and Pant (2019). The selected truck size (20-26t) is the truck size most often reported by the participating companies for transport of agricultural products to their site.

4.3.2. LIFE CYCLE INVENTORY RAW MATERIALS ACQUISITION AND PRE-PROCESSING: CRUDE OIL AND TRANSPORT

For palm oil, palm kernel oil and coconut oil, raw material acquisition concerns the acquisition of respectively crude palm oil, crude palm kernel oil and crude coconut oil. The data on crude oil production have been taken from the Agri-footprint database and as such represent a generic situation. Similar to the inventory data for agricultural production, data on crude oil production might differ between different sources. Testing of the influence of different sources of LCI data on crude oil production is outside the scope of this study, but the uncertainty related to the inventory should be kept in mind when interpreting the results. For palm oil, there is a big difference in GHG emissions if methane capture from palm oil mill effluent is applied or not. Methane capture is not included in the generic record on palm (kernel) oil production. Sourcing crude palm (kernel) oil from plants applying methane capture will have an effect on the results. Effects of land use change of palm and coconut cultivation are taken into account in the Agri-footprint database.

Crude palm oil

Modelled with average background data from Agri-footprint.

Crude palm oil is sourced from different regions in the world (Colombia, Guatemala, Papua New Guinea…). The Agri-footprint database however only contains data for crude palm oil from Indonesia, Malaysia and Thailand. Other countries are not available in the database. The input of crude oil from Indonesia and Malaysia as reported by the companies was therefore scaled to 100%[8].

Crude palm kernel oil

Modelled with average background data from Agri-footprint.

Similar to crude palm oil, crude palm kernel oil is sourced from different regions in the world (Colombia, Guatemala, Papua New Guinea…), but Agri-footprint database contains data for crude palm kernel oil only from Indonesia, Malaysia and Thailand. Other countries are not available in the database. The input of crude palm kernel oil from Indonesia and Malaysia as reported by the companies was therefore scaled to 100%[8].

Crude coconut oil

Modelled with average background data from Agri-footprint.

Crude coconut oil is sourced from different regions in the world and has been modelled with Agri-footprint datasets. No information on the country of origin of the crude coconut oil can be given because confidentiality must be safeguarded.

The LCI on **transport of these raw materials** (crude palm oil, crude palm kernel oil, crude coconut oil) **to the FEDIOL refineries** is given in the Excel file 'PEFCR vegetable oil products – Life Cycle Inventory'. Company-specific information on transport loads, distances and transport modes was provided by (almost) all sites. This data was combined into an averaged and weighted dataset. For road transport, Euro 4, diesel driven trucks (20 - 26t) with a loading rate of 50% were assumed. The loading rate and

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[8] Only Malaysia and Indonesia where used as proxies and not Thailand, as a substantial part of the crude oil purchased by Fediol Member companies already comes from these two countries.

Euro class are the defaults suggested for bulk transport by Zampori and Pant (2019). The selected truck size (20-26t) is the truck size most often reported by the participating companies for transport of crude oil to their sites.

4.3.3. LIFE CYCLE INVENTORY MANUFACTURING: CRUSHING

This life cycle stage starts with the reception and storage of the raw materials. The life cycle stage includes the production of electricity, steam, water and chemicals needed for crushing. The life cycle stage also includes emission to air (e.g. hexane emission or emissions from burning of fuels) and the release of emissions to water via wastewater treatment. For this life cycle stage, company specific data have been collected for rapeseed, soybean, sunflower seed and maize germ crushing. For each of the input and output flows a weighted average dataset (based on the total output volume of the crush) has been established. Crushing uses hexane, most of which is released during the crushing process itself. However, part of the hexane will be released further down the value chain. The emissions of hexane are modelled according to the instructions of the PEFCR, which means that all hexane is emitted during the crushing phase.
The life cycle inventory data are available in the Excel file ‘PEFCR vegetable oil products – Life Cycle Inventory’.

Crushing of palm, palm kernel and coconut does not take place in Europe by FEDIOL member companies. Data on the crushing of these products has therefore been taken from the Agri-footprint database and is for these products included in the life cycle stages ‘raw materials acquisition and pre-processing’, see section 4.3.2.Life cycle inventory manufacturing: transport to oil processing
The transport of crude palm, crude palm kernel and crude coconut oil is already included in the life cycle stage ‘raw materials acquisition and pre-processing: crude oil and transport.
In case of rapeseed, sunflower, soybean, maize, it can happen that externally crushed oils (this can concern crushing by the same company at another location or crushing by another company) are processed by the refining company. The crude oil is transported to the oil processing facility.

4.3.4. LIFE CYCLE INVENTORY MANUFACTURING: OIL PROCESSING

This life cycle stage starts with the reception of crude oil. Oil processing includes refining, either chemical refining or physical refining and in some cases also modification. It turned out to be very difficult for the companies to split inputs and outputs for refining and modifications. Therefore, it was decided to not split this life cycle stage into the two sub-processes refining and modification, but rather to keep both processing steps together in oil processing. Oil processing includes the production of electricity, steam, chemicals. Also, emissions to air and water (via wastewater) can take place. For this life cycle stage, company specific data have been collected for all oil types included in the study. For each oil type, a weighted average dataset (based on the total output volume of the refining) has been established. The life cycle inventory data are available in the Excel file ‘PEFCR vegetable oil products – Life Cycle Inventory’.

4.3.5. LIFE CYCLE INVENTORY DISTRIBUTION

→ Transport of output products from crushing

For this study, it is assumed that output products of crushing are transported over 150 km with a large truck. This distance is in line with the distance applied in the FEED PEFCR (page 115/119, PEFCR FEED) for transport of meal from the feed mill to the farm. Company specific data were not collected for this transport step. We have used a >32t EURO 4 truck, which is the default truck type, proposed by Zampori and Pant (2019) for direct transport from factory to final client. The applied loading rate is 50%, the default rate for bulk products.

→ **Transport of output products from oil processing**

For bulk co-products from oil refining, similar to crude oil and co-products of the crushing process, a distance of 150 km with a large truck has been assumed for outbound transport.

The transport scenario for bulk refined oils consist of 329 km per truck, 1.75 E-5 km per train, 7.53 km per barge and 106.5 km witch a transoceanic ship (weighted average company specific data).

Storage in warehouses is not included. Most products go directly to the customer.

4.4. DATA QUALITY RATING

Calculations of DQR scores as required by the PEF method are not part of this project. Below we provide some qualitative information on data quality.

Time-related data coverage: primary data obtained from companies are data for one year, in most case 2020 has been used as a reference year. In case this year was deemed not representative by the company (due to COVID pandemic), they switched to 2019 which rarely happened. The background data are taken from the Agri-footprint database v5 and the EF 2.0 database. The time representativeness differs between the different datasets but is in general lower compared to the time representativeness of primary data. Agricultural processes heavily determine the environmental profile. Crop yield data are averaged over the years 2012-2016, nutritional input from manure is based on data from FAOSTAT 2012-2016 , water use values are from 2010. Data on crushing of palm, palm kernel and coconut are data taken from publications dating between 2006 and 2012. Time representativeness of data from EF database is as indicated in the datasets. Electricity datasets for example have 2012 as reference year.

Geographical coverage: primary data on the crushing and refining process are weighted average data from companies participating in the data collection. All sites are located in Europe. The electricity mix is weighted pro rata the mass of oilseeds crushed and mass of oil refined in the respective countries of sites which delivered data. For heat and steam, the average European mix (EU28+3) as provided in the EF database has been used. Data for auxiliary materials come from EF database and can either represent a production in EU or a Global production, depending on data availability. Data on agricultural production taken from Agri-footprint are country specific. For the agricultural production of rapeseed, sunflower, soyabeans and maize, in exceptional cases there was no dataset available for a specific geographic origin. In these cases, a proxy was used, the proxy chosen being a nearby country (e.g. proxy for Croatia is Italy). For crude palm and crude palm kernel oil production, few geographies were available in the Agri-footprint database (only Indonesia and Malaysia), meaning that often proxies had to be selected. For crude palm oil originating from Columbia, Guatemala, Honduras, Papua New Guinea and other confidential origins, crude palm oil from Indonesia and Malaysia has been used as a proxy. For crude palm kernel oil originating from Colombia, Guatemala, Papua New Guinea and other confidential origins, crude palm kernel oil from Indonesia and Malaysia has been used as a proxy.

Technological coverage: Primary data represent weighted averages of companies participating in the data collection and as such represent as good as possible the average technology within Europe. It contains both multi-refineries as well as single refineries and both chemical and physical refining.

Precision: Data on crushing and refining are primary data. Background data are taken from the indicated databases and have different precision levels.

Completeness: All relevant data have been considered. Some processes were not included as their contribution is below the cut-off limit of 3% in total. These processes are capital goods for the manufacturing processes of the vegetable oil and proteinmeal industry; packaging of incoming auxiliary materials; storage of refining products; resources and tools for logistic operations at the vegetable oil and proteinmeal plants; process waste (excluding wastewater). Company specific data have been checked for each site on their completeness and were discussed in bilateral meetings with the companies.

Representativeness: the study is representative for the European oilseed crushing and vegetable oil refining industry.

Consistency: Data consistency has been checked thoroughly by comparing overall site level data with crop/process specific data, mass balance check, check on outliers in the entire dataset. Data consistency was discussed with the individual companies during bilateral meetings.

Reproducibility: Detailed life cycle inventory data are provided in the accompanying excel file allowing for reproduction of the results.

Data sources: Primary data are provided directly by FEDIOL member companies, secondary data have been retrieved from established databases, being Agri-footprint v5 and EF v2.0.

4.5. LIFE CYCLE INVENTORY RESULTS

In this section, exemplary results of the LCI are presented for the crushing and refining processes. The results presented in Table 7 are results for one tonne of product output from either the crushing or refining process.

Table 7: LCI results for crushing and refining process, per tonne output

	CO_2 fossil (kg)	CH_4 fossil (kg)	SO_2 (kg)	NO_x (kg)
rapeseed crushing	63,44	0,18	0,03	0,05
soybean crushing	66,52	0,19	0,02	0,05
sunflower crushing	47,80	0,13	0,04	0,07
maize germ crushing	45,47	0,13	0,05	0,09
rapeseed refining	57,86	0,15	0,06	0,06
soybean refining	118,84	0,29	0,13	0,15
sunflower refining	56,18	0,15	0,07	0,08
maize germ refining	60,76	0,16	0,09	0,10
palm refining	114,66	0,29	0,11	0,13
palm kernel refining	87,78	0,23	0,11	0,10
coconut refining	80,84	0,20	0,05	0,08

CHAPTER 5 IMPACT ASSESSMENT RESULTS

Usually, the inventory process generates a long list of data, which may be difficult to interpret. Life cycle impact assessment (LCIA) is a tool to relate 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 comprehensible. In section 5.1 the characterised results are given for each of the products and co-products mentioned in Table 1. Section 5.2 contains a sensitivity assessment, testing the influence of the choice of allocation method. Section 5.3 contains normalised and weighted environmental profiles.

5.1. INDIVIDUAL ENVIRONMENTAL PROFILES

This paragraph discusses the individual environmental profiles of the vegetable oil and proteinmeal industry products. This allows to get a clear insight into 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 of reference product”.

The environmental profile can be subdivided into different life cycle phases (Raw material acquisition and pre-processing: agriculture; Raw material acquisition and pre-processing: packaging; Raw material acquisition and pre-processing: transportation; Manufacturing and Distribution). For the life cycle phases which occur at the FEDIOL member companies, contribution to the environmental impact can be attributed to different process elements, i.e. the use of auxiliary materials, energy or water, water treatment and transportation. The interpretation of the results is described in CHAPTER 6, following PEF methodology. Normalised and weighted results as absolute values and weighted results as single scores are presented in Annex II (see also section 5.3).

5.1.1. CRUDE OIL AND CO-PRODUCTS FROM RAPESEED

During the production of crude oil from rapeseeds, two co-products are produced. The co-products considered in this study are meal and lecithin. The environmental profiles from crude oil and the co-products from the crushing process are presented below (Figure 8 till Figure 10) together with the absolute values of the characterised results (Table 8 till Table 10). Impacts are expressed per tonne output product. The three products are outputs of the crushing process, but due to the energy allocation method, they receive different impacts per tonne product.

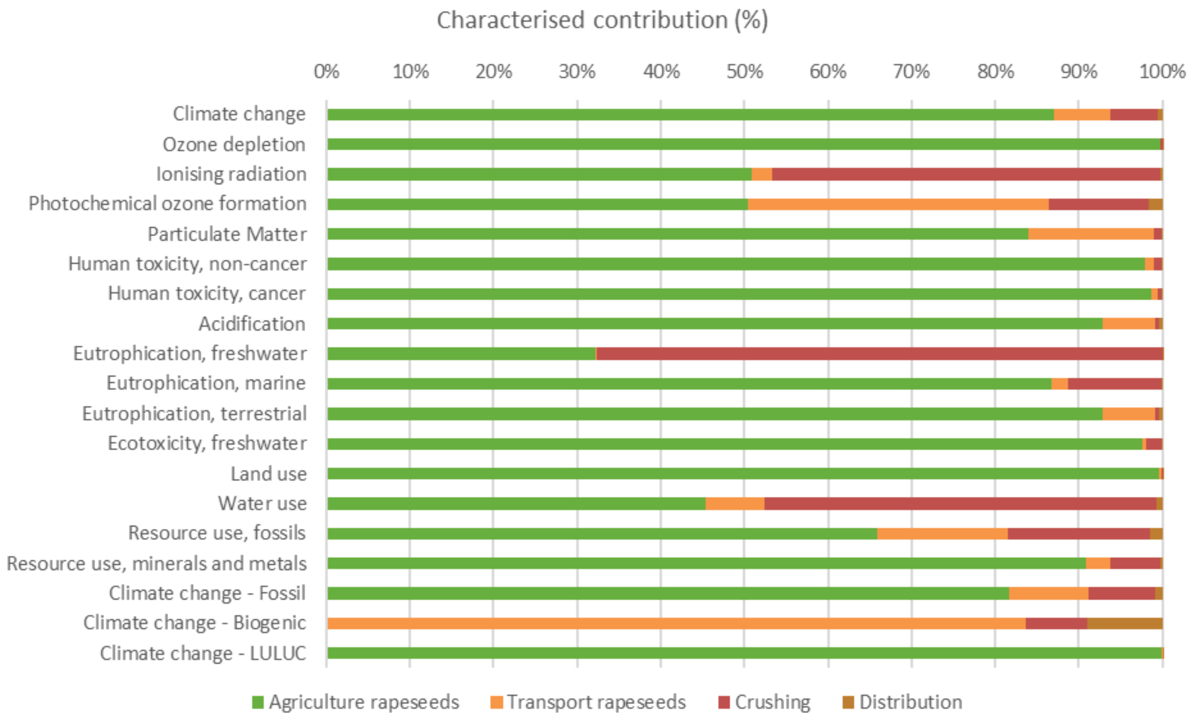

Figure 8: Environmental profile of 1 tonne crude oil from rapeseeds

Table 8: Characterised results per tonne crude oil from rapeseeds

Characterised contribution	Unit	Total	Agriculture rapeseeds	Transport rapeseed	Crushing	Distribution
Climate change	*kg CO_2 eq*	1,86E+03	1,62E+03	1,27E+02	1,03E+02	1,18E+01
Ozone depletion	*kg CFC11 eq*	6,22E-06	6,20E-06	7,33E-10	1,81E-08	4,47E-11
Ionising radiation	*kBq U-235 eq*	2,04E+01	1,02E+01	8,18E-01	9,31E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	4,25E+00	2,14E+00	1,53E+00	5,10E-01	6,96E-02
Particulate Matter	*disease inc.*	1,78E-04	1,50E-04	2,66E-05	1,59E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	9,95E-05	9,75E-05	1,04E-06	9,38E-07	8,47E-08
Human toxicity, cancer	*CTUh*	2,63E-06	2,60E-06	1,96E-08	1,16E-08	1,87E-09
Acidification	*mol H^+ eq*	2,21E+01	2,05E+01	1,37E+00	1,19E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	1,25E+00	4,04E-01	6,94E-04	8,47E-01	7,38E-05
Eutrophication, marine	*kg N eq*	2,74E+01	2,38E+01	5,68E-01	3,05E+00	3,68E-02
Eutrophication, terrestrial	*mol N eq*	9,83E+01	9,13E+01	6,24E+00	3,82E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	2,34E+05	2,28E+05	1,23E+03	4,28E+03	1,17E+02
Land use	*Pt*	2,26E+05	2,25E+05	4,53E+02	2,61E+02	4,82E+01
Water use	*m^3 depriv.*	6,09E+01	2,76E+01	4,40E+00	2,85E+01	4,55E-01
Resource use, fossils	*MJ*	1,04E+04	6,84E+03	1,65E+03	1,75E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,68E-04	2,44E-04	8,14E-06	1,59E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	1,31E+03	1,07E+03	1,26E+02	1,03E+02	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	2,35E-01	0,00E+00	1,97E-01	1,73E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	5,46E+02	5,45E+02	7,89E-01	1,47E-02	8,42E-02

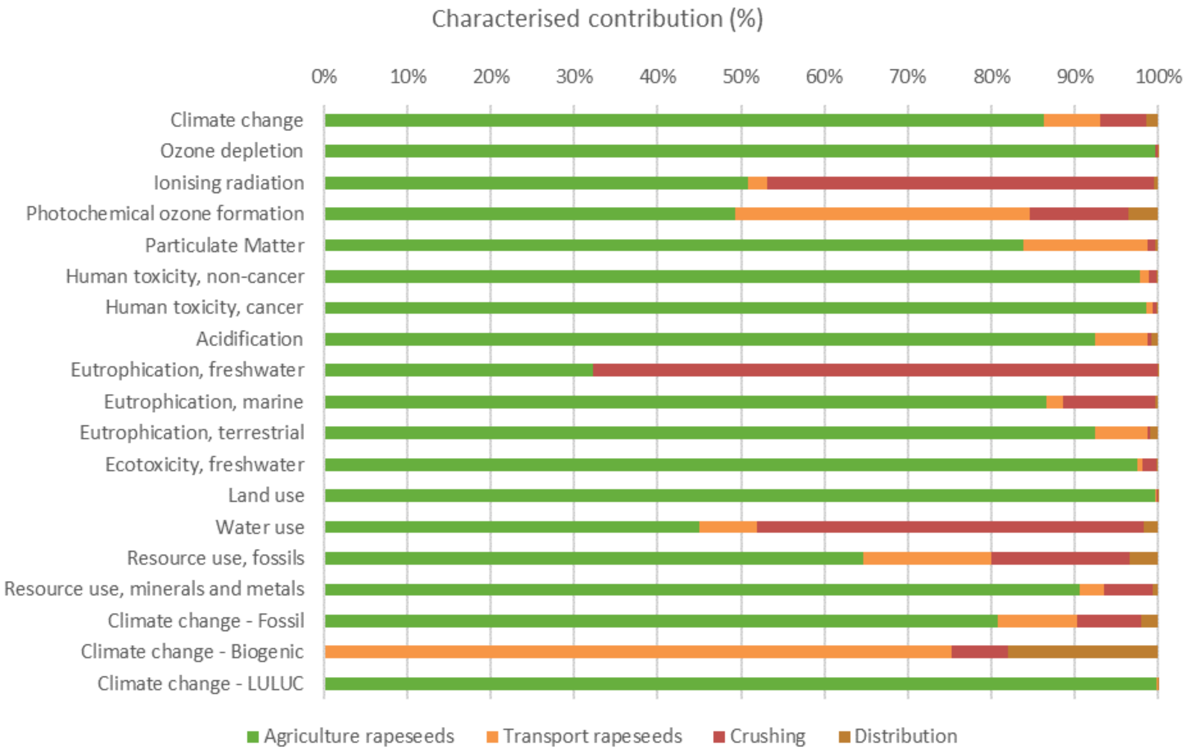

Figure 9: Environmental profile of 1 tonne meal from rapeseeds

Table 9: Characterised results per tonne meal from rapeseeds

Characterised contribution	Unit	Total	Agriculture rapeseeds	Transport rapeseeds	Crushing	Distribution
Climate change	*kg CO_2 eq*	8,35E+02	7,21E+02	5,67E+01	4,61E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	2,77E-06	2,77E-06	3,27E-10	8,07E-09	4,47E-11
Ionising radiation	*kBq U-235 eq*	9,12E+00	4,56E+00	3,65E-01	4,15E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	1,93E+00	9,54E-01	6,83E-01	2,27E-01	6,96E-02
Particulate Matter	*disease inc.*	7,97E-05	6,69E-05	1,19E-05	7,08E-07	2,94E-07
Human toxicity, non-cancer	*CTUh*	4,44E-05	4,35E-05	4,64E-07	4,18E-07	8,47E-08
Human toxicity, cancer	*CTUh*	1,17E-06	1,16E-06	8,76E-09	5,18E-09	1,87E-09
Acidification	*mol H^+ eq*	9,88E+00	9,14E+00	6,12E-01	5,30E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	5,58E-01	1,80E-01	3,10E-04	3,78E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,23E+01	1,06E+01	2,53E-01	1,36E+00	3,68E-02
Eutrophication, terrestrial	*mol N eq*	4,41E+01	4,07E+01	2,78E+00	1,70E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,04E+05	1,02E+05	5,49E+02	1,91E+03	1,17E+02
Land use	*Pt*	1,01E+05	1,01E+05	2,02E+02	1,16E+02	4,82E+01
Water use	*m^3 depriv.*	2,74E+01	1,23E+01	1,96E+00	1,27E+01	4,55E-01
Resource use, fossils	*MJ*	4,73E+03	3,05E+03	7,34E+02	7,81E+02	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	1,20E-04	1,09E-04	3,63E-06	7,08E-06	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	5,92E+02	4,78E+02	5,63E+01	4,61E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	1,16E-01	0,00E+00	8,80E-02	7,70E-03	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	2,43E+02	2,43E+02	3,52E-01	6,54E-03	8,42E-02

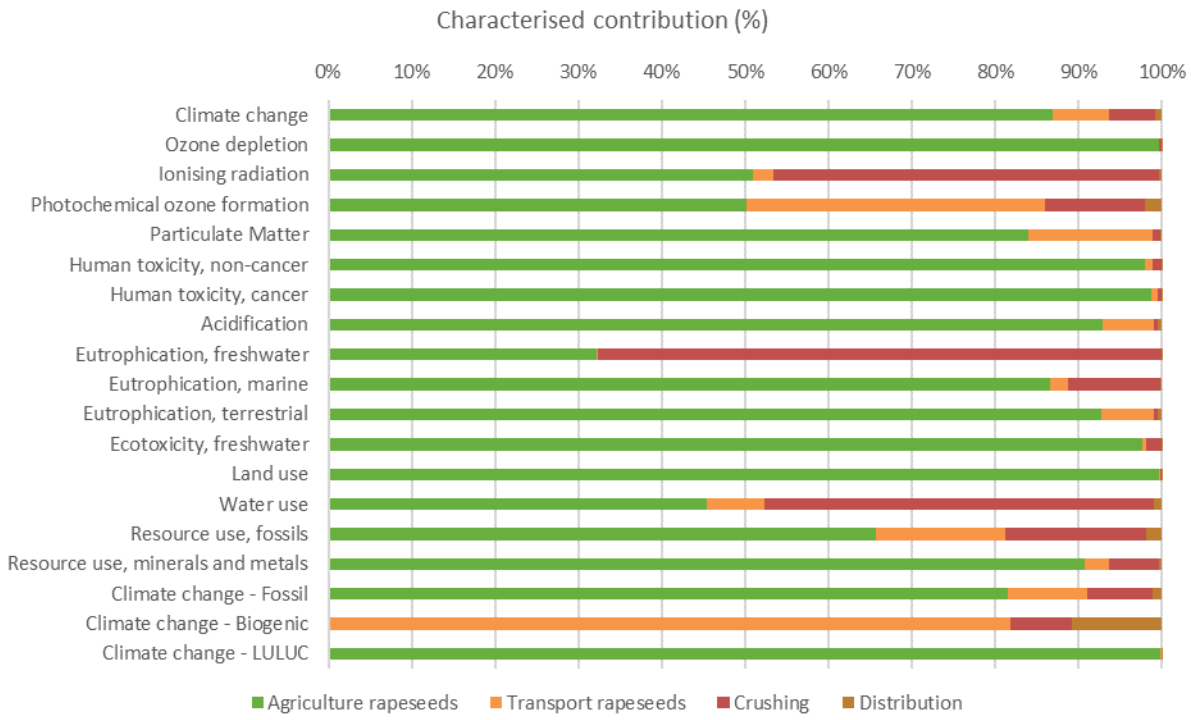

Figure 10: Environmental profile of 1 tonne lecithin from rapeseeds

Table 10: Characterised results per tonne lecithin from rapeseeds

Characterised contribution	Unit	Total	Agriculture rapeseeds	Transport rapeseeds	Crushing	Distribution
Climate change	*kg CO_2 eq*	1,51E+03	1,31E+03	1,03E+02	8,39E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	5,04E-06	5,03E-06	5,95E-10	1,47E-08	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,65E+01	8,28E+00	6,64E-01	7,54E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	3,46E+00	1,74E+00	1,24E+00	4,13E-01	6,96E-02
Particulate Matter	*disease inc.*	1,45E-04	1,22E-04	2,16E-05	1,29E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	8,07E-05	7,90E-05	8,43E-07	7,61E-07	8,47E-08
Human toxicity, cancer	*CTUh*	2,13E-06	2,11E-06	1,59E-08	9,41E-09	1,87E-09
Acidification	*mol H^+ eq*	1,79E+01	1,66E+01	1,11E+00	9,64E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	1,01E+00	3,27E-01	5,63E-04	6,87E-01	7,38E-05
Eutrophication, marine	*kg N eq*	2,23E+01	1,93E+01	4,61E-01	2,47E+00	3,68E-02
Eutrophication, terrestrial	*mol N eq*	7,98E+01	7,40E+01	5,06E+00	3,10E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,89E+05	1,85E+05	9,98E+02	3,47E+03	1,17E+02
Land use	*Pt*	1,83E+05	1,83E+05	3,68E+02	2,11E+02	4,82E+01
Water use	*m^3 depriv.*	4,95E+01	2,24E+01	3,57E+00	2,31E+01	4,55E-01
Resource use, fossils	*MJ*	8,46E+03	5,55E+03	1,33E+03	1,42E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,18E-04	1,97E-04	6,60E-06	1,29E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	1,07E+03	8,69E+02	1,02E+02	8,38E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	1,95E-01	0,00E+00	1,60E-01	1,40E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	4,42E+02	4,42E+02	6,40E-01	1,19E-02	8,42E-02

In order to gain more insight into the crushing process' inputs and outputs causing the environmental impact, the crushing process (red bars in Figure 8 till Figure 10) is subdivided in Figure 11. In this graph, the contributions to the total impact generated by the crushing process of electricity, heat, auxiliary materials, water use, wastewater and emissions to air are shown.

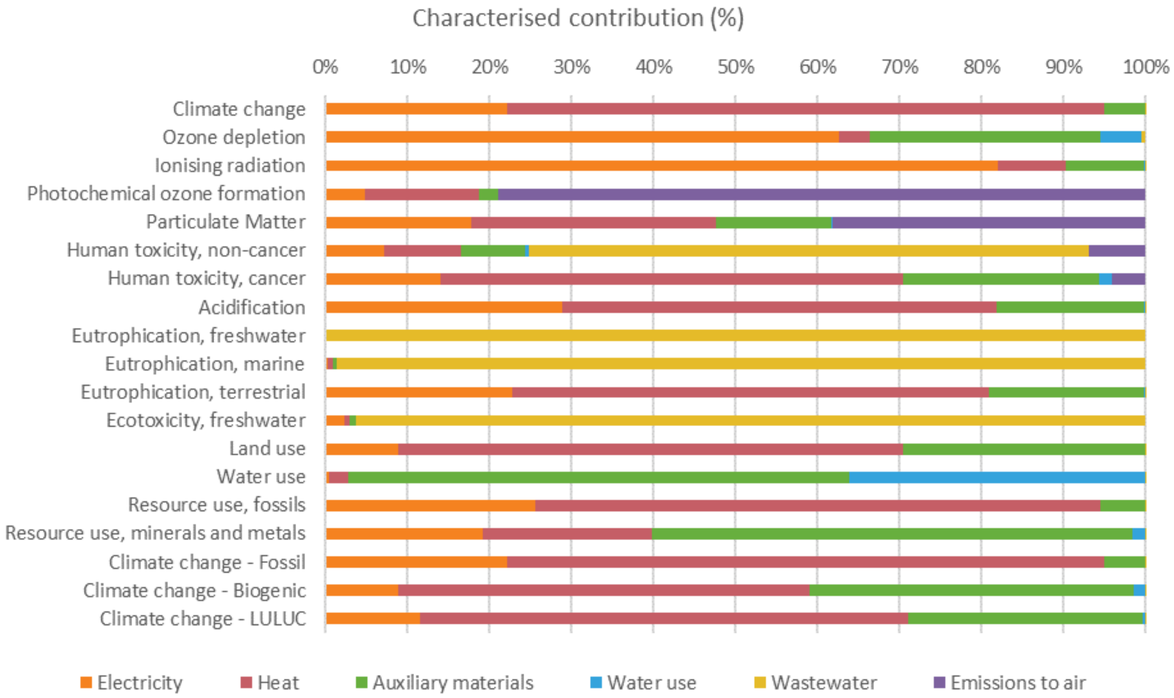

Figure 11: Contribution of inputs to environmental impact of the crushing process (of rapeseeds)

The energy use of the process, entailing both electricity and heat, is generally the main contributor to the environmental impact caused by the crushing process. Some examples where the contribution of energy is very high (80% and higher contribution to impact category), are climate change, ionising radiation, acidification, eutrophication terrestrial, resource use fossils and climate change - fossil. The use of auxiliary materials makes a rather small contribution to the environmental impact of the rapeseed crushing process, except to ozone depletion, human toxicity cancer, land use, water use, resource use minerals and metals, climate change – biogenic and - land use and land use change (LULUC) where the contribution is higher than 20%. Wastewater treatment has an important contribution to the impact categories human toxicity non-cancer, eutrophication freshwater and marine, ecotoxicity freshwater and climate change biogenic. The emissions to air, which take place during the crushing process are hexane emissions and emissions of particulates. The contribution of the hexane emission to air is clearly visible in the impact category photochemical ozone formation and hexane emissions also contribute to the impact categories human toxicity non-cancer and cancer. Emissions of particulates to air contribute to particulate matter.

5.1.2. REFINED OIL AND CO-PRODUCTS FROM RAPESEEDS

During the production of refined oil from rapeseed, several co-products are produced. The co-products considered in this study are soap stock, acid oil, deodistillates and fatty acid distillates. The environmental profiles from refined oil and the co-products from the refining process are presented below (Figure 12 till Figure 14) together with the absolute values of the characterised results (Table 11 till Table 13). The five products are outputs of the refining process, but due to the energy allocation method, they receive different impacts per tonne product. The impact reported for distribution is the same for the four co-products acid oil, deodistillates, fatty acid distillates and soap stock, but different for refined oil, as described in 4.3.5 and 5.1.

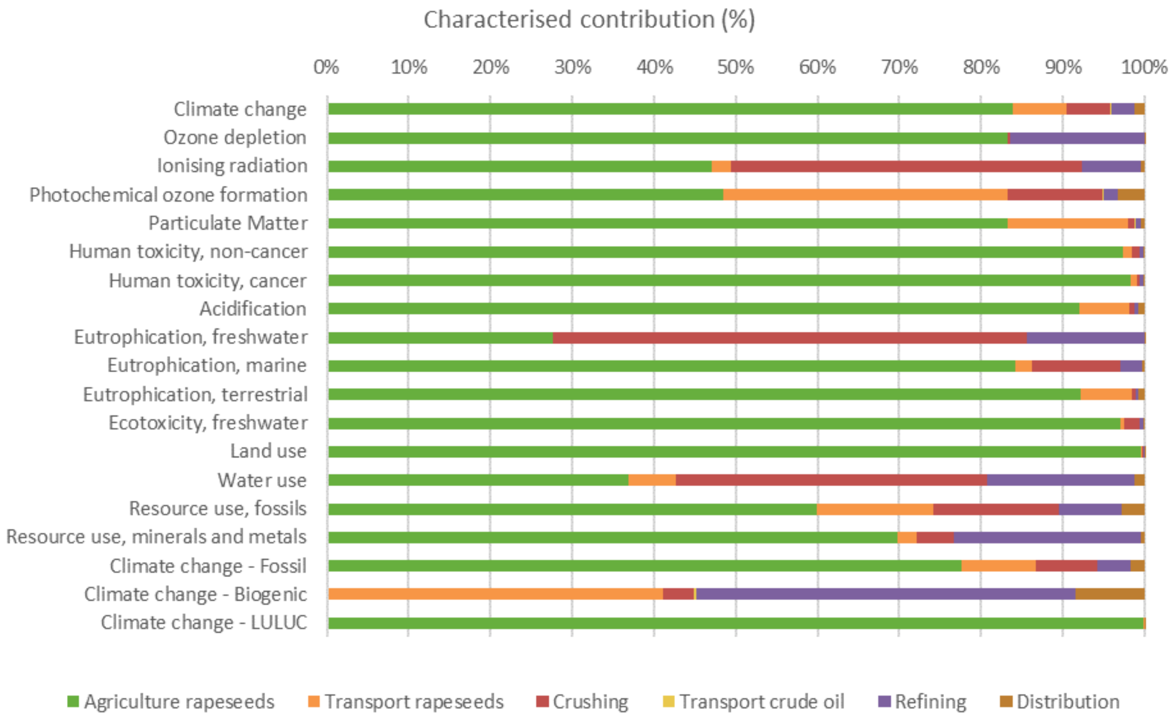

Figure 12: Environmental profile of 1 tonne refined oil from rapeseeds

Table 11: Characterised results per tonne refined oil from rapeseeds

Characterised contribution	Unit	Total	Agriculture rapeseeds	Transport rapeseeds	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	2,22E+03	1,86E+03	1,47E+02	1,19E+02	9,56E-01	6,50E+01	2,65E+01
Ozone depletion	*kg CFC11 eq*	8,59E-06	7,15E-06	8,45E-10	2,09E-08	3,39E-12	1,42E-06	9,93E-11
Ionising radiation	*kBq U-235 eq*	2,54E+01	1,18E+01	9,44E-01	1,07E+01	3,83E-03	1,81E+00	1,12E-01
Photochemical ozone formation	*kg NMVOC eq*	5,08E+00	2,47E+00	1,76E+00	5,88E-01	1,25E-02	8,56E-02	1,67E-01
Particulate Matter	*disease inc.*	2,08E-04	1,73E-04	3,07E-05	1,83E-06	2,70E-07	1,34E-06	8,24E-07
Human toxicity, non-cancer	*CTUh*	1,15E-04	1,12E-04	1,20E-06	1,08E-06	8,63E-09	5,78E-07	1,89E-07
Human toxicity, cancer	*CTUh*	3,05E-06	2,99E-06	2,26E-08	1,34E-08	1,42E-10	1,23E-08	4,22E-09
Acidification	*mol H^+ eq*	2,57E+01	2,36E+01	1,58E+00	1,37E-01	8,83E-03	1,32E-01	1,88E-01
Eutrophication, freshwater	*kg P eq*	1,69E+00	4,65E-01	8,00E-04	9,76E-01	5,59E-06	2,43E-01	1,63E-04
Eutrophication, marine	*kg N eq*	3,26E+01	2,74E+01	6,55E-01	3,52E+00	4,29E-03	8,91E-01	8,57E-02
Eutrophication, terrestrial	*mol N eq*	1,14E+02	1,05E+02	7,20E+00	4,41E-01	4,74E-02	3,06E-01	9,29E-01
Ecotoxicity, freshwater	*CTUe*	2,71E+05	2,63E+05	1,42E+03	4,94E+03	8,87E+00	1,37E+03	2,64E+02
Land use	*Pt*	2,61E+05	2,60E+05	5,23E+02	3,01E+02	3,65E+00	2,83E+02	1,06E+02
Water use	*m^3 depriv.*	8,63E+01	3,18E+01	5,08E+00	3,28E+01	3,45E-02	1,55E+01	1,00E+00
Resource use, fossils	*MJ*	1,32E+04	7,89E+03	1,90E+03	2,02E+03	1,21E+01	1,01E+03	3,60E+02
Resource use, minerals & metals	*kg Sb eq*	4,03E-04	2,81E-04	9,38E-06	1,83E-05	5,88E-08	9,23E-05	1,74E-06
Climate change - Fossil	*kg CO_2 eq*	1,59E+03	1,24E+03	1,45E+02	1,19E+02	9,48E-01	6,46E+01	2,62E+01
Climate change - Biogenic	*kg CO_2 eq*	5,47E-01	0,00E+00	2,27E-01	1,99E-02	1,57E-03	2,52E-01	4,58E-02
Climate change - LULUC	*kg CO_2 eq*	6,29E+02	6,28E+02	9,09E-01	1,69E-02	6,38E-03	1,06E-01	1,86E-01

Deodistillates and acid oils have an equal environmental profile as their energy content and distribution scenario is equal. Their environmental profile is presented in Figure 13.

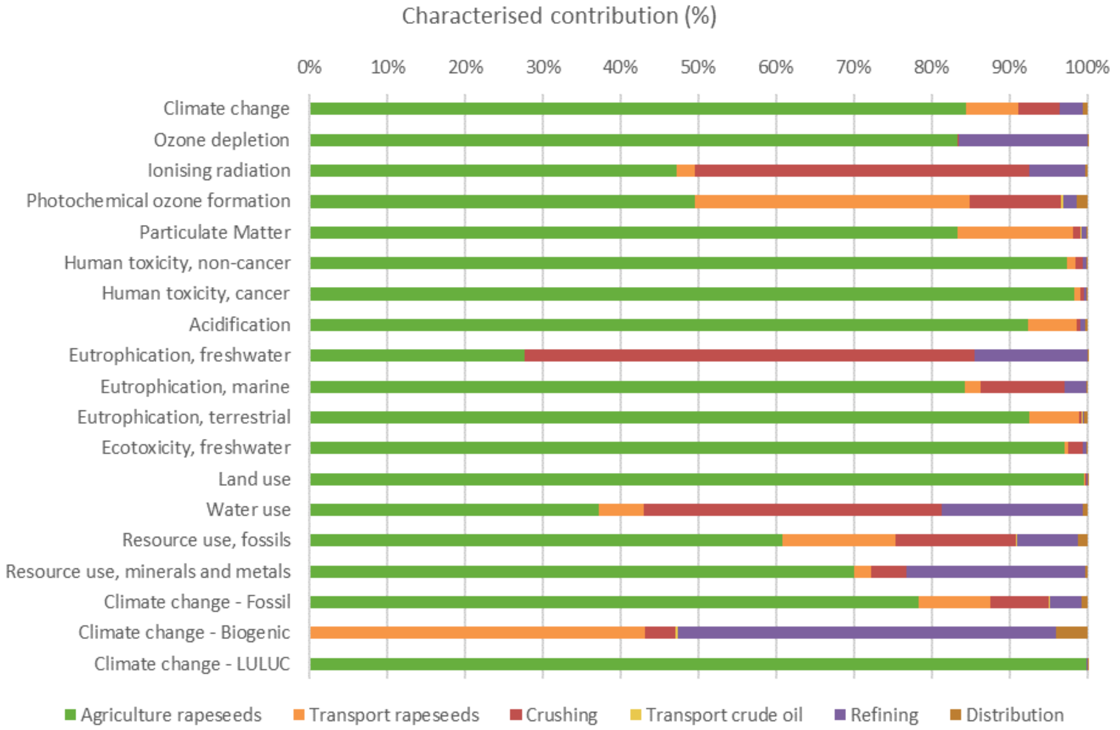

Figure 13: Environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from rapeseeds

Table 12: Characterised results per tonne acid oil, deodistillates or fatty acid distillates from rapeseeds

Characterised contribution	Unit	Total	Agriculture rapeseeds	Transport rapeseeds	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	2,21E+03	1,86E+03	1,47E+02	1,19E+02	9,47E-01	6,50E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	8,59E-06	7,15E-06	8,45E-10	2,09E-08	3,36E-12	1,42E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	2,53E+01	1,18E+01	9,44E-01	1,07E+01	3,79E-03	1,81E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	4,99E+00	2,47E+00	1,76E+00	5,88E-01	1,24E-02	8,56E-02	6,96E-02
Particulate Matter	*disease inc.*	2,07E-04	1,73E-04	3,07E-05	1,83E-06	2,68E-07	1,34E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	1,15E-04	1,12E-04	1,20E-06	1,08E-06	8,55E-09	5,78E-07	8,47E-08
Human toxicity, cancer	*CTUh*	3,04E-06	2,99E-06	2,26E-08	1,34E-08	1,40E-10	1,23E-08	1,87E-09
Acidification	*mol H^+ eq*	2,56E+01	2,36E+01	1,58E+00	1,37E-01	8,75E-03	1,32E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	1,69E+00	4,65E-01	8,00E-04	9,76E-01	5,54E-06	2,43E-01	7,38E-05
Eutrophication, marine	*kg N eq*	3,25E+01	2,74E+01	6,55E-01	3,52E+00	4,25E-03	8,91E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	1,14E+02	1,05E+02	7,20E+00	4,41E-01	4,70E-02	3,06E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	2,71E+05	2,63E+05	1,42E+03	4,94E+03	8,79E+00	1,37E+03	1,17E+02
Land use	*Pt*	2,61E+05	2,60E+05	5,23E+02	3,01E+02	3,62E+00	2,83E+02	4,82E+01
Water use	*m^3 depriv.*	8,57E+01	3,18E+01	5,08E+00	3,28E+01	3,42E-02	1,55E+01	4,55E-01
Resource use, fossils	*MJ*	1,30E+04	7,89E+03	1,90E+03	2,02E+03	1,20E+01	1,01E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	4,02E-04	2,81E-04	9,38E-06	1,83E-05	5,83E-08	9,23E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	1,58E+03	1,24E+03	1,45E+02	1,19E+02	9,39E-01	6,46E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	5,22E-01	0,00E+00	2,27E-01	1,99E-02	1,56E-03	2,52E-01	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	6,29E+02	6,28E+02	9,09E-01	1,69E-02	6,32E-03	1,06E-01	8,42E-02

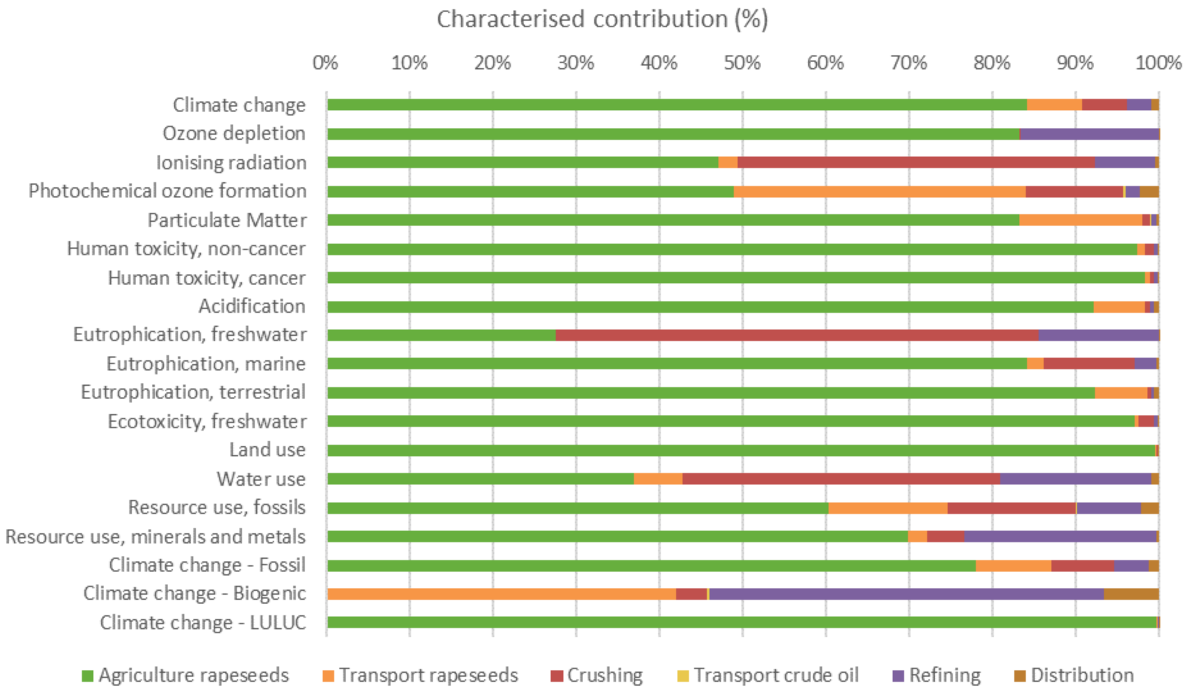

Figure 14: Environmental profile of 1 tonne soap stock from rapeseeds

Table 13: Characterised results per tonne soap stock from rapeseeds

Characterised contribution	Unit	Total	Agriculture rapeseeds	Transport rapeseeds	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	1,33E+03	1,12E+03	8,80E+01	7,15E+01	5,73E-01	3,90E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	5,15E-06	4,29E-06	5,07E-10	1,25E-08	2,03E-12	8,51E-07	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,52E+01	7,07E+00	5,66E-01	6,44E+00	2,30E-03	1,09E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	3,02E+00	1,48E+00	1,06E+00	3,53E-01	7,49E-03	5,14E-02	6,96E-02
Particulate Matter	*disease inc.*	1,24E-04	1,04E-04	1,84E-05	1,10E-06	1,62E-07	8,04E-07	2,94E-07
Human toxicity, non-cancer	*CTUh*	6,92E-05	6,74E-05	7,19E-07	6,49E-07	5,18E-09	3,47E-07	8,47E-08
Human toxicity, cancer	*CTUh*	1,83E-06	1,80E-06	1,36E-08	8,03E-09	8,49E-11	7,40E-09	1,87E-09
Acidification	*mol H^+ eq*	1,54E+01	1,42E+01	9,49E-01	8,23E-02	5,30E-03	7,92E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	1,01E+00	2,79E-01	4,80E-04	5,86E-01	3,36E-06	1,46E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,95E+01	1,65E+01	3,93E-01	2,11E+00	2,58E-03	5,35E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	6,83E+01	6,31E+01	4,32E+00	2,64E-01	2,84E-02	1,83E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,62E+05	1,58E+05	8,52E+02	2,96E+03	5,32E+00	8,24E+02	1,17E+02
Land use	*Pt*	1,57E+05	1,56E+05	3,14E+02	1,80E+02	2,19E+00	1,70E+02	4,82E+01
Water use	*m^3 depriv.*	5,16E+01	1,91E+01	3,05E+00	1,97E+01	2,07E-02	9,33E+00	4,55E-01
Resource use, fossils	*MJ*	7,86E+03	4,73E+03	1,14E+03	1,21E+03	7,28E+00	6,08E+02	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,41E-04	1,68E-04	5,63E-06	1,10E-05	3,53E-08	5,54E-05	7,76E-07
Climate change – Fossil	*kg CO_2 eq*	9,51E+02	7,41E+02	8,73E+01	7,15E+01	5,69E-01	3,88E+01	1,17E+01
Climate change – Biogenic	*kg CO_2 eq*	3,22E-01	0,00E+00	1,36E-01	1,19E-02	9,45E-04	1,51E-01	2,08E-02
Climate change – LULUC	*kg CO_2 eq*	3,78E+02	3,77E+02	5,46E-01	1,02E-02	3,83E-03	6,36E-02	8,42E-02

In order to gain more insight into the refining process' inputs and outputs causing the environmental impact, the refining process (purple bars in Figure 12 to Figure 14) is subdivided in Figure 15. In this graph, the contributions to the total impact generated by the refining process of electricity, heat, auxiliary materials, water use, wastewater and emissions to air are shown.

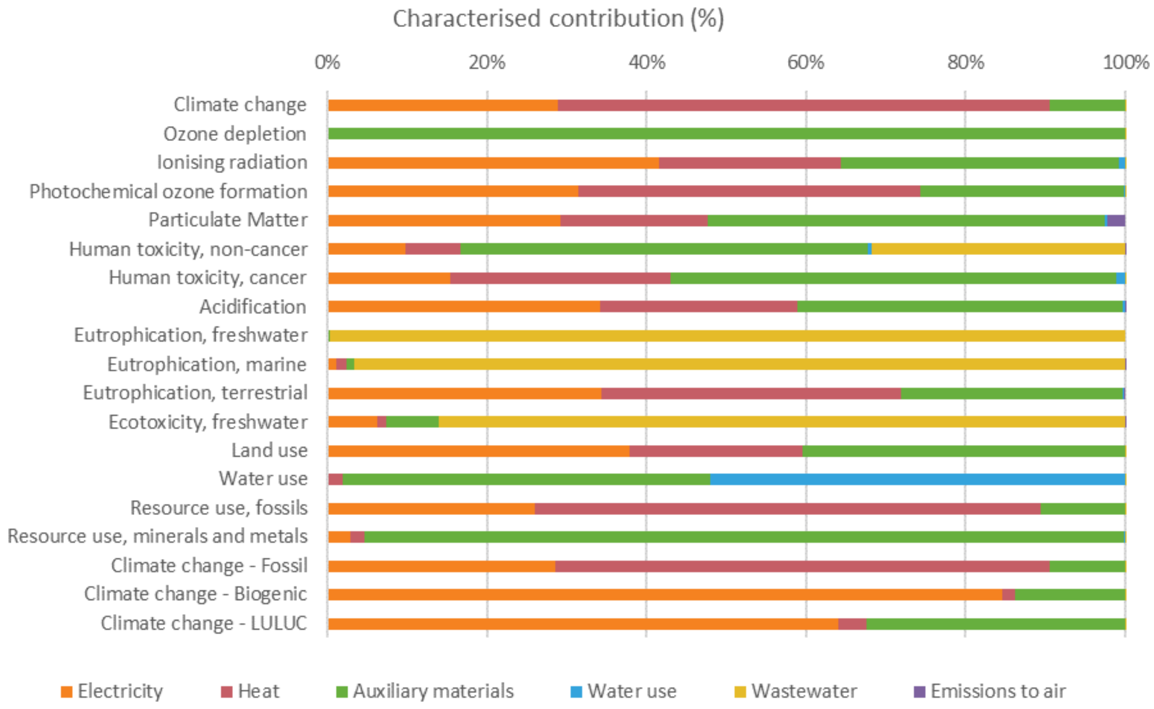

Figure 15: Contribution of inputs to environmental impact of the refining process (of crude rapeseed oil)

Energy use and auxiliary materials are the main contributors to the environmental impact of the refining process. The contribution of auxiliary materials is very high (50% and higher contribution to impact category) in the impact categories ozone depletion, particulate matter, human toxicity non-cancer and cancer and resource use minerals and metals. The use of energy (electricity and heat) makes an important contribution to the environmental impact of the rapeseed refining process in the impact categories climate change (total, fossil, biogenic and LULUC), ionising radiation, photochemical ozone formation, acidification, eutrophication terrestrial, land use and resource use fossils. Wastewater treatment has a relevant contribution to the impact categories eutrophication freshwater and marine and ecotoxicity freshwater.

5.1.3. CRUDE OIL AND CO-PRODUCTS FROM SOYBEANS

During the production of crude oil from soybeans, three co-products are produced. The co-products considered in this study are meal, lecithin and hulls. The environmental profiles from crude oil and the co-products from the crushing process are presented below (Figure 16 - Figure 19) together with the absolute values of the characterised results (Table 18 - Table 21). Impacts are expressed per tonne output product. Due to the energy allocation method, the 3 co-products receive different impacts per tonne product. The LCI of soybeans can be quite different from different sources, especially considering land use change. In this project the Agri-footprint database has been consistently applied, its generic character should however be kept in mind when interpreting the results. Different agricultural practices might lead to different results in the agriculture life cycle stage, which is the most important life cycle stage.

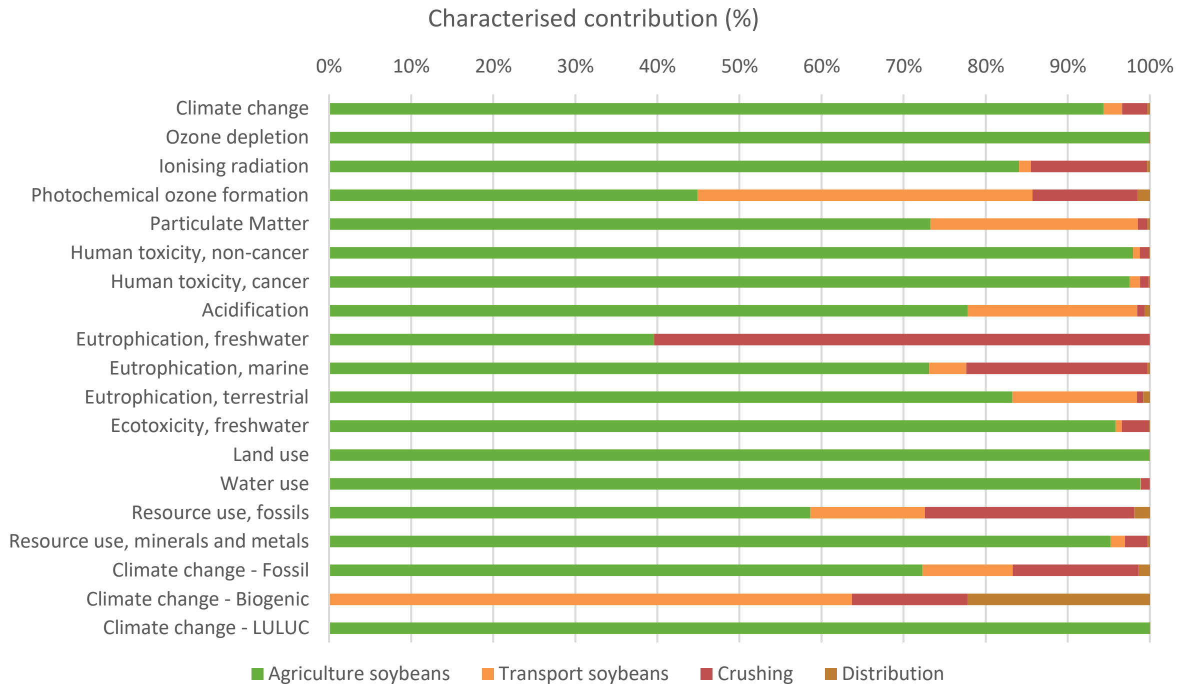

Figure 16: Environmental profile of 1 tonne crude oil from soybeans

Table 14: Characterised results per tonne crude oil from soybeans

Characterised contribution	Unit	Total	Agriculture soybeans	Transport soybeans	Crushing	Distribution
Climate change	*kg CO_2 eq*	4,23E+03	3,99E+03	9,48E+01	1,32E+02	1,18E+01
Ozone depletion	*kg CFC11 eq*	8,06E-06	8,06E-06	2,28E-10	5,00E-09	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,55E+01	1,30E+01	2,24E-01	2,19E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	4,73E+00	2,12E+00	1,93E+00	6,06E-01	6,96E-02
Particulate Matter	*disease inc.*	1,05E-04	7,68E-05	2,65E-05	1,25E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	7,79E-05	7,63E-05	6,23E-07	8,88E-07	8,47E-08
Human toxicity, cancer	*CTUh*	1,32E-06	1,29E-06	1,67E-08	1,39E-08	1,87E-09
Acidification	*mol H^+ eq*	1,20E+01	9,35E+00	2,48E+00	1,10E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	1,55E+00	6,14E-01	2,21E-04	9,36E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,52E+01	1,11E+01	6,83E-01	3,36E+00	3,68E-02
Eutrophication, terrestrial	*mol N eq*	4,94E+01	4,11E+01	7,49E+00	3,78E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,39E+05	1,33E+05	1,05E+03	4,63E+03	1,17E+02
Land use	*Pt*	3,10E+05	3,10E+05	1,38E+02	2,06E+01	4,82E+01
Water use	*m^3 depriv.*	2,20E+03	2,18E+03	1,50E+00	2,31E+01	4,55E-01
Resource use, fossils	*MJ*	8,41E+03	4,93E+03	1,18E+03	2,14E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	3,25E-04	3,09E-04	5,65E-06	9,07E-06	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	8,58E+02	6,20E+02	9,45E+01	1,32E+02	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	9,36E-02	0,00E+00	5,96E-02	1,32E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	3,37E+03	3,37E+03	2,40E-01	7,44E-03	8,42E-02

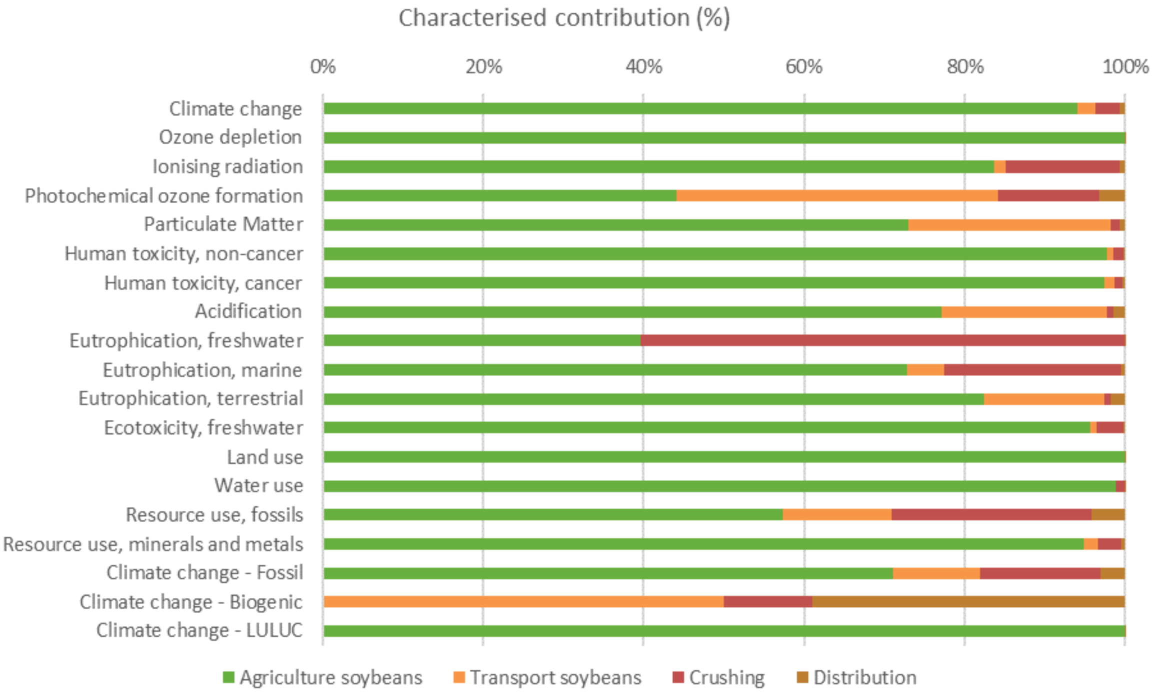

Figure 17: Environmental profile of 1 tonne meal from soybeans

Table 15: Characterised results per tonne meal from soybeans

Characterised contribution	Unit	Total	Agriculture soybeans	Transport soybeans	Crushing	Distribution
Climate change	*kg CO_2 eq*	1,89E+03	1,78E+03	4,23E+01	5,87E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	3,60E-06	3,59E-06	1,02E-10	2,23E-09	4,47E-11
Ionising radiation	*kBq U-235 eq*	6,92E+00	5,79E+00	1,00E-01	9,76E-01	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	2,15E+00	9,47E-01	8,60E-01	2,70E-01	6,96E-02
Particulate Matter	*disease inc.*	4,69E-05	3,43E-05	1,18E-05	5,55E-07	2,94E-07
Human toxicity, non-cancer	*CTUh*	3,48E-05	3,40E-05	2,78E-07	3,96E-07	8,47E-08
Human toxicity, cancer	*CTUh*	5,91E-07	5,75E-07	7,46E-09	6,18E-09	1,87E-09
Acidification	*mol H^+ eq*	5,40E+00	4,17E+00	1,11E+00	4,90E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	6,91E-01	2,74E-01	9,84E-05	4,17E-01	7,38E-05
Eutrophication, marine	*kg N eq*	6,79E+00	4,95E+00	3,05E-01	1,50E+00	3,68E-02
Eutrophication, terrestrial	*mol N eq*	2,22E+01	1,83E+01	3,34E+00	1,68E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	6,21E+04	5,95E+04	4,67E+02	2,07E+03	1,17E+02
Land use	*Pt*	1,38E+05	1,38E+05	6,15E+01	9,18E+00	4,82E+01
Water use	*m^3 depriv.*	9,82E+02	9,71E+02	6,70E-01	1,03E+01	4,55E-01
Resource use, fossils	*MJ*	3,84E+03	2,20E+03	5,25E+02	9,55E+02	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	1,45E-04	1,38E-04	2,52E-06	4,05E-06	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	3,89E+02	2,77E+02	4,22E+01	5,87E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	5,32E-02	0,00E+00	2,66E-02	5,87E-03	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	1,50E+03	1,50E+03	1,07E-01	3,32E-03	8,42E-02

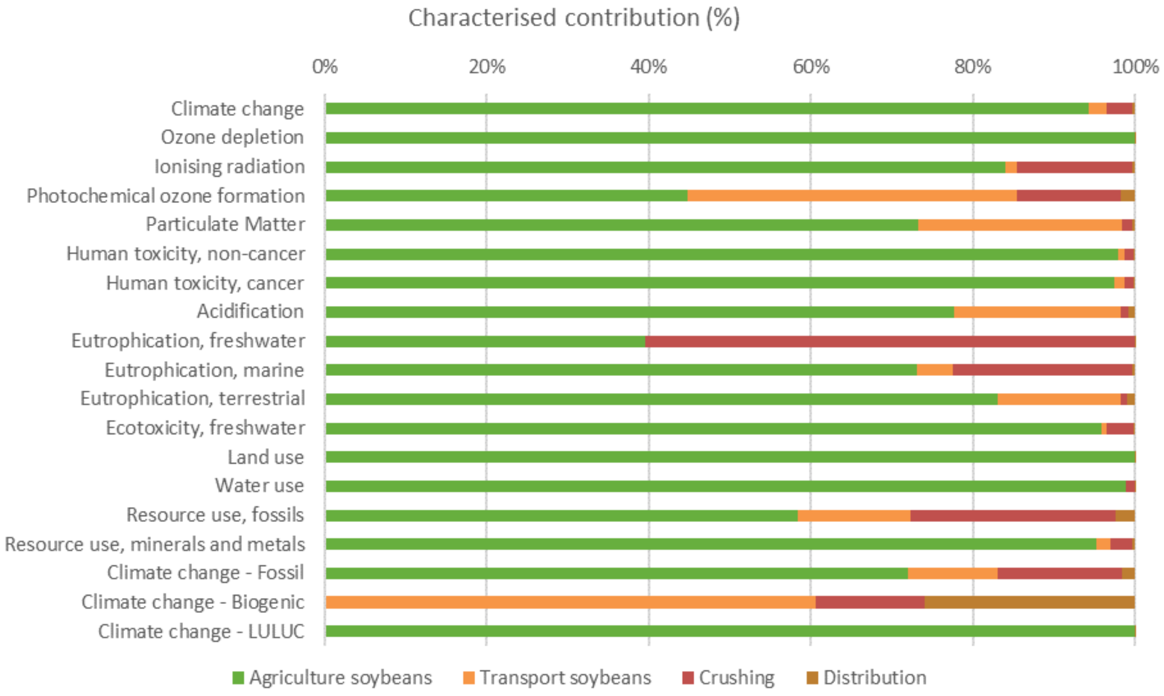

Figure 18: Environmental profile of 1 tonne lecithin from soybeans

Table 16: Characterised results per tonne lecithin from soybeans

Characterised contribution	Unit	Total	Agriculture soybeans	Transport soybeans	Crushing	Distribution
Climate change	*kg CO_2 eq*	3,43E+03	3,24E+03	7,69E+01	1,07E+02	1,18E+01
Ozone depletion	*kg CFC11 eq*	6,54E-06	6,53E-06	1,85E-10	4,05E-09	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,25E+01	1,05E+01	1,82E-01	1,77E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	3,85E+00	1,72E+00	1,56E+00	4,91E-01	6,96E-02
Particulate Matter	*disease inc.*	8,51E-05	6,23E-05	2,15E-05	1,01E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	6,32E-05	6,19E-05	5,05E-07	7,20E-07	8,47E-08
Human toxicity, cancer	*CTUh*	1,07E-06	1,05E-06	1,36E-08	1,12E-08	1,87E-09
Acidification	*mol H^+ eq*	9,76E+00	7,58E+00	2,01E+00	8,91E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	1,26E+00	4,98E-01	1,79E-04	7,59E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,23E+01	9,00E+00	5,54E-01	2,72E+00	3,68E-02
Eutrophication, terrestrial	*mol N eq*	4,01E+01	3,33E+01	6,08E+00	3,06E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,13E+05	1,08E+05	8,50E+02	3,76E+03	1,17E+02
Land use	*Pt*	2,51E+05	2,51E+05	1,12E+02	1,67E+01	4,82E+01
Water use	*m^3 depriv.*	1,79E+03	1,77E+03	1,22E+00	1,87E+01	4,55E-01
Resource use, fossils	*MJ*	6,85E+03	4,00E+03	9,54E+02	1,74E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,63E-04	2,51E-04	4,58E-06	7,36E-06	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	6,98E+02	5,03E+02	7,66E+01	1,07E+02	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	7,98E-02	0,00E+00	4,83E-02	1,07E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	2,73E+03	2,73E+03	1,95E-01	6,03E-03	8,42E-02

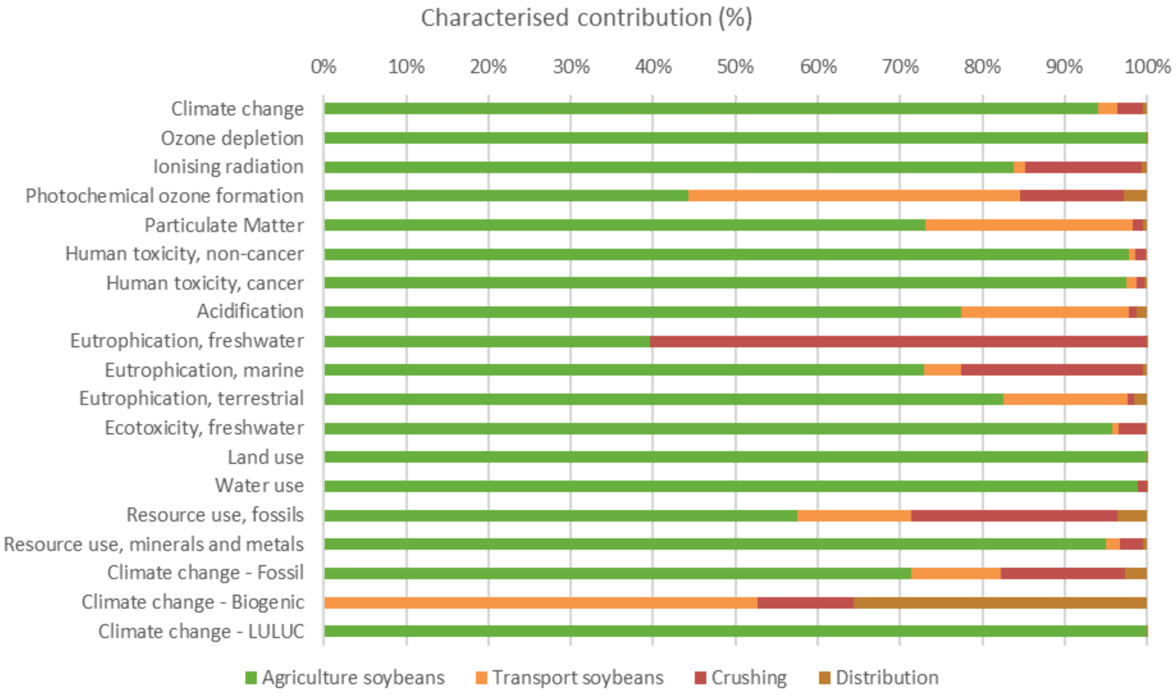

Figure 19: Environmental profile of 1 tonne hulls from soybeans

Table 17: Characterised results per tonne hulls from soybeans

Characterised contribution	Unit	Total	Agriculture soybeans	Transport soybeans	Crushing	Distribution
Climate change	*kg CO_2 eq*	2,18E+03	2,05E+03	4,87E+01	6,76E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	4,14E-06	4,14E-06	1,17E-10	2,57E-09	4,47E-11
Ionising radiation	*kBq U-235 eq*	7,96E+00	6,67E+00	1,15E-01	1,12E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	2,46E+00	1,09E+00	9,90E-01	3,11E-01	6,96E-02
Particulate Matter	*disease inc.*	5,40E-05	3,94E-05	1,36E-05	6,40E-07	2,94E-07
Human toxicity, non-cancer	*CTUh*	4,01E-05	3,92E-05	3,20E-07	4,56E-07	8,47E-08
Human toxicity, cancer	*CTUh*	6,80E-07	6,62E-07	8,59E-09	7,11E-09	1,87E-09
Acidification	*mol H^+ eq*	6,21E+00	4,80E+00	1,27E+00	5,64E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	7,96E-01	3,15E-01	1,13E-04	4,81E-01	7,38E-05
Eutrophication, marine	*kg N eq*	7,81E+00	5,70E+00	3,51E-01	1,72E+00	3,68E-02
Eutrophication, terrestrial	*mol N eq*	2,55E+01	2,11E+01	3,85E+00	1,94E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	7,15E+04	6,85E+04	5,38E+02	2,38E+03	1,17E+02
Land use	*Pt*	1,59E+05	1,59E+05	7,09E+01	1,06E+01	4,82E+01
Water use	*m^3 depriv.*	1,13E+03	1,12E+03	7,71E-01	1,19E+01	4,55E-01
Resource use, fossils	*MJ*	4,39E+03	2,53E+03	6,04E+02	1,10E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	1,67E-04	1,59E-04	2,90E-06	4,66E-06	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	4,46E+02	3,18E+02	4,85E+01	6,76E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	5,82E-02	0,00E+00	3,06E-02	6,76E-03	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	1,73E+03	1,73E+03	1,23E-01	3,82E-03	8,42E-02

In order to gain more insight into the crushing process' inputs and outputs causing the environmental impact, the crushing process (red bars in Figure 16 - Figure 19) is subdivided in Figure 20. In this graph, the contributions to the total impact generated by the crushing process of electricity, heat, auxiliary materials, water use, wastewater and emissions to air are shown.

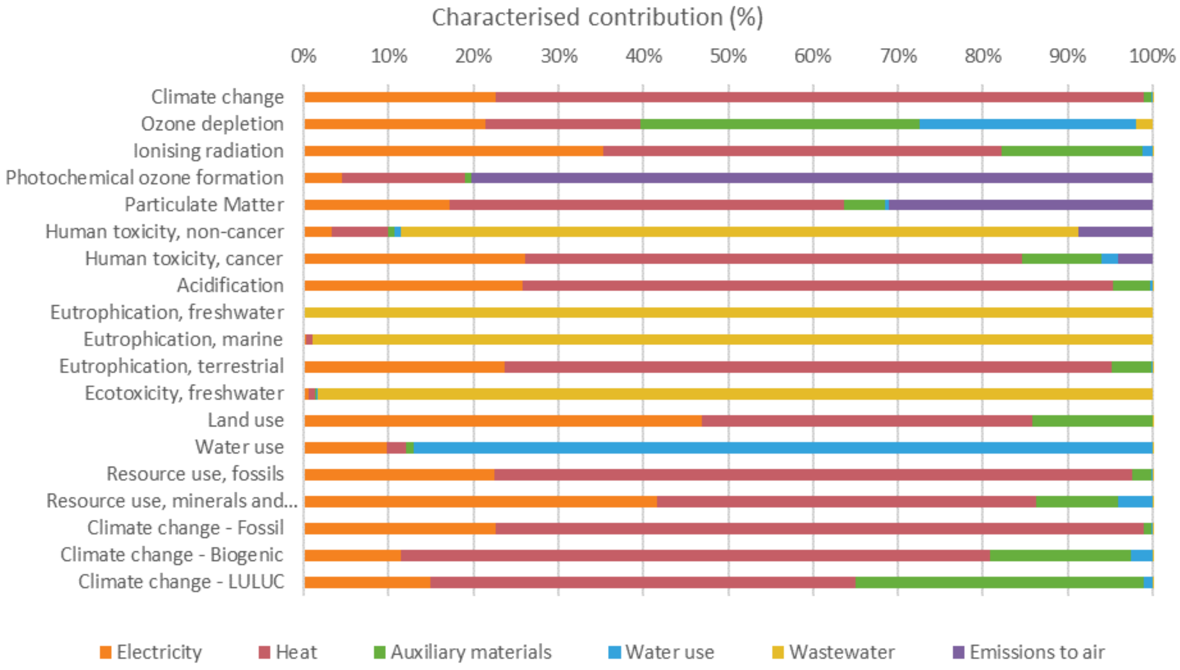

Figure 20: Contribution of inputs to environmental impact of the crushing process (of soybeans)

The energy use of the process, entailing both electricity and heat, is generally the main contributor to the environmental impact caused by the crushing process. Some examples where the contribution of energy is very high (80% and higher contribution to impact category), are climate change, ionising radiation, human toxicity cancer, acidification, eutrophication terrestrial, land use, resource use fossils and minerals and metals and climate change fossil and biogenic. The use of auxiliary materials has rather small contributions to the environmental impact of the soybean crushing process, except to ozone depletion and climate change LULUC, the contribution is higher than 20%. Wastewater treatment has an important contribution to the impact categories human toxicity non-cancer, eutrophication freshwater and marine and ecotoxicity freshwater. The emissions to air, which take place during the crushing process are hexane emissions and emissions of particulates. The contribution of the hexane emission to air is clearly visible in the impact category photochemical ozone formation and hexane emissions also contribute to the impact categories human toxicity non-cancer and cancer. Emissions of particulates to air contribute to particulate matter.

5.1.4. REFINED OIL AND CO-PRODUCTS FROM SOYBEANS

During refining of crude soybean oil, refined oil is produced, together with four co-products. The environmental profiles are provided for refined oil in Figure 21, for acid oil, deodistillates and fatty acid distillates in Figure 22 and for soap stock in Figure 23. Acid oil, deodistillates and fatty acid distillates have the same environmental profile as their energy content and transport scenario is equal. All graphs are accompanied by the absolute values of the characterised results (Table 18 - Table 20).

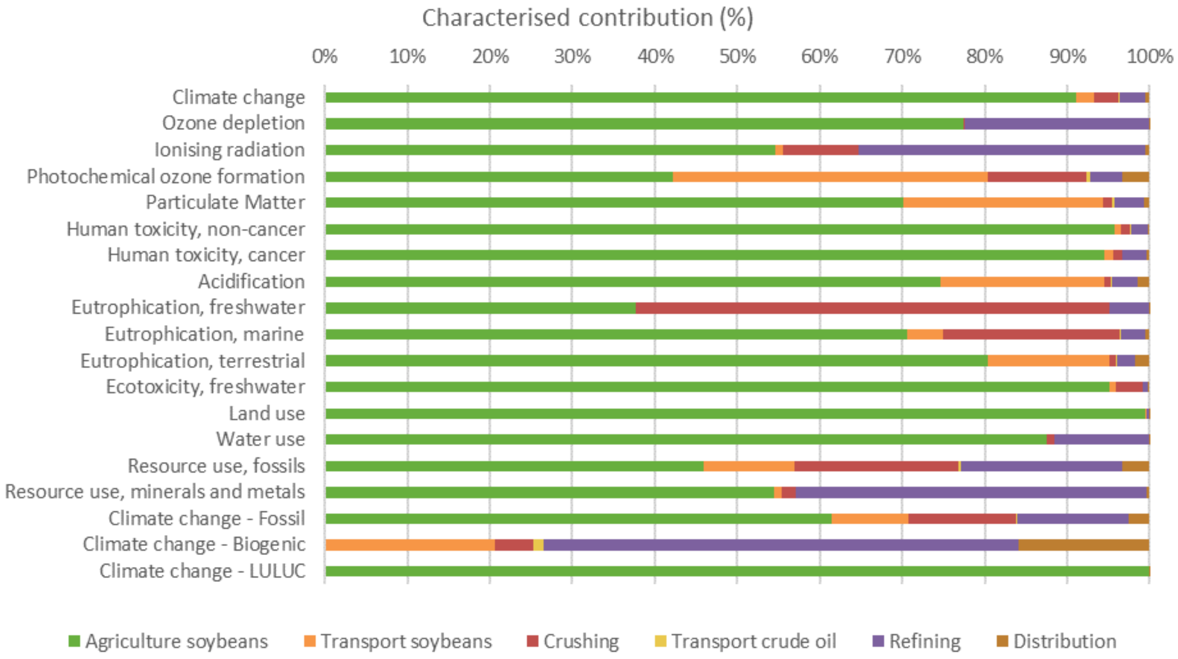

Figure 21: Environmental profile of 1 tonne refined oil from soybeans

Table 18: Characterised results per tonne refined oil from soybeans

Characterised contribution	Unit	Total	Agriculture soybeans	Transport soybeans	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	4,38E+03	3,99E+03	9,48E+01	1,32E+02	2,23E+00	1,36E+02	2,65E+01
Ozone depletion	*kg CFC11 eq*	1,04E-05	8,05E-06	2,28E-10	5,00E-09	8,16E-12	2,34E-06	9,93E-11
Ionising radiation	*kBq U-235 eq*	2,38E+01	1,30E+01	2,24E-01	2,19E+00	9,22E-03	8,27E+00	1,12E-01
Photochemical ozone formation	*kg NMVOC eq*	5,04E+00	2,12E+00	1,93E+00	6,06E-01	2,23E-02	1,96E-01	1,67E-01
Particulate Matter	*disease inc.*	1,10E-04	7,68E-05	2,65E-05	1,24E-06	3,83E-07	3,82E-06	8,24E-07
Human toxicity, non-cancer	*CTUh*	7,96E-05	7,63E-05	6,23E-07	8,88E-07	1,84E-08	1,65E-06	1,89E-07
Human toxicity, cancer	*CTUh*	1,37E-06	1,29E-06	1,67E-08	1,38E-08	3,41E-10	4,10E-08	4,22E-09
Acidification	*mol H^+ eq*	1,25E+01	9,35E+00	2,48E+00	1,10E-01	1,81E-02	3,77E-01	1,88E-01
Eutrophication, freshwater	*kg P eq*	1,63E+00	6,14E-01	2,20E-04	9,35E-01	1,35E-05	7,96E-02	1,63E-04
Eutrophication, marine	*kg N eq*	1,57E+01	1,11E+01	6,83E-01	3,36E+00	8,73E-03	4,72E-01	8,57E-02
Eutrophication, terrestrial	*mol N eq*	5,11E+01	4,11E+01	7,49E+00	3,78E-01	9,58E-02	1,09E+00	9,29E-01
Ecotoxicity, freshwater	*CTUe*	1,40E+05	1,33E+05	1,05E+03	4,63E+03	2,13E+01	8,74E+02	2,64E+02
Land use	*Pt*	3,11E+05	3,10E+05	1,38E+02	2,06E+01	8,80E+00	1,25E+03	1,06E+02
Water use	*m^3 depriv.*	2,49E+03	2,18E+03	1,50E+00	2,31E+01	8,30E-02	2,84E+02	1,00E+00
Resource use, fossils	*MJ*	1,07E+04	4,92E+03	1,18E+03	2,14E+03	2,93E+01	2,09E+03	3,60E+02
Resource use, minerals & metals	*kg Sb eq*	5,67E-04	3,09E-04	5,64E-06	9,07E-06	1,42E-07	2,42E-04	1,74E-06
Climate change – Fossil	*kg CO_2 eq*	1,01E+03	6,20E+02	9,45E+01	1,31E+02	2,22E+00	1,36E+02	2,62E+01
Climate change – Biogenic	*kg CO_2 eq*	2,89E-01	0,00E+00	5,96E-02	1,32E-02	3,79E-03	1,66E-01	4,58E-02
Climate change – LULUC	*kg CO_2 eq*	3,37E+03	3,37E+03	2,40E-01	7,43E-03	1,54E-02	1,24E-01	1,86E-01

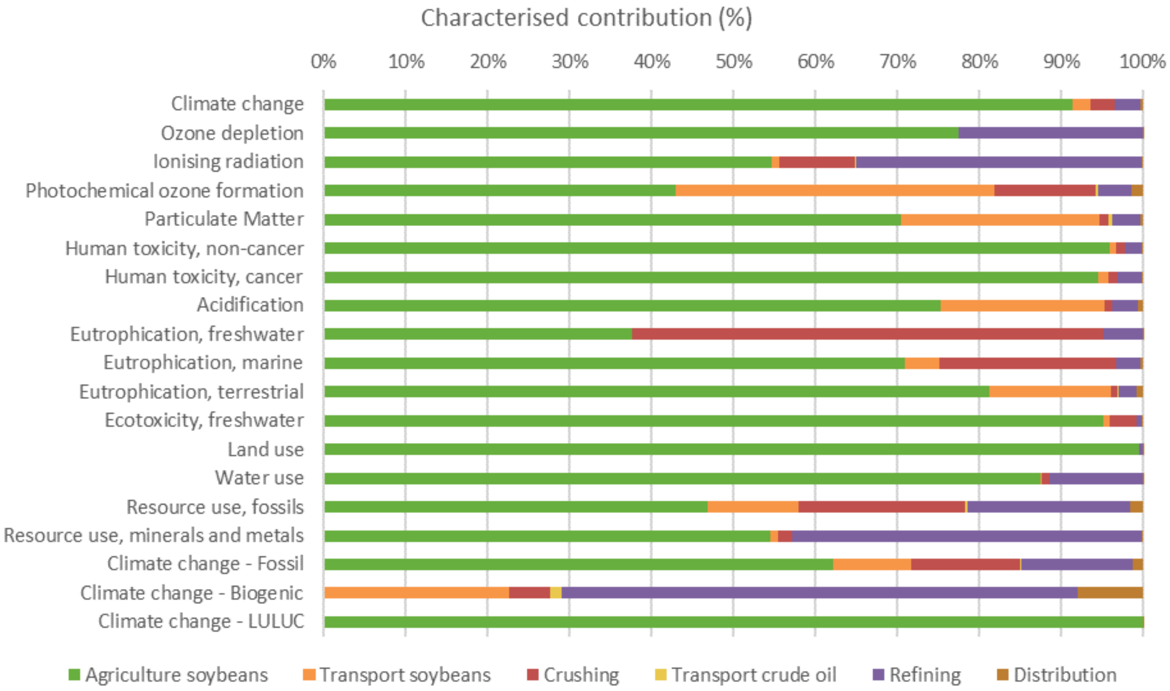

Figure 22: Environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from soybeans

Table 19: Characterised results per tonne acid oil, deodistillates or fatty acid distillates from soybeans

Characterised contribution	Unit	Total	Agriculture soybeans	Transport soybeans	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	4,37E+03	3,99E+03	9,48E+01	1,32E+02	2,23E+00	1,36E+02	1,18E+01
Ozone depletion	*kg CFC11 eq*	1,04E-05	8,05E-06	2,28E-10	5,00E-09	8,16E-12	2,34E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	2,37E+01	1,30E+01	2,24E-01	2,19E+00	9,22E-03	8,27E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	4,94E+00	2,12E+00	1,93E+00	6,06E-01	2,23E-02	1,96E-01	6,96E-02
Particulate Matter	*disease inc.*	1,09E-04	7,68E-05	2,65E-05	1,24E-06	3,83E-07	3,82E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	7,95E-05	7,63E-05	6,23E-07	8,88E-07	1,84E-08	1,65E-06	8,47E-08
Human toxicity, cancer	*CTUh*	1,36E-06	1,29E-06	1,67E-08	1,38E-08	3,41E-10	4,10E-08	1,87E-09
Acidification	*mol H^+ eq*	1,24E+01	9,35E+00	2,48E+00	1,10E-01	1,81E-02	3,77E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	1,63E+00	6,14E-01	2,20E-04	9,35E-01	1,35E-05	7,96E-02	7,38E-05
Eutrophication, marine	*kg N eq*	1,56E+01	1,11E+01	6,83E-01	3,36E+00	8,73E-03	4,72E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	5,05E+01	4,11E+01	7,49E+00	3,78E-01	9,58E-02	1,09E+00	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,40E+05	1,33E+05	1,05E+03	4,63E+03	2,13E+01	8,74E+02	1,17E+02
Land use	*Pt*	3,11E+05	3,10E+05	1,38E+02	2,06E+01	8,80E+00	1,25E+03	4,82E+01
Water use	*m^3 depriv.*	2,49E+03	2,18E+03	1,50E+00	2,31E+01	8,30E-02	2,84E+02	4,55E-01
Resource use, fossils	*MJ*	1,05E+04	4,92E+03	1,18E+03	2,14E+03	2,93E+01	2,09E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	5,66E-04	3,09E-04	5,64E-06	9,07E-06	1,42E-07	2,42E-04	7,76E-07
Climate change – Fossil	*kg CO_2 eq*	9,96E+02	6,20E+02	9,45E+01	1,31E+02	2,22E+00	1,36E+02	1,17E+01
Climate change – Biogenic	*kg CO_2 eq*	2,64E-01	0,00E+00	5,96E-02	1,32E-02	3,79E-03	1,66E-01	2,08E-02
Climate change – LULUC	*kg CO_2 eq*	3,37E+03	3,37E+03	2,40E-01	7,43E-03	1,54E-02	1,24E-01	8,42E-02

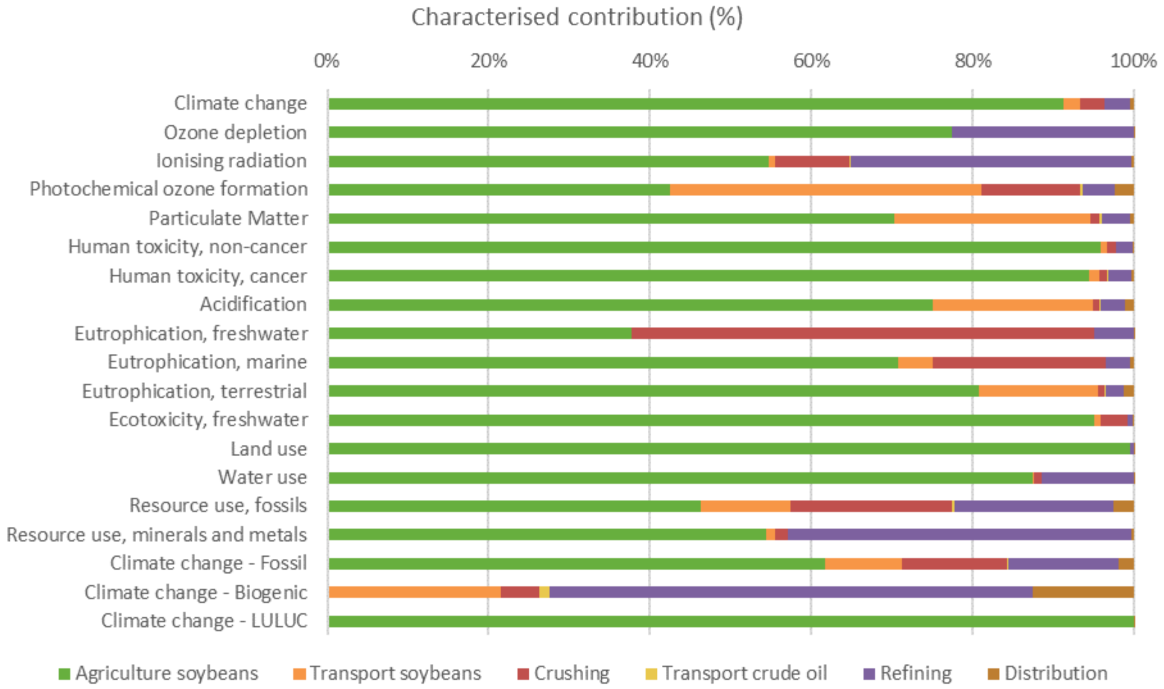

Figure 23: Environmental profile of 1 tonne soap stock from soybeans

Table 20: Characterised results per tonne soap stock from soybeans

Characterised contribution	Unit	Total	Agriculture soybeans	Transport soybeans	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	2,63E+03	2,39E+03	5,69E+01	7,89E+01	1,34E+00	8,17E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	6,24E-06	4,83E-06	1,37E-10	3,00E-09	4,89E-12	1,40E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,43E+01	7,79E+00	1,35E-01	1,31E+00	5,53E-03	4,96E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	2,99E+00	1,27E+00	1,16E+00	3,63E-01	1,34E-02	1,18E-01	6,96E-02
Particulate Matter	*disease inc.*	6,55E-05	4,61E-05	1,59E-05	7,47E-07	2,30E-07	2,29E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	4,78E-05	4,58E-05	3,74E-07	5,33E-07	1,11E-08	9,88E-07	8,47E-08
Human toxicity, cancer	*CTUh*	8,18E-07	7,73E-07	1,00E-08	8,31E-09	2,05E-10	2,46E-08	1,87E-09
Acidification	*mol H^+ eq*	7,48E+00	5,61E+00	1,49E+00	6,59E-02	1,08E-02	2,26E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	9,77E-01	3,68E-01	1,32E-04	5,61E-01	8,08E-06	4,77E-02	7,38E-05
Eutrophication, marine	*kg N eq*	9,40E+00	6,65E+00	4,10E-01	2,01E+00	5,24E-03	2,83E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	3,05E+01	2,46E+01	4,49E+00	2,27E-01	5,75E-02	6,57E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	8,40E+04	8,00E+04	6,28E+02	2,78E+03	1,28E+01	5,24E+02	1,17E+02
Land use	*Pt*	1,87E+05	1,86E+05	8,28E+01	1,23E+01	5,28E+00	7,49E+02	4,82E+01
Water use	*m^3 depriv.*	1,49E+03	1,31E+03	9,00E-01	1,39E+01	4,98E-02	1,71E+02	4,55E-01
Resource use, fossils	*MJ*	6,38E+03	2,95E+03	7,06E+02	1,28E+03	1,76E+01	1,26E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	3,40E-04	1,85E-04	3,39E-06	5,44E-06	8,50E-08	1,45E-04	7,76E-07
Climate change – Fossil	*kg CO_2 eq*	6,02E+02	3,72E+02	5,67E+01	7,89E+01	1,33E+00	8,15E+01	1,17E+01
Climate change – Biogenic	*kg CO_2 eq*	1,66E-01	0,00E+00	3,58E-02	7,90E-03	2,28E-03	9,98E-02	2,08E-02
Climate change – LULUC	*kg CO_2 eq*	2,02E+03	2,02E+03	1,44E-01	4,46E-03	9,22E-03	7,46E-02	8,42E-02

In order to gain more insight into the refining process' inputs and outputs causing the environmental impact, the refining process (purple bars in Figure 21-Figure 23) is subdivided in Figure 24. In this graph, the contributions to the total impact generated by the refining process of electricity, heat, auxiliary materials, water use, wastewater and emissions to air are shown.

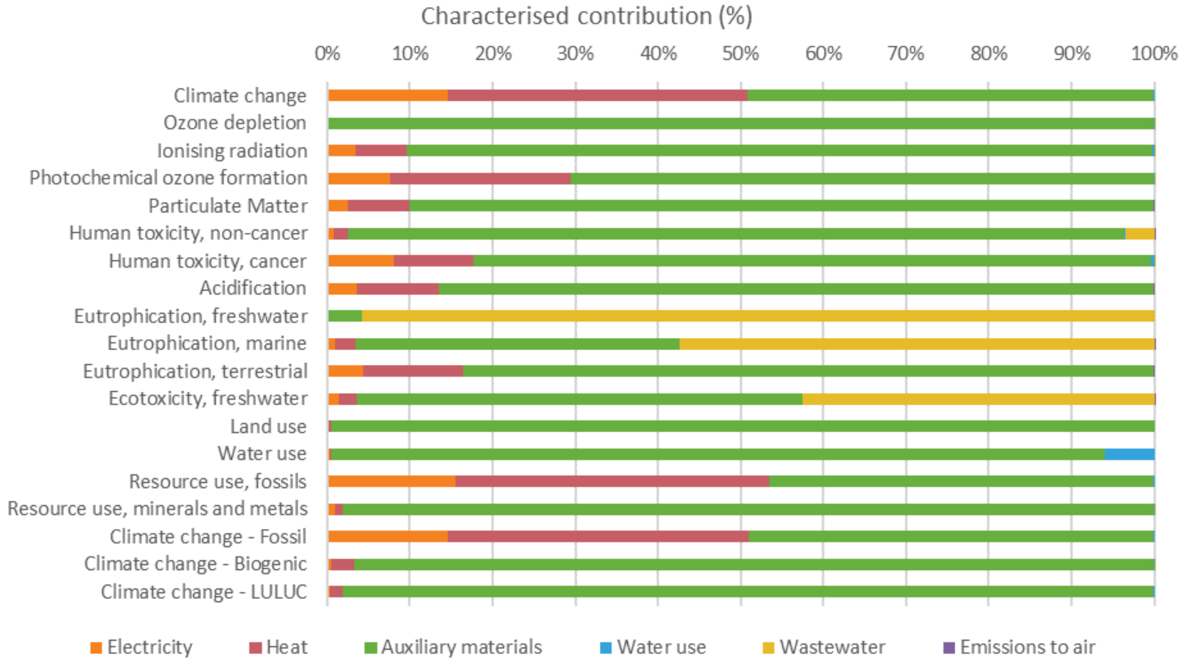

Figure 24: Contribution of inputs to environmental impact of the refining process (of crude soybean oil)

The auxiliary materials used in the refining process are the main contributor to almost all environmental impact caused by the refining process. Only for climate change (total and fossil) and resource use, fossils energy use has an equally important contribution and in the impact categories eutrophication freshwater and marine the main contributor is wastewater treatment. The contribution of the auxiliary materials comes mainly from the use of citric acid and, to a lesser extent, bleaching earth. The impact of direct process emissions to air which take place during the refining process are too small to be seen on the graph.

5.1.5. CRUDE OIL AND CO-PRODUCTS FROM SUNFLOWER SEEDS

Crushing of sunflower seeds produces crude oil and the co-products meal, lecithin and husks. The environmental profiles from crude oil and the co-products are presented below (Figure 25-Figure 28), together with the absolute values of the characterized results (Table 21 - Table 24). The distribution scenario is the same for all 4 co-products.

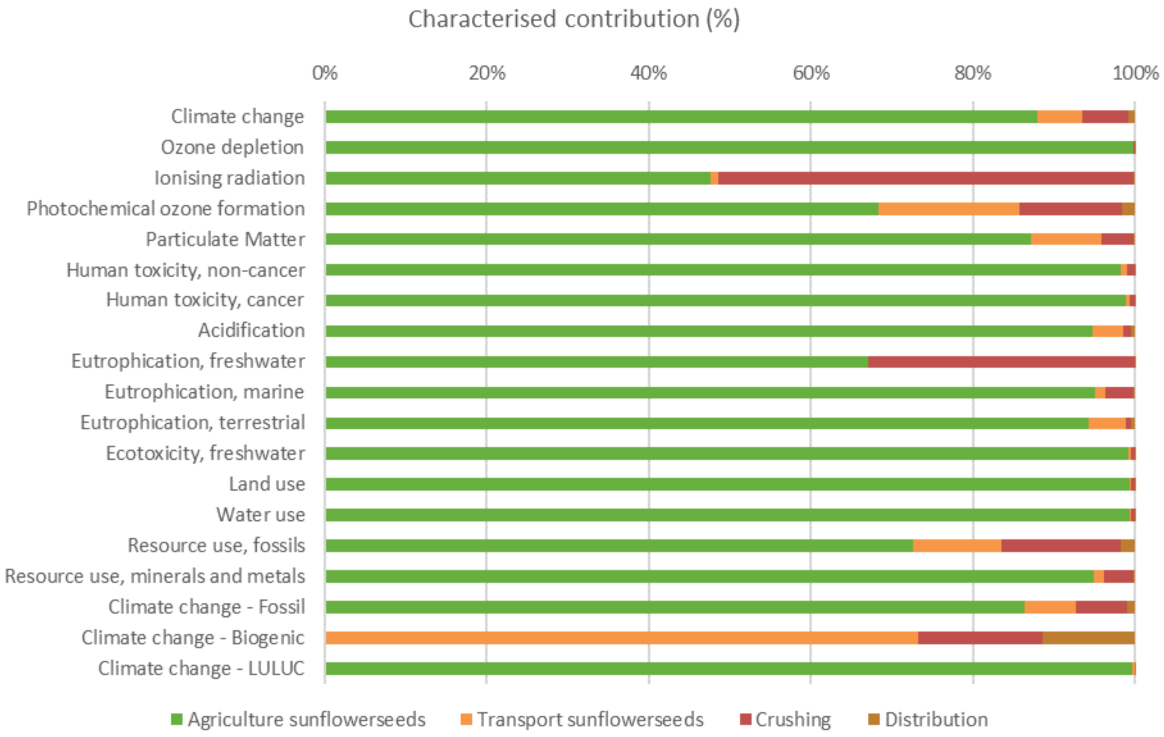

Figure 25: Environmental profile of 1 tonne crude oil from sunflower seeds

Table 21: Characterised results per tonne crude oil from sunflower seeds

Characterised contribution	Unit	Total	Agriculture sunflower seeds	Transport sunflower seeds	Crushing	Distribution
Climate change	*kg CO_2 eq*	1,38E+03	1,22E+03	8,03E+01	7,73E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	9,64E-06	9,63E-06	4,08E-10	1,73E-08	4,47E-11
Ionising radiation	*kBq U-235 eq*	3,27E+01	1,55E+01	4,60E-01	1,67E+01	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	4,37E+00	2,99E+00	7,69E-01	5,56E-01	6,96E-02
Particulate Matter	*disease inc.*	1,43E-04	1,25E-04	1,26E-05	5,70E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	8,88E-05	8,72E-05	6,54E-07	8,50E-07	8,47E-08
Human toxicity, cancer	*CTUh*	2,53E-06	2,50E-06	1,23E-08	1,31E-08	1,87E-09
Acidification	*mol H^+ eq*	1,65E+01	1,56E+01	6,36E-01	1,54E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	6,10E-01	4,09E-01	4,84E-04	2,00E-01	7,38E-05
Eutrophication, marine	*kg N eq*	2,21E+01	2,10E+01	3,07E-01	7,64E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	7,33E+01	6,91E+01	3,37E+00	4,68E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	2,42E+05	2,40E+05	7,69E+02	1,19E+03	1,17E+02
Land use	*Pt*	3,45E+05	3,43E+05	3,17E+02	1,65E+03	4,82E+01
Water use	*m^3 depriv.*	3,48E+03	3,45E+03	3,02E+00	1,81E+01	4,55E-01
Resource use, fossils	*MJ*	9,51E+03	6,90E+03	1,06E+03	1,41E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	4,02E-04	3,82E-04	5,18E-06	1,47E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	1,22E+03	1,05E+03	7,96E+01	7,72E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	1,84E-01	0,00E+00	1,37E-01	2,82E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	1,66E+02	1,65E+02	5,52E-01	6,88E-02	8,42E-02

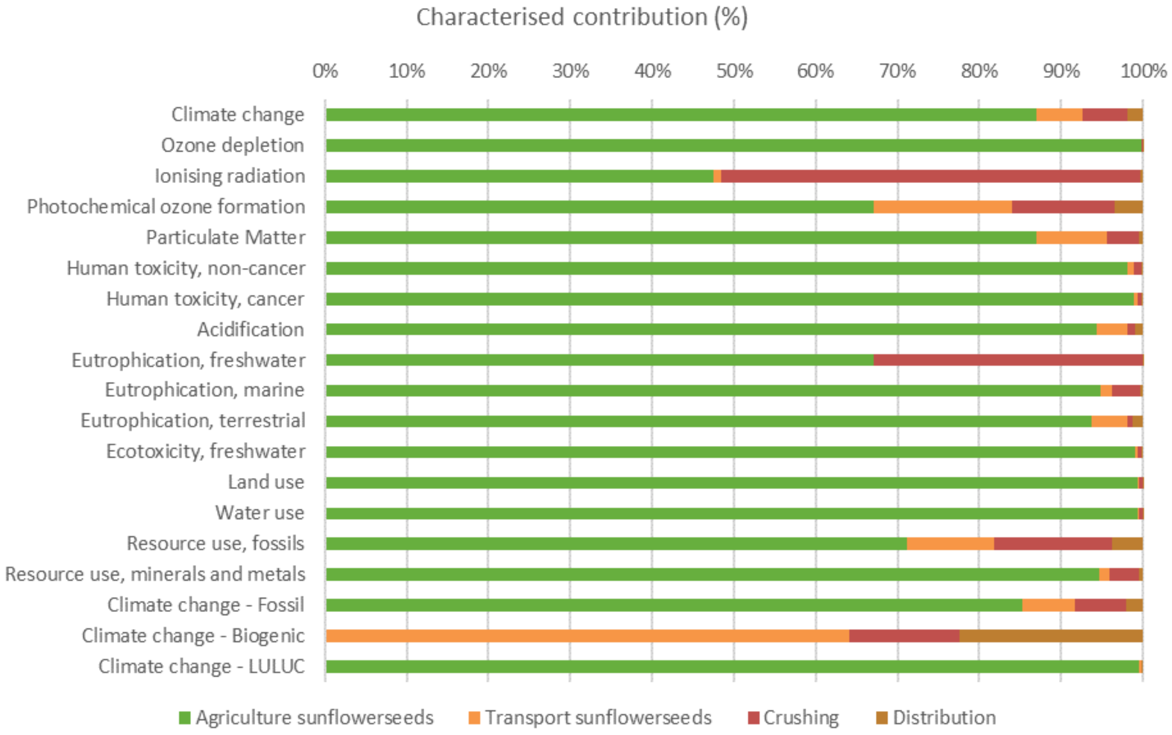

Figure 26: Environmental profile of 1 tonne meal from sunflower seeds

Table 22: Characterised results per tonne meal from sunflower seeds

Characterised contribution	Unit	Total	Agriculture sunflower seeds	Transport sunflower seeds	Crushing	Distribution
Climate change	*kg CO_2 eq*	6,24E+02	5,43E+02	3,52E+01	3,45E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	4,30E-06	4,29E-06	1,79E-10	7,72E-09	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,46E+01	6,90E+00	2,01E-01	7,44E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	1,99E+00	1,33E+00	3,37E-01	2,48E-01	6,96E-02
Particulate Matter	*disease inc.*	6,40E-05	5,57E-05	5,53E-06	2,54E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	3,96E-05	3,89E-05	2,86E-07	3,79E-07	8,47E-08
Human toxicity, cancer	*CTUh*	1,13E-06	1,12E-06	5,38E-09	5,86E-09	1,87E-09
Acidification	*mol H^+ eq*	7,39E+00	6,96E+00	2,79E-01	6,86E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	2,72E-01	1,83E-01	2,12E-04	8,94E-02	7,38E-05
Eutrophication, marine	*kg N eq*	9,87E+00	9,36E+00	1,35E-01	3,41E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	3,29E+01	3,08E+01	1,47E+00	2,09E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,08E+05	1,07E+05	3,37E+02	5,33E+02	1,17E+02
Land use	*Pt*	1,54E+05	1,53E+05	1,39E+02	7,36E+02	4,82E+01
Water use	*m^3 depriv.*	1,55E+03	1,54E+03	1,32E+00	8,08E+00	4,55E-01
Resource use, fossils	*MJ*	4,33E+03	3,08E+03	4,63E+02	6,28E+02	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	1,80E-04	1,70E-04	2,27E-06	6,54E-06	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	5,50E+02	4,69E+02	3,49E+01	3,44E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	9,35E-02	0,00E+00	6,01E-02	1,26E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	7,39E+01	7,36E+01	2,42E-01	3,07E-02	8,42E-02

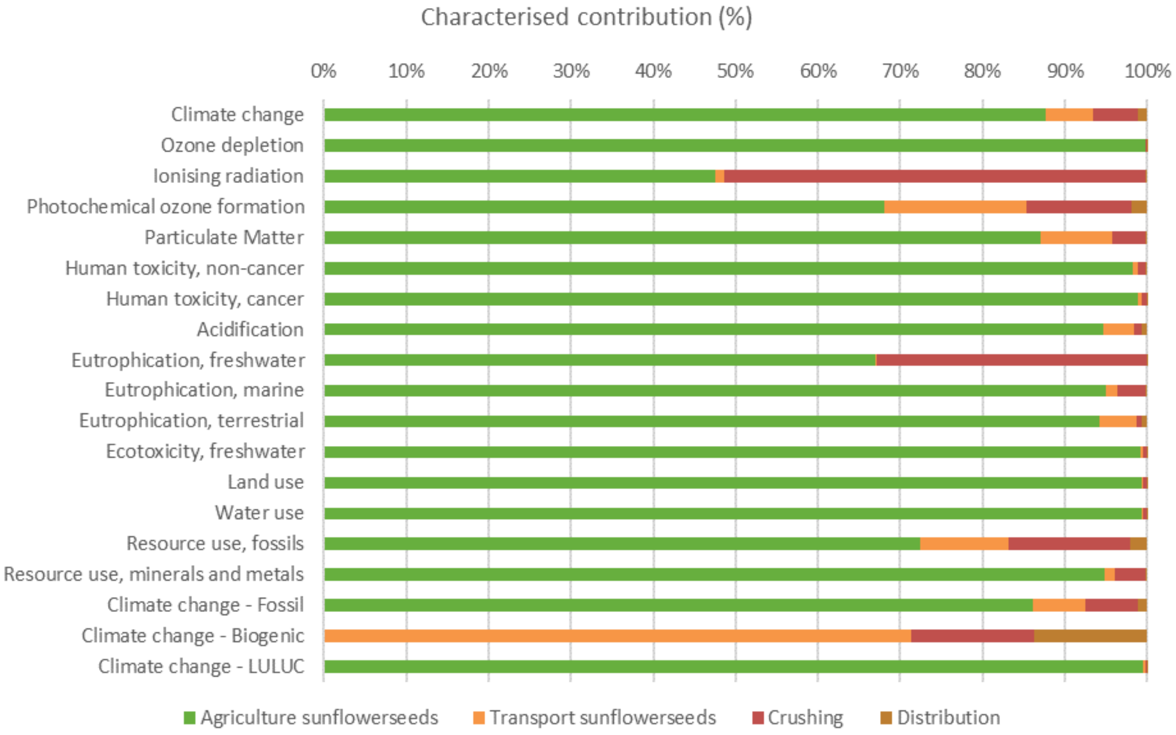

Figure 27: Environmental profile of 1 tonne lecithin from sunflower seeds

Table 23: Characterised results per tonne lecithin from sunflower seeds

Characterised contribution	Unit	Total	Agriculture sunflower seeds	Transport sunflower seeds	Crushing	Distribution
Climate change	*kg CO_2 eq*	1,12E+03	9,86E+02	6,39E+01	6,27E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	7,82E-06	7,81E-06	3,25E-10	1,40E-08	4,47E-11
Ionising radiation	*kBq U-235 eq*	2,65E+01	1,26E+01	3,66E-01	1,35E+01	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	3,56E+00	2,42E+00	6,13E-01	4,51E-01	6,96E-02
Particulate Matter	*disease inc.*	1,16E-04	1,01E-04	1,01E-05	4,62E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	7,20E-05	7,07E-05	5,21E-07	6,89E-07	8,47E-08
Human toxicity, cancer	*CTUh*	2,05E-06	2,03E-06	9,78E-09	1,06E-08	1,87E-09
Acidification	*mol H^+ eq*	1,34E+01	1,27E+01	5,06E-01	1,25E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	4,95E-01	3,32E-01	3,86E-04	1,63E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,79E+01	1,70E+01	2,45E-01	6,20E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	5,95E+01	5,60E+01	2,68E+00	3,80E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,96E+05	1,95E+05	6,12E+02	9,68E+02	1,17E+02
Land use	*Pt*	2,80E+05	2,78E+05	2,52E+02	1,34E+03	4,82E+01
Water use	*m^3 depriv.*	2,82E+03	2,80E+03	2,41E+00	1,47E+01	4,55E-01
Resource use, fossils	*MJ*	7,74E+03	5,60E+03	8,41E+02	1,14E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	3,26E-04	3,10E-04	4,13E-06	1,19E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	9,90E+02	8,53E+02	6,34E+01	6,26E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	1,53E-01	0,00E+00	1,09E-01	2,29E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	1,34E+02	1,34E+02	4,40E-01	5,58E-02	8,42E-02

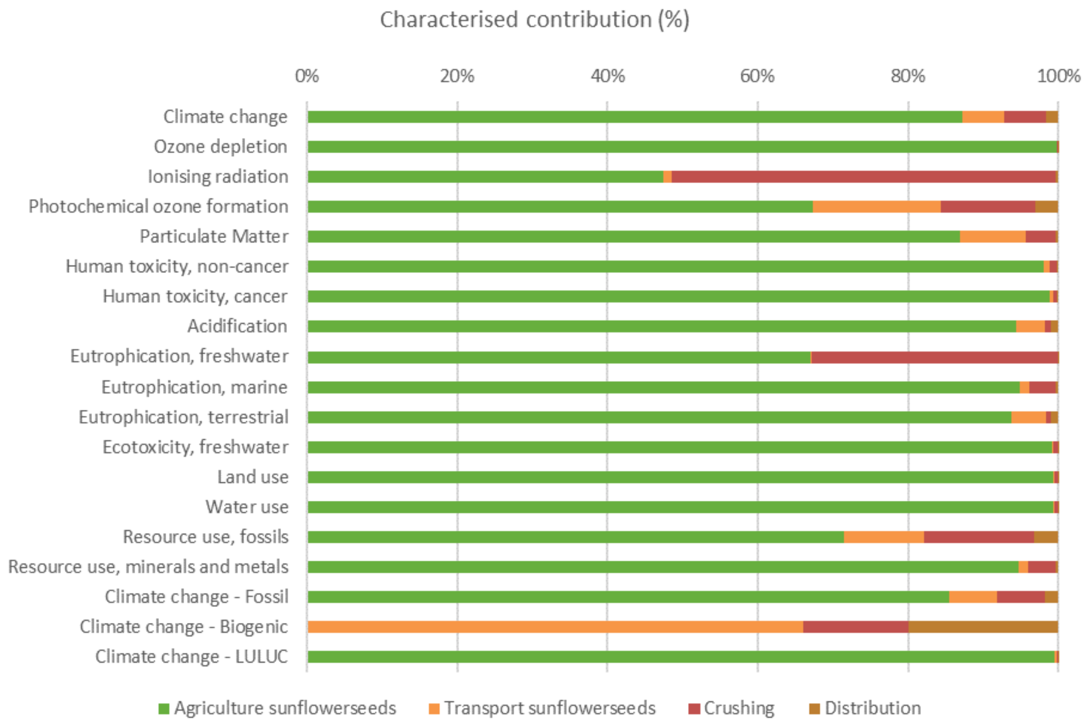

Figure 28: Environmental profile of 1 tonne husks from sunflower seeds

Table 24: Characterised results per tonne husks from sunflower seeds

Characterised contribution	Unit	Total	Agriculture sunflower seeds	Transport sunflower seeds	Crushing	Distribution
Climate change	*kg CO_2 eq*	7,17E+02	6,25E+02	4,05E+01	3,97E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	4,95E-06	4,94E-06	2,06E-10	8,89E-09	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,68E+01	7,95E+00	2,32E-01	8,57E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	2,28E+00	1,53E+00	3,88E-01	2,86E-01	6,96E-02
Particulate Matter	*disease inc.*	7,37E-05	6,41E-05	6,37E-06	2,93E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	4,56E-05	4,48E-05	3,30E-07	4,36E-07	8,47E-08
Human toxicity, cancer	*CTUh*	1,30E-06	1,28E-06	6,19E-09	6,74E-09	1,87E-09
Acidification	*mol H^+ eq*	8,49E+00	8,02E+00	3,21E-01	7,90E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	3,13E-01	2,10E-01	2,44E-04	1,03E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,14E+01	1,08E+01	1,55E-01	3,92E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	3,78E+01	3,55E+01	1,70E+00	2,40E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,24E+05	1,23E+05	3,88E+02	6,13E+02	1,17E+02
Land use	*Pt*	1,77E+05	1,76E+05	1,60E+02	8,47E+02	4,82E+01
Water use	*m^3 depriv.*	1,79E+03	1,77E+03	1,53E+00	9,30E+00	4,55E-01
Resource use, fossils	*MJ*	4,96E+03	3,54E+03	5,33E+02	7,23E+02	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,07E-04	1,96E-04	2,61E-06	7,53E-06	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	6,31E+02	5,40E+02	4,01E+01	3,96E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	1,04E-01	0,00E+00	6,92E-02	1,45E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	8,51E+01	8,47E+01	2,79E-01	3,53E-02	8,42E-02

In order to gain more insight into the crushing process' inputs and outputs causing the environmental impact, the crushing process (red bars in Figure 25-Figure 28) is subdivided in Figure 29. In this graph, the contributions to the total impact generated by the crushing process of electricity, heat, auxiliary materials, water use wastewater and emissions to air are shown.

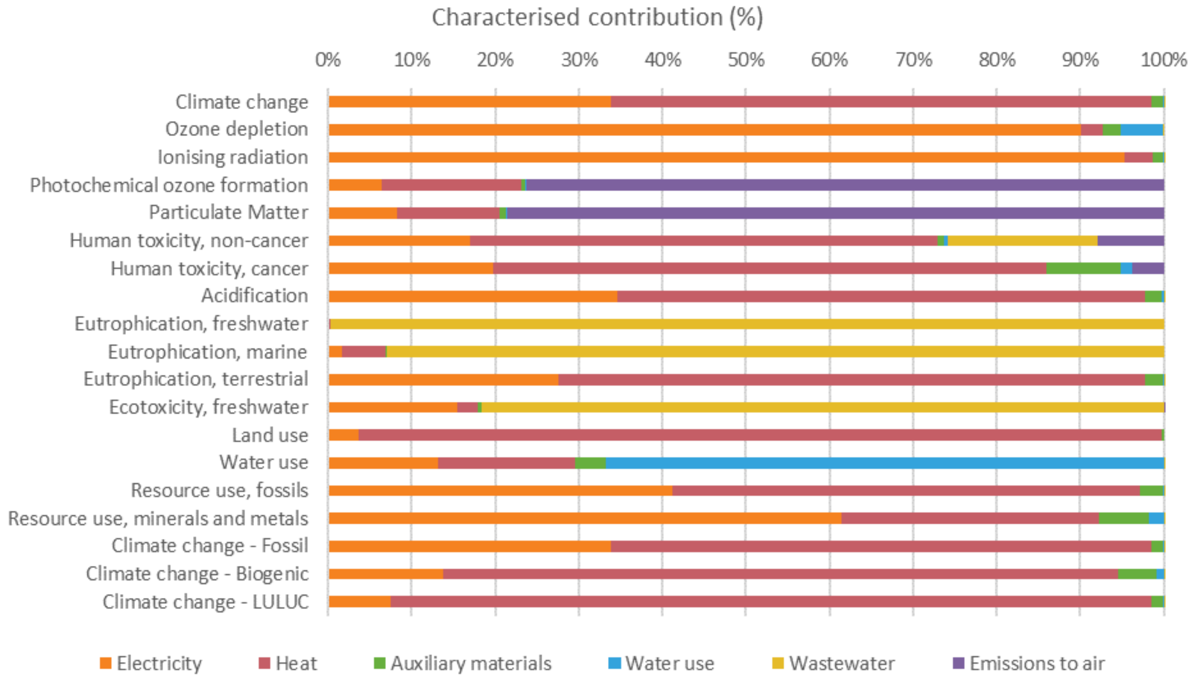

Figure 29: Contribution of inputs to environmental impact of the crushing process (of sunflower seeds)

The energy use of the process, entailing both electricity and heat, is generally the main contributor to the environmental impact caused by the crushing process. Some examples where the contribution of energy is very high (80% and higher contribution to impact category), are climate change (, ozone depletion, ionising radiation, human toxicity cancer, acidification, eutrophication marine, land use and resource use (fossils and minerals and metals). The use of auxiliary materials accounts for rather small contributions to the environmental impact of the sunflower seed crushing process. Wastewater treatment has an important contribution to the impact categories eutrophication freshwater and marine and ecotoxicity freshwater. The emissions to air, which take place during the crushing process are hexane emissions and emissions of particulates. The contribution of the hexane emission to air is clearly visible in the impact category photochemical ozone formation and hexane emissions also contribute to the impact categories human toxicity non-cancer and cancer. Emissions of particulates to air contribute to particulate matter.

5.1.6. REFINED OIL AND CO-PRODUCTS FROM SUNFLOWER

Next to refined oil (Figure 30), the refining process also produces three co-products considered in this study: acid oil, deodistillates, and fatty acid distillates. Since the energy content of these 3 co-products are equal, they have the same environmental profile, Figure 31. The graphs are accompanied with the absolute values of the characterised results (Table 25 - Table 26).

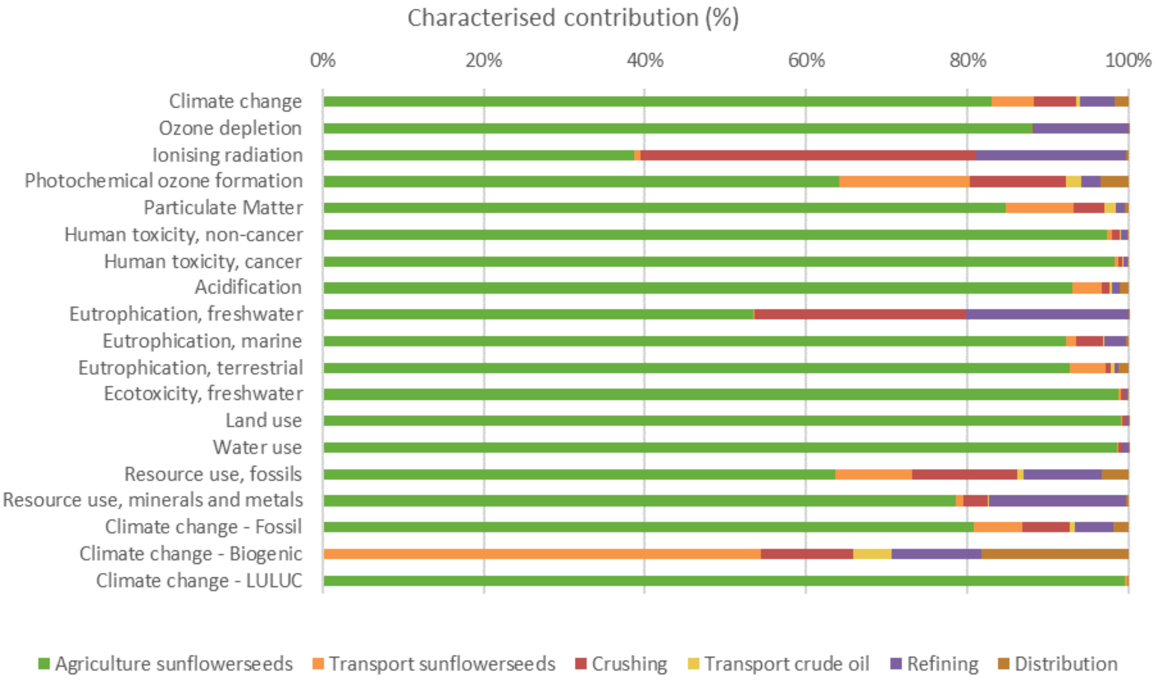

Figure 30: Environmental profile of 1 tonne refined oil from sunflower seeds

Table 25: Characterised results per tonne refined oil from sunflower seeds

Characterised contribution	Unit	Total	Agriculture sunflower seeds	Transport sunflower seeds	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO$_2$ eq*	1,49E+03	1,24E+03	8,03E+01	7,87E+01	7,32E+00	6,25E+01	2,65E+01
Ozone depletion	*kg CFC11 eq*	1,11E-05	9,80E-06	4,08E-10	1,76E-08	2,59E-11	1,31E-06	9,93E-11
Ionising radiation	*kBq U-235 eq*	4,09E+01	1,58E+01	4,60E-01	1,70E+01	2,93E-02	7,58E+00	1,12E-01
Photochemical ozone formation	*kg NMVOC eq*	4,75E+00	3,04E+00	7,69E-01	5,66E-01	9,56E-02	1,09E-01	1,67E-01
Particulate Matter	*disease inc.*	1,50E-04	1,27E-04	1,26E-05	5,80E-06	2,07E-06	1,61E-06	8,24E-07
Human toxicity, non-cancer	*CTUh*	9,13E-05	8,88E-05	6,54E-07	8,65E-07	6,61E-08	7,47E-07	1,89E-07
Human toxicity, cancer	*CTUh*	2,59E-06	2,55E-06	1,23E-08	1,34E-08	1,08E-09	1,38E-08	4,22E-09
Acidification	*mol H$^+$ eq*	1,71E+01	1,59E+01	6,36E-01	1,57E-01	6,76E-02	1,62E-01	1,88E-01
Eutrophication, freshwater	*kg P eq*	7,79E-01	4,17E-01	4,84E-04	2,04E-01	4,28E-05	1,57E-01	1,63E-04
Eutrophication, marine	*kg N eq*	2,32E+01	2,14E+01	3,07E-01	7,78E-01	3,29E-02	5,99E-01	8,57E-02
Eutrophication, terrestrial	*mol N eq*	7,59E+01	7,03E+01	3,37E+00	4,76E-01	3,63E-01	3,96E-01	9,29E-01
Ecotoxicity, freshwater	*CTUe*	2,48E+05	2,44E+05	7,69E+02	1,22E+03	6,79E+01	9,91E+02	2,64E+02
Land use	*Pt*	3,52E+05	3,49E+05	3,17E+02	1,68E+03	2,80E+01	1,03E+03	1,06E+02
Water use	*m^3 depriv.*	3,57E+03	3,52E+03	3,02E+00	1,84E+01	2,64E-01	2,73E+01	1,00E+00
Resource use, fossils	*MJ*	1,10E+04	7,03E+03	1,06E+03	1,43E+03	9,29E+01	1,08E+03	3,60E+02
Resource use, minerals & metals	*kg Sb eq*	4,95E-04	3,89E-04	5,18E-06	1,49E-05	4,50E-07	8,40E-05	1,74E-06
Climate change - Fossil	*kg CO$_2$ eq*	1,32E+03	1,07E+03	7,96E+01	7,86E+01	7,26E+00	6,24E+01	2,62E+01
Climate change - Biogenic	*kg CO$_2$ eq*	2,52E-01	0,00E+00	1,37E-01	2,87E-02	1,21E-02	2,77E-02	4,58E-02
Climate change - LULUC	*kg CO$_2$ eq*	1,69E+02	1,68E+02	5,52E-01	7,00E-02	4,89E-02	4,50E-02	1,86E-01

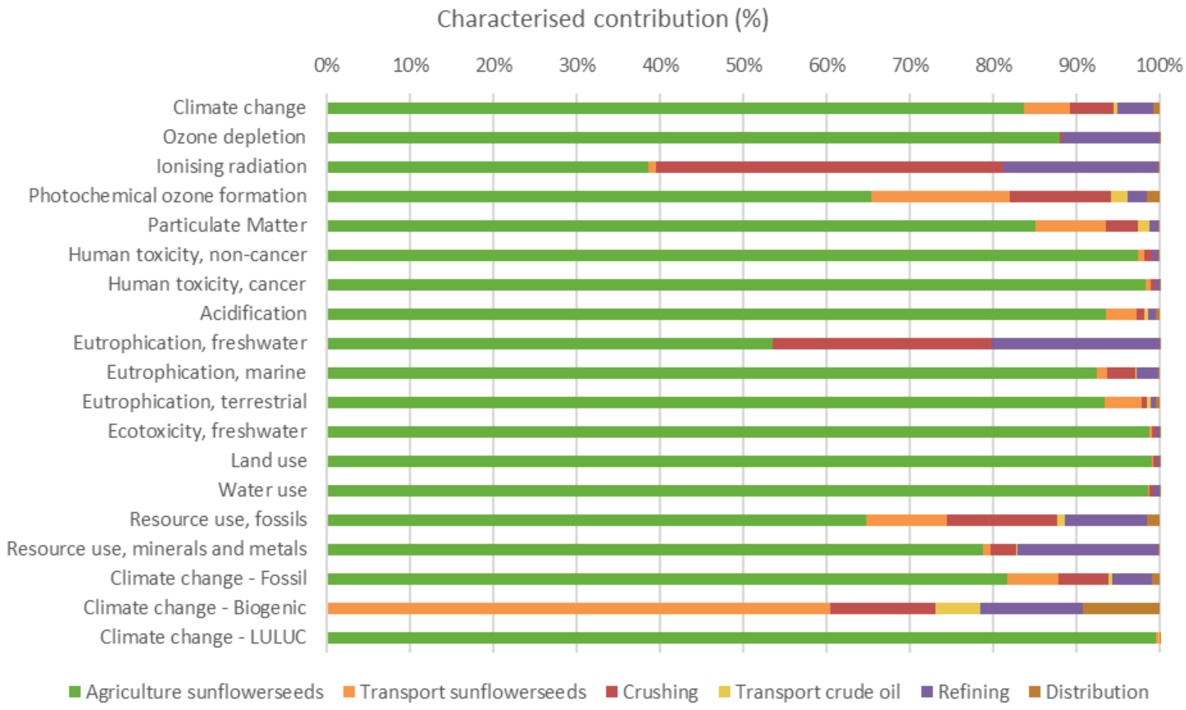

Figure 31: Environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from sunflower seeds

Table 26: Characterised results per tonne acid oil, deodistillates or fatty acid distillates from sunflower seeds

Characterised contribution	Unit	Total	Agriculture sunflower seeds	Transport sunflower seeds	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	1,48E+03	1,24E+03	8,03E+01	7,87E+01	7,32E+00	6,25E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	1,11E-05	9,80E-06	4,08E-10	1,76E-08	2,59E-11	1,31E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	4,09E+01	1,58E+01	4,60E-01	1,70E+01	2,93E-02	7,58E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	4,65E+00	3,04E+00	7,69E-01	5,66E-01	9,56E-02	1,09E-01	6,96E-02
Particulate Matter	*disease inc.*	1,49E-04	1,27E-04	1,26E-05	5,80E-06	2,07E-06	1,61E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	9,12E-05	8,88E-05	6,54E-07	8,65E-07	6,61E-08	7,47E-07	8,47E-08
Human toxicity, cancer	*CTUh*	2,59E-06	2,55E-06	1,23E-08	1,34E-08	1,08E-09	1,38E-08	1,87E-09
Acidification	*mol H^+ eq*	1,70E+01	1,59E+01	6,36E-01	1,57E-01	6,76E-02	1,62E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	7,79E-01	4,17E-01	4,84E-04	2,04E-01	4,28E-05	1,57E-01	7,38E-05
Eutrophication, marine	*kg N eq*	2,31E+01	2,14E+01	3,07E-01	7,78E-01	3,29E-02	5,99E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	7,53E+01	7,03E+01	3,37E+00	4,76E-01	3,63E-01	3,96E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	2,47E+05	2,44E+05	7,69E+02	1,22E+03	6,79E+01	9,91E+02	1,17E+02
Land use	*Pt*	3,52E+05	3,49E+05	3,17E+02	1,68E+03	2,80E+01	1,03E+03	4,82E+01
Water use	*m^3 depriv.*	3,57E+03	3,52E+03	3,02E+00	1,84E+01	2,64E-01	2,73E+01	4,55E-01
Resource use, fossils	*MJ*	1,08E+04	7,03E+03	1,06E+03	1,43E+03	9,29E+01	1,08E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	4,94E-04	3,89E-04	5,18E-06	1,49E-05	4,50E-07	8,40E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	1,31E+03	1,07E+03	7,96E+01	7,86E+01	7,26E+00	6,24E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	2,26E-01	0,00E+00	1,37E-01	2,87E-02	1,21E-02	2,77E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	1,69E+02	1,68E+02	5,52E-01	7,00E-02	4,89E-02	4,50E-02	8,42E-02

In order to gain more insight into the refining process' inputs and outputs causing the environmental impact, the refining process (purple bars in Figure 30-Figure 31) is subdivided in Figure 32. In this graph, the contributions to the total impact generated by the refining process of electricity, heat, auxiliary materials, water use, wastewater and emissions to air are shown.

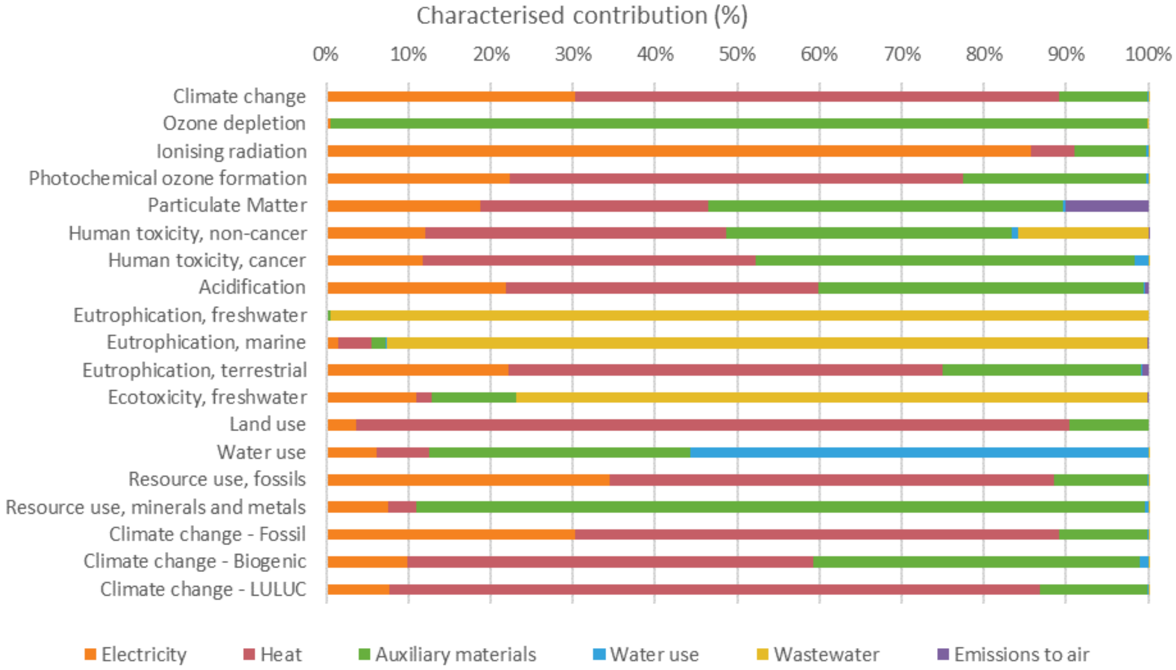

Figure 32: Contribution of inputs to environmental impact of the refining process (of crude sunflower oil)

The energy use of the process, entailing both electricity and heat, is generally the main contributor to the environmental impact caused by the refining process. The contribution of energy is very high (80% or higher contribution to impact category) in climate change (all except biogenic), ionising radiation, land use and fossil resource use. The use of auxiliary materials is the main contributor to ozone depletion and resource use, minerals and metals. Also, for photochemical ozone formation, particulate matter, human toxicity, acidification, eutrophication terrestrial, ecotoxicity freshwater, water use and climate change biogenic its contribution is higher than 20%. The main contributing auxiliary materials are bleaching earth, phosphoric acid and caustic soda. Wastewater treatment has a relevant contribution to the impact category eutrophication freshwater and marine and ecotoxicity freshwater. Particulate matter emissions to air which take place during the refining process have a small contribution to the impact category particulate matter.

5.1.7. CRUDE OIL AND CO-PRODUCTS FROM MAIZE GERMS

Crushing of maize germs produces crude oil and meal. The environmental profiles from crude oil and meal from maize germs are presented below (Figure 33 and Figure 34), together with the absolute values of the characterised results (Table 27 - Table 28). Impacts are expressed per tonne output product. The two products are outputs of the crushing process, but due to the energy allocation method, they receive different impacts per tonne product.
Due to confidentiality, no detailed analysis of the crushing process can be shared.

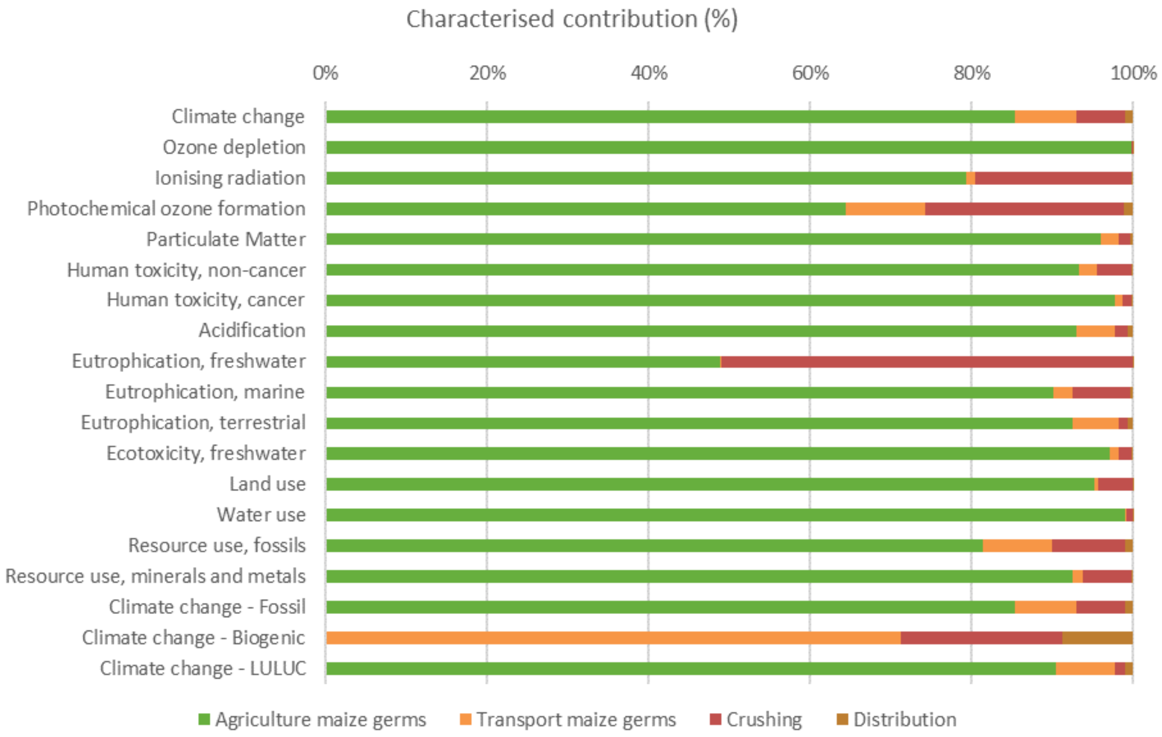

Figure 33: Environmental profile of 1 tonne crude oil from maize germs

Table 27: Characterised results per tonne crude oil from maize germs

Characterised contribution	Unit	Total	Agriculture maize germs	Transport maize germs	Crushing	Distribution
Climate change	*kg CO_2 eq*	1,27E+03	1,08E+03	9,58E+01	7,68E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	2,00E-05	1,99E-05	3,63E-10	2,40E-08	4,47E-11
Ionising radiation	*kBq U-235 eq*	4,04E+01	3,21E+01	4,11E-01	7,85E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	5,81E+00	3,74E+00	5,69E-01	1,42E+00	6,96E-02
Particulate Matter	*disease inc.*	1,09E-04	1,04E-04	2,43E-06	1,55E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	3,23E-05	3,01E-05	6,92E-07	1,37E-06	8,47E-08
Human toxicity, cancer	*CTUh*	1,68E-06	1,65E-06	1,52E-08	1,95E-08	1,87E-09
Acidification	*mol H^+ eq*	1,30E+01	1,21E+01	6,28E-01	2,06E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	4,68E-01	2,29E-01	6,00E-04	2,39E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,28E+01	1,15E+01	3,01E-01	9,23E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	5,71E+01	5,29E+01	3,26E+00	6,21E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	8,51E+04	8,26E+04	9,50E+02	1,45E+03	1,17E+02
Land use	*Pt*	7,20E+04	6,86E+04	3,92E+02	3,01E+03	4,82E+01
Water use	*m^3 depriv.*	3,83E+03	3,79E+03	3,70E+00	3,38E+01	4,55E-01
Resource use, fossils	*MJ*	1,54E+04	1,26E+04	1,31E+03	1,40E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	5,07E-04	4,70E-04	6,31E-06	3,06E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	1,26E+03	1,07E+03	9,50E+01	7,66E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	2,37E-01	0,00E+00	1,69E-01	4,72E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	9,35E+00	8,46E+00	6,85E-01	1,19E-01	8,42E-02

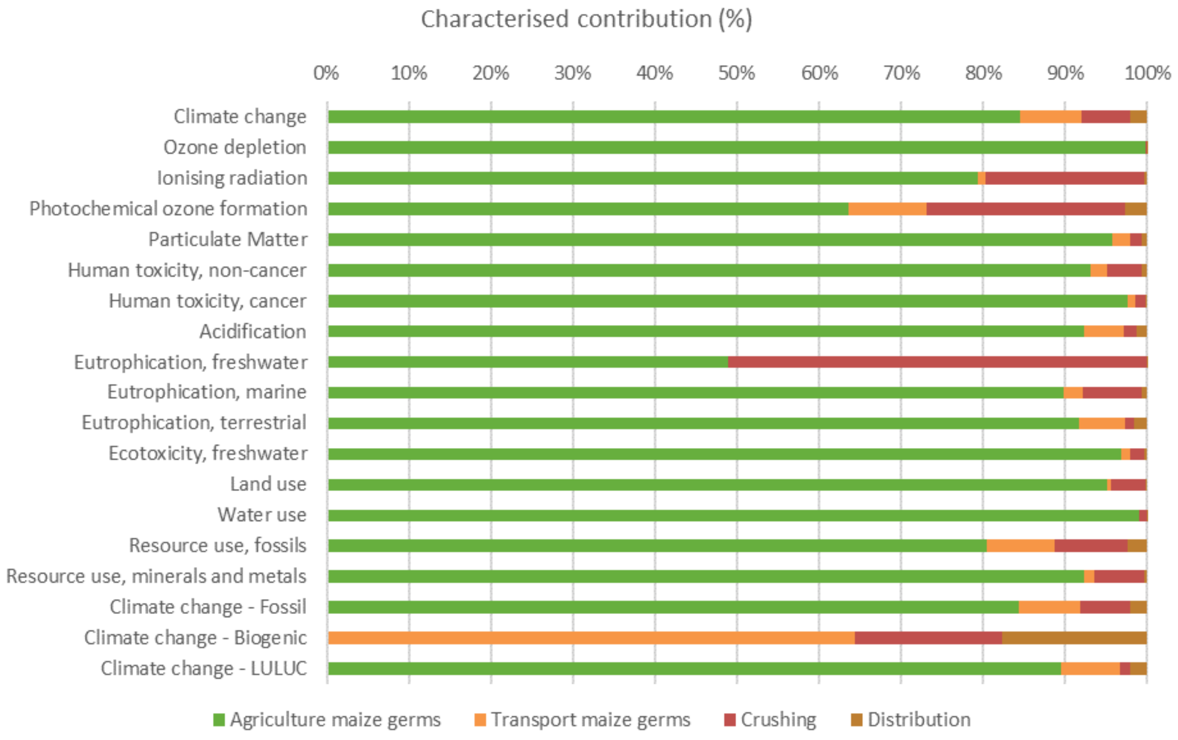

Figure 34: Environmental profile of 1 tonne meal from maize germs

Table 28: Characterised results per tonne meal from maize germs

Characterised contribution	Unit	Total	Agriculture maize germs	Transport maize germs	Crushing	Distribution
Climate change	*kg CO_2 eq*	5,71E+02	4,82E+02	4,27E+01	3,42E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	8,91E-06	8,90E-06	1,62E-10	1,07E-08	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,80E+01	1,43E+01	1,83E-01	3,50E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	2,63E+00	1,67E+00	2,54E-01	6,35E-01	6,96E-02
Particulate Matter	*disease inc.*	4,86E-05	4,65E-05	1,08E-06	6,89E-07	2,94E-07
Human toxicity, non-cancer	*CTUh*	1,44E-05	1,34E-05	3,09E-07	6,11E-07	8,47E-08
Human toxicity, cancer	*CTUh*	7,51E-07	7,34E-07	6,78E-09	8,68E-09	1,87E-09
Acidification	*mol H^+ eq*	5,84E+00	5,40E+00	2,80E-01	9,18E-02	7,68E-02
Eutrophication, freshwater	*kg P eq*	2,09E-01	1,02E-01	2,68E-04	1,07E-01	7,38E-05
Eutrophication, marine	*kg N eq*	5,73E+00	5,15E+00	1,34E-01	4,12E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	2,57E+01	2,36E+01	1,45E+00	2,77E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	3,80E+04	3,68E+04	4,24E+02	6,47E+02	1,17E+02
Land use	*Pt*	3,21E+04	3,06E+04	1,75E+02	1,34E+03	4,82E+01
Water use	*m^3 depriv.*	1,71E+03	1,69E+03	1,65E+00	1,51E+01	4,55E-01
Resource use, fossils	*MJ*	6,98E+03	5,61E+03	5,82E+02	6,22E+02	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,27E-04	2,09E-04	2,81E-06	1,37E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	5,67E+02	4,78E+02	4,24E+01	3,42E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	1,17E-01	0,00E+00	7,53E-02	2,10E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	4,22E+00	3,77E+00	3,05E-01	5,32E-02	8,42E-02

5.1.8. REFINED OIL AND CO-PRODUCTS FROM MAIZE GERMS

Next to refined oil (Figure 35), the refining process also produces two co-products considered in this study: acid oil and deodistillates. Since the energy content and distribution scenario of these 2 co-products are equal, they have the same environmental profile, Figure 36. The graphs are accompanied with the absolute values of the characterised results (Table 29 - Table 30). The distribution scenarios of refined oil and the 2 other co-products differ, as discussed in section 4.3.8 and 5.1.

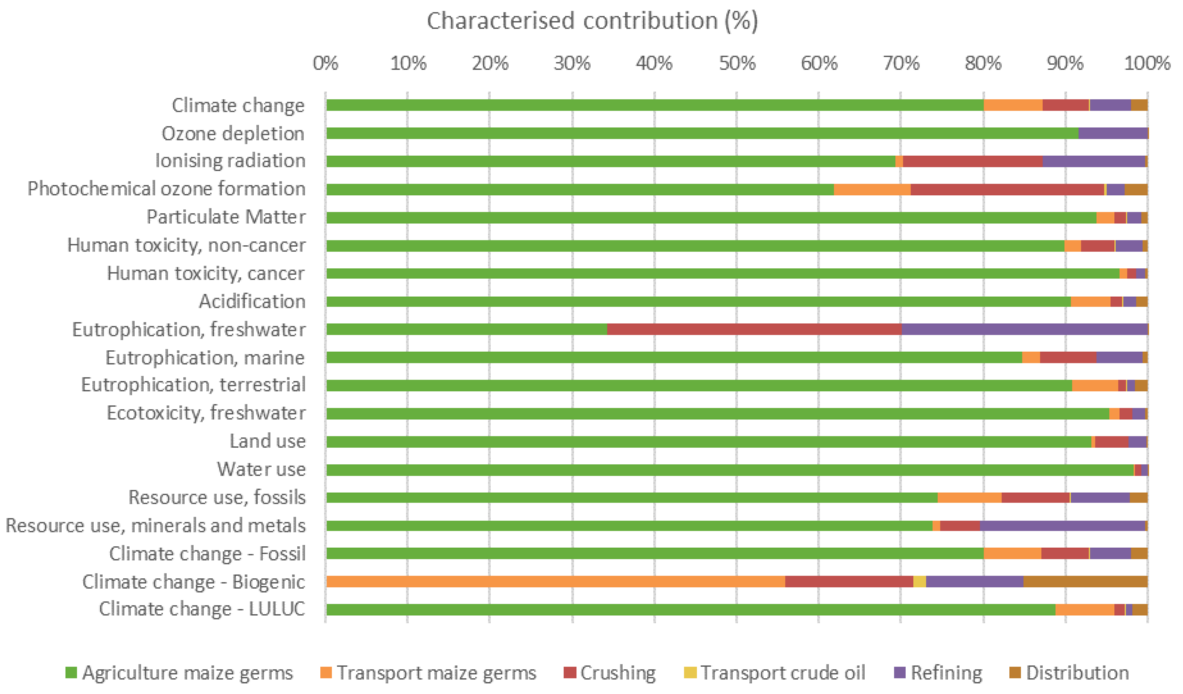

Figure 35: Environmental profile of 1 tonne refined oil from maize germs

Table 29: Characterised results per tonne refined oil from maize germs

Characterised contribution	Unit	Total	Agriculture maize germs	Transport maize germs	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	1,36E+03	1,09E+03	9,63E+01	7,71E+01	2,57E+00	6,78E+01	2,65E+01
Ozone depletion	*kg CFC11 eq*	2,19E-05	2,00E-05	3,65E-10	2,41E-08	9,73E-12	1,83E-06	9,93E-11
Ionising radiation	*kBq U-235 eq*	4,65E+01	3,22E+01	4,13E-01	7,89E+00	1,10E-02	5,85E+00	1,12E-01
Photochemical ozone formation	*kg NMVOC eq*	6,08E+00	3,76E+00	5,72E-01	1,43E+00	1,52E-02	1,38E-01	1,67E-01
Particulate Matter	*disease inc.*	1,12E-04	1,05E-04	2,44E-06	1,55E-06	6,50E-08	2,01E-06	8,24E-07
Human toxicity, non-cancer	*CTUh*	3,37E-05	3,03E-05	6,96E-07	1,38E-06	1,85E-08	1,13E-06	1,89E-07
Human toxicity, cancer	*CTUh*	1,71E-06	1,65E-06	1,53E-08	1,96E-08	4,07E-10	1,84E-08	4,22E-09
Acidification	*mol H^+ eq*	1,34E+01	1,22E+01	6,31E-01	2,07E-01	1,68E-02	2,03E-01	1,88E-01
Eutrophication, freshwater	*kg P eq*	6,72E-01	2,30E-01	6,03E-04	2,40E-01	1,61E-05	2,01E-01	1,63E-04
Eutrophication, marine	*kg N eq*	1,37E+01	1,16E+01	3,02E-01	9,27E-01	8,05E-03	7,62E-01	8,57E-02
Eutrophication, terrestrial	*mol N eq*	5,85E+01	5,31E+01	3,28E+00	6,24E-01	8,73E-02	4,95E-01	9,29E-01
Ecotoxicity, freshwater	*CTUe*	8,70E+04	8,30E+04	9,55E+02	1,46E+03	2,54E+01	1,29E+03	2,64E+02
Land use	*Pt*	7,40E+04	6,89E+04	3,94E+02	3,02E+03	1,05E+01	1,59E+03	1,06E+02
Water use	*m^3 depriv.*	3,87E+03	3,81E+03	3,72E+00	3,40E+01	9,90E-02	2,68E+01	1,00E+00
Resource use, fossils	*MJ*	1,70E+04	1,26E+04	1,31E+03	1,40E+03	3,49E+01	1,22E+03	3,60E+02
Resource use, minerals & metals	*kg Sb eq*	6,40E-04	4,72E-04	6,34E-06	3,08E-05	1,69E-07	1,29E-04	1,74E-06
Climate change - Fossil	*kg CO_2 eq*	1,35E+03	1,08E+03	9,54E+01	7,70E+01	2,54E+00	6,77E+01	2,62E+01
Climate change - Biogenic	*kg CO_2 eq*	3,03E-01	0,00E+00	1,70E-01	4,74E-02	4,52E-03	3,60E-02	4,58E-02
Climate change - LULUC	*kg CO_2 eq*	9,58E+00	8,50E+00	6,88E-01	1,20E-01	1,83E-02	6,48E-02	1,86E-01

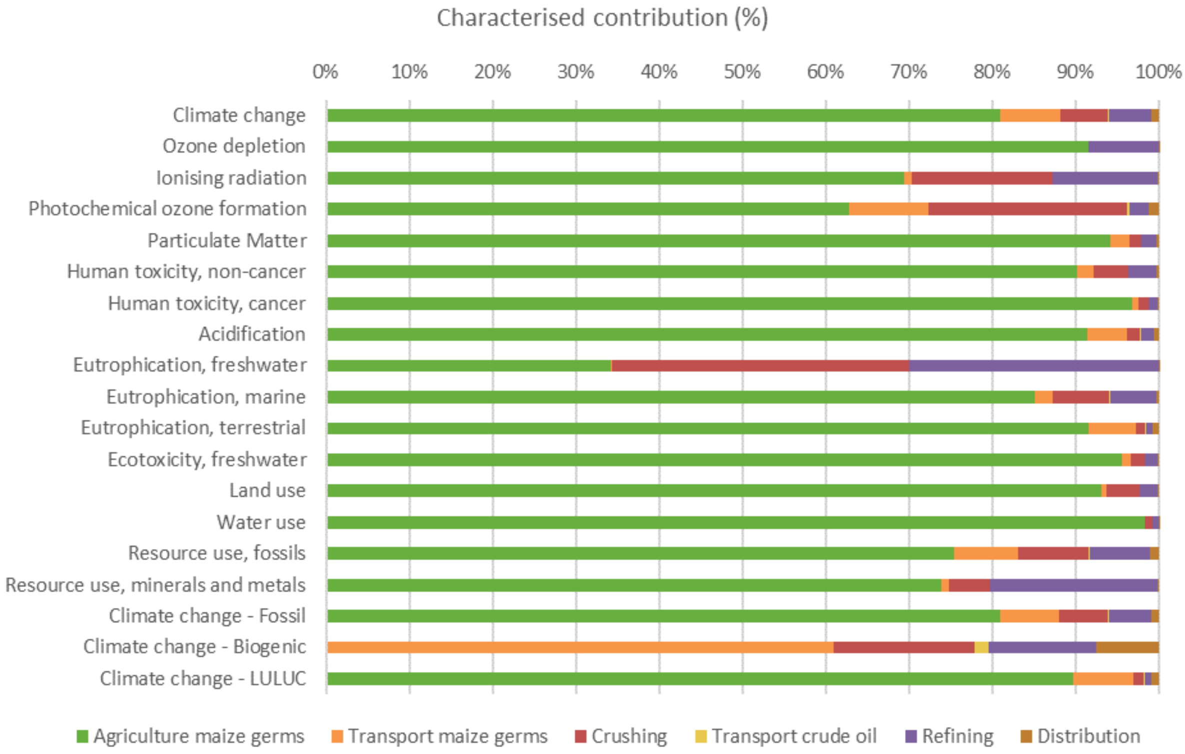

Figure 36: Environmental profile of 1 tonne acid oil or deodistillates from maize germs

Table 30: Characterised results per tonne acid oil or deodistillates from maize germs

Characterised contribution	Unit	Total	Agriculture maize germs	Transport maize germs	Crushing	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	1,34E+03	1,09E+03	9,63E+01	7,71E+01	2,57E+00	6,78E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	2,19E-05	2,00E-05	3,65E-10	2,41E-08	9,73E-12	1,83E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	4,64E+01	3,22E+01	4,13E-01	7,89E+00	1,10E-02	5,85E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	5,99E+00	3,76E+00	5,72E-01	1,43E+00	1,52E-02	1,38E-01	6,96E-02
Particulate Matter	*disease inc.*	1,11E-04	1,05E-04	2,44E-06	1,55E-06	6,50E-08	2,01E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	3,36E-05	3,03E-05	6,96E-07	1,38E-06	1,85E-08	1,13E-06	8,47E-08
Human toxicity, cancer	*CTUh*	1,71E-06	1,65E-06	1,53E-08	1,96E-08	4,07E-10	1,84E-08	1,87E-09
Acidification	*mol H^+ eq*	1,33E+01	1,22E+01	6,31E-01	2,07E-01	1,68E-02	2,03E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	6,72E-01	2,30E-01	6,03E-04	2,40E-01	1,61E-05	2,01E-01	7,38E-05
Eutrophication, marine	*kg N eq*	1,36E+01	1,16E+01	3,02E-01	9,27E-01	8,05E-03	7,62E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	5,80E+01	5,31E+01	3,28E+00	6,24E-01	8,73E-02	4,95E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	8,68E+04	8,30E+04	9,55E+02	1,46E+03	2,54E+01	1,29E+03	1,17E+02
Land use	*Pt*	7,39E+04	6,89E+04	3,94E+02	3,02E+03	1,05E+01	1,59E+03	4,82E+01
Water use	*m^3 depriv.*	3,87E+03	3,81E+03	3,72E+00	3,40E+01	9,90E-02	2,68E+01	4,55E-01
Resource use, fossils	*MJ*	1,68E+04	1,26E+04	1,31E+03	1,40E+03	3,49E+01	1,22E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	6,39E-04	4,72E-04	6,34E-06	3,08E-05	1,69E-07	1,29E-04	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	1,33E+03	1,08E+03	9,54E+01	7,70E+01	2,54E+00	6,77E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	2,78E-01	0,00E+00	1,70E-01	4,74E-02	4,52E-03	3,60E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	9,48E+00	8,50E+00	6,88E-01	1,20E-01	1,83E-02	6,48E-02	8,42E-02

In order to gain more insight into the refining process' inputs and outputs causing the environmental impact, the refining process (purple bars in Figure 35-Figure 36) is subdivided in Figure 37. In this graph, the contributions to the total impact generated by the refining process of electricity, heat, auxiliary materials, water use, wastewater and emissions to air are shown.

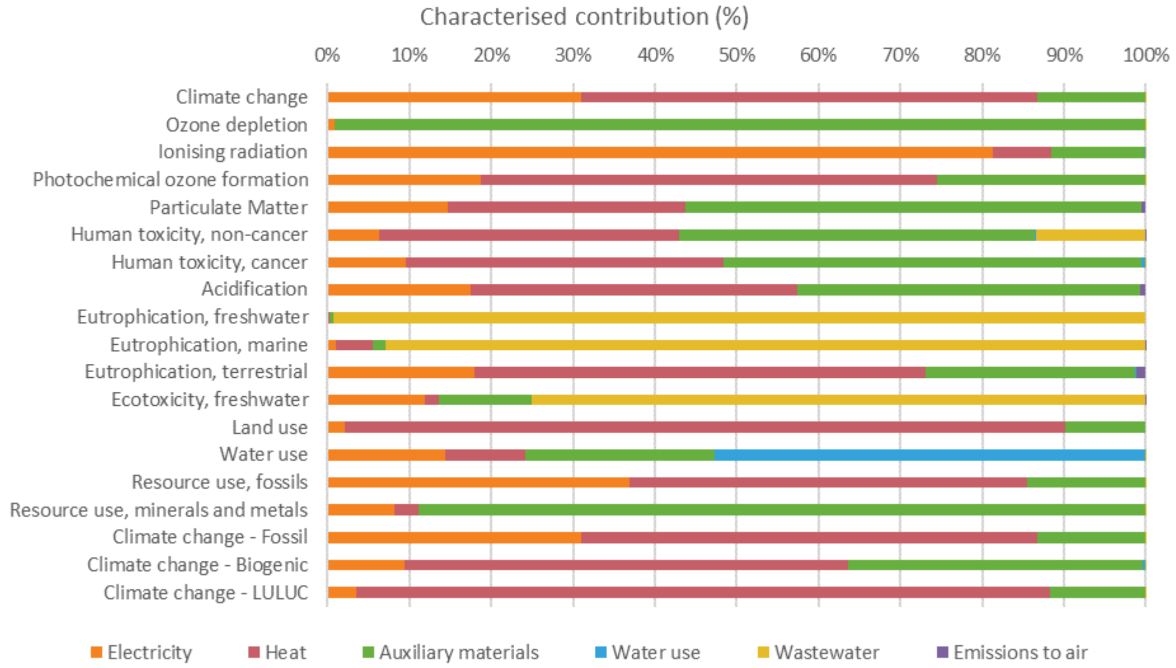

Figure 37: Contribution of inputs to environmental impact of the refining process (of crude maize oil)

The energy use of the process, entailing both electricity and heat, is generally the main contributor to the environmental impact caused by the refining process. The contribution of energy is very high (80% or higher contribution to impact category) in climate change (all except biogenic), ionising radiation, land use and fossil resource use. The use of auxiliary materials is the main contributor to ozone depletion and resource use, minerals and metals. Also, for photochemical ozone formation, particulate matter, human toxicity, acidification, eutrophication terrestrial and water use, its contribution is higher than 20%. The contribution of auxiliary materials comes for a large extent from the use of bleaching earth. Wastewater treatment has a relevant contribution to the impact category eutrophication freshwater and marine and ecotoxicity freshwater.

5.1.9. REFINED OIL AND CO-PRODUCTS FROM PALM

Next to refined oil (Figure 38), the refining process also produces three co-products considered in this study: acid oil, deodistillates and fatty acid distillates. Since the energy content and distribution scenario of these three co-products are equal, they have the same environmental profile, Figure 39. The graphs are accompanied with the absolute values of the characterised results (Table 31 - Table 32). Impacts are expressed per tonne output product. The distribution scenarios of refined oil and the 3 co-products differ, as discussed in section 4.3.8 and 5.1. FEDIOL member companies purchase crude palm oil from different regions in the world. However, the background database only contains palm oil from Indonesia, Malaysia and Thailand. Malaysia and Indonesia where used as proxies for other regions in the world (see also section 4.3.2). Palm cultivation in Indonesia is subject to peatland conversion, which results in a contribution to the climate change LULUC impact category. The contribution of climate change LULUC to climate change total is about 10%. On the figures, a benefit in the impact category water use is visible. This benefit arises from the treatment of wastewater during crude palm oil production. The LCI of palm cultivation can be quite different from different sources, especially considering land use change and palm oil mill effluent treatment. In this project the Agri-footprint database has been consistently applied, its generic character should however be kept in mind when interpreting the results. Different agricultural practices and technologies to produce crude palm oil might lead to different results in the agriculture life cycle stage, which is the most important life cycle stage. Methane capture from palm oil mill effluent treatment is not included in the Agri-footprint dataset on crude palm oil production.

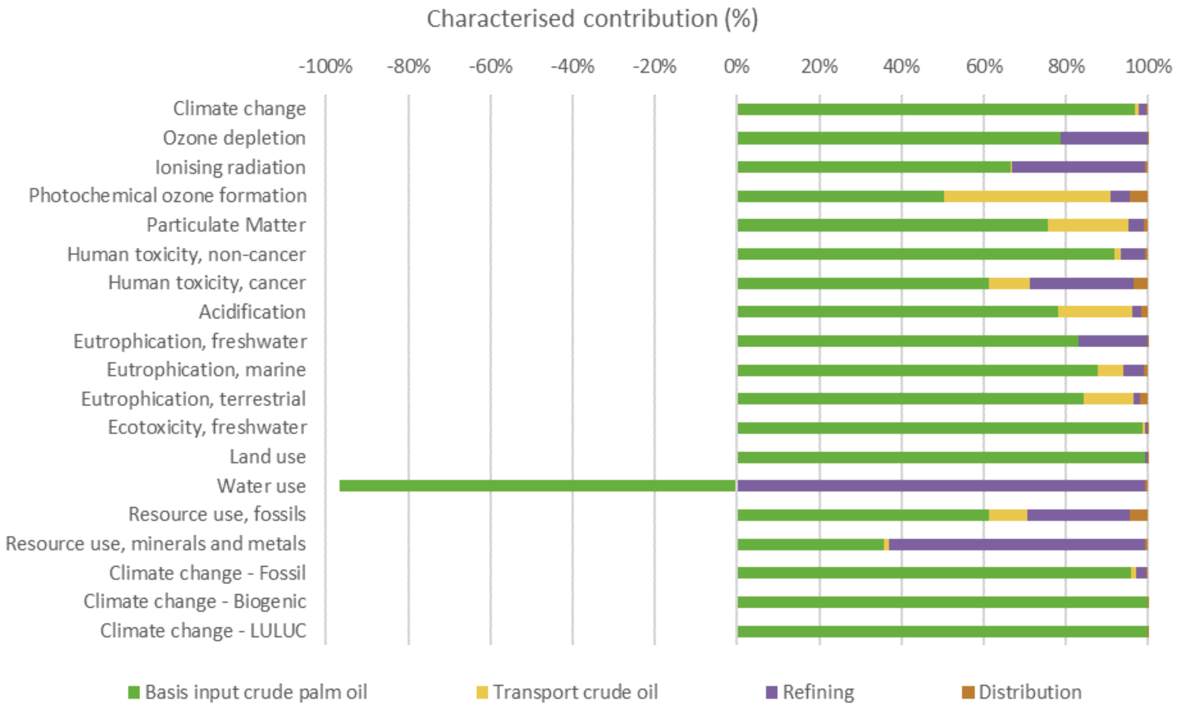

Figure 38: Environmental profile of 1 tonne refined oil from palm

Table 31: Characterised results per tonne refined oil from palm

Characterised contribution	Unit	Total	Basis input crude palm oil	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	6,86E+03	6,64E+03	6,07E+01	1,29E+02	2,65E+01
Ozone depletion	*kg CFC11 eq*	9,74E-06	7,67E-06	1,05E-10	2,07E-06	9,93E-11
Ionising radiation	*kBq U-235 eq*	1,79E+01	1,19E+01	8,46E-02	5,80E+00	1,12E-01
Photochemical ozone formation	*kg NMVOC eq*	3,73E+00	1,88E+00	1,50E+00	1,79E-01	1,67E-01
Particulate Matter	*disease inc.*	8,78E-05	6,64E-05	1,73E-05	3,37E-06	8,24E-07
Human toxicity, non-cancer	*CTUh*	2,37E-05	2,18E-05	3,14E-07	1,41E-06	1,89E-07
Human toxicity, cancer	*CTUh*	1,16E-07	7,11E-08	1,17E-08	2,91E-08	4,22E-09
Acidification	*mol H^+ eq*	1,22E+01	9,57E+00	2,20E+00	2,87E-01	1,88E-01
Eutrophication, freshwater	*kg P eq*	5,65E-01	4,69E-01	1,46E-05	9,62E-02	1,63E-04
Eutrophication, marine	*kg N eq*	8,62E+00	7,56E+00	5,36E-01	4,38E-01	8,57E-02
Eutrophication, terrestrial	*mol N eq*	4,86E+01	4,10E+01	5,87E+00	7,86E-01	9,29E-01
Ecotoxicity, freshwater	*CTUe*	1,36E+05	1,34E+05	7,33E+02	8,79E+02	2,64E+02
Land use	*Pt*	1,25E+05	1,25E+05	3,42E+00	6,17E+02	1,06E+02
Water use	*m^3 depriv.*	3,95E+00	-1,18E+02	2,34E-01	1,21E+02	1,00E+00
Resource use, fossils	*MJ*	8,01E+03	4,91E+03	7,41E+02	2,00E+03	3,60E+02
Resource use, minerals & metals	*kg Sb eq*	2,91E-04	1,04E-04	3,54E-06	1,81E-04	1,74E-06
Climate change - Fossil	*kg CO_2 eq*	5,22E+03	5,01E+03	6,07E+01	1,29E+02	2,62E+01
Climate change - Biogenic	*kg CO_2 eq*	9,41E+02	9,41E+02	1,61E-03	5,36E-02	4,58E-02
Climate change - LULUC	*kg CO_2 eq*	6,94E+02	6,94E+02	4,92E-03	3,46E-02	1,86E-01

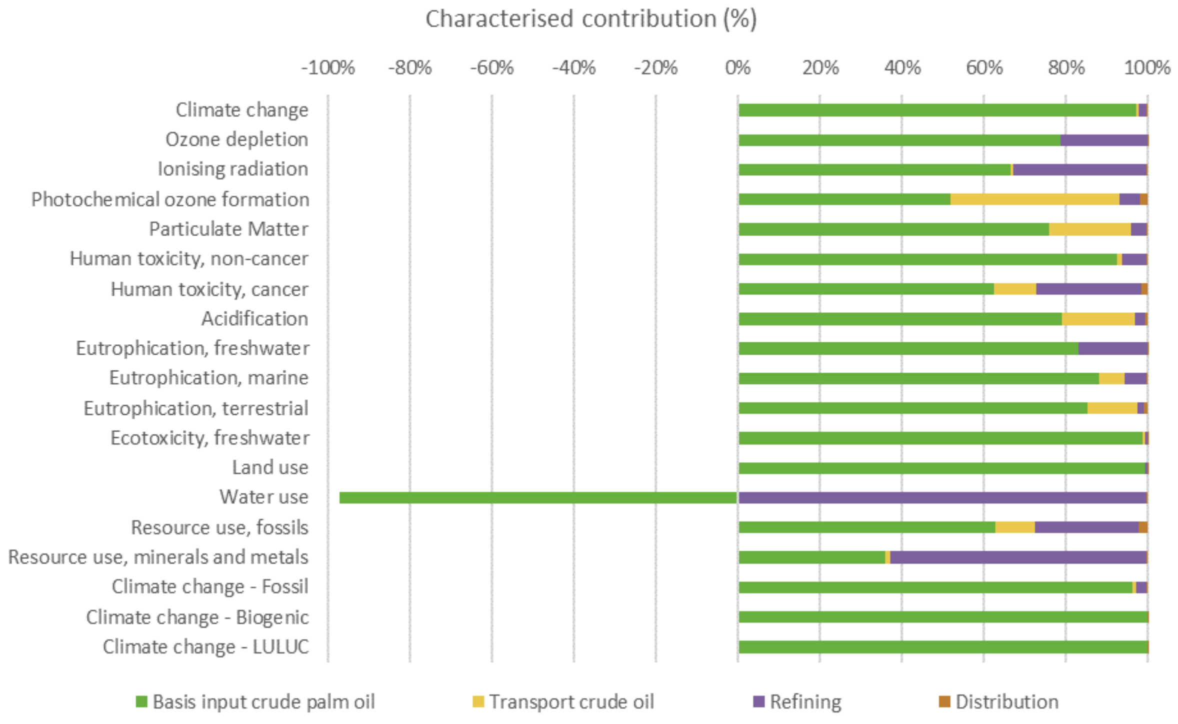

Figure 39: Environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from palm

Table 32: Characterised results per tonne acid oil, deodistillates or fatty acid distillates from palm

Characterised contribution	Unit	Total	Basis input crude palm oil	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	6,84E+03	6,64E+03	6,07E+01	1,29E+02	1,18E+01
Ozone depletion	*kg CFC11 eq*	9,74E-06	7,67E-06	1,05E-10	2,07E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,78E+01	1,19E+01	8,46E-02	5,80E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	3,63E+00	1,88E+00	1,50E+00	1,79E-01	6,96E-02
Particulate Matter	*disease inc.*	8,73E-05	6,64E-05	1,73E-05	3,37E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	2,36E-05	2,18E-05	3,14E-07	1,41E-06	8,47E-08
Human toxicity, cancer	*CTUh*	1,14E-07	7,11E-08	1,17E-08	2,91E-08	1,87E-09
Acidification	*mol H^+ eq*	1,21E+01	9,57E+00	2,20E+00	2,87E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	5,65E-01	4,69E-01	1,46E-05	9,62E-02	7,38E-05
Eutrophication, marine	*kg N eq*	8,57E+00	7,56E+00	5,36E-01	4,38E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	4,81E+01	4,10E+01	5,87E+00	7,86E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,36E+05	1,34E+05	7,33E+02	8,79E+02	1,17E+02
Land use	*Pt*	1,25E+05	1,25E+05	3,42E+00	6,17E+02	4,82E+01
Water use	*m^3 depriv.*	3,40E+00	-1,18E+02	2,34E-01	1,21E+02	4,55E-01
Resource use, fossils	*MJ*	7,81E+03	4,91E+03	7,41E+02	2,00E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,90E-04	1,04E-04	3,54E-06	1,81E-04	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	5,21E+03	5,01E+03	6,07E+01	1,29E+02	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	9,41E+02	9,41E+02	1,61E-03	5,36E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	6,94E+02	6,94E+02	4,92E-03	3,46E-02	8,42E-02

In order to gain more insight into the refining process' inputs and outputs causing the environmental impact, the refining process (purple bars in Figure 38-Figure 39) is subdivided in Figure 40. In this graph, the contributions to the total impact generated by the refining process of electricity, heat, auxiliary materials, water use wastewater and emissions to air are shown.

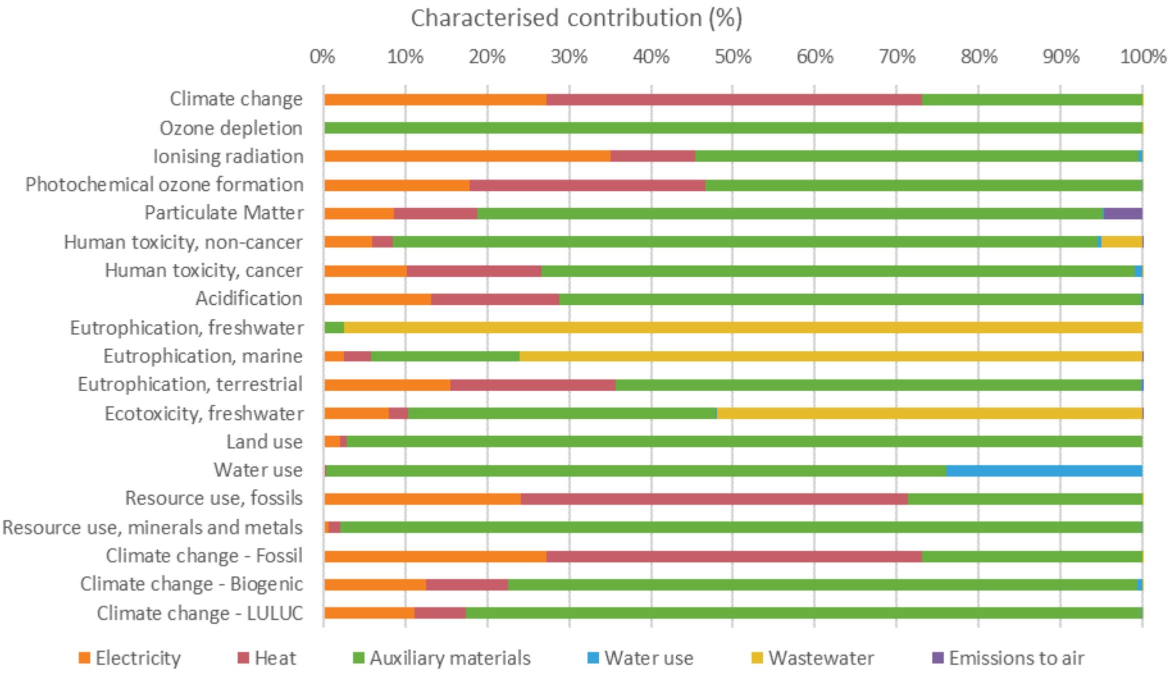

Figure 40: Contribution of inputs to environmental impact of the refining process (of crude palm oil)

The auxiliary materials used in the refining process are generally the main contributor to the environmental impact caused by the refining process. Some examples where the contribution of auxiliary materials is high (around 70% and higher contribution to impact category), are ozone depletion, human toxicity non-cancer, acidification, land use, water use, resource use minerals and metals and climate change biogenic and LULUC. The auxiliary materials which mainly contribute to the environmental impact are bleaching earth and citric acid. The use of energy (electricity and heat) has large contributions to climate change (total and fossil) and fossil resource use. Also, for ionizing radiation, photochemical ozone formation, human toxicity (cancer), acidification, eutrophication terrestrial, and climate change biogenic, its contribution is higher than 20%. Wastewater treatment has a relevant contribution to the impact category eutrophication freshwater and marine and ecotoxicity freshwater.

5.1.10. REFINED OIL AND CO-PRODUCTS FROM PALM KERNEL

The refining of palm kernel oil produces refined oil and fatty acid distillates. The environmental profiles from refined oil and fatty acid distillates are presented below (Figure 41 and Figure 42) together with the absolute values of the characterised results (Table 33 - Table 34). Impacts are expressed per tonne output product. Like for processing of crude palm oil, FEDIOL member companies purchase crude palm kernel oil from different regions in the world. Again, the background database only contains palm kernel oil from Indonesia, Malaysia and Thailand. Malaysia and Indonesia where used as proxies for other regions in the world (see also section 4.3.2). Palm kernel cultivation in Indonesia is subject to peatland conversion, which results in a contribution to the climate change LULUC impact category. The contribution of climate change LULUC to climate change total is about 7%. On the figures, a benefit in the impact category water use is visible. This benefit arises from the treatment of wastewater during crude palm kernel oil production. Also, for palm kernel oil, the LCI can be differ between different sources. It should be kept in mind when interpreting the results for the life cycle stage on crude oil production.

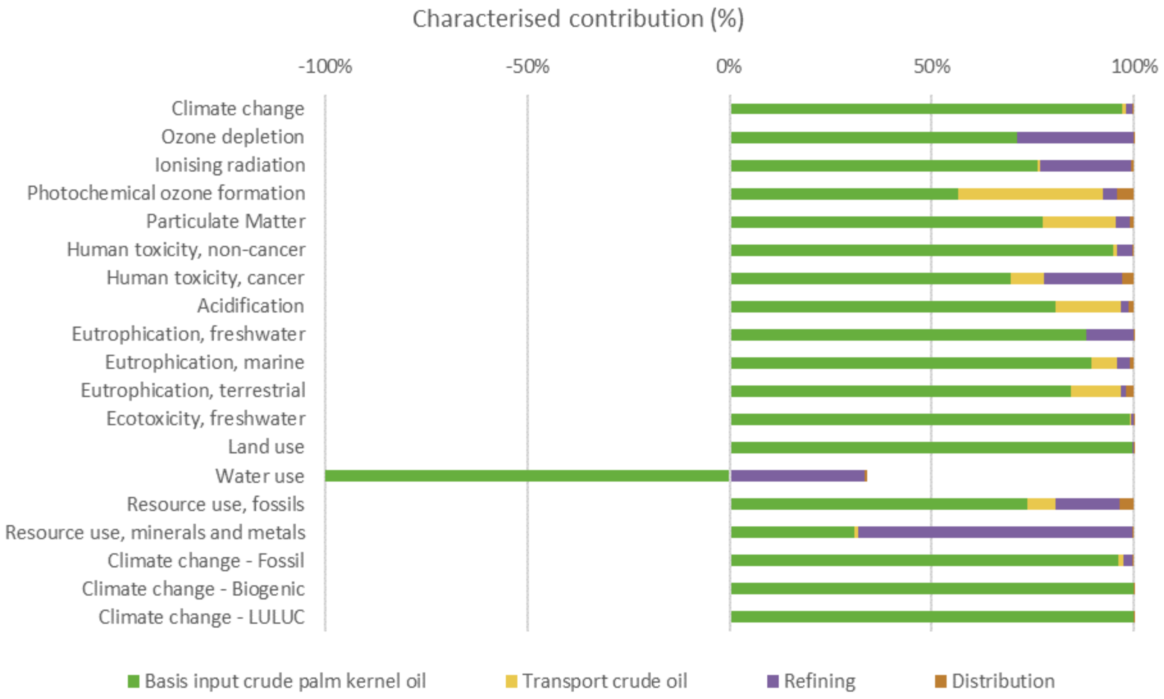

Figure 41: Environmental profile of 1 tonne refined oil from palm kernel

Table 33: Characterised results per tonne refined oil from palm kernel

Characterised contribution	Unit	Total	Basis input crude palm kernel oil	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	6,07E+03	5,88E+03	5,84E+01	9,69E+01	2,65E+01
Ozone depletion	*kg CFC11 eq*	1,09E-05	7,73E-06	1,01E-10	3,15E-06	9,93E-11
Ionising radiation	*kBq U-235 eq*	1,57E+01	1,20E+01	8,16E-02	3,55E+00	1,12E-01
Photochemical ozone formation	*kg NMVOC eq*	4,06E+00	2,30E+00	1,45E+00	1,47E-01	1,67E-01
Particulate Matter	*disease inc.*	9,19E-05	7,11E-05	1,66E-05	3,38E-06	8,24E-07
Human toxicity, non-cancer	*CTUh*	4,10E-05	3,90E-05	3,02E-07	1,58E-06	1,89E-07
Human toxicity, cancer	*CTUh*	1,38E-07	9,58E-08	1,12E-08	2,65E-08	4,22E-09
Acidification	*mol H^+ eq*	1,31E+01	1,06E+01	2,11E+00	2,38E-01	1,88E-01
Eutrophication, freshwater	*kg P eq*	4,97E-01	4,39E-01	1,45E-05	5,81E-02	1,63E-04
Eutrophication, marine	*kg N eq*	8,08E+00	7,24E+00	5,15E-01	2,43E-01	8,57E-02
Eutrophication, terrestrial	*mol N eq*	4,58E+01	3,87E+01	5,64E+00	5,18E-01	9,29E-01
Ecotoxicity, freshwater	*CTUe*	1,53E+05	1,52E+05	7,04E+02	6,73E+02	2,64E+02
Land use	*Pt*	1,16E+05	1,15E+05	3,62E+00	4,48E+02	1,06E+02
Water use	*m^3 depriv.*	-7,93E+01	-1,21E+02	2,28E-01	4,00E+01	1,00E+00
Resource use, fossils	*MJ*	1,00E+04	7,38E+03	7,13E+02	1,57E+03	3,60E+02
Resource use, minerals & metals	*kg Sb eq*	3,36E-04	1,04E-04	3,40E-06	2,27E-04	1,74E-06
Climate change - Fossil	*kg CO_2 eq*	4,74E+03	4,56E+03	5,83E+01	9,68E+01	2,62E+01
Climate change - Biogenic	*kg CO_2 eq*	9,04E+02	9,04E+02	1,69E-03	3,96E-02	4,58E-02
Climate change - LULUC	*kg CO_2 eq*	4,22E+02	4,22E+02	5,30E-03	1,68E-02	1,86E-01

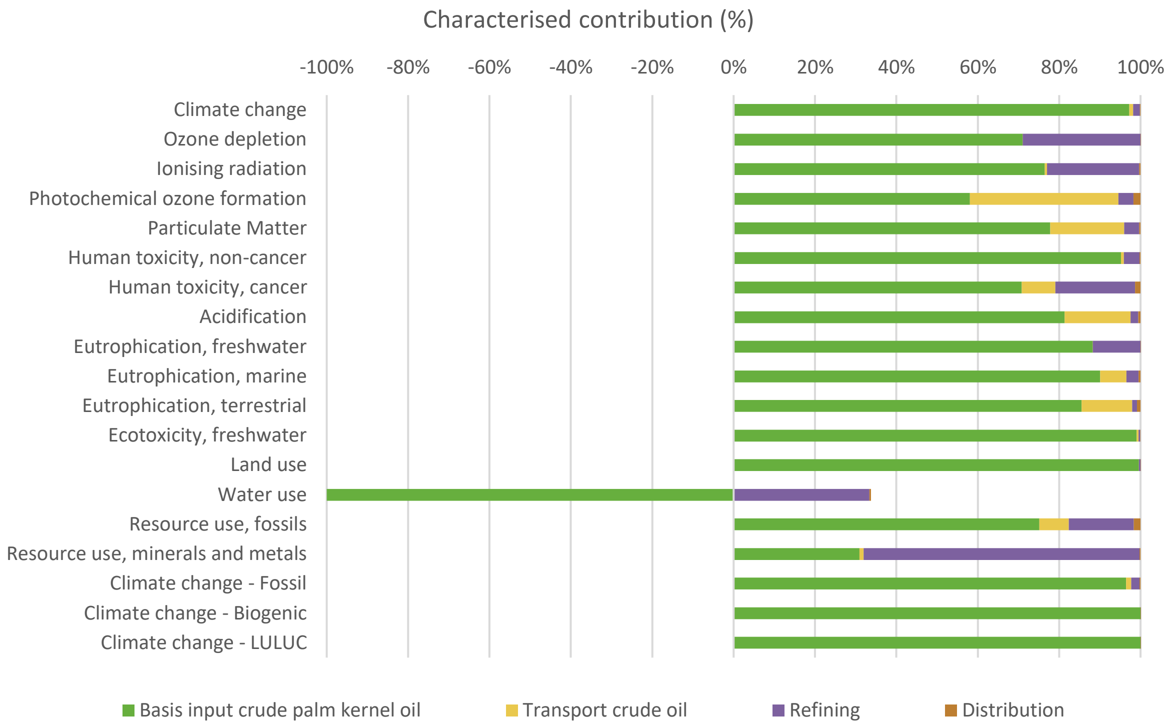

Figure 42: Environmental profile of 1 tonne fatty acid distillates from palm kernel

Table 34: Characterised results per tonne fatty acid distillates from palm kernel

Characterised contribution	Unit	Total	Basis input crude palm kernel oil	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	6,05E+03	5,88E+03	5,84E+01	9,69E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	1,09E-05	7,73E-06	1,01E-10	3,15E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,57E+01	1,20E+01	8,16E-02	3,55E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	3,96E+00	2,30E+00	1,45E+00	1,47E-01	6,96E-02
Particulate Matter	*disease inc.*	9,14E-05	7,11E-05	1,66E-05	3,38E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	4,09E-05	3,90E-05	3,02E-07	1,58E-06	8,47E-08
Human toxicity, cancer	*CTUh*	1,35E-07	9,58E-08	1,12E-08	2,65E-08	1,87E-09
Acidification	*mol H^+ eq*	1,30E+01	1,06E+01	2,11E+00	2,38E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	4,97E-01	4,39E-01	1,45E-05	5,81E-02	7,38E-05
Eutrophication, marine	*kg N eq*	8,03E+00	7,24E+00	5,15E-01	2,43E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	4,52E+01	3,87E+01	5,64E+00	5,18E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	1,53E+05	1,52E+05	7,04E+02	6,73E+02	1,17E+02
Land use	*Pt*	1,16E+05	1,15E+05	3,62E+00	4,48E+02	4,82E+01
Water use	*m^3 depriv.*	-7,99E+01	-1,21E+02	2,28E-01	4,00E+01	4,55E-01
Resource use, fossils	*MJ*	9,83E+03	7,38E+03	7,13E+02	1,57E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	3,35E-04	1,04E-04	3,40E-06	2,27E-04	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	4,73E+03	4,56E+03	5,83E+01	9,68E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	9,04E+02	9,04E+02	1,69E-03	3,96E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	4,22E+02	4,22E+02	5,30E-03	1,68E-02	8,42E-02

In order to gain more insight into the refining process' inputs and outputs causing the environmental impact, the refining process (purple bars in Figure 41-Figure 42) is subdivided in Figure 43. In this graph, the contributions to the total impact generated by the refining process of electricity, heat, auxiliary materials, water use wastewater and emissions to air are shown.

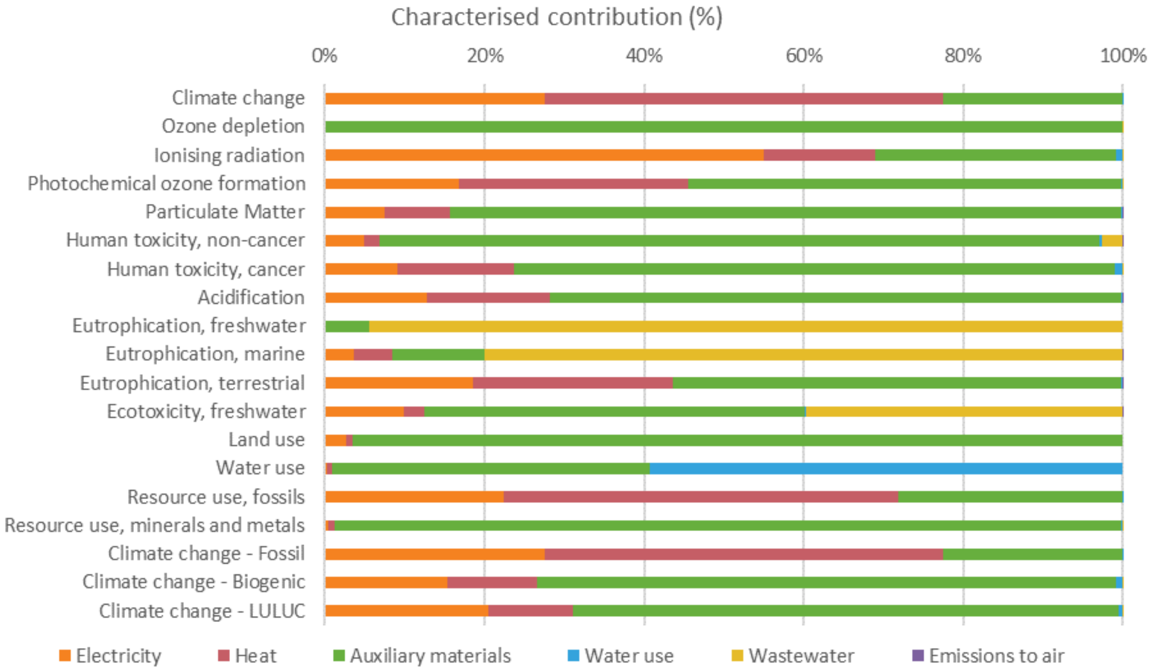

Figure 43: Contribution of inputs to environmental impact of the refining process (of crude palm kernel oil)

The auxiliary materials, mainly bleaching earth, used in the refining process are generally the main contributor to the environmental impact caused by the refining process. Some examples where the contribution of auxiliary materials is high (around 70% and higher contribution to impact category), are ozone depletion, particulate matter, human toxicity (non-cancer and cancer), acidification, eutrophication (terrestrial), ecotoxicity freshwater, land use, resource use minerals and metals and climate change biogenic. The use of energy (electricity and heat) has large contributions to climate change (totals and fossil), ionising radiation and fossil resource use. Also, for photochemical ozone formation, human toxicity (cancer), acidification, eutrophication terrestrial, and climate change (biogenic and LULUC) the contribution of energy is higher than 20%. Wastewater treatment has a relevant contribution to the impact categories eutrophication freshwater and marine. The impact of emissions to air are too small to be seen on the graph.

5.1.11. REFINED OIL AND CO-PRODUCTS FROM COCONUT

Next to refined oil (Figure 44), the refining process also produces three co-products considered in this study: acid oil, deodistillates and fatty acid distillates. Since the energy content of these three co-products are equal and they follow the same distribution scenario (for bulk products), they have the same environmental profile (Figure 45). The graphs are accompanied with the absolute values of the characterised results (Table 35 - Table 36). Due to confidentiality, no detailed analysis of the refining process can be shared. On the figures, a benefit in the impact category water use is visible. This benefit arises from the treatment of wastewater during crude coconut oil production.

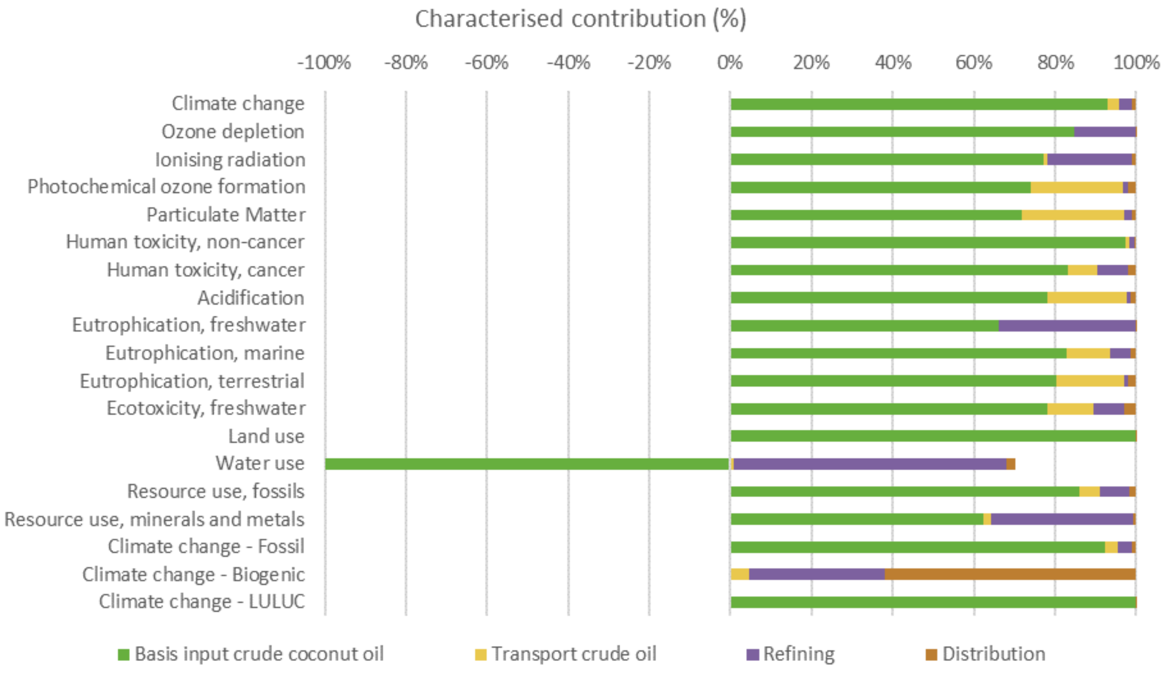

Figure 44: Environmental profile of 1 tonne refined oil from coconut

Table 35: Characterised results per tonne refined oil from coconut

Characterised contribution	Unit	Total	Basis input crude coconut oil	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	2,73E+03	2,54E+03	8,06E+01	8,87E+01	2,65E+01
Ozone depletion	*kg CFC11 eq*	6,87E-06	5,82E-06	1,41E-10	1,05E-06	9,93E-11
Ionising radiation	*kBq U-235 eq*	1,21E+01	9,37E+00	1,14E-01	2,52E+00	1,12E-01
Photochemical ozone formation	*kg NMVOC eq*	8,69E+00	6,44E+00	1,98E+00	1,04E-01	1,67E-01
Particulate Matter	*disease inc.*	9,03E-05	6,49E-05	2,27E-05	1,80E-06	8,24E-07
Human toxicity, non-cancer	*CTUh*	4,69E-05	4,57E-05	4,18E-07	6,39E-07	1,89E-07
Human toxicity, cancer	*CTUh*	2,06E-07	1,71E-07	1,55E-08	1,51E-08	4,22E-09
Acidification	*mol H^+ eq*	1,46E+01	1,14E+01	2,89E+00	1,36E-01	1,88E-01
Eutrophication, freshwater	*kg P eq*	2,61E-01	1,73E-01	2,36E-05	8,83E-02	1,63E-04
Eutrophication, marine	*kg N eq*	6,59E+00	5,45E+00	7,08E-01	3,43E-01	8,57E-02
Eutrophication, terrestrial	*mol N eq*	4,60E+01	3,69E+01	7,75E+00	3,64E-01	9,29E-01
Ecotoxicity, freshwater	*CTUe*	8,62E+03	6,73E+03	9,71E+02	6,53E+02	2,64E+02
Land use	*Pt*	7,15E+05	7,14E+05	7,36E+00	1,63E+02	1,06E+02
Water use	*m^3 depriv.*	-1,36E+01	-4,55E+01	3,35E-01	3,06E+01	1,00E+00
Resource use, fossils	*MJ*	1,98E+04	1,70E+04	9,85E+02	1,40E+03	3,60E+02
Resource use, minerals & metals	*kg Sb eq*	2,32E-04	1,44E-04	4,70E-06	8,08E-05	1,74E-06
Climate change - Fossil	*kg CO_2 eq*	2,50E+03	2,31E+03	8,06E+01	8,86E+01	2,62E+01
Climate change - Biogenic	*kg CO_2 eq*	7,39E-02	0,00E+00	3,35E-03	2,47E-02	4,58E-02
Climate change - LULUC	*kg CO_2 eq*	2,28E+02	2,28E+02	1,15E-02	1,52E-02	1,86E-01

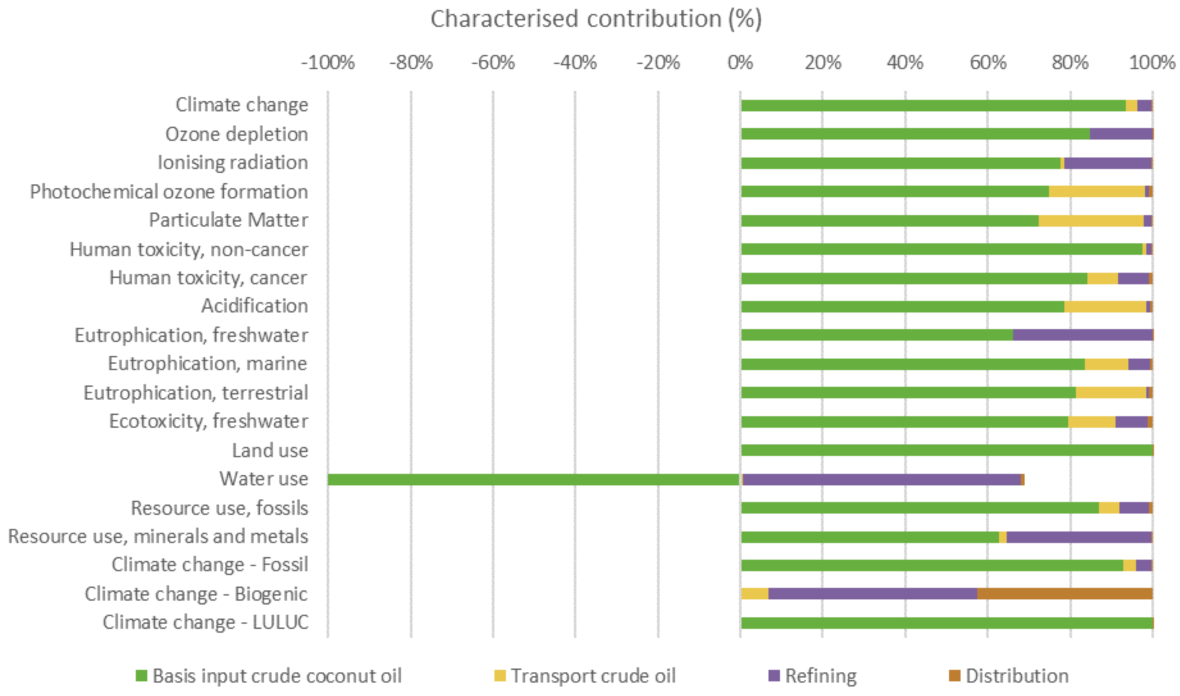

Figure 45: Environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from coconut

Table 36: Characterised results per tonne acid oil, deodistillates or fatty acid distillates from coconut

Characterised contribution	Unit	Total	Basis input crude coconut oil	Transport crude oil	Refining	Distribution
Climate change	*kg CO_2 eq*	2,72E+03	2,54E+03	8,06E+01	8,87E+01	1,18E+01
Ozone depletion	*kg CFC11 eq*	6,87E-06	5,82E-06	1,41E-10	1,05E-06	4,47E-11
Ionising radiation	*kBq U-235 eq*	1,21E+01	9,37E+00	1,14E-01	2,52E+00	5,05E-02
Photochemical ozone formation	*kg NMVOC eq*	8,60E+00	6,44E+00	1,98E+00	1,04E-01	6,96E-02
Particulate Matter	*disease inc.*	8,97E-05	6,49E-05	2,27E-05	1,80E-06	2,94E-07
Human toxicity, non-cancer	*CTUh*	4,68E-05	4,57E-05	4,18E-07	6,39E-07	8,47E-08
Human toxicity, cancer	*CTUh*	2,03E-07	1,71E-07	1,55E-08	1,51E-08	1,87E-09
Acidification	*mol H^+ eq*	1,45E+01	1,14E+01	2,89E+00	1,36E-01	7,68E-02
Eutrophication, freshwater	*kg P eq*	2,61E-01	1,73E-01	2,36E-05	8,83E-02	7,38E-05
Eutrophication, marine	*kg N eq*	6,54E+00	5,45E+00	7,08E-01	3,43E-01	3,68E-02
Eutrophication, terrestrial	*mol N eq*	4,54E+01	3,69E+01	7,75E+00	3,64E-01	3,99E-01
Ecotoxicity, freshwater	*CTUe*	8,47E+03	6,73E+03	9,71E+02	6,53E+02	1,17E+02
Land use	*Pt*	7,15E+05	7,14E+05	7,36E+00	1,63E+02	4,82E+01
Water use	*m^3 depriv.*	-1,42E+01	-4,55E+01	3,35E-01	3,06E+01	4,55E-01
Resource use, fossils	*MJ*	1,96E+04	1,70E+04	9,85E+02	1,40E+03	1,61E+02
Resource use, minerals & metals	*kg Sb eq*	2,31E-04	1,44E-04	4,70E-06	8,08E-05	7,76E-07
Climate change - Fossil	*kg CO_2 eq*	2,49E+03	2,31E+03	8,06E+01	8,86E+01	1,17E+01
Climate change - Biogenic	*kg CO_2 eq*	4,88E-02	0,00E+00	3,35E-03	2,47E-02	2,08E-02
Climate change - LULUC	*kg CO_2 eq*	2,28E+02	2,28E+02	1,15E-02	1,52E-02	8,42E-02

5.2. SENSITIVITY ANALYSIS

The results of an LCA depend on different factors. Sensitivity analyses assess the influence of the most relevant and most uncertain factors on the results of the study. The results of these sensitivity analyses are compared to the basic scenarios. Sensitivity analyses do not make the basic data of a study more reliable but allow to assess the effect of a change in inventory data or methodology on the results and conclusions of the study.

In this study the following sensitivity analysis have been done:

- Change of allocation method for agricultural production: switch to mass allocation (1) and switch to economic allocation (2)
- Change of allocation method for FEDIOL processes (crushing and refining): switch to mass allocation (3) and switch to economic allocation (4)

Graphs have been made for the climate change impact category. Results for the remaining impact categories are available in Annex III. The results have been calculated for a selection of products, being, crude oil, meal and refined oil.

5.2.1. SENSITIVITY ANALYSIS ALLOCATION OF AGRICULTURAL PROCESSES

To show the effect of choosing mass allocation or economic allocation instead of energy allocation for agricultural production, comparative environmental profiles per oil type have been made. The results for the impact category climate change are available in Figure 46 to Figure 52.

For all oil and meal types, mass allocation leads to the lowest results, except for sunflower. For products from sunflower, there is very little to no difference in output results between the different allocation methods chosen (see Figure 48). For all other oil and meal types, economic allocation of agricultural production leads to the highest results and results for energy allocation are between those of mass and economic allocation. Results for other impact categories are available in Annex III.

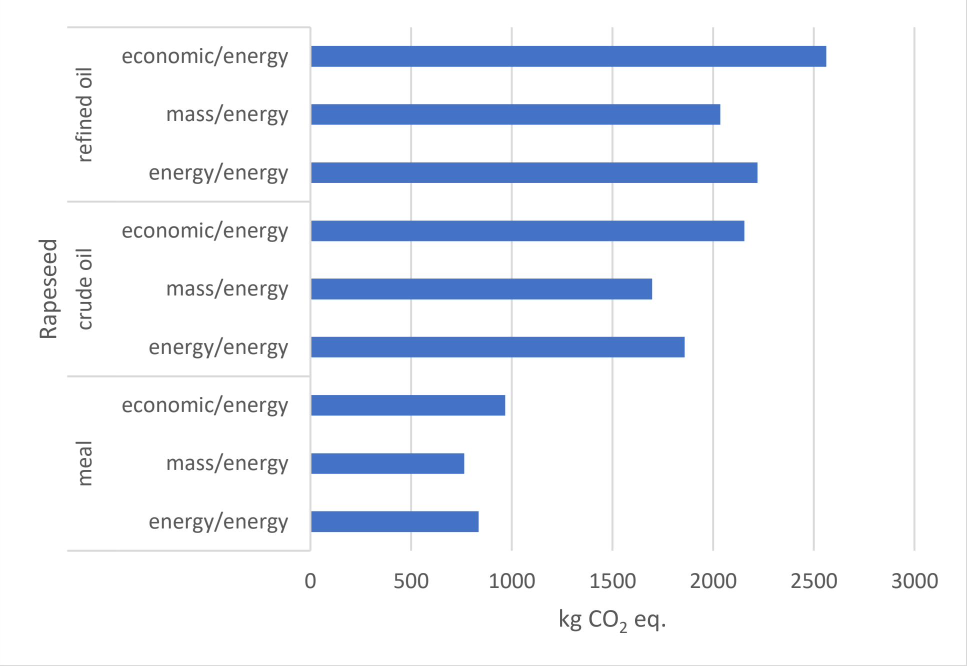

Figure 46: Comparison of different allocation methods for agricultural production and products from ***rapeseeds*** *– economic/energy: economic allocation for agricultural production, energy allocation for crushing and refining process; mass/energy: energy allocation for agricultural production, energy allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

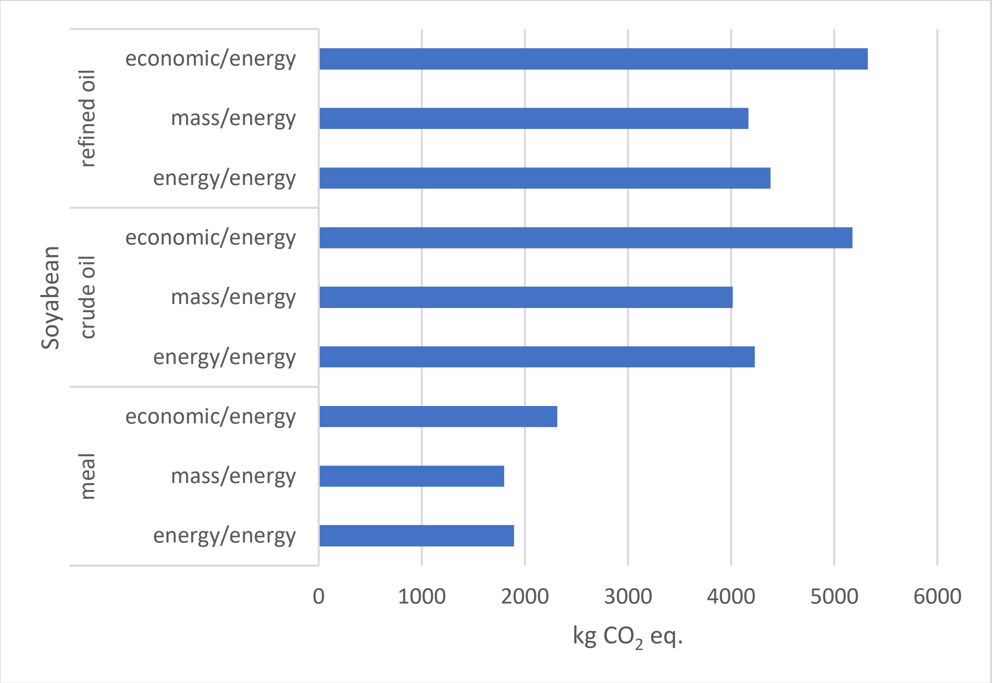

*Figure 47: Comparison of different allocation methods for agricultural production and products from **soybeans** – economic/energy: economic allocation for agricultural production, energy allocation for crushing and refining process; mass/energy: energy allocation for agricultural production, energy allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

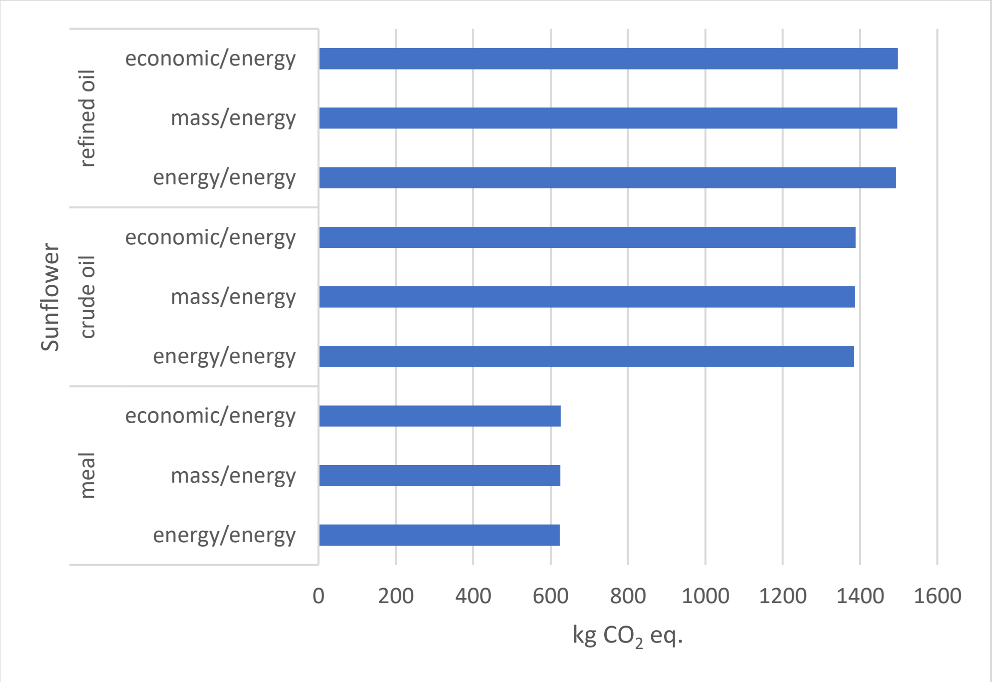

*Figure 48: Comparison of different allocation methods for agricultural production and products from **sunflower seeds** – economic/energy: economic allocation for agricultural production, energy allocation for crushing and refining process; mass/energy: energy allocation for agricultural production, energy allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

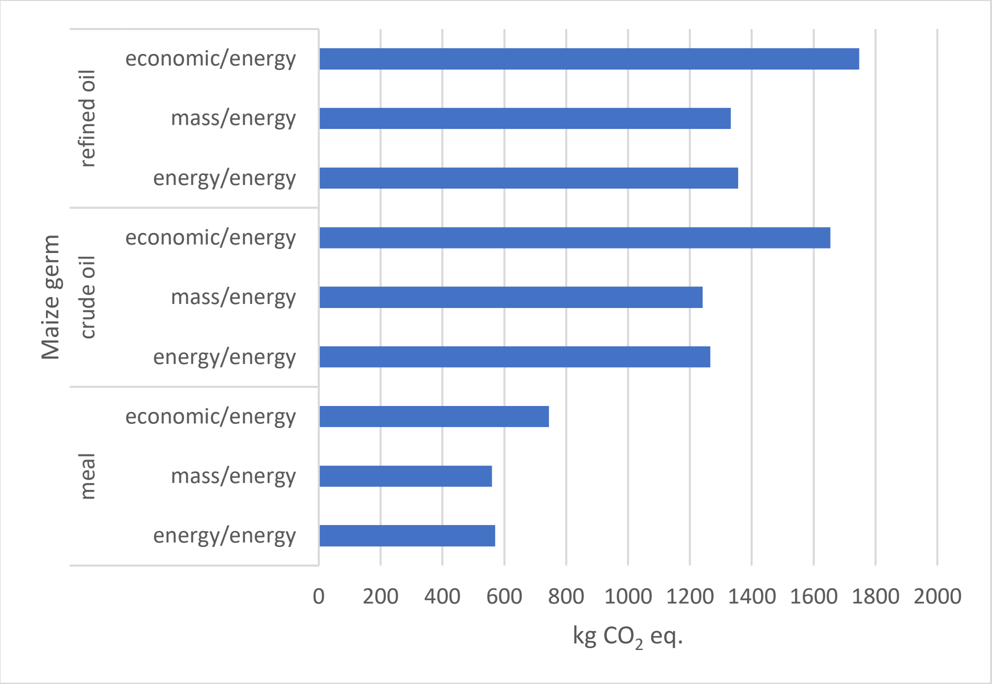

*Figure 49: Comparison of different allocation methods for agricultural production and products from **maize germs** – economic/energy: economic allocation for agricultural production, energy allocation for crushing and refining process; mass/energy: energy allocation for agricultural production, energy allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

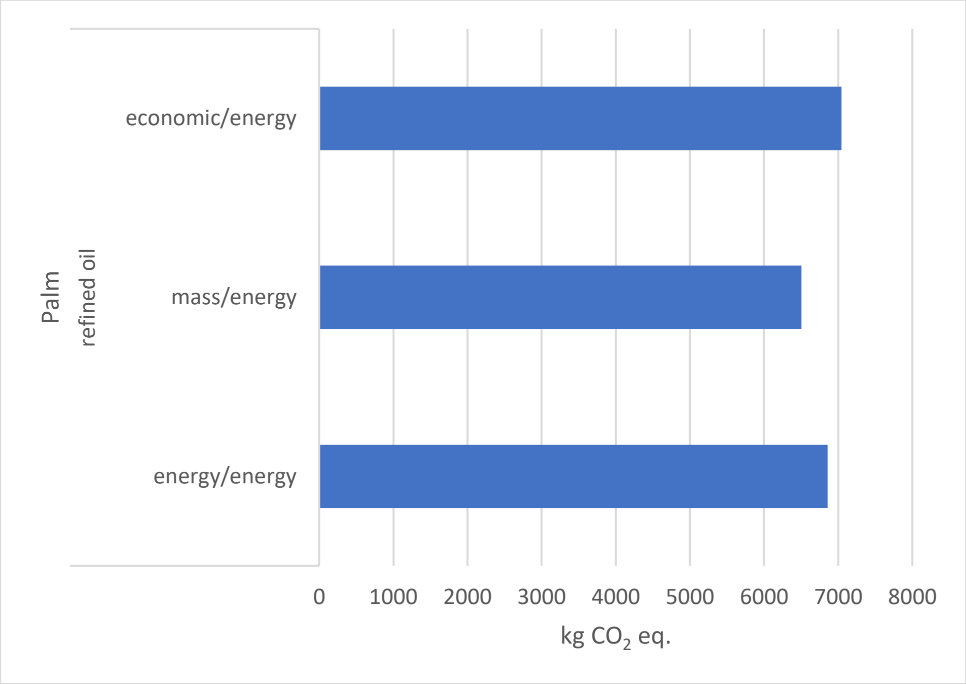

*Figure 50: Comparison of different allocation methods for agricultural production and products from **palm** – economic/energy: economic allocation for agricultural production, energy allocation for crushing and refining process; mass/energy: energy allocation for agricultural production, energy allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

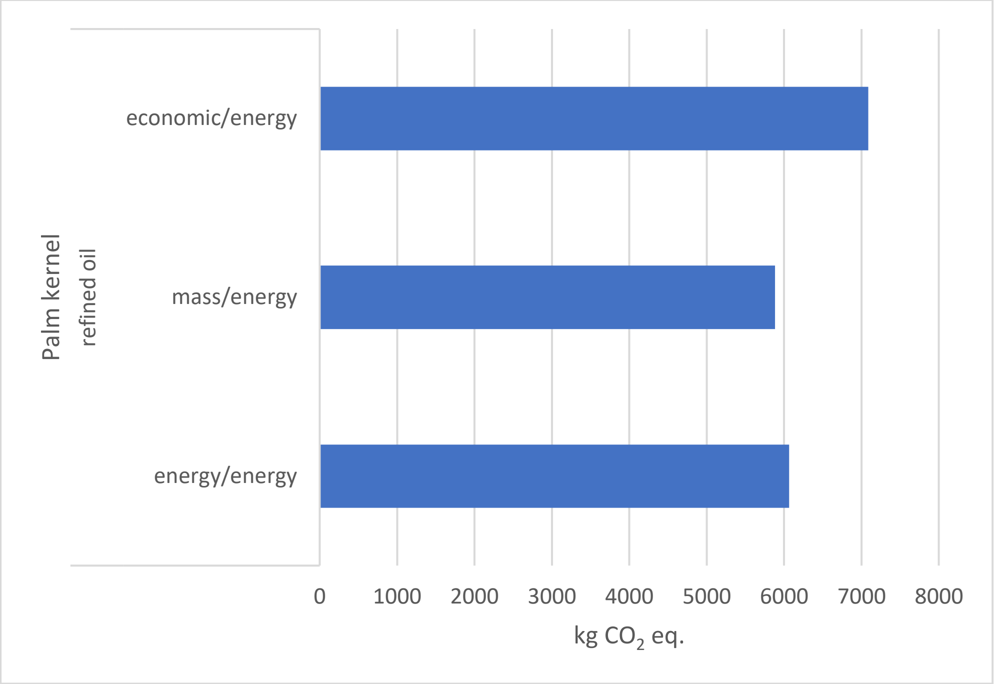

Figure 51: Comparison of different allocation methods for agricultural production and products from ***palm kernel*** *– economic/energy: economic allocation for agricultural production, energy allocation for crushing and refining process; mass/energy: energy allocation for agricultural production, energy allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

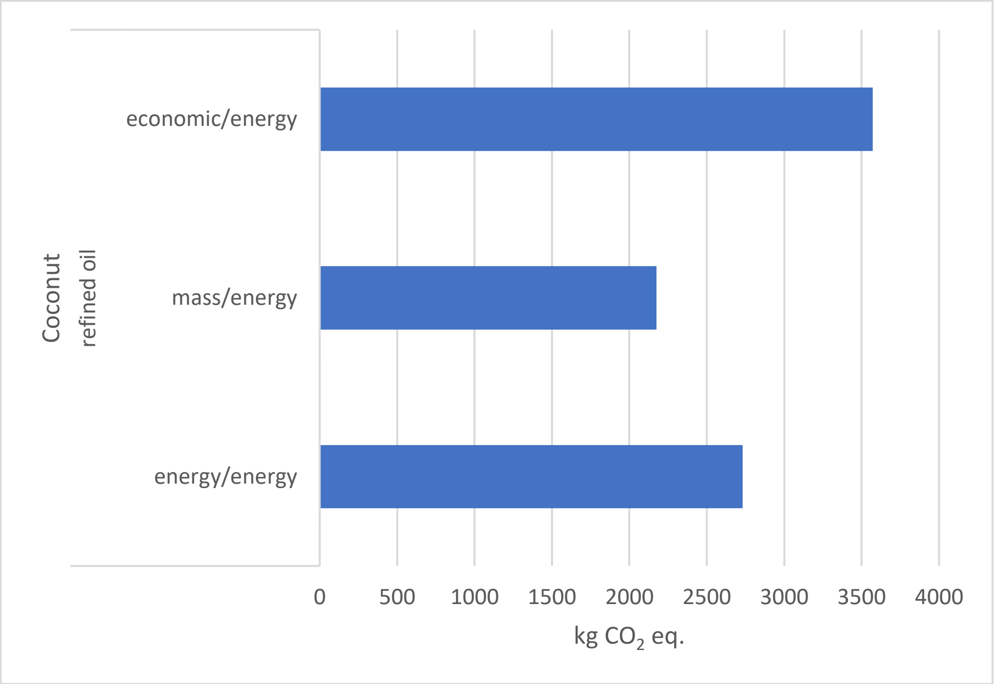

Figure 52: Comparison of different allocation methods for agricultural production and products from ***coconut*** *– economic/energy: economic allocation for agricultural production, energy allocation for crushing and refining process; mass/energy: energy allocation for agricultural production, energy allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

5.2.2. SENSITIVITY ANALYSIS ALLOCATION OF CRUSHING AND REFINING PROCESS

Figure 53 to Figure 56 compares different allocation methods for crushing and refining process of rapeseeds, soybeans, sunflower seeds and maize. For the co-products from the crushing process (meal and crude-oil) mass allocation results are equal. Economic and energy allocation shift the impact more to the crude oil and less to meal. For refined oil, energy allocation leads to a higher impact for the oil compared to mass allocation. This is mainly due to the use of mass or energy allocated crude oil as the LHV values for the co-products from refining are equal (except for the LHV of soap stock).
Results for other impact categories are available in Annex III.

For palm, palm kernel, coconut adapting the generic crushing process is outside the scope of this sensitivity assessment and the energy values (LHV) are equal for all output products of the refining process.

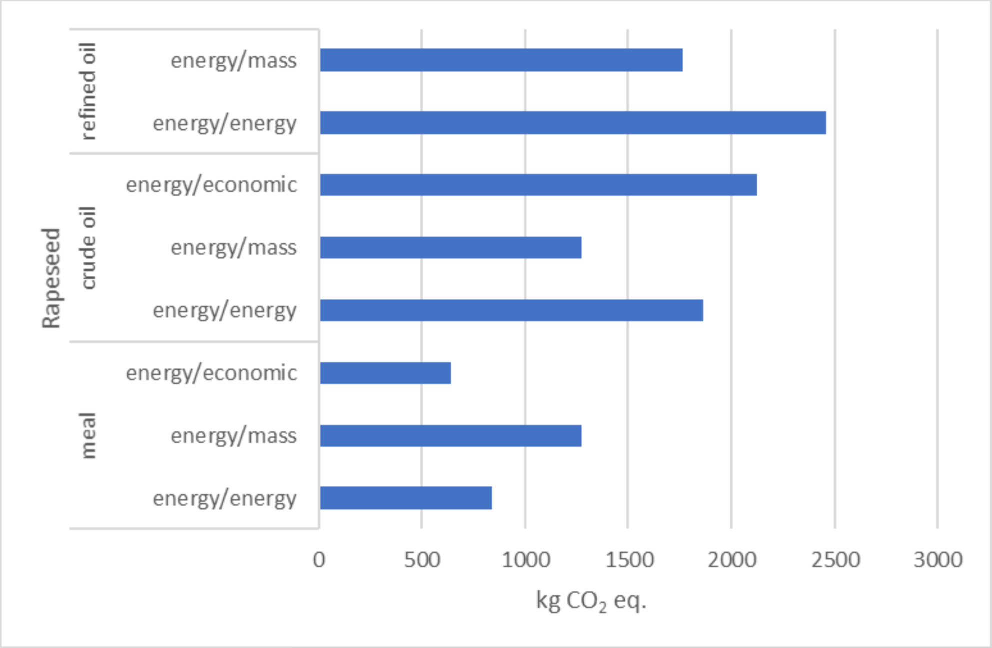

*Figure 53: Comparison of different allocation methods for crushing and refining process for products from **rapeseeds** – energy/economic: energy allocation for agricultural production, economic allocation for crushing and refining process; energy/mass: energy allocation for agricultural production, mass allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

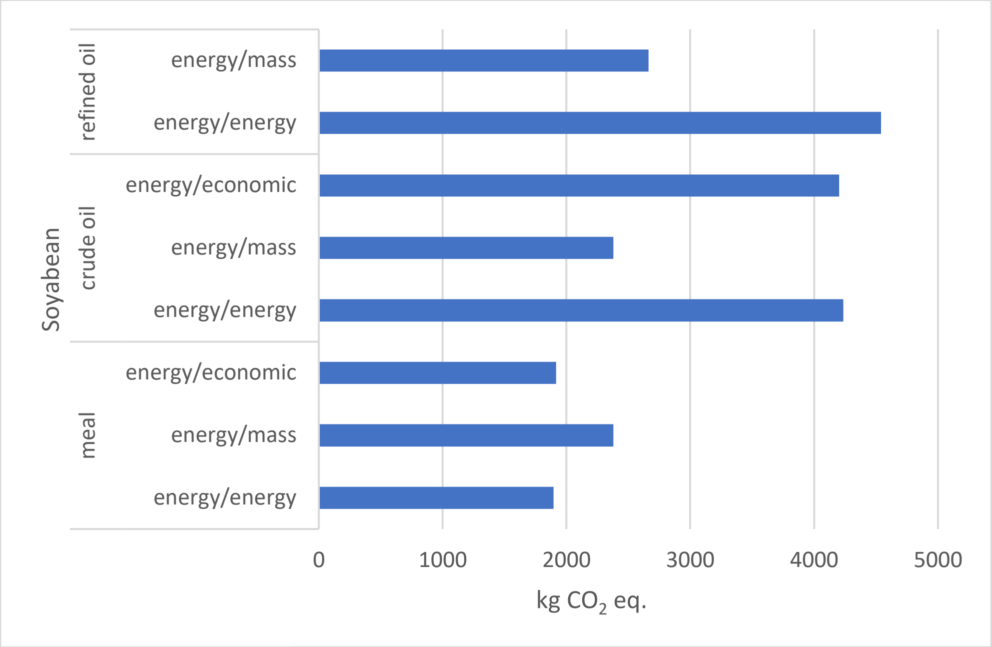

*Figure 54: Comparison of different allocation methods for crushing and refining process for products from **soybeans** – energy/economic: energy allocation for agricultural production, economic allocation for crushing and refining process; energy/mass: energy allocation for agricultural production, mass allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

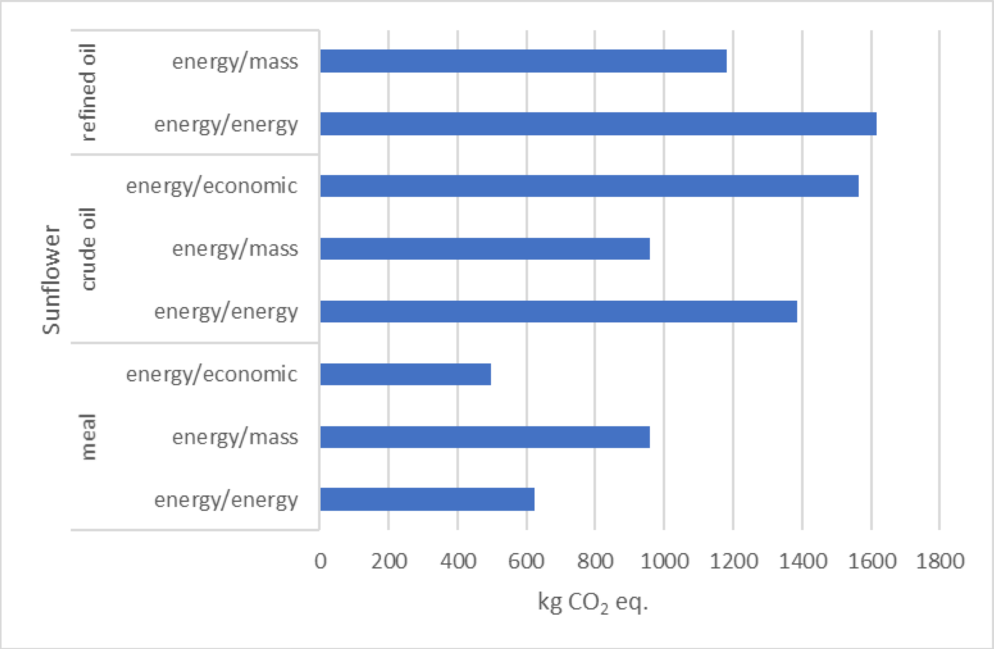

*Figure 55: Comparison of different allocation methods for crushing and refining process for products from **sunflower seeds** – energy/economic: energy allocation for agricultural production, economic allocation for crushing and refining process; energy/mass: energy allocation for agricultural production, mass allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

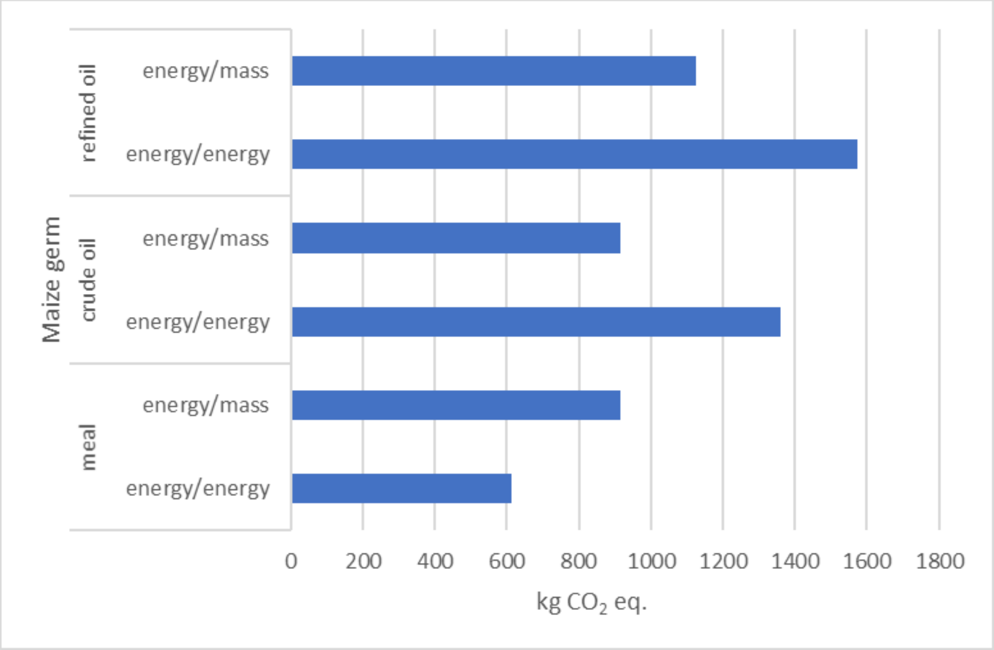

Figure 56: Comparison of different allocation methods for crushing and refining process for products from ***maize germs*** *– energy/economic: energy allocation for agricultural production, economic allocation for crushing and refining process; energy/mass: energy allocation for agricultural production, mass allocation for crushing and refining process; energy/energy: energy allocation for both agricultural production and for crushing and refining process.*

5.3. NORMALISED AND WEIGHTED ENVIRONMENTAL PROFILES

After the characterisation step, normalisation is the step in which the life cycle impact assessment results are divided by normalisation factors that represent the overall inventory of a reference unit (e.g. a whole country or an average citizen). Normalised life cycle impact assessment results express the relative shares of the impacts of the analysed system in terms of the total contributions to each impact category per reference unit. Global normalisation factors are applied within the EF method, expressing the global impact per person. How these normalisation factors have been built is explained in a paper by Crenna et al. (2019). The paper provides an evaluation of the robustness of the global normalisation factors. For the three toxicity impact categories both the inventory coverage completeness and robustness are low. On inventory coverage for example this means that the elementary flows taken into account to establish the normalisation factor cover 0% to 29% of the elementary flows taken into account by the EF method. This can of course heavily distort the results and lead to an overestimation of the importance of the impact category for a product group. The normalisation factors for the other impact categories also suffer to a greater or lesser extent from incomplete or non-robust inventory data. However, the problem seems largest for the toxicity impact categories.

Normalised results can in a third step, thus after normalisation, be multiplied by a set of weighting factors, which reflect the perceived relative importance of the impact categories considered. Weighted EF results may be directly compared across impact categories and summed across impact categories to obtain a single overall score. When interpreting these results, it is important to keep the limitations of the normalisation factors and the fact that weighting factors are implicitly subjective. A list of normalisation and weighting factors can be found in Annex 2 of the PEFCR for vegetable oil and proteinmeal industry products document.

All normalised and weighted environmental profiles can be found in Annex II of this document.

The normalised profiles of all products, except products from coconut, show that freshwater ecotoxicity is the most relevant impact category, mainly related to the contribution of the agriculture life cycle phase. However, as discussed before, this outcome is most probably the result of an incomplete normalisation factor for the ecotoxicity impact category. For products from rapeseeds, sunflower seeds, maize and soybeans marine eutrophication is also a relevant impact category. For products from soybeans, palm and palm kernel climate change is a relevant impact category. For products from coconut, land use is the most relevant impact category, mainly due to the raw material life cycle phase. Also, climate change, fossil resource use, marine, and to a lesser extent, terrestrial eutrophication and acidification are relevant impact categories.

The normalised and weighted profiles of all crops, except coconut, show that freshwater ecotoxicity and climate change are relevant impact categories, mostly due to the raw material phase. As discussed before, the normalisation factors for the toxicity impact categories are based on rather incomplete and not very robust inventory data. Freshwater ecotoxicity is the most relevant category for products from rapeseeds, sunflower seeds and maize, while climate change is the most relevant impact category for products from soybeans, palm and palm kernel. Water use, marine eutrophication and fossil resource use are also relevant impact categories for products from maize germs. For products from coconut the most relevant impact categories are climate change, land use and to a lesser extent resource use, fossils, mostly due to the raw material phase.

The industry processes (crushing and oil processing) mainly effect the fossil resource use and climate change impact categories.

5.4. ADDITIONAL INFORMATION

5.4.1. BIOGENIC CARBON CONTENT

In principle, according to the PEFCR for vegetable oil and proteinmeal industry products, the biogenic carbon content of the investigated products at the factory gate shall be reported. Few companies participating in the data collection where able to provide these data. Where possible, the biogenic carbon content has been calculated, based on the molecular formula of the products.

Table 37: Biogenic carbon content at factory gate of products included in scope of this PEF

Raw material		Rapeseed		Soybean		Sunflower		Coconut		Maize germs		Palm		Palm kernel	
Products	Crushing	Crude oil	76,6% [9]	Crude oil	76,6% [9]	Crude oil	76,6% [9]			Crude oil	76,6% [9]				
		Meal	NA	Meal	NA	Meal	NA			Meal	NA				
		Lecithin	NA	Lecithin	NA	Lecithin	NA								
				Hulls	NA	Husks	NA								
	Oil processing	Refined oil	76,6% [9]	Refined oil	76,6% [9]	Refined oil	76,6% [9]	Refined oil	76,6% [9]	Refined oil	76,6% [9]	Refined oil	76,6% [9]	Refined oil	76,6% [9]
		Soap stock	NA	Soap stock	NA	Acid oil/ Deo-distillates /Fatty acid distillates	NA	Acid oil/ Deo-distillates /Fatty acid distillates	NA	Acid oil/ Deo-distillates	NA	Acid oil/ Deo-distillates /Fatty acid distillates	NA	Fatty acid distillates	NA
		Acid oil/ Deo-distillates /Fatty acid distillates	NA	Acid oil/ Deo-distillates /Fatty acid distillates	NA										

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[9] Based on following composition of maize oil (source: FAO, 1992): 11.8% palmitic acid, 3.5% stearic acid, 40.1% oleic acid, 44.7% linoleic acid.

5.4.2. BIODIVERSITY

Biodiversity is considered relevant for the product group.
According to the PEFCR, impacts on biodiversity shall be calculated with ReCiPe 2016 Endpoint (H) (RVIM, 2017)). The results per tonne product (expressed in species.yr) are shown in Table 38.
For vegetable oil and protein meal industry products, biodiversity impact is driven by the agricultural life cycle phase. The result on biodiversity highly depends on the completeness of the secondary inventory data in the background database.

Table 38: Impacts on biodiversity with ReCiPe Endpoint (H) per tonne product expressed in species.yr

Raw material		Rapeseed		Soybean		Sunflower		Coconut		Maize germs		Palm		Palm kernel	
Products	Crushing	Crude oil	4,90E-05	Crude oil	6,86E-05	Crude oil	6,88E-05			Crude oil	1,93E-05				
		Meal	1,97E-05	Meal	3,06E-05	Meal	3,07E-05			Meal	8,66E-06				
		Lecithin	3,97E-05	Lecithin	5,56E-05	Lecithin	5,58E-05								
				Hulls	3,53E-05	Husks	3,54E-05								
	Oil processing	Refined oil	5,70E-05	Refined oil	6,96E-05	Refined oil	7,07E-05	Refined oil	9,95E-05	Refined oil	2,02E-05	Refined oil	**3,64E-05**	Refined oil	**3,38E-05**
		Soap stock	3,42E-05	Soap stock	4,17E-05	Acid oil/ Deo-distillates /Fatty acid distillates	9,94E-05	Acid oil/ Deo-distillates /Fatty acid distillates	0,03%	Acid oil/ Deo-distillates	2,01E-05	Acid oil/ Deo-distillates /Fatty acid distillates	3,64E-05	Fatty acid distillates	3,37E-05
		Acid oil/ Deo-distillates /Fatty acid distillates	5,69E-05	Acid oil/ Deo-distillates /Fatty acid distillates	6,95E-05										

5.4.3. RECYCLED CONTENT (R1)

For intermediate products the PEF method requires to report recycled content (R1) values. **R_1** is the proportion of material in the input to the production that has been recycled from a previous system. The recycled content in the products in scope of this study is 0%.

CHAPTER 6 INTERPRETING PEF RESULTS

6.1. INTRODUCTION

In this final chapter of the PEF study, the obtained results are interpreted. Interpretation of the results serves two purposes:

- the first purpose is to ensure that the performance of the PEF model corresponds to the goals and quality requirements of the study. In this sense, life cycle interpretation may inform iterative improvements of the PEF model until all goals and requirements are met;
- the second purpose is to derive robust conclusions and recommendations from the analysis, for example in support of environmental improvements.

The interpretation of the results is according to the instruction of the PEF method, which requires the identification of the most relevant impact categories and life cycle stages for each of the products in scope of this study. In addition, this chapter contains an assessment of the robustness of the PEF model and conclusions and recommendations.

6.2. ASSESSMENT OF THE ROBUSTNESS OF THE PEF MODEL

The assessment of the robustness of the PEF model evaluates the extent to which methodological choices such as the system boundary, data sources, and allocation choices influence the analytical outcomes. This assessment consists of completeness, sensitivity and consistency checks.

6.2.1. COMPLETENESS CHECKS

The Life Cycle Inventory data are checked to ensure that it is complete relative to the defined goals, scope, system boundary and quality criteria. This includes completeness of process coverage (i.e. all processes at each supply chain stage considered have been included) and input/ output coverage (i.e. all material or energy inputs and emissions associated with each process have been included).

The Life Cycle Inventory data used in this study are sector average data. In total 10 companies provided data from 28 sites. All processes at each supply chain stage have been considered for the development of the PEFCR. In this PEF study, the processes that may be excluded based on cut-off rule according to the PEFCR were excluded. It concerns the following processes: capital goods for the manufacturing processes of the vegetable oil and protein meal industry, packaging of incoming auxiliary materials, storage at warehouses, resources and tools for logistic operations at the FEDIOL plants and process waste (except wastewater, which needs to be included).

Following the PEFCR, no data gaps are allowed. In case specific data were unavailable, a proxy has been used. Proxy datasets have mainly been used for the production of auxiliary materials, for electricity production from CHP's and for heat production. For the agricultural production of rapeseed, sunflower, soyabeans and maize, in exceptional cases there was no dataset available for a specific geographic origin. In these cases, a proxy was used, the proxy chosen being a nearby country (e.g. proxy for Croatia is Italy). For crude palm and crude palm kernel oil production, few geographies were available in the Agri-footprint database (only Indonesia and Malaysia), meaning that often proxies had to be selected. For crude palm oil originating from Columbia, Guatemala, Honduras, Papua New Guinea and other confidential origins, crude palm oil from Indonesia and Malaysia has been used as a proxy.

For crude palm kernel oil originating from Colombia, Guatemala, Papua New Guinea and other confidential origins, crude palm kernel oil from Indonesia and Malaysia has been used as a proxy.

6.2.2. SENSITIVITY CHECKS

Sensitivity checks assess the extent to which the results are determined by specific methodological choices, and the impact of implementing alternative choices where these are identifiable. An important aspect is the applied allocation method. The PEF study follows the allocation rules set out in the PEFCR. In a sensitivity analysis, the use of an alternative allocation method for the agricultural production and for crushing and oil processing has been tested. The results are provided in section 5.2. Using mass allocation instead of energy allocation for the agricultural life cycle stages leads to a lower impact, whereas economic allocation leads to a higher impact for all the considered impact categories. Different allocation methods were also tested for crushing and oil processing process of rapeseeds, soybeans, sunflower seeds and maize. For the co-products from the crushing process (meal and crude-oil) mass allocation results in an equal environmental impact for the co-products from crushing. Economic and energy allocation shift the impact more to the crude oil and less to meal. For refined oil, energy allocation leads to a higher impact for oil compared to mass allocation.

6.2.3. CONSISTENCY CHECKS

Consistency checks assess the extent to which assumptions, methods, and data quality considerations have been applied consistently throughout the PEF study. Assumptions, methods and data quality considerations have been applied in conformance with the PEFCR.

The databases used for the PEF study are the EF 2.0 database in combination with the Agri-footprint database is used for agricultural production[10]. In principle, the EF 2.0 database has to be used together with the EF 2.0 method. The EF 3.0 method is already available at the time of writing the study, while the EF 3.0 database is not. To make sure databases and LCIA method are consistent, this study uses an adapted version of the EF 3.0 method. In SimaPro, such a compatible version is available: EF 3.0 method (adapted). In this adapted method, flow names are aligned with SimaPro nomenclature (and thus also Agri-footprint). Nevertheless, this method does not include all flows of the original EF 3.0 method. Therefore, for this study, a combined method has been made, containing all flows and characterisation factors of the original as well as the adapted EF 3.0 method to be compatible with both the EF database and the Agri-footprint database.

The databases used in this project are as consistent as possible with the PEF method and the EF reference package, however, the EF database consists of nodes operated by different data providers. Although in principle all data providers should have followed the same approach to establish the datasets, there may be differences in, for example, the wastewater treatment model applied.

In this project, primary data have been collected for the crushing and refining process. The primary data obtained from companies are representative for the year 2019-2020. Background data in database are often older. The data for the agricultural life cycle stage for example, which is the most important life cycle stage, are taken from sources dating between 2006 and 2016. Time representativeness of data from EF database is as indicated in the datasets. Electricity datasets for example have 2012 as reference year.

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[10] At the time of publication of this PEF report, it is not possible to obtain the node on Feed, which contains agricultural production, outside the official PEF track. Therefore, the Agri-footprint database is used.

6.3. MOST RELEVANT EF IMPACT CATEGORIES AND LIFE CYCLE STAGES, PROCESSES AND ELEMENTARY FLOWS

The section below contains the analysis of the most important life cycle stages and impact categories for each of the investigated products. The analysis of the most important processes and elementary flows is made on the level of the representative product and is available in the PEFCR. The results presented below are an outcome of a numerical exercise according to the PEF rules and may alter if different choices would have been made during the process of establishing the LCA models (e.g. choice of allocation method, choice of background database for agricultural production modelling, choice of proxies…).

6.3.1. MOST RELEVANT EF IMPACT CATEGORIES AND LIFE CYCLE STAGES

For each of the products, it has been investigated which impact categories contribute cumulatively to at least 80% of the total environmental impact (on the weighted result). For each of those impact categories, the life cycle stages contributing cumulatively more than 80% to that impact category are listed. The considered life cycle stages are:

- R: Raw material acquisition and pre-processing (including transport to production facility)
- M: Manufacturing
- D: Distribution

a. Most relevant impact categories and life cycle stages for crude oil and co-products from rapeseed:

Table 39: Most relevant impact categories and life cycle stages for crude oil and co-products from rapeseed With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Crude oil		*Meal*		*Lecithin*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*14,2%*	*R: 93,8%*	*14,2%*	*R: 93,07%*	*14,2%*	*R: 93,7%*
Particulate matter	*7,9%*	*R: 98,9%*	*7,9%*	*R: 98,74%*	*7,9%*	*R: 98,9%*
Acidification	*7,2%*	*R: 99,1%*	*7,2%*	*R: 98,69%*	*7,2%*	*R: 99,0%*
Eutrophication, freshwater	*6,4%*	*M: 67,7%* *R: 32,3%*	*6,4%*	*M: 67,7%* *R: 32,3%*	*6,4%*	*M: 67,7%* *R: 32,3%*
Eutrophication, marine	*12,2%*	*R: 88,8%*	*12,2%*	*R: 88,61%*	*12,2%*	*R: 88,7%*
Ecotoxicity, freshwater	*30,8%*	*R: 98,1%*	*30,7%*	*R: 98,06%*	*30,8%*	*R: 98,1%*
Land use	*6,4%*	*R: 99,9%*	*6,4%*	*R: 99,84%*	*6,4%*	*R: 99,9%*

The most relevant impact categories are climate change, particulate matter, acidification, eutrophication marine and freshwater, ecotoxicity freshwater and land use. These are the same most relevant impact categories as identified for the representative product in the PEFCR. The most relevant life cycle stage is the raw material acquisition (R), which includes agriculture life cycle stage and transport of rapeseeds to the manufacturing facility. For the impact category 'Eutrophication, freshwater', manufacturing is the most important life cycle stage. This result is driven by emissions in the wastewater.

b. Most relevant impact categories and life cycle stages for refined oil and co-products from rapeseed:

Table 40: Most relevant impact categories and life cycle stages for refined oil and co-products from rapeseed With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Refined oil		*Acid oil/ deodistillates/ Fatty acid distillates*		*Soap stock*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*14,3%*	*R: 90,5%*	*14,2%*	*R: 91,1%*	*14,2%*	*R: 90,8%*
Particulate Matter	*7,7%*	*R: 98,1%*	*7,7%*	*R: 98,3%*	*7,7%*	*R: 98,2%*
Acidification	*7,1%*	*R: 99,0%*	*7,1%*	*R: 98,6%*	*7,1%*	*R: 98,4%*
Eutrophication, freshwater	*7,3%*	*M: 72,4%* *R: 27,6%*	*7,3%*	*M: 72,4%* *R: 27,6%*	*7,3%*	*M: 72,4%* *R: 27,6%*
Eutrophication, marine	*12,2%*	*R: 86,2%*	*12,2%*	*R: 86,3%*	*12,2%*	*R: 86,3%*
Ecotoxicity, freshwater	*30,1%*	*R: 97,6%*	*30,2%*	*R: 97,6%*	*30,1%*	*R: 97,6%*
Land use	*6,2%*	*R: 99,7%*	*6,3%*	*R: 99,8%*	*6,3%*	*R: 99,7%*

The most relevant impact categories are climate change, particulate matter, acidification, eutrophication freshwater and marine, ecotoxicity freshwater and land use. These are the same most relevant impact categories as identified for the representative product in the PEFCR. The most relevant life cycle stage is raw material acquisition (R) which includes agriculture life cycle stage and transport of rapeseeds to the manufacturing facility for all most relevant impact categories, except for eutrophication freshwater, where both raw material acquisition and manufacturing are most relevant life cycle stage.

c. Most relevant impact categories and life cycle stages for crude oil and co-products from soybeans

Table 41: Most relevant impact categories and life cycle stages for crude oil and co-products from soybeans With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Crude oil		*Meal*		*Lecithin*		*Hulls*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*33,0%*	*R: 96,6%*	*33,0%*	*R: 96,3%*	*33,0%*	*R: 96,5%*	*33,0%*	*R: 96,4%*
Eutrophication, freshwater	*8,1%*	*M:60,4%* *R: 39,6%*	*8,1%*	*M:60,4%* *R: 39,6%*	*8,1%*	*M:60,4%* *R: 39,6%*	*8,1%*	*M:60,4%* *R: 39,6%*
Eutrophication, marine	*6,9%*	*R: 77,6%* *M:22,1%*	*6,9%*	*R: 77,4%* *M:22,1%*	*6,9%*	*R: 77,6%* *M:22,1%*	*6,9%*	*R: 77,4%* *M:22,1%*
Ecotoxicity, freshwater	*18,8%*	*R: 96,6%*	*18,7%*	*R: 96,5%*	*18,8%*	*R: 96,6%*	*18,7%*	*R: 96,5%*
Land use	*9,0%*	*R: 100%*	*9,0%*	*R: 100%*	*9,0%*	*R: 100%*	*9,0%*	*R: 100%*
Water use	*4,9%*	*R: 98,9%*	*4,9%*	*R: 98,9%*	*4,9%*	*R: 98,9%*	*4,9%*	*R: 98,9%*

The most relevant impact categories are climate change, eutrophication freshwater and marine, ecotoxicity freshwater, land use and water use. Compared to the most relevant environmental impact categories from the representative product, water use is added while acidification and particulate matter are not in the list for products from soybean crushing. The most relevant life cycle stage is raw material acquisition (R), which includes agriculture life cycle stage and transport of soybeans to the manufacturing facility. Again, in the impact category eutrophication freshwater manufacturing is the most relevant life cycle stage.

d. Most relevant impact categories and life cycle stages for refined oil and co-products from soybeans

Table 42: Most relevant impact categories and life cycle stages for refined oil and co-products from soybeans With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Refined oil		Acid oil/deodistillates/ fatty acid distillates		Soap stock	
Most relevant IC:	Contribution IC:	Most relevant LCS:	Contribution IC:	Most relevant LCS:	Contribution IC:	Most relevant LCS:
Climate change	32,8%	R: 93,3%	32,8%	R: 93,6%	32,8%	R: 93,4%
Particulate Matter	4,7%	R: 94,6%				
Eutrophication, freshwater	8,2%	M:62,3% R: 37,7%	8,2%	M:62,3% R: 37,7%	8,2%	M:62,3% R: 37,7%
Eutrophication, marine	6,8%	R: 75,1% M: 24,9%	6,8%	R: 75,3% M: 24,5%	6,8%	R: 75,2% M: 24,4%
Ecotoxicity, freshwater	18,1%	R: 95,9%	18,2%	R: 96,0%	18,2%	R: 95,9%
Land use	8,7%	R: 99,6%	8,7%	R: 99,6%	8,7%	R: 99,6%
Water use	5,3%	R: 87,6%	5,3%	R: 87,6%	5,3%	R: 87,6%

The most relevant impact categories are climate change, particulate matter, eutrophication freshwater and marine, ecotoxicity freshwater, land use and water use. Compared to the most relevant environmental impact categories from the representative product, water use is added while acidification is not in the list for refined oil from soybeans The most relevant life cycle stage is raw material acquisition (R) which includes agriculture life cycle stage and transport of soybeans and crude soybean oil to the manufacturing facility for all most relevant impact categories and manufacturing for the impact category eutrophication freshwater

e. Most relevant impact categories and life cycle stages for crude oil and co-products from sunflower seeds

Table 43: Most relevant impact categories and life cycle stages for crude oil and co-products from sunflower seeds With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Crude oil		Meal		Lecithin		Husks	
Most relevant IC:	Contribution IC:	Most relevant LCS:	Contribution IC:	Most relevant LCS:	Contribution IC:	Most relevant LCS:	Contribution IC:	Most relevant LCS:
Climate change	10,8%	R: 93,6%	10,9%	R: 92,6%	10,9%	R: 93,4%	10,9%	R: 92,8%
Particulate matter	6,5%	R: 95,8%	6,5%	R: 95,6%	6,5%	R: 95,8%	6,5%	R: 95,6%
Acidification	5,5%	R: 98,6%	5,5%	R: 98,0%	5,5%	R: 98,5%	5,5%	R: 98,2%
Eutrophication, marine	10,1%	R: 96,4%	10,1%	R: 96,2%	10,1%	R: 96,3%	10,1%	R: 96,2%
Ecotoxicity, freshwater	32,8%	R: 99,5%	32,7%	R: 99,4%	32,8%	R: 99,4%	32,7%	R: 99,4%
Land use	10,1%	R: 99,5%	10,0%	R: 99,5%	10,1%	R: 99,5%	10,0%	R: 99,5%

The most relevant impact categories are climate change, particulate matter, acidification, eutrophication marine, ecotoxicity freshwater, land use and water use. Compared to the most relevant environmental impact categories from the representative product, the most important impact categories for crude sunflower oil and co-products additionally include water use, while eutrophication freshwater is not included. The most relevant life cycle stage is raw material acquisition (R), which includes agriculture life cycle stage and transport of sunflower seeds to the manufacturing facility.

f. Most relevant impact categories and life cycle stages for refined oil and co-products from sunflower seeds

Table 44: Most relevant impact categories and life cycle stages for refined oil and co-products from sunflower seeds With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Refined oil		*Acid oil/deodistillates/ fatty acid distillates*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*11,1%*	*R: 84,1%*	*11,1%*	*R: 89,7%*
Particulate matter	*6,5%*	*R: 88,8%*	*6,5%*	*R: 94,8%*
Acidification	*5,5%*	*R: 89,6%*	*5,5%*	*R: 97,7%*
Eutrophication, marine	*10,1%*	*R: 92,0%*	*10,1%*	*R: 93,9%*
Ecotoxicity, freshwater	*32,0%*	*R: 98,7%*	*32,1%*	*R: 99,1%*
Land use	*9,8%*	*R: 99,1%*	*9,8%*	*R: 99,2%*
Water use	*7,6%*	*R: 98,6%*	*7,6%*	*R: 98,7%*

The most relevant impact categories are climate change, particulate matter, acidification, eutrophication marine, ecotoxicity freshwater, land use and water use. Compared to the most relevant environmental impact categories from the representative product, water use is included in the list for refined oil and co-products from sunflower seed, while eutrophication freshwater is excluded. The most relevant life cycle stage is raw material acquisition (R) which includes agriculture life cycle stage and transport of sunflower seeds and crude sunflower oil to the manufacturing facility for all most relevant impact categories.

g. Most relevant impact categories and life cycle stages for crude oil and co-products from maize germs

Table 45: Most relevant impact categories and life cycle stages for crude oil and co-products from maize germs With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Crude oil		*Meal*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*15,7%*	*R: 93,0%*	*15,8%*	*R: 93,0%*
Particulate matter	*7,8%*	*R: 98,3%*	*7,8%*	*R: 98,3%*
Acidification	*6,9%*	*R: 97,8%*	*6,9%*	*R: 97,8%*
Eutrophication, marine	*9,3%*	*R: 92,5%*	*9,2%*	*R: 92,5%*
Ecotoxicity, freshwater	*18,3%*	*R: 98,2%*	*18,2%*	*R: 98,2%*
Water use	*13,6%*	*R: 99,1%*	*13,5%*	*R: 99,1%*
Resource use, fossils	*9,4%*	*R: 89,9%*	*9,5%*	*R: 89,9%*

The most relevant impact categories are climate change, particulate matter, acidification, eutrophication marine, ecotoxicity freshwater, land use, water use and resource use fossils. Water use and fossil resource use are in the list of most relevant impact categories for crude maize oil and co-products, while this impact category was not listed in the PEFCR for the representative product. The most relevant life cycle stage is raw material acquisition (R), which includes agriculture life cycle stage and transport of maize germs to the manufacturing facility.

h. Most relevant impact categories and life cycle stages for refined oil and co-products from maize germs

Table 46: Most relevant impact categories and life cycle stages for refined oil and co-products from maize germs
With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Refined oil		*Acid oil/deodistillates*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*15,9%*	*R: 82,4%*	*15,8%*	*R: 88,3%*
Particulate matter	*7,6%*	*R: 88,4%*	*7,6%*	*R: 96,5%*
Acidification	*6,7%*	*R: 86,4%*	*6,7%*	*R: 96,3%*
Eutrophication, marine	*9,3%*	*R: 84,4%*	*9,4%*	*R: 87,3%*
Eutrophication, terrestrial	*5,5%*	*R: 89,4%*	*5,5%*	*R: 97,4%*
Ecotoxicity, freshwater	*17,6%*	*R: 95,6%*	*17,7%*	*R: 96,7%*
Water use	*13,0%*	*R: 98,3%*	*13,0%*	*R: 98,4%*
Resource use, fossils	*9,8%*	*R: 77,5%* *M: 17,6%*	*9,7%*	*R: 83,4%*

The most relevant impact categories are climate change, particulate matter, acidification, eutrophication marine and terrestrial, ecotoxicity freshwater, water use and resource use fossils. Compared to the most relevant environmental impact categories from the representative product, eutrophication terrestrial, water use and resource use, fossil are added while eutrophication freshwater and land use are not in the list for products from maize germ oil processing. The most relevant life cycle stage is the raw material acquisition (R) which includes agriculture life cycle stage and transport of maize germs and crude maize oil to the manufacturing facility for all most relevant impact categories.

i. Most relevant impact categories and life cycle stages for refined oil and co-products from palm

Table 47: Most relevant impact categories and life cycle stages for refined oil and co-products from palm
With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Refined oil		*Acid oil/deodistillates/ fatty acid distillates*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*54,2%*	*R: 97,7%*	*54,3%*	*R: 97,9%*
Particulate matter	*4,0%*	*R: 95,2%*	*4,0%*	*R: 95,8%*
Acidification	*4,2%*	*R: 96,1%*	*4,1%*	*R: 97,0%*
Eutrophication, marine	*18,6%*	*R: 99,2%*	*18,7%*	*R: 99,3%*
Ecotoxicity, freshwater	*54,2%*	*R: 97,7%*	*54,3%*	*R: 97,9%*

The most relevant impact categories are climate change, particulate matter, acidification, eutrophication marine and ecotoxicity freshwater. These are the same most relevant environmental impact categories as identified for the representative product, excluding eutrophication freshwater and land use. The most relevant life cycle stage is raw material acquisition (R) which includes the production of crude palm oil (including agricultural production) and transport of crude palm oil to the manufacturing facility for all most relevant impact categories.

j. Most relevant impact categories and life cycle stages for refined oil and co-products from palm kernel

Table 48: Most relevant impact categories and life cycle stages for refined oil and co-products from palm kernel With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Refined oil		*Fatty acid distillates*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*49,6%*	*R: 98,0%*	*49,7%*	*R: 98,2%*
Particulate matter	*4,4%*	*R: 95,4%*	*4,3%*	*R: 96,0%*
Acidification	*4,6%*	*R: 96,8%*	*4,6%*	*R: 97,6%*
Ecotoxicity, freshwater	*21,7%*	*R: 99,4%*	*21,8%*	*R: 99,5%*
Resource use, fossils	*4,0%*	*R: 80,7%* *M: 19,3*		

The most relevant impact categories are climate change, particulate matter, acidification, ecotoxicity freshwater and resource use fossils. Resource use fossils was not mentioned in the PEFCR as most relevant impact category for the product group, while eutrophication freshwater and marine and land use were additionally identified as relevant impact categories. The most relevant life cycle stage is raw material acquisition (R) which includes the production of crude palm oil (including agricultural production) and transport of crude palm kernel oil to the manufacturing facility for all most relevant impact categories.

k. Most relevant impact categories and life cycle stages for refined oil and co-products from coconut

Table 49: Most relevant impact categories and life cycle stages for refined oil and co-products from coconut With: R: Raw material acquisition and pre-processing; M: Manufacturing; D: Distribution

	Refined oil		*Acid oil/deodistillates/ fatty acid distillates*	
Most relevant IC:	*Contribution IC:*	*Most relevant LCS:*	*Contribution IC:*	*Most relevant LCS:*
Climate change	*29,8%*	*R: 95,8%*	*29,8%*	*R: 96,3%*
Particulate matter	*5,7%*	*R: 97,1%*	*5,7%*	*R: 97,7%*
Acidification	*6,8%*	*R: 97,8%*	*6,8%*	*R: 98,5%*
Land use	*29,1%*	*R: 100,0%*	*29,2%*	*R: 100,0%*
Resource use, fossils	*10,6%*	*R: 91,1%*	*10,6%*	*R: 92,0%*

The most relevant impact categories are climate change, particulate matter, acidification, land use and resource use fossils. Only resource use fossils is not mentioned in the PEFCR as a most relevant impact category for the representative product, while ecotoxicity freshwater and eutrophication freshwater and marine where identified as relevant impact categories for the product group in the PEFCR. The most relevant life cycle stage is raw material acquisition (R) which includes the production of crude coconut oil (including agricultural production) and transport of crude coconut oil to the manufacturing facility for all most relevant impact categories.

6.4. CONCLUSIONS

The PEF study clearly shows the importance of the agricultural life cycle phase for the environmental impact of vegetable oil and proteinmeal products. The agricultural life cycle phase is the most important contributor to all of the investigated impact categories with the exception of eutrophication freshwater, where emissions from wastewater treatment are the largest contributors and climate change biogenic where transport (mainly barge transport) is the most important contributor. In the impact categories ozone depletion, ionising radiation, photochemical ozone depletion and fossil resource depletion the contribution of agriculture is less dominant. These impact categories are mainly driven by energy use and transport and the impact category photochemical oxidation is additionally influenced by the hexane emissions taking place during the crushing processes. The contribution of distribution is negligible for all bulk products. Only for refined oils, distribution has in some of the investigated impact categories a non-negligible contribution.

Focussing on the crushing process, it is the use of electricity and heat that drives the environmental impact. The use of auxiliary materials makes a rather small contribution to the environmental impact of the crushing process. Emissions from wastewater treatment have a large contribution to the impact category eutrophication freshwater. The emissions to air, which take place during the crushing process are hexane emissions and emissions of particulates. The contribution of the hexane emission to air is clearly visible in the impact category photochemical ozone formation and hexane emissions also contribute to the impact categories human toxicity non-cancer and cancer. Emissions of particulates to air contribute to particulate matter.

Energy use and auxiliary materials are the main contributors to the environmental impact of the refining process. For rapeseed refining, both energy use and auxiliary materials play an important role, the dominance of one over the other depends on the impact category. For soybean refining, palm and palm kernel refining, the contribution of auxiliary materials is more dominant. The contribution comes mainly form citric acid and from bleaching earth. For sunflower seed refining and maize refining, the energy use has in most of the environmental impact categories a more important contribution compared to the use of auxiliary materials.
The impact of direct process emissions to air taking place during the refining process are not important in the refining process.

As previously discussed in this report, the choice of allocation method has an important influence on the results. For the agricultural processes, energy allocation has been used as the default allocation method. In a sensitivity analysis, two other allocation methods, mass and economic allocation, have been tested. For all oil and meal types, mass allocation of agricultural processes leads to the lowest results, except for sunflower. For products from sunflower, there is very little to no difference in output results between the different allocation methods chosen. For all other oil and meal types, economic allocation of agricultural production leads to the highest results and results for energy allocation are between those of mass and economic allocation. Also, the crushing and refining processes are processes which generate several outputs. The default allocation method used in this study is again energy allocation. The sensitivity analysis reveals that mass allocation of the co-products from the crushing process leads to equal environmental impacts per ton of output product of the crushing process, while economic and energy allocation shift the impact more to the crude oil and less to meal. For refined oil, energy allocation leads to a higher impact for the oil compared to mass allocation. This is mainly due to the use of mass or energy allocated crude oil as the LHV values for the co-products from refining are equal (except for the LHV of soap stock) and as a result get an equal allocation.

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ANNEX I

1. REPRESENTATIVE PRODUCT

The representative product is included to use as a reference for the development of the PEFCR. The representative product is a virtual vegetable oil and proteinmeal industry product, composed of all products covered by this PEF (Table 50). Its composition is based on weighted average quantities (mass) of European sales to end user industries. Statistics reported by FEDIOL on its website and shares of co-products estimated for the share of output products as reported by the participating member companies were used to establish the representative product. The FEDIOL statistics used are:

for rapeseed, sunflower, soybean and maize germs:
'EU-27* + UK 2020 PRODUCTION OF CRUDE VEGETABLE OILS AND FATS', and,
'EU-27* + UK 2020 PRODUCTION OF MEALS'

for palm, palm kernel and coconut:
'EU-27* + UK 2020 IMPORTS OF VEGETABLE OILS AND FATS'
An average value of the years 2016, 2017 and 2018 has been used. The share of the different products is calculated as the share of the mass of the product within the total mass of all sold products.

Table 50: Composition of the representative product (weighted average shares)

Raw material		Rapeseed		Soybean		Sunflower		Coconut		Maize germs		Palm		Palm kernel	
Products	Crushing	Crude oil	**8,44%**	Crude oil	**4,47%**	Crude oil	0,49%			Crude oil	0,10%				
		Meal	**22,11 %**	Meal	**23,01 %**	Meal	**6,28%**			Meal	0,59%				
		Lecithin	0,02%	Lecithin	0,09%	Lecithin	0,02%								
			8,44%	Hulls	**4,47%**	Husks	0,52%								
	Oil processing	Refined oil	**9,34%**	Refined oil	**1,86%**	Refined oil	**6,63%**	Refined oil	0,95%	Refined oil	0,43%	Refined oil	**11,89 %**	Refined oil	**1,19%**
		Soap stock	0,22%	Soap stock	0,05%	Acid oil/ Deo-distillates /Fatty acid distillates	0,14%	Acid oil/ Deo-distillates /Fatty acid distillates	0,03%	Acid oil/ Deo-distillates	0,02%	Acid oil/ Deo-distillates /Fatty acid distillates	0,95%	Fatty acid distillates	0,02%
		Acid oil/ Deo-distillates /Fatty acid distillates	0,14%	Acid oil/ Deo-distillates /Fatty acid distillates	0,01%										
				Others	0,01%										

The representative product is used to derive the most representative live cycle stages, impact categories, processes and elementary flows and to identify which processes can be put under cut-off. As the products under investigation concern intermediate products, benchmarking is not allowed and life cycle impact assessment results for the representative product shall therefore not be used to make compare with.

2. SCREENING STEP TO DETERMINE CUT-OFF

In the first screening no cut-off of processes, emissions to the environment and resources from the environment is done. All the life cycle stages (relevant for an intermediate product) and processes are included (incl. capital goods). However, activities such as staff commuting, canteens at production sites, consumables not strictly related to the production processes, marketing, business trips and R&D activities are excluded.

2.1. LIFE CYCLE INVENTORY

The LCI of the screening step is equal to the LCI reported in chapter 5, but including additional processes:

- capital goods for the manufacturing processes of the vegetable oil and proteinmeal industry;
- packaging of incoming auxiliary materials;
- storage of refining products;
- resources and tools for logistic operations at the vegetable oil and proteinmeal plants;
- process waste (excluding wastewater).

In this paragraph, only the life cycle inventories of these additional processes are given and discussed.

The **capital goods** input required for the manufacture of 1 tonne vegetable oil and proteinmeal industry product was estimated using an annual production capacity of 200 kilotonnes of sugar over a lifetime of 50 years.

Table 51: LCI capital goods per tonne vegetable and proteinmeal industry product

CAPITAL GOODS							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
Capital goods sugar refinery - construction	$1*10^{-7}$	piece	Ecoinvent + EF2.0	Sugar refinery {GLO}| construction _ adapted to EF2.0	0187b260-5ac6-4bc6-a9ac-b44e01a92d7c	Partly compliant	Proxy based on sugar refinery included in the Ecoinvent v3.6 (=v2.2) database

Data on **packaging of incoming auxiliary materials** were provided by several companies. Based on the types of packaging materials that were supplied by the companies, estimates were made on the materials used to package auxiliaries. The materials that were modelled are jerrycans, IBC's, big bags (1000 kg, 800 kg) and plastic bags (20 kg, 25 kg), the modelling of which required proxies, as mentioned in the 'comment' column of Table 52. The table shows the packaging materials of the incoming auxiliaries per vegetable oil and proteinmeal industry per kg chemical packed. The overview below gives the type of packaging materials per production process and the weighted average amount of chemicals which are packed.

Rapeseed crushing
- 2.13E-04 tonne auxiliaries packed in plastic bag, 25 kg + wooden pallet
- 2.13E-04 tonne auxiliaries packed in IBC 1000 l

Rapeseed refining
- 1.19E-04 tonne auxiliaries packed in plastic bag 20 kg + wooden pallet
- 6.27E-07 tonne auxiliaries packed in IBC 1000 l

Soybean crushing
- 3.77E-06 tonne auxiliaries packed in IBC 1000 l

- 4.69E-07 tonne auxiliaries packed in 20 l can

Soybean refining

- 2.38E-06 tonne auxiliaries packed in IBC
- 9.23E-03 tonne auxiliaries packed in 20 kg bag + wooden pallet
- 9.59E-03 tonne packed in 1000 kg bag
- 7.03E-06 tonne auxiliaries packed in 25 l can

Sunflower crushing

- 1.28E-05 tonne auxiliaries packed in plastic bag 20 kg + wooden pallet
- 4.62E-04 tonne auxiliaries packed in IBC 1000 l

Sunflower refining

- 8.50E-05 tonne auxiliaries packed in 20 kg bag + wooden pallet
- 8.50E-05 tonne auxiliaries packed in IBC 1000 l
- 3.31E-03 tonne packed in 800 kg bigbag + wooden pallet

Maize crushing

- 1.00E-04 tonne auxiliaries packed in plastic bag 20 kg + wooden pallet

Maize refining:

- Cannot be reported for reasons of confidentiality

Coconut refining:

- Cannot be reported for reasons of confidentiality

Palm refining:

- No packaging materials reported for incoming raw materials

Palm kernel refining

- No packaging materials reported for incoming raw materials

Table 52: LCI packaging materials, per kg chemical packed

PACKAGING: PLASTIC BAG 25 KG + WOODEN PALLET – EXPRESSED PER KG PACKED							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
25 kg plastic bag	0.29	m^2	EF2.0 Sphera node	Plastic bag, PP {EU-28+EFTA} | raw material production, plastic extrusion | production mix, at plant | thickness: 0.03 mm, grammage: 0.0275 kg/m2 | LCI result	9127181c-e424-4cc3-9083-3dff8e1b090e	Fully compliant	Total weight 25 kg bag: 0,2 kg 0,0275 kg/m2
Wooden pallet for plastic bag 25 kg	0.030	kg	EF2.0 Sphera node	Pallet, wood (100x120) {EU-28+EFTA} | sawing, piling, nailing | single route, at plant | 30 kg/piece, nominal loading capacity of 1000kg | LCI result	Fedca7cf-97df-4d02-a3d3-8e53bb5ee8b7	Fully compliant	Weight pallet: 30 kg Loading capacity: 1000 kg
PACKAGING: PLASTIC BAG 20 KG + WOODEN PALLET – EXPRESSED PER KG PACKED							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
20 kg plastic bag	0.36	m^2	EF2.0 Sphera node	Plastic bag, PP {EU-28+EFTA} | raw material production, plastic extrusion | production mix, at plant | thickness: 0.03 mm, grammage: 0.0275 kg/m2 | LCI result	9127181c-e424-4cc3-9083-3dff8e1b090e	Fully compliant	Total weight 20 kg bag: 0.2 kg 0.0275 kg/m2
Wooden pallet for plastic bag 20 kg	0.038	kg	EF2.0 Sphera node	Pallet, wood (100x120) {EU-28+EFTA} | sawing, piling, nailing | single route, at plant | 30 kg/piece, nominal loading capacity of 1000kg | LCI result	Fedca7cf-97df-4d02-a3d3-8e53bb5ee8b7	Fully compliant	Weight pallet: 30 kg Loading capacity: 1000 kg
PACKAGING: IBC – EXPRESSED PER KG PACKED							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
IBC's	0.034	kg	EF 2.0 Sphera node	Plastic can, body HDPE {EU-28+EFTA} | raw material production, blow moulding | production mix, at plant | 0.91-0.96 g/cm3, 28 g/mol per repeating unit | LCI result	bc8c10af-6e3b-44a9-925d-181d1d4f605b	Fully compliant	Proxy for IBC. Assumption: 1000 l IBC 68 kg, assume 1/2 HDPE, 1/2 galvanised steel, density chemical 1 kg/l
IBC frames	0.034	kg	EF 2.0 Sphera node	Cap, ECCS steel {EU-28+EFTA} | metal production, cap manufacturing | production mix, at plant | ESSC steel | LCI result	ef4e440e-05b3-4dd7-afbc-f24b4e625634	Fully compliant	Proxy for IBC frame. Assumption: 1000 l IBC 68 kg, assume 1/2 HDPE, 1/2 galvanised steel, density chemical 1 kg/l
PACKAGING: 20 LITER CAN – EXPRESSED PER KG PACKED							

Input flow	Amount	Unit	Data source	Record	UUID	Compliance with EF reference package	Comment
Jerry cans	0.05	kg	EF 2.0 Sphera node	Plastic can, body HDPE {EU-28+EFTA} | raw material production, blow moulding | production mix, at plant | 0.91-0.96 g/cm3, 28 g/mol per repeating unit | LCI result	bc8c10af-6e3b-44a9-925d-181d1d4f605b	Fully compliant	Proxy for jerrycan. Assumption: 20 l HDPE jerry cans 1000 grams, density chemical 1 kg/l
PACKAGING: 25 LITER CAN – EXPRESSED PER KG PACKED							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
Jerry cans	0.05	kg	EF 2.0 Sphera node	Plastic can, body HDPE {EU-28+EFTA} | raw material production, blow moulding | production mix, at plant | 0.91-0.96 g/cm3, 28 g/mol per repeating unit | LCI result	bc8c10af-6e3b-44a9-925d-181d1d4f605b	Fully compliant	Proxy for jerrycan. Assumption: 25 l HDPE jerry cans 1000 grams, density chemical 1 kg/l
PACKAGING: PLASTIC BAG 1000 KG – EXPRESSED PER KG PACKED							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
1000 kg plastic bag	0.021	m^2	EF2.0 Sphera node	Plastic bag, PP {EU-28+EFTA} | raw material production, plastic extrusion | production mix, at plant | thickness: 0.03 mm, grammage: 0.0275 kg/m2 | LCI result	9127181c-e424-4cc3-9083-3dff8e1b090e	Fully compliant	Assumptions: Weight big bag: 0.567 kg EF record: 0.0275 kg/m2
PACKAGING: PLASTIC BIGBAG 800 KG + WOODEN PALLET– EXPRESSED PER KG PACKED							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
800 kg plastic bigbag	0.021	m^2	EF2.0 Sphera node	Plastic bag, PP {EU-28+EFTA} | raw material production, plastic extrusion | production mix, at plant | thickness: 0.03 mm, grammage: 0.0275 kg/m2 | LCI result	9127181c-e424-4cc3-9083-3dff8e1b090e	Fully compliant	Assumptions: Weight big bag: 0.567 kg (same weight as 1000 kg bag, assumption) EF record: 0.0275 kg/m2
Wooden pallet for plastic bag 20 kg	0.038	kg	EF2.0 Sphera node	Pallet, wood (100x120) {EU-28+EFTA} | sawing, piling, nailing | single route, at plant | 30 kg/piece, nominal loading capacity of 1000kg | LCI result	Fedca7cf-97df-4d02-a3d3-8e53bb5ee8b7	Fully compliant	Weight pallet: 30 kg Loading capacity: 1000 kg

Storage involves energy (electricity and heat) use. Storage is applicable to refined oil and its co-products. Some companies provided data for energy use during storage. A weighted average of the data has been made and subsequently the dataset has been used for all oil types. The datasets used to model storage are found in Table 53.

Table 53: LCI warehouse storage per tonne refined oil and co-products

STORAGE AT WAREHOUSES							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
Electricity	3.12	kWh	EF 2.0 Sphera node	Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1kV - 60kV | LCI result	8fb75312-431d-42f6-9a4f-22fa886f7fe3	Fully compliant	/
Heat from natural gas	125.18	MJ	EF 2.0 Sphera node	Thermal energy from natural gas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 100% efficiency | LCI result	81675341-f1af-44b0-81d3-d108caef5c28	Fully compliant	/

Also, data on **logistic resources and tools** were provided by some companies. Again, a weighted average has been made and the data have been applied to all output products.
The datasets used to model logistic resources and tools are found in Table 54.

Table 54: LCI logistic resources and tools per tonne vegetable oil and proteinmeal product

STORAGE AT WAREHOUSES							
Input flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
Diesel used in forklifts and cranes	0.000915	tkm	EF 2.0 Sphera node	Articulated lorry transport, Euro 4, Total weight <7.5 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | up to 7,5t gross weight / 3,3t payload capacity | Unit process, single operation_with fuel	686faab0-46e7-4e3c-9a18-43e3f3e28e2a	Fully compliant	Diesel added. 0,0416 kg diesel/tkm
Electricity for electrical forklifts	0.00698	kWh	EF 2.0 Sphera node	Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1kV - 60kV | LCI result	8fb75312-431d-42f6-9a4f-22fa886f7fe3	Fully compliant	/
LPG used in forklifts	0.0314	MJ	EF 2.0 Sphera node	Thermal energy from LPG {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 100% efficiency | LCI result	ade98dea-0c74-4ebb-94ef-f9686eb0ddc5	Fully compliant	32MJ/l

In order to model the **waste** output generated by the manufacture of 1 tonne vegetable oil and proteinmeal industry product, company-specific data from all participating sites was averaged and weighted to create an aggregated dataset. Note that recycling of mainly packaging, paper, plastic, metal, wood etc. is not included in the dataset. This choice was made for two reasons: (i) their production was not included in the first place, and (ii) in many cases these materials are not linked to the crushing and refining processes but to supporting activities such as office work etc. The LCI is given in Table 55.

Table 55: LCI waste per tonne vegetable oil and proteinmeal industry product

WASTE							
Output flow	**Amount**	**Unit**	**Data source**	**Record**	**UUID**	**Compliance with EF reference package**	**Comment**
Organic waste to landfill	0.128	kg	EF 2.0 Ecoinvent node	Landfill of biodegradable waste {EU-28+EFTA} | LCI result	52a86303-7d24-49ba-8161-a1b04dabc4b7	Fully compliant	/
Inorganic waste to landfill	0.0093	kg	EF 2.0 Ecoinvent node	Landfill of polluted inorganic waste {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites), at landfill site | LCI result	749b650d-aa86-4027-95a1-f20f712a5631	Fully compliant	/
Hazardous waste to landfill	0.0011	kg	EF 2.0 Ecoinvent node	Landfill of polluted inorganic waste {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites), at landfill site | LCI result	749b650d-aa86-4027-95a1-f20f712a5631	Fully compliant	/
Waste to incineration	0.851	kg	Ecoinvent	Waste incineration of hazardous waste {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | hazardous waste | LCI result	fa158634-c471-4b0e-afef-407d1073b086	Fully compliant	/
Organic waste to incineration	1.272	kg	Ecoinvent	Waste incineration of untreated wood {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | wood waste | LCI result	a1ae691d-268e-4ba6-b4e6-f3b7263fd17b	Fully compliant	/
Waste to incineration	1.589	kg	Ecoinvent	Waste incineration of hazardous waste {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | hazardous waste | LCI result	fa158634-c471-4b0e-afef-407d1073b086	Fully compliant	Proxy for waste from filters etc.

2.2. PEF RESULTS

The characterised, normalised and weighted results for the representative product without any cut-offs are shown in Table 56, Table 57 and Table 58 respectively.

Table 56: Characterised results for the representative product (virtual vegetable oil and proteinmeal industry product) without cut-off

Impact category	Unit	Total life cycle
Climate change, total	kg CO_2 eq	2,44E+03
Climate change - fossil		1,47E+03
Climate change - biogenic		1,32E+02
Climate change – land use and land use change		8,38E+02
Ozone depletion	kg CFC11 eq	6,07E-06
Ionising radiation, human health	kBq U-235 eq	1,58E+01
Photochemical ozone formation, human health	kg NMVOC eq	3,56E+00
Particulate Matter	disease inc.	1,03E-04
Human toxicity, non-cancer	CTUh	5,62E-05
Human toxicity, cancer	CTUh	1,30E-06
Acidification	mol H^+ eq	1,27E+01
Eutrophication, freshwater	kg P eq	8,12E-01
Eutrophication, marine	kg N eq	1,46E+01
Eutrophication, terrestrial	mol N eq	5,43E+01
Ecotoxicity	CTUe	1,38E+05
Land use	Pt	1,80E+05
Water use	m^3 depriv.	7,91E+02
Resource use, fossils	MJ	7,61E+03
Resource use, minerals and metals	kg Sb eq	2,81E-04

Table 57: Normalised results for the representative product (virtual vegetable oil and proteinmeal industry product) without cut-off

Impact category	Total life cycle
Climate change, total	3,01E-01
Climate change - fossil	1,81E-01
Climate change - biogenic	1,63E-02
Climate change – land use and land use change	1,03E-01
Ozone depletion	1,13E-04
Particulate matter	3,74E-03
Ionising radiation, human health	8,78E-02
Photochemical ozone formation, human health	1,73E-01
Acidification	2,45E-01
Eutrophication, terrestrial	7,69E-02
Eutrophication, freshwater	2,29E-01
Eutrophication, marine	5,05E-01
Human toxicity, cancer	7,46E-01
Human toxicity, non-cancer	3,07E-01
Ecotoxicity	3,23E+00
Land use	2,19E-01
Water use	6,89E-02
Resource use, fossils	1,17E-01
Resource use, minerals and metals	4,42E-03

Table 58: Weighted results for the representative product (virtual vegetable oil and proteinmeal industry product) without cut-off, in mPt

Impact category	**Total life cycle**
Climate change, total	6,34E+01
Climate change - fossil	3,82E+01
Climate change - biogenic	3,44E+00
Climate change – land use and land use change	2,18E+01
Ozone depletion	7,14E-03
Particulate matter	1,87E-01
Ionising radiation, human health	4,20E+00
Photochemical ozone formation, human health	1,55E+01
Acidification	4,50E+00
Eutrophication, terrestrial	1,64E+00
Eutrophication, freshwater	1,42E+01
Eutrophication, marine	1,41E+01
Human toxicity, cancer	2,21E+01
Human toxicity, non-cancer	1,14E+01
Ecotoxicity	6,20E+01
Land use	1,74E+01
Water use	5,87E+00
Resource use, fossils	9,73E+00
Resource use, minerals and metals	3,34E-01
Total	**2,47E+02**

Based on the results for the representative product without any cut-offs, it was decided to exclude the following processes from the system boundaries:

- capital goods for the manufacturing processes of the vegetable oil and proteinmeal industry;
- packaging of incoming auxiliary materials;
- storage of refining products;
- resources and tools for logistic operations at the vegetable oil and proteinmeal plants;
- process waste (excluding wastewater).

Table 59 shows the contribution of these processes to the total characterised results for the representative product. Based on the 3% cut-off rule, all these processes can be excluded from the system boundaries, except for capital goods. Nevertheless, it was decided to exclude capital goods anyway[11], as it only has a relevant contribution to impact category "Resource use, minerals and metals", which is not included in the most relevant impact categories[12]. This does not seem to justify the very time-consuming process of collecting data on capital goods for the manufacturing processes of the vegetable oil and protein meal industry.

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[11] This is not PEF compliant.

[12] Resource use, minerals and metals is the second less relevant impact category for the FEDIOL products when no cut-off has been applied, only ozone depletion has a lower contribution to the weighted results for the representative product.

Table 59: Contribution of the processes that are cut-off to the total characterised results for the representative product

Impact category	Capital goods	Packaging incoming materials	Storage of refining products	Logistic resources and tools	Process waste	**Total**
Climate change, total	0,02%	0,00%	0,14%	0,00%	0,02%	0,18%
Ozone depletion	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Ionising radiation	0,29%	0,02%	1,46%	0,01%	-1,81%	-0,04%
Photochemical ozone formation	0,05%	0,00%	0,09%	0,00%	0,09%	0,23%
Particulate matter	0,12%	0,01%	0,03%	0,00%	-0,02%	0,14%
Human toxicity, non-cancer	0,03%	0,00%	0,01%	0,00%	0,03%	0,07%
Human toxicity, cancer	0,06%	0,00%	0,02%	0,00%	0,00%	0,08%
Acidification	0,07%	0,00%	0,03%	0,00%	0,01%	0,10%
Eutrophication, freshwater	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Eutrophication, marine	0,00%	0,00%	0,01%	0,00%	0,01%	0,02%
Eutrophication, terrestrial	0,01%	0,00%	0,02%	0,00%	0,03%	0,06%
Ecotoxicity, freshwater	0,01%	0,00%	0,00%	0,00%	0,00%	0,01%
Land use	0,03%	0,00%	0,00%	0,00%	0,00%	0,03%
Water use	0,02%	0,00%	0,01%	0,00%	0,08%	0,11%
Resource use, fossils	0,08%	0,01%	0,72%	0,00%	-0,35%	0,46%
Resource use, minerals and metals	12,79%	0,20%	0,07%	0,00%	-0,04%	13,02%

ANNEX II – NORMALISED AND WEIGHTED RESULTS

1. NORMALISED RESULTS

1.1. PRODUCTS FROM RAPESEEDS

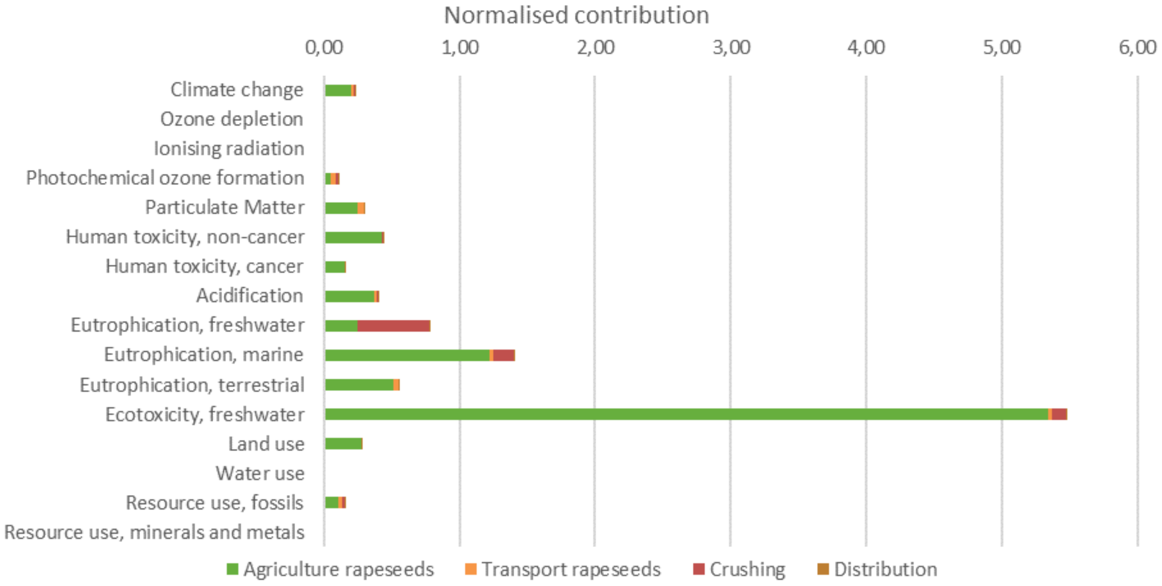

Figure 57: Normalised environmental profile of 1 tonne crude oil from rapeseeds

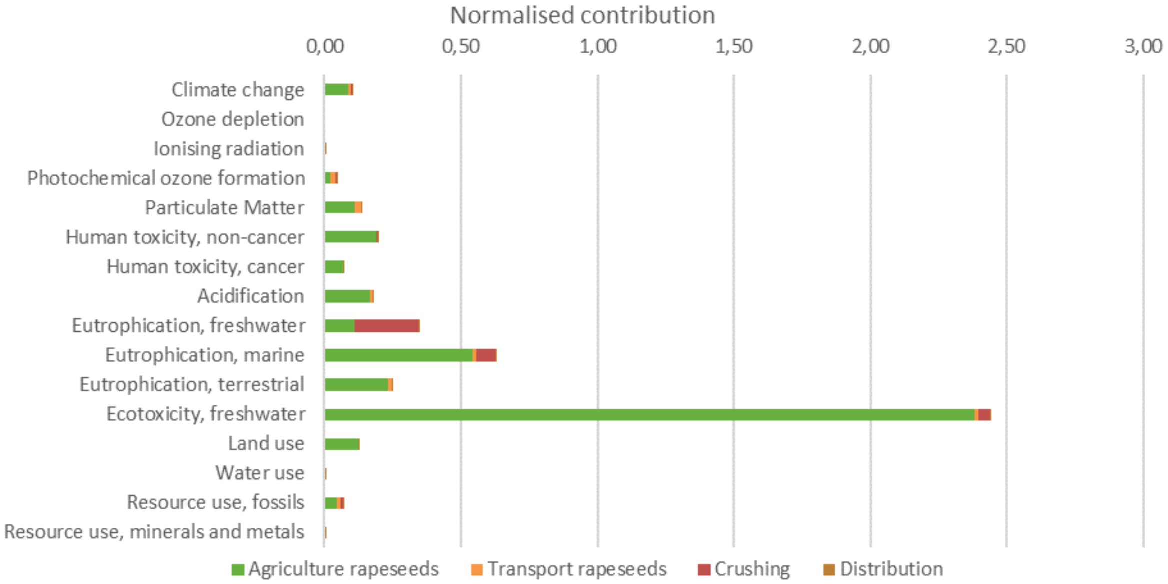

Figure 58: Normalised environmental profile of 1 tonne meal from rapeseeds

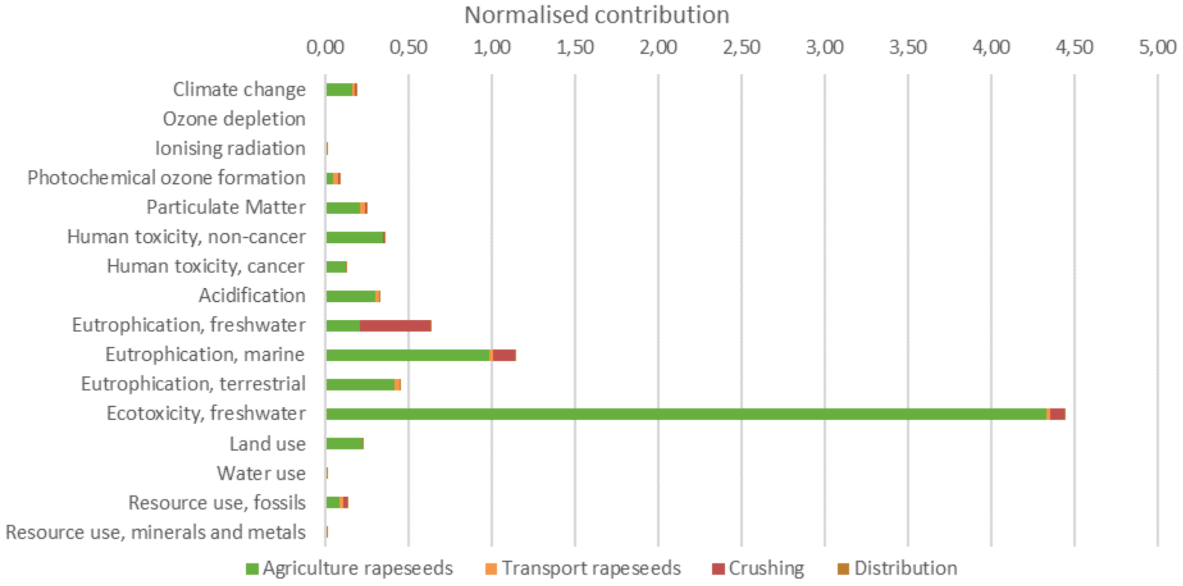

Figure 59: Normalised environmental profile of 1 tonne lecithin from rapeseeds

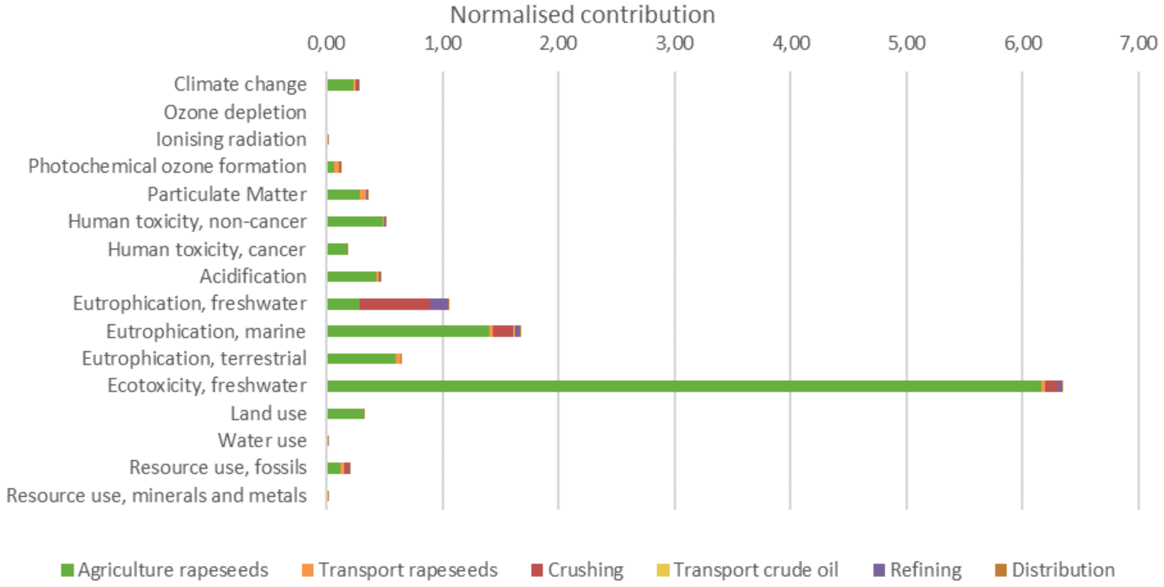

Figure 60: Normalised environmental profile of 1 tonne refined oil from rapeseeds

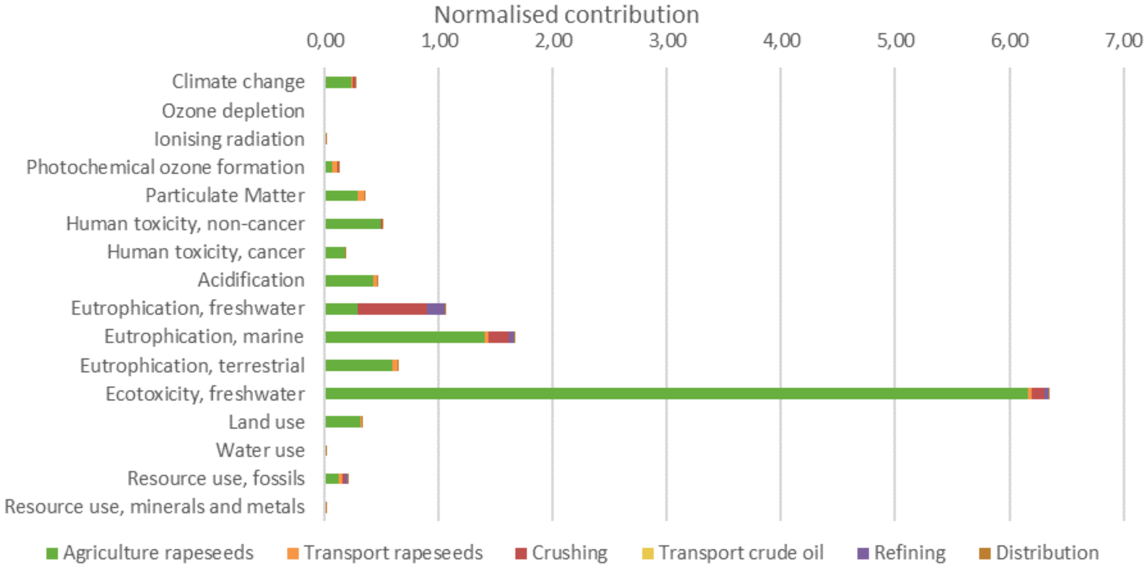

Figure 61: Normalised environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from rapeseeds

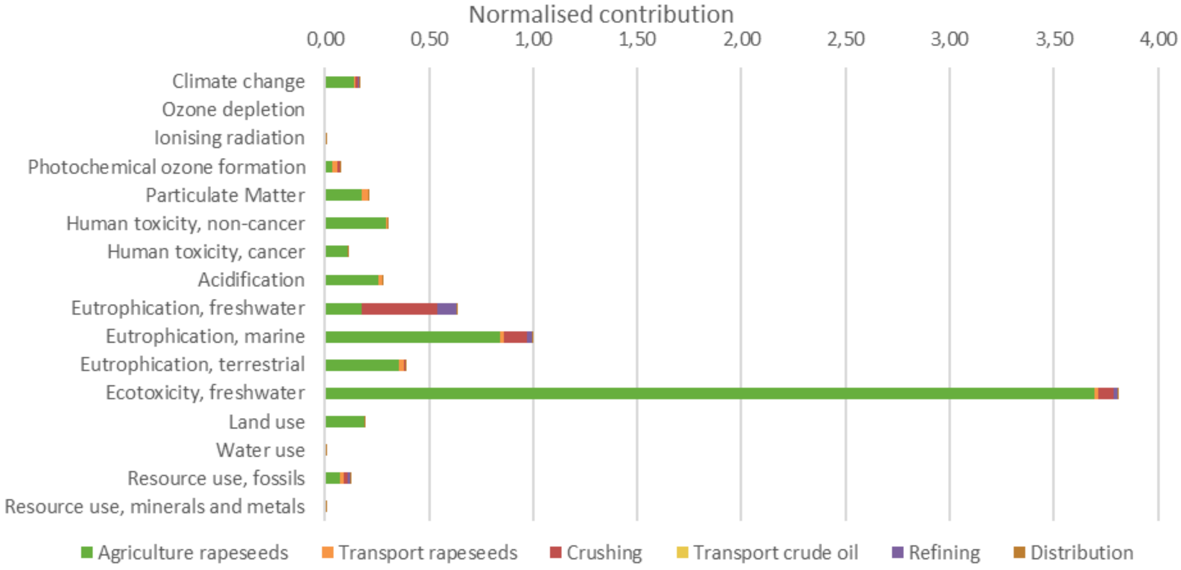

Figure 62: Normalised environmental profile of 1 tonne soap stock from rapeseeds

1.2. PRODUCTS FROM SOYBEANS

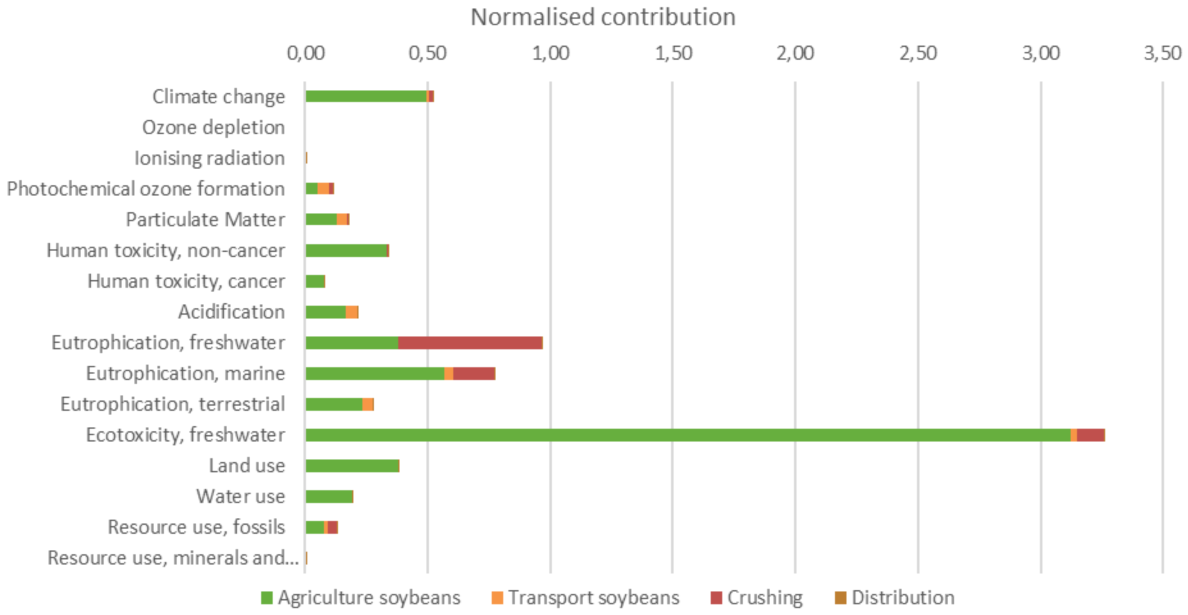

Figure 63: Normalised environmental profile of 1 tonne crude oil from soybeans

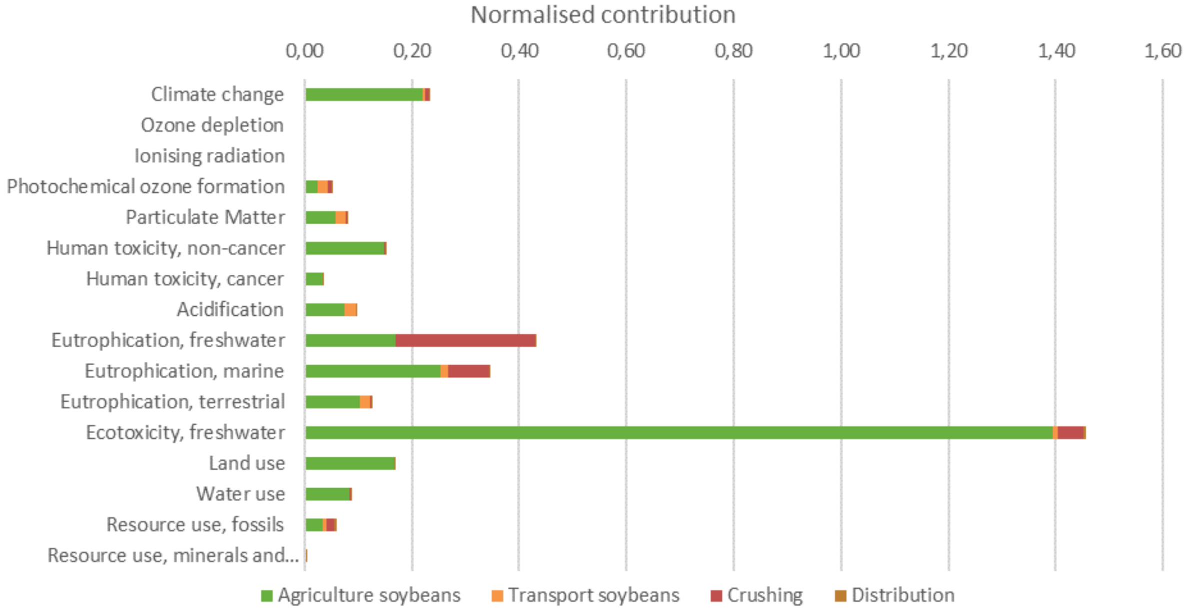

Figure 64: Normalised environmental profile of 1 tonne meal from soybeans

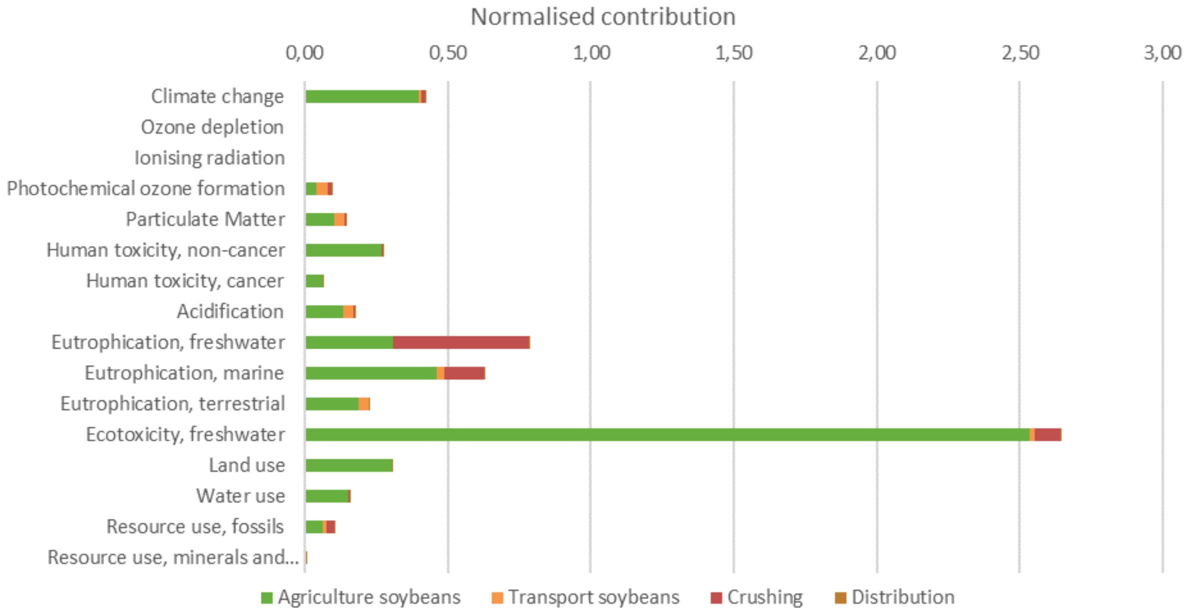

Figure 65: Normalised environmental profile of 1 tonne lecithin from soybeans

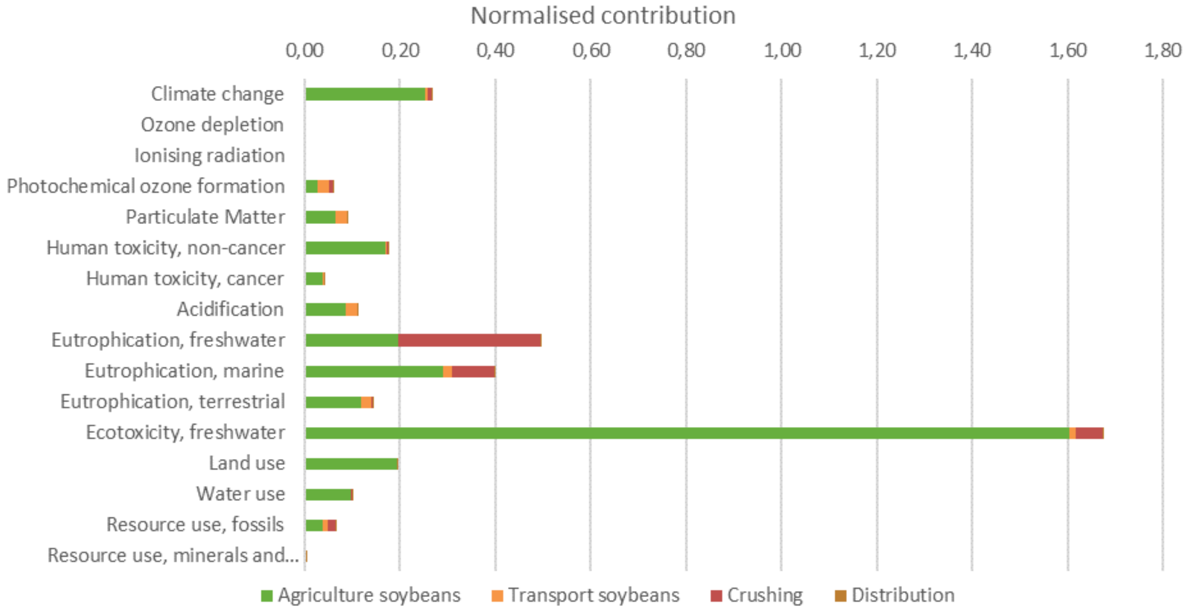

Figure 66: Normalised environmental profile of 1 tonne hulls from soybeans

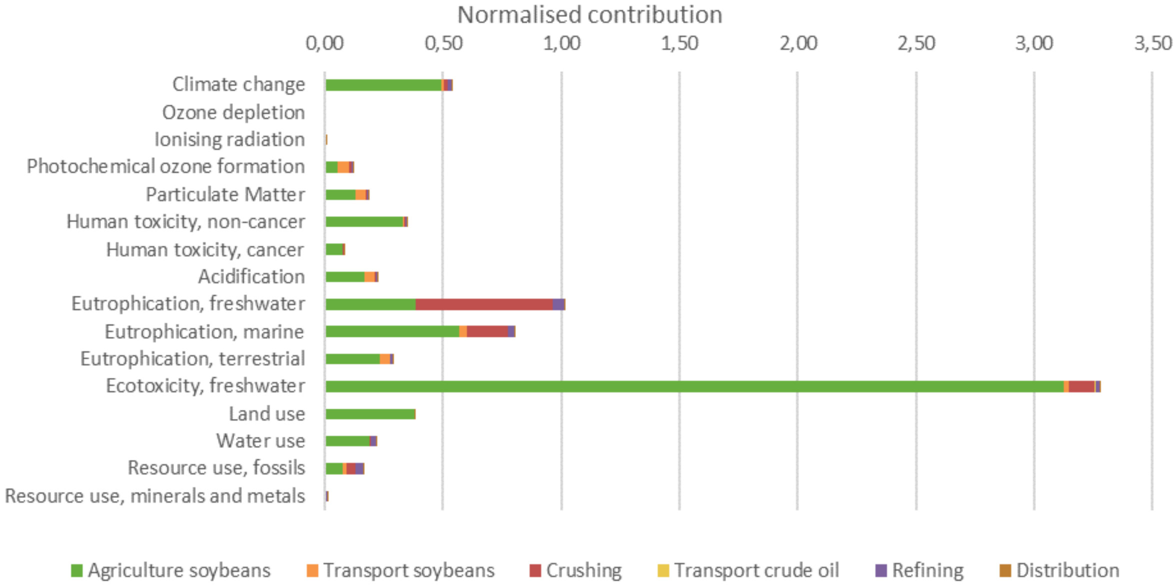

Figure 67: Normalised environmental profile of 1 tonne refined oil from soybeans

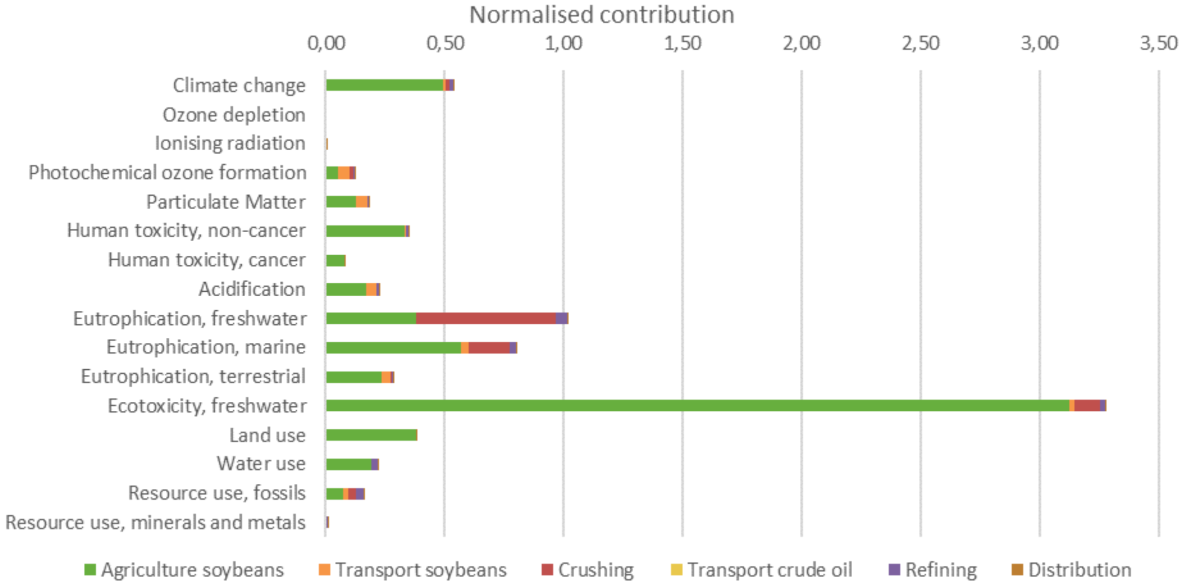

Figure 68: Normalised environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from soybeans

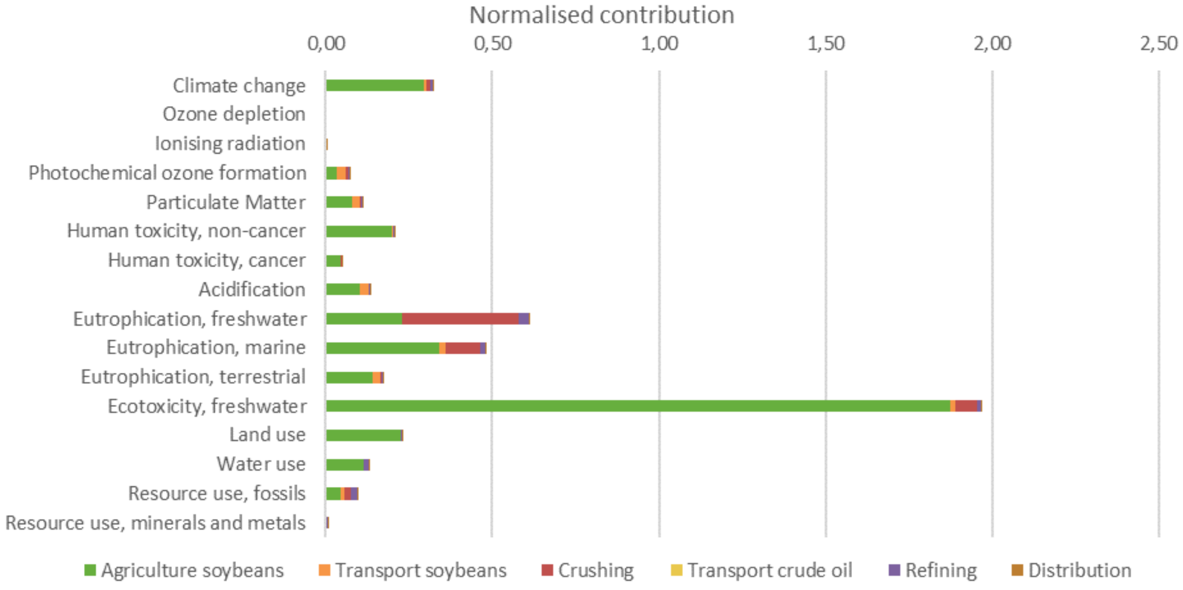

Figure 69: Normalised environmental profile of 1 tonne soap stock from soybeans

1.3. PRODUCTS FROM SUNFLOWER SEEDS

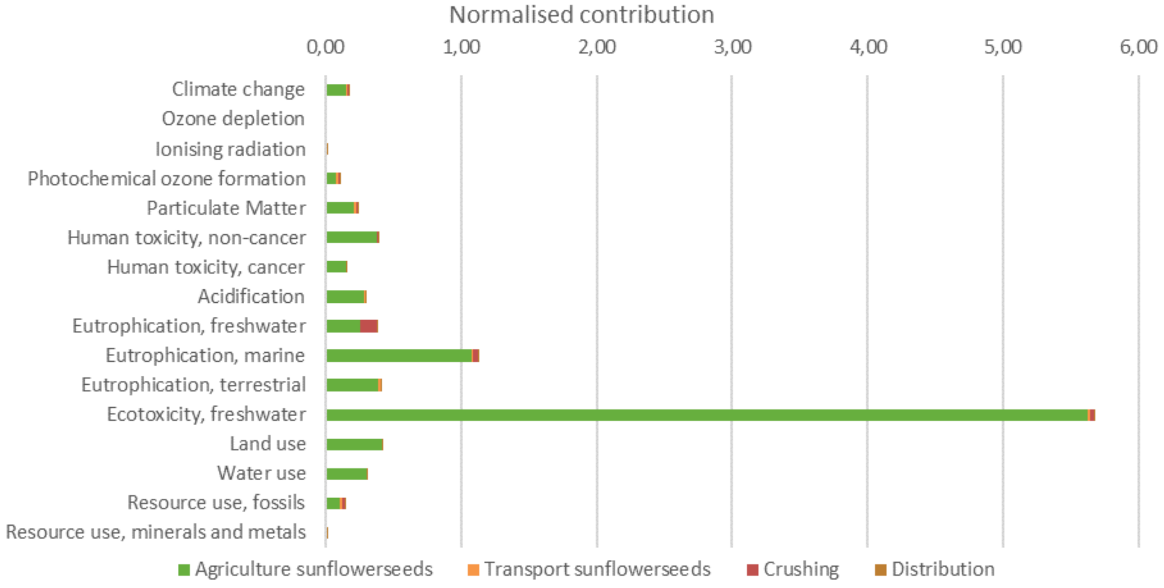

Figure 70: Normalised environmental profile of 1 tonne crude oil from sunflower seeds

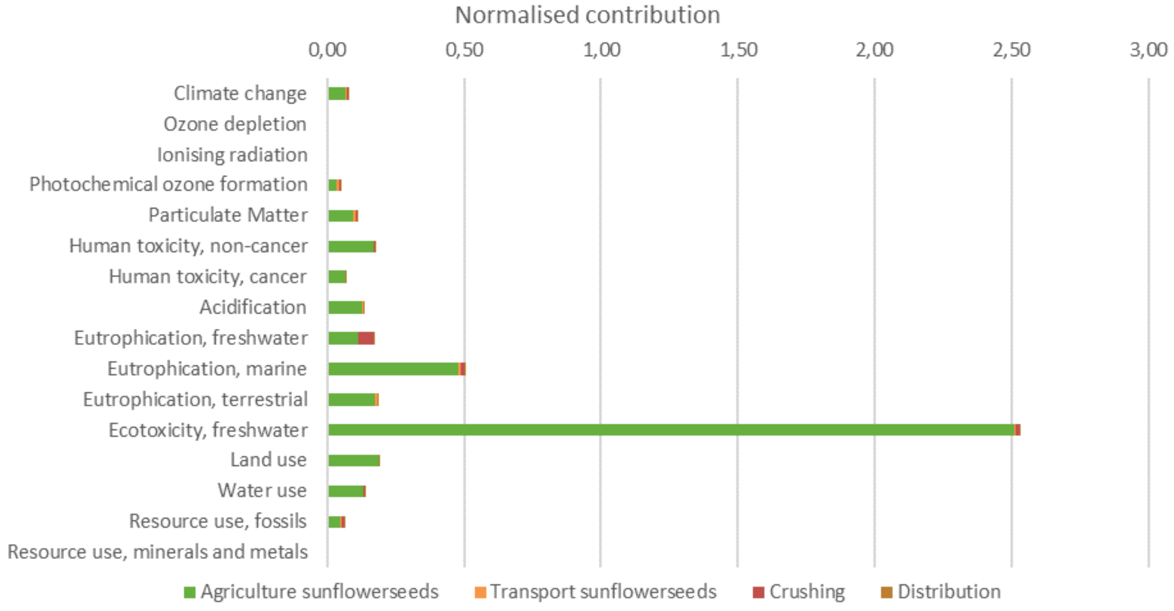

Figure 71: Normalised environmental profile of 1 tonne meal from sunflower seeds

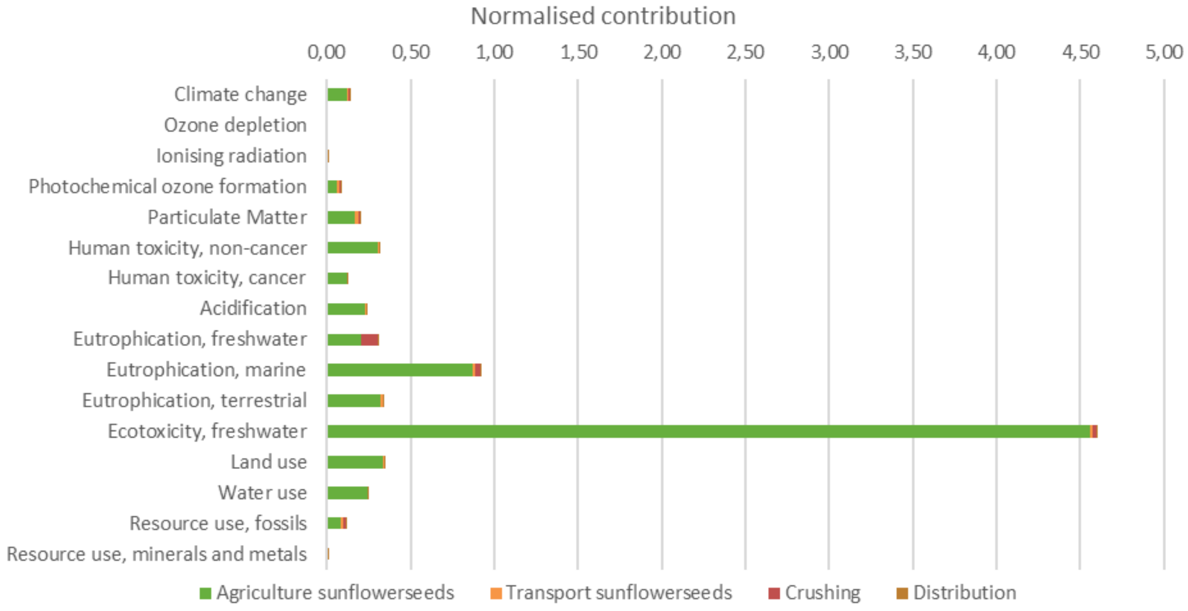

Figure 72: Normalised environmental profile of 1 tonne lecithin from sunflower seeds

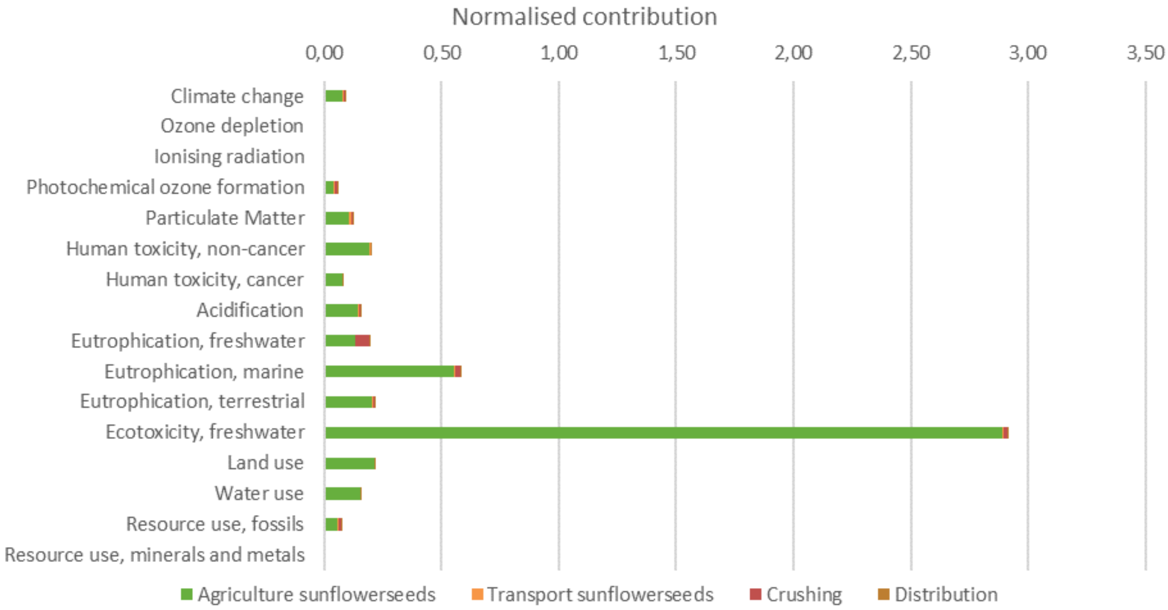

Figure 73: Normalised environmental profile of 1 tonne husks from sunflower seeds

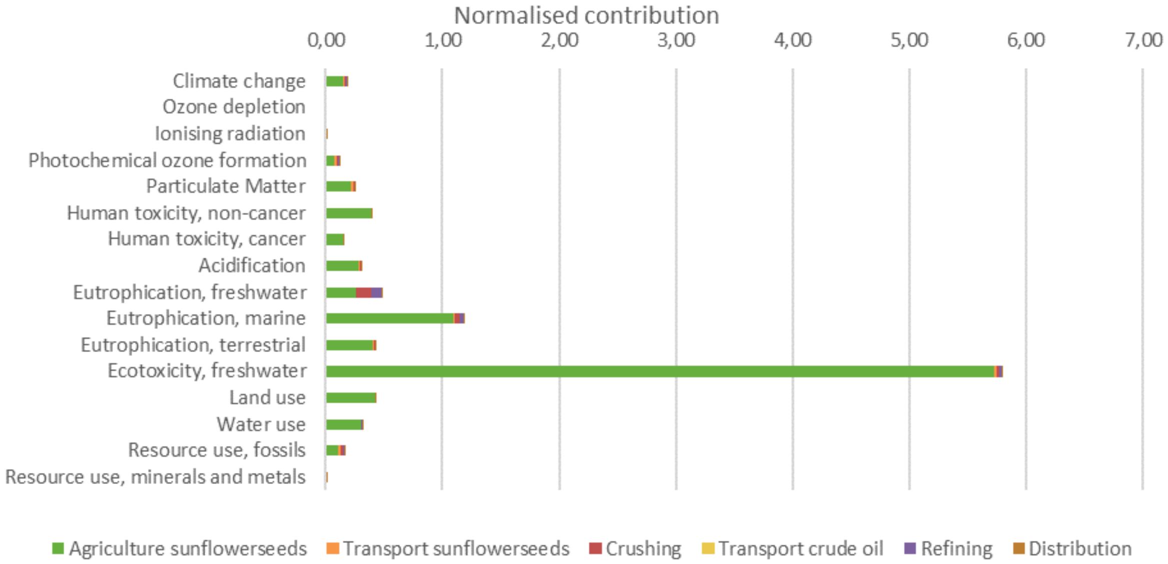

Figure 74: Normalised environmental profile of 1 tonne refined oil from sunflower seeds

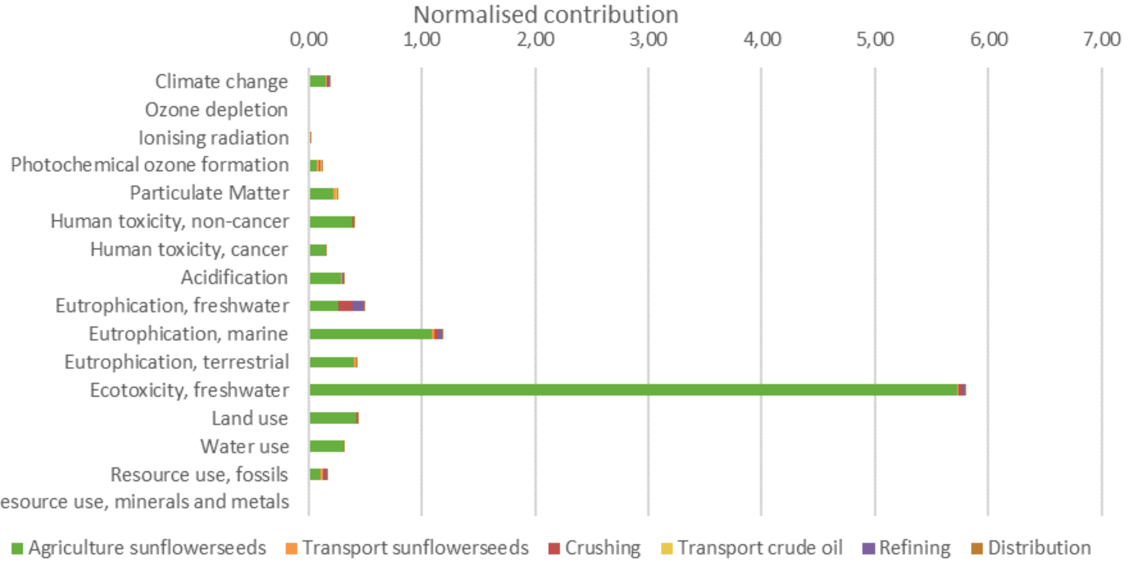

Figure 75: Normalised environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from sunflower seeds

1.4. PRODUCTS FROM MAIZE GERMS

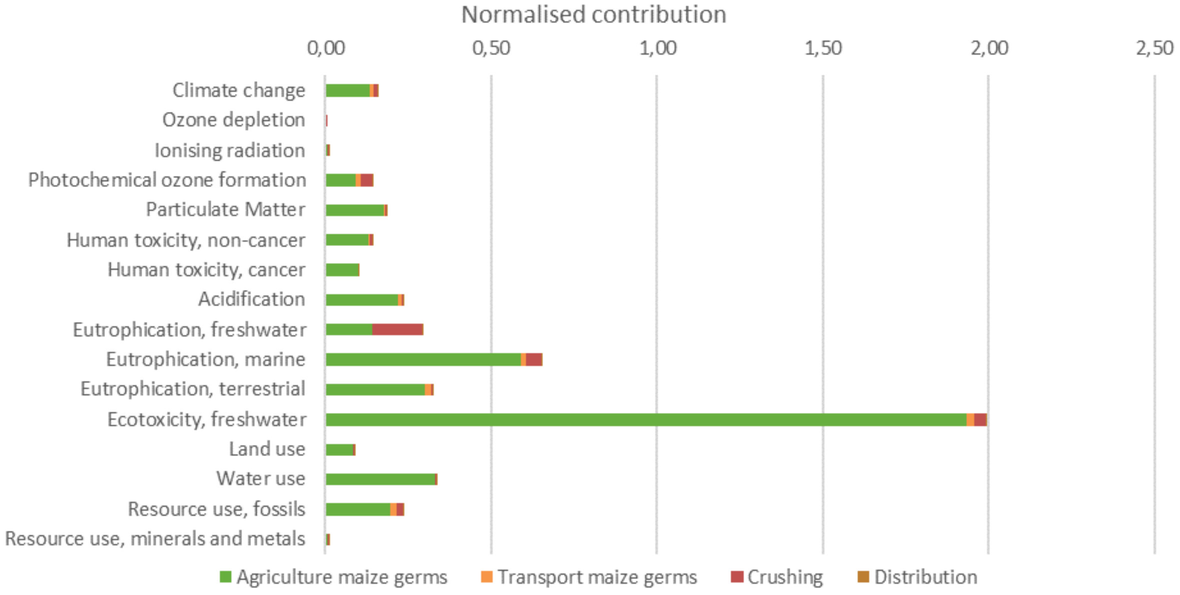

Figure 76: Normalised environmental profile of 1 tonne crude oil from maize germs

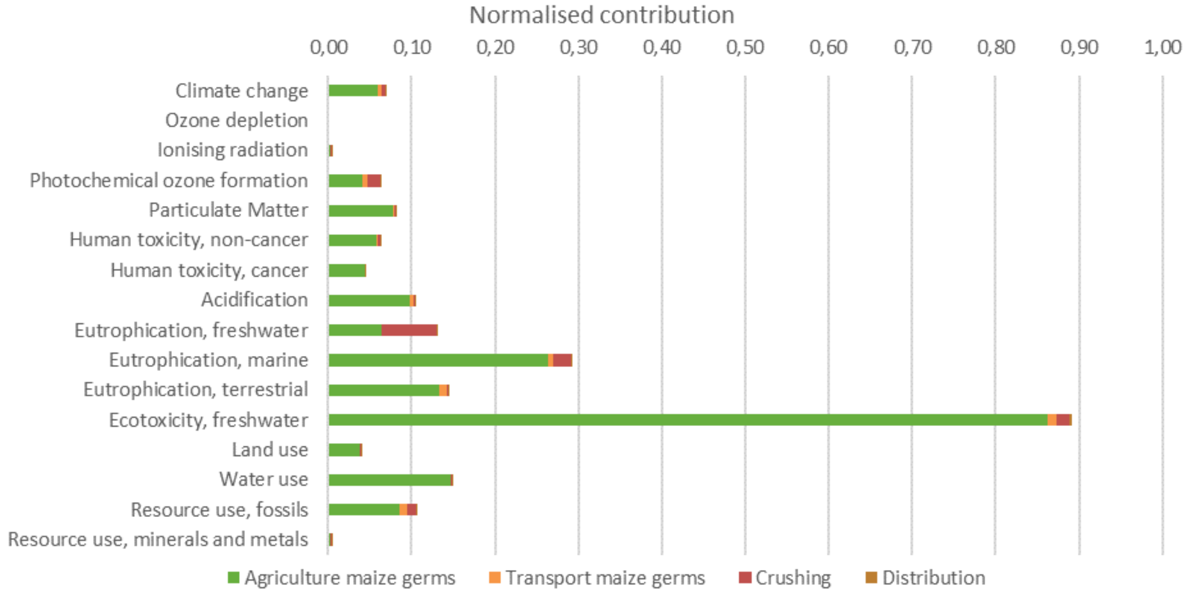

Figure 77: Normalised environmental profile of 1 tonne meal from maize germs

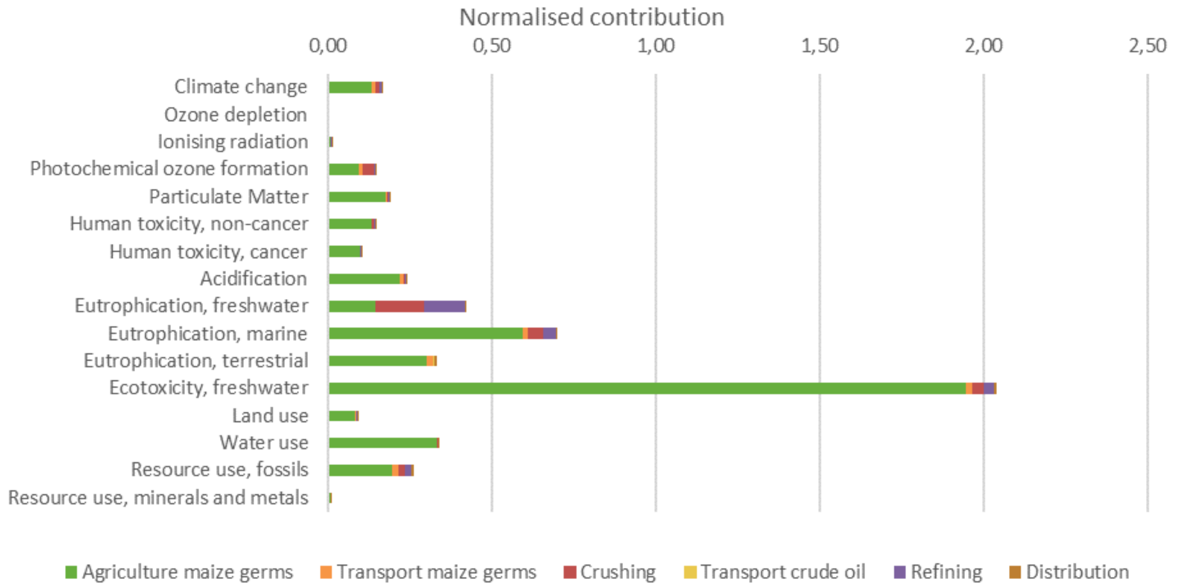

Figure 78: Normalised environmental profile of 1 tonne refined oil from maize germs

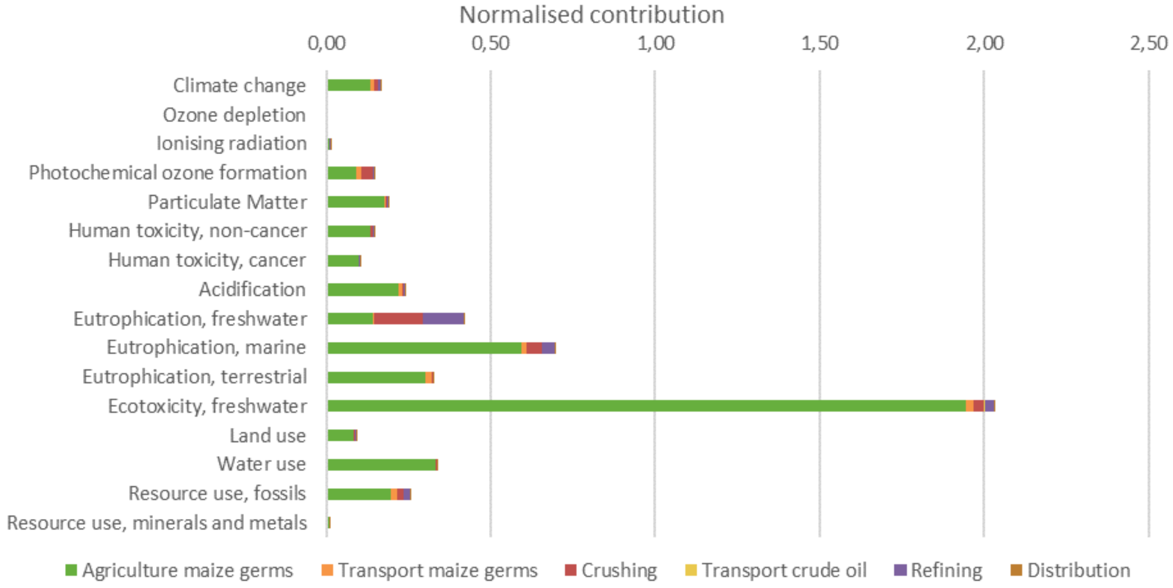

Figure 79: Normalised environmental profile of 1 tonne acid oil or deodistillates from maize germs

1.5. PRODUCTS FROM PALM

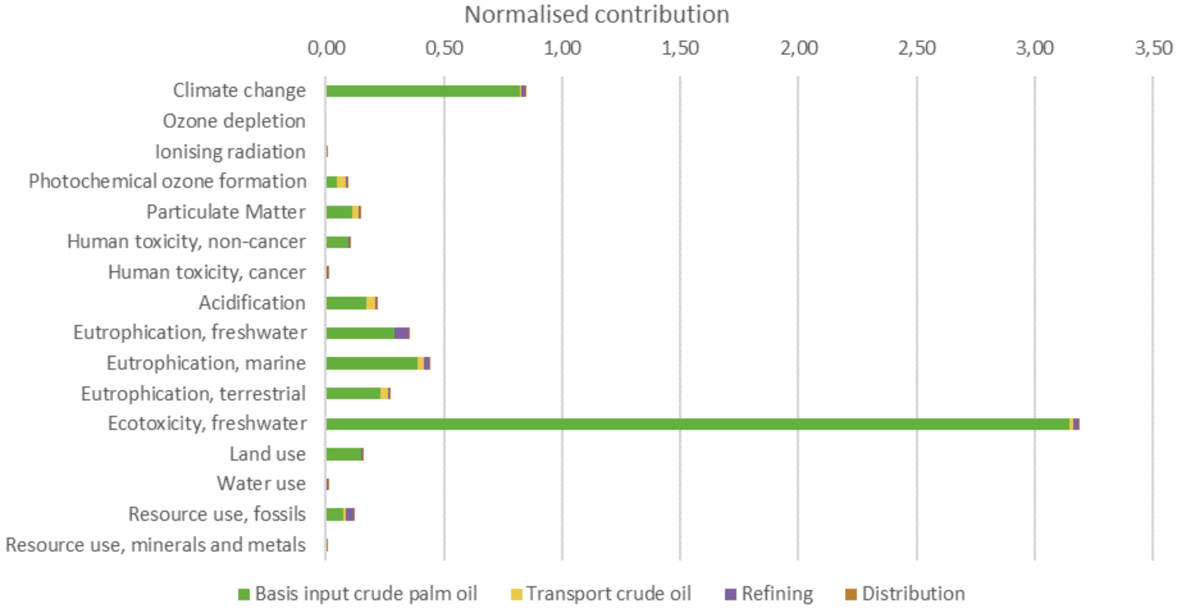

Figure 80: Normalised environmental profile of 1 tonne refined oil from palm

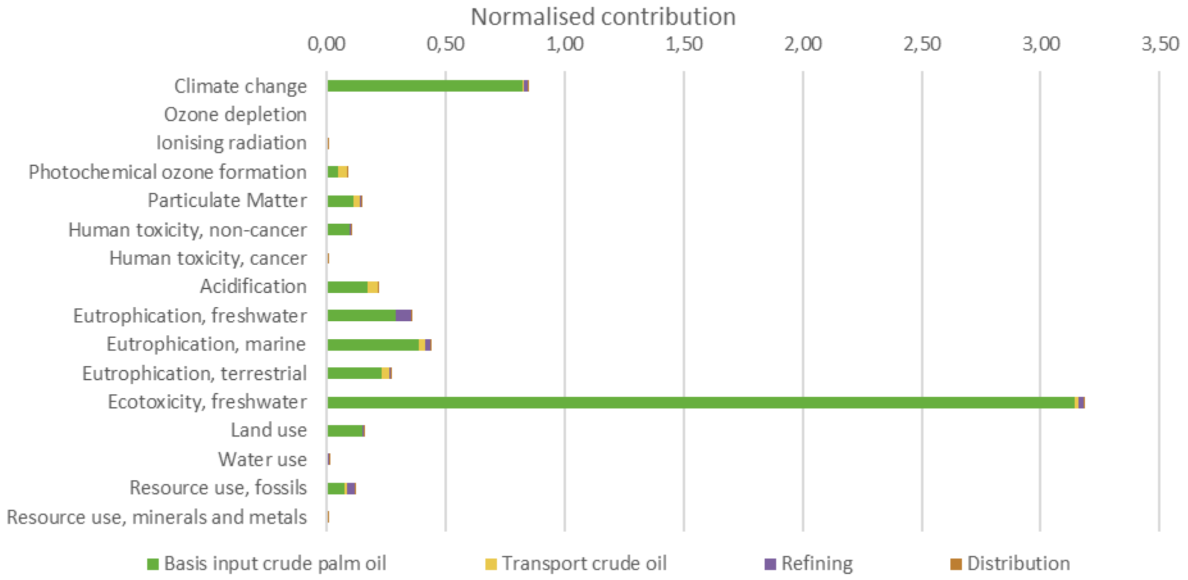

Figure 81: Normalised environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from palm

1.6. PRODUCTS FROM PALM KERNEL

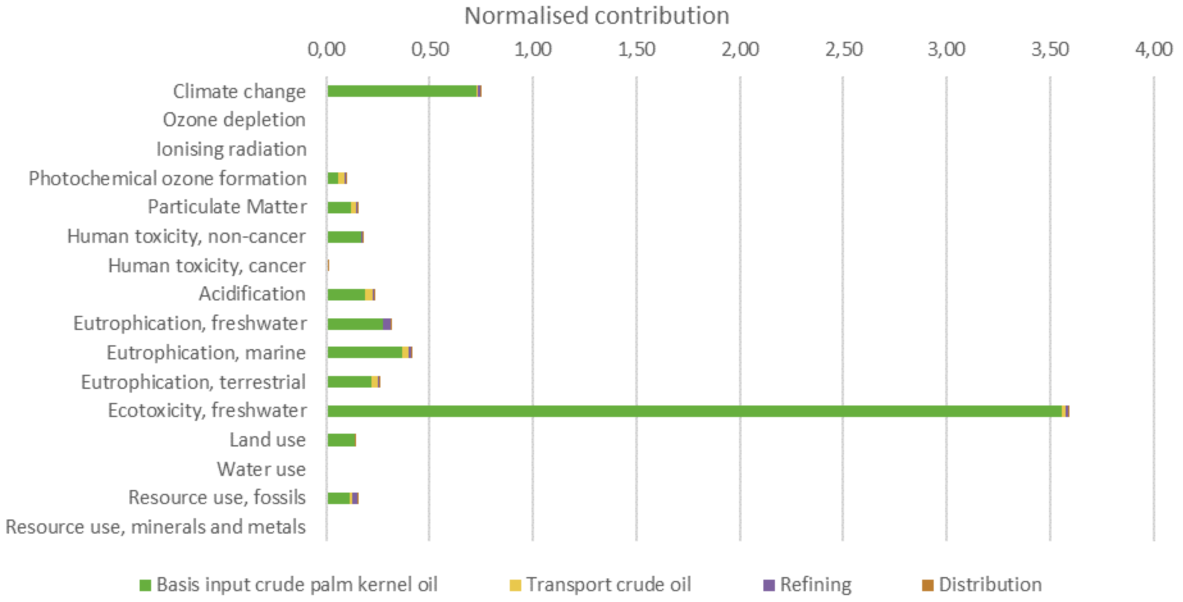

Figure 82: Normalised environmental profile of 1 tonne refined oil from palm kernel

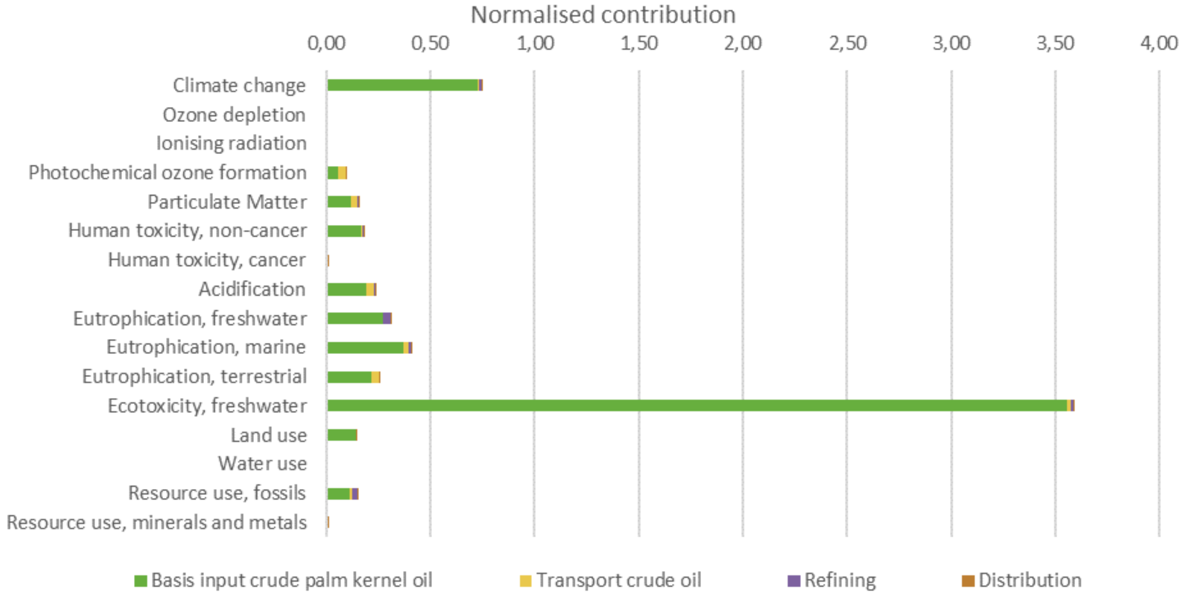

Figure 83: Normalised environmental profile of 1 tonne fatty acid distillates from palm kernel

1.7. PRODUCTS FROM COCONUT

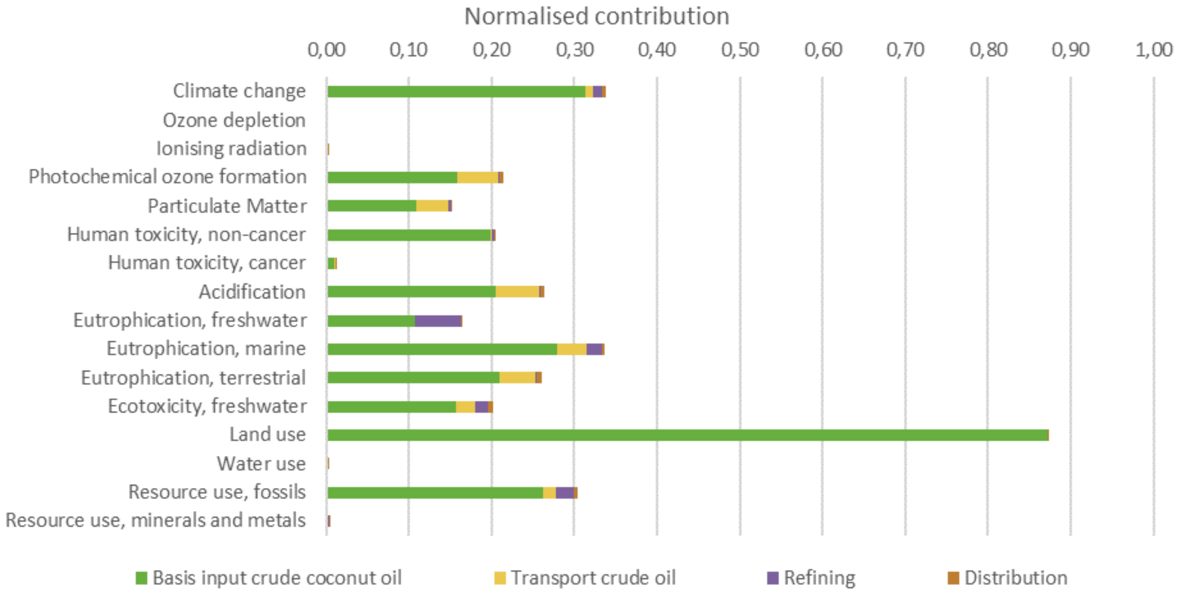

Figure 84: Normalised environmental profile of 1 tonne refined oil from coconut

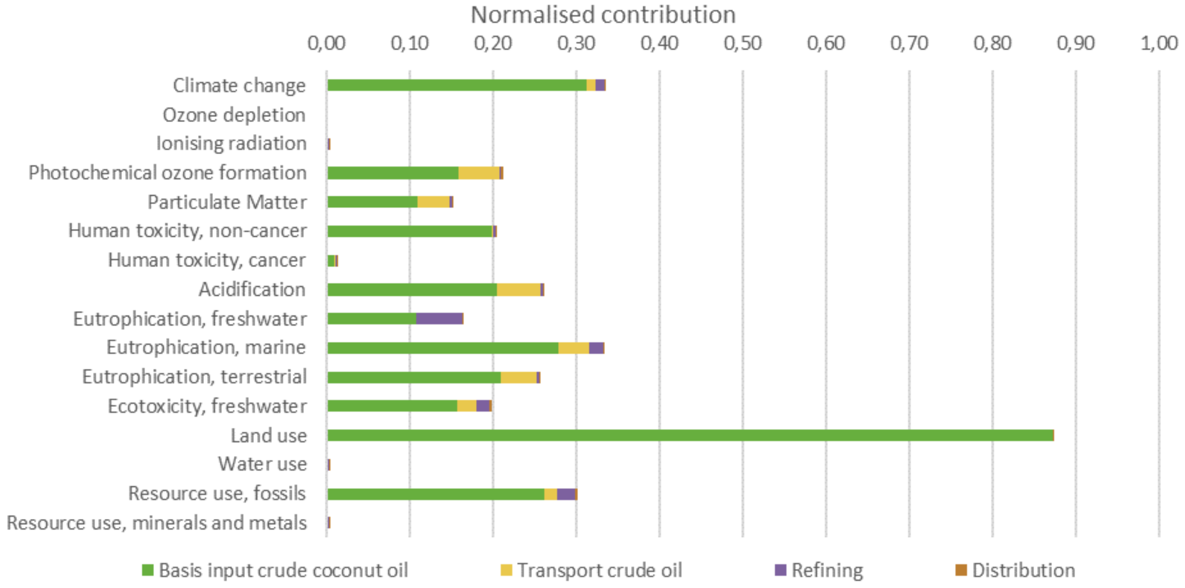

Figure 85: Normalised environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from coconut

2. WEIGHTED RESULTS

2.1. PRODUCTS FROM RAPESEEDS

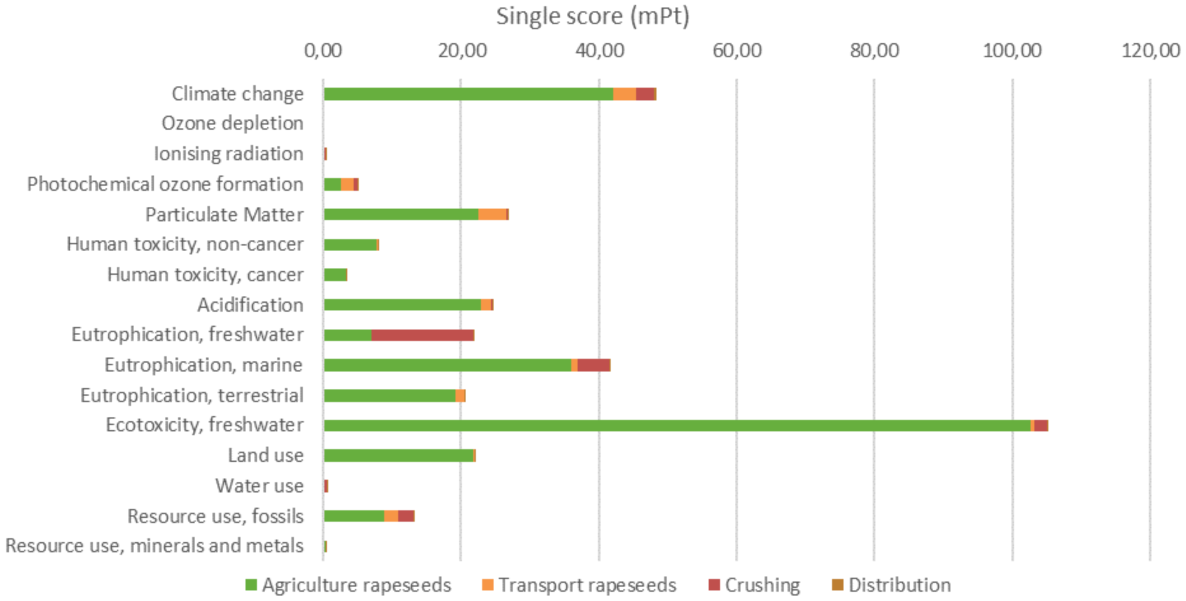

Figure 86: Weighted environmental profile of 1 tonne crude oil from rapeseeds

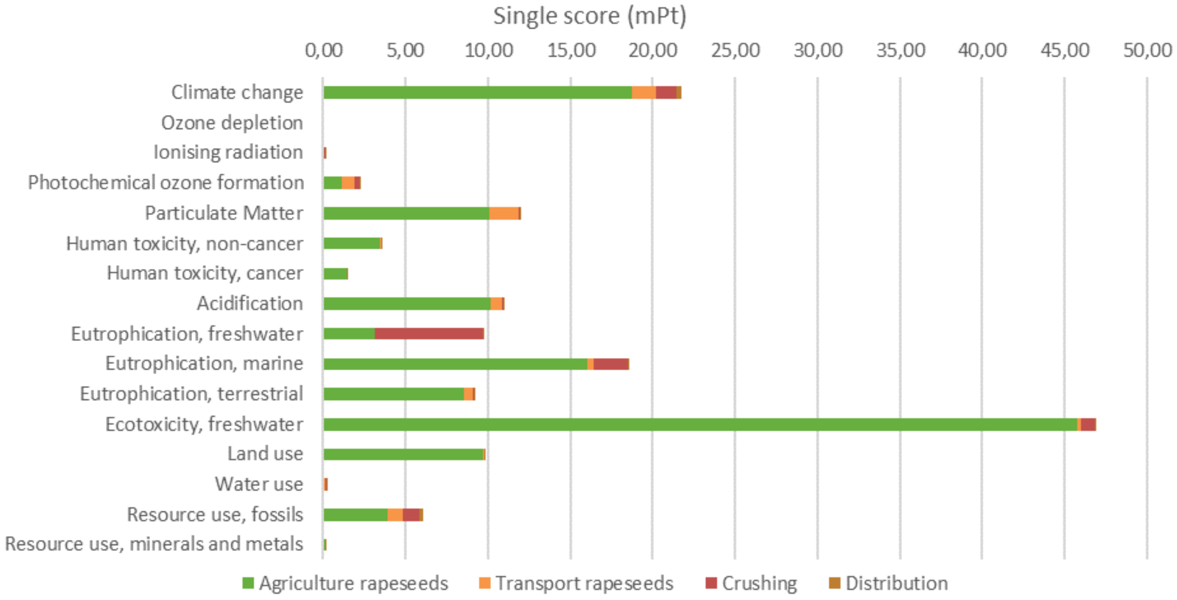

Figure 87: Weighted environmental profile of 1 tonne meal from rapeseeds

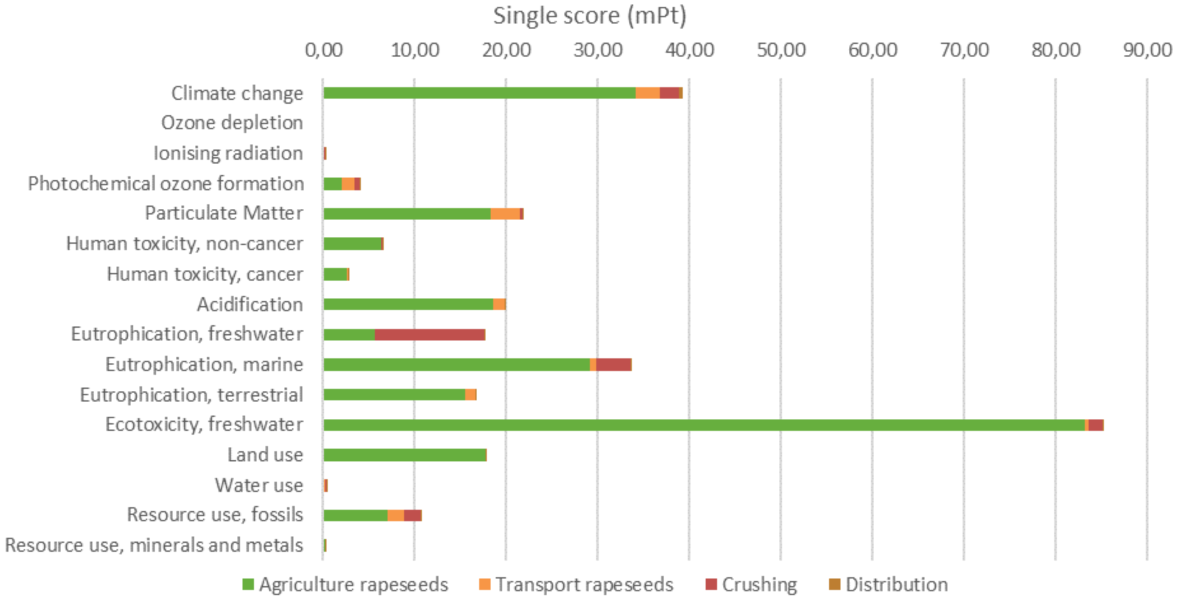

Figure 88: Weighted environmental profile of 1 tonne lecithin from rapeseeds

Figure 89: Weighted environmental profile of 1 tonne refined oil from rapeseeds

Figure 90: Weighted environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from rapeseeds

Figure 91: Weighted environmental profile of 1 tonne soap stock from rapeseeds

2.2. PRODUCTS FROM SOYBEANS

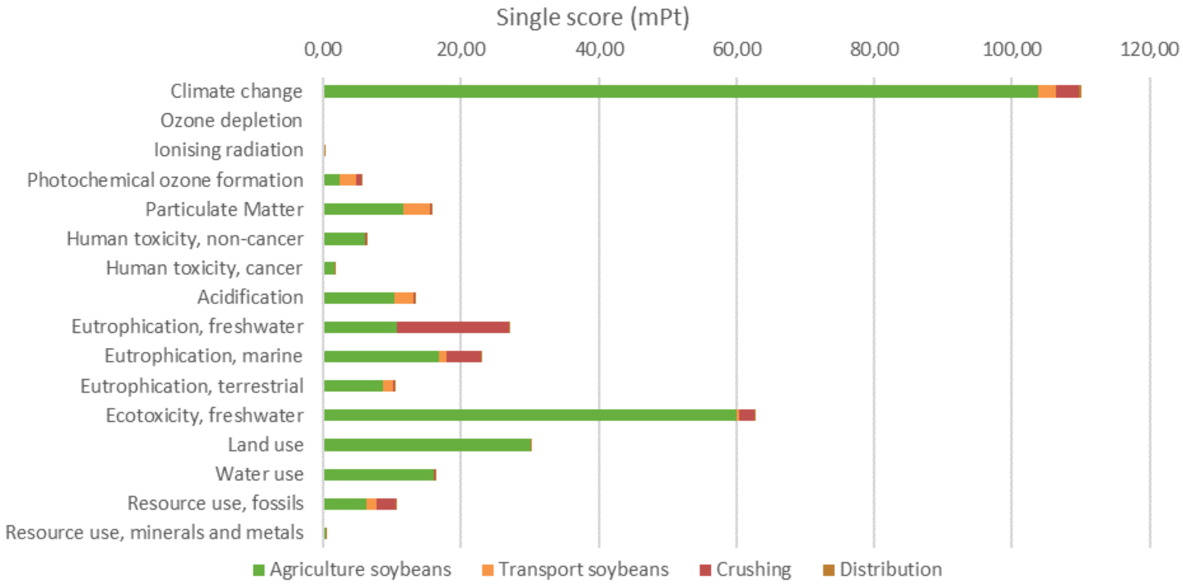

Figure 92: Weighted environmental profile of 1 tonne crude oil from soybeans

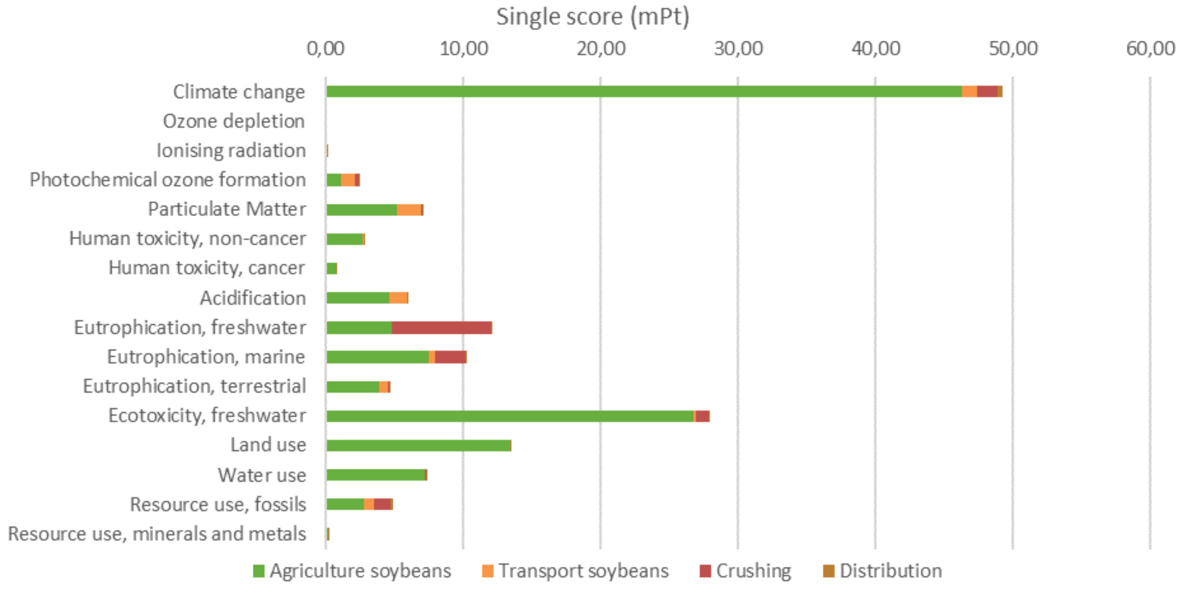

Figure 93: Weighted environmental profile of 1 tonne meal from soybeans

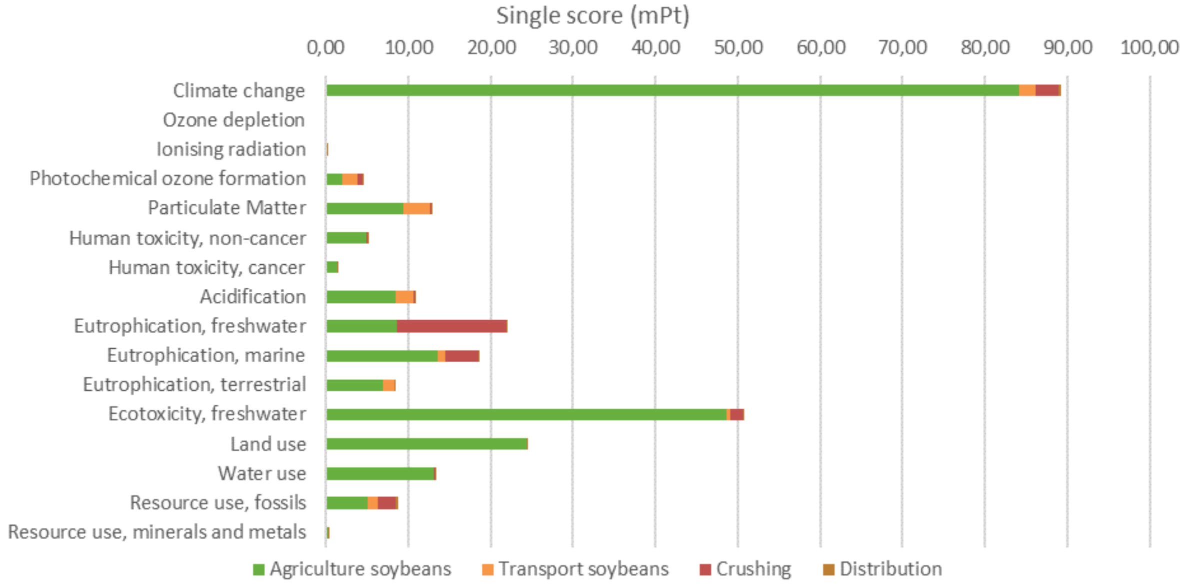

Figure 94: Weighted environmental profile of 1 tonne lecithin from soybeans

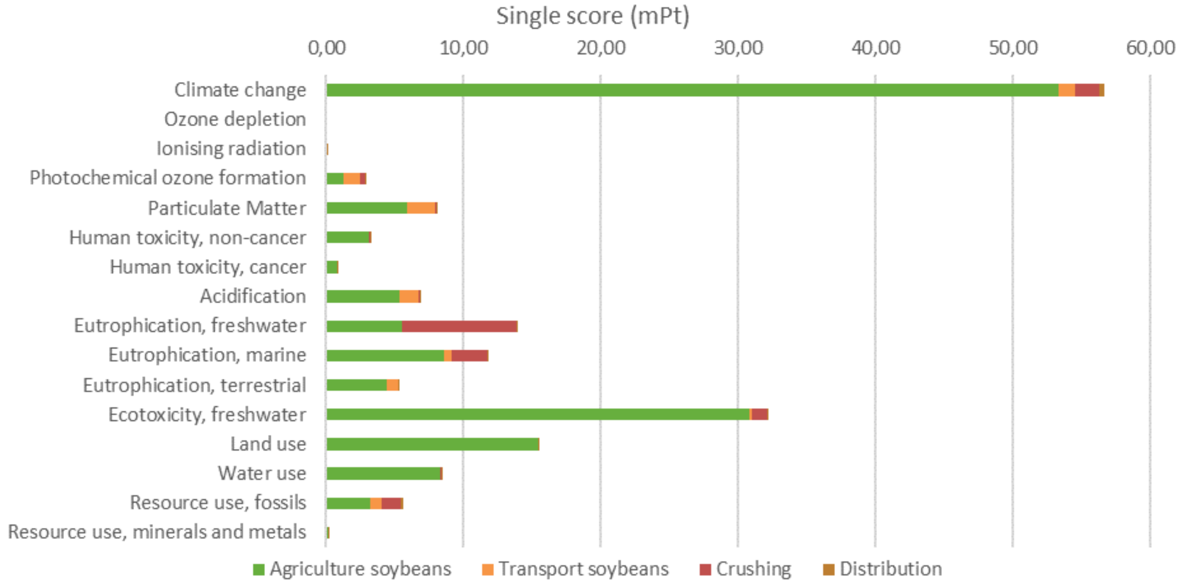

Figure 95: Weighted environmental profile of 1 tonne hulls from soybeans

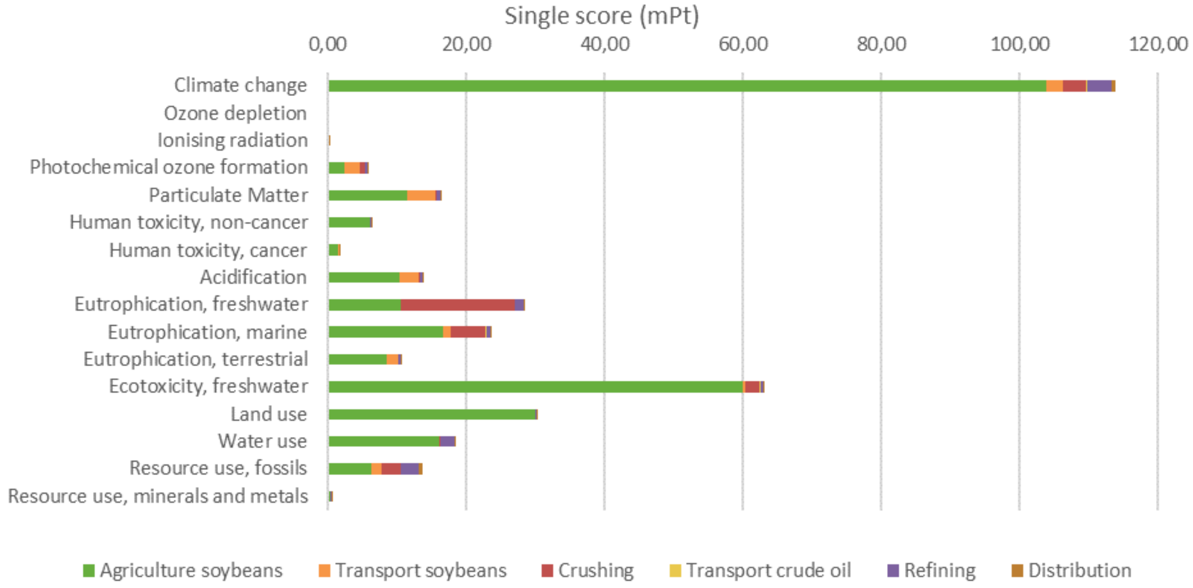

Figure 96: Weighted environmental profile of 1 tonne refined oil from soybeans

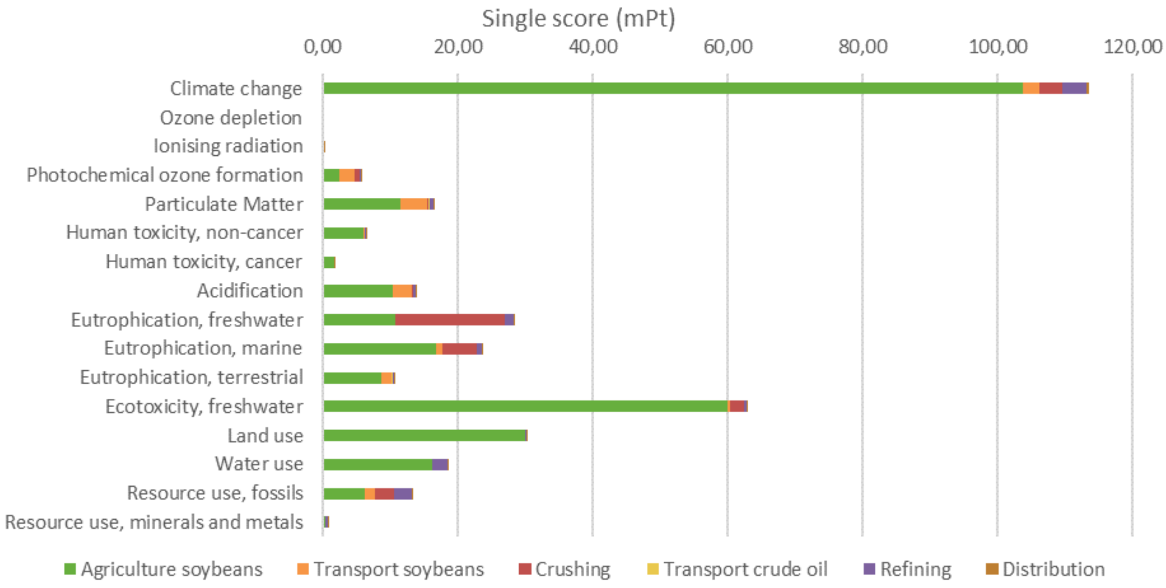

Figure 97: Weighted environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from soybeans

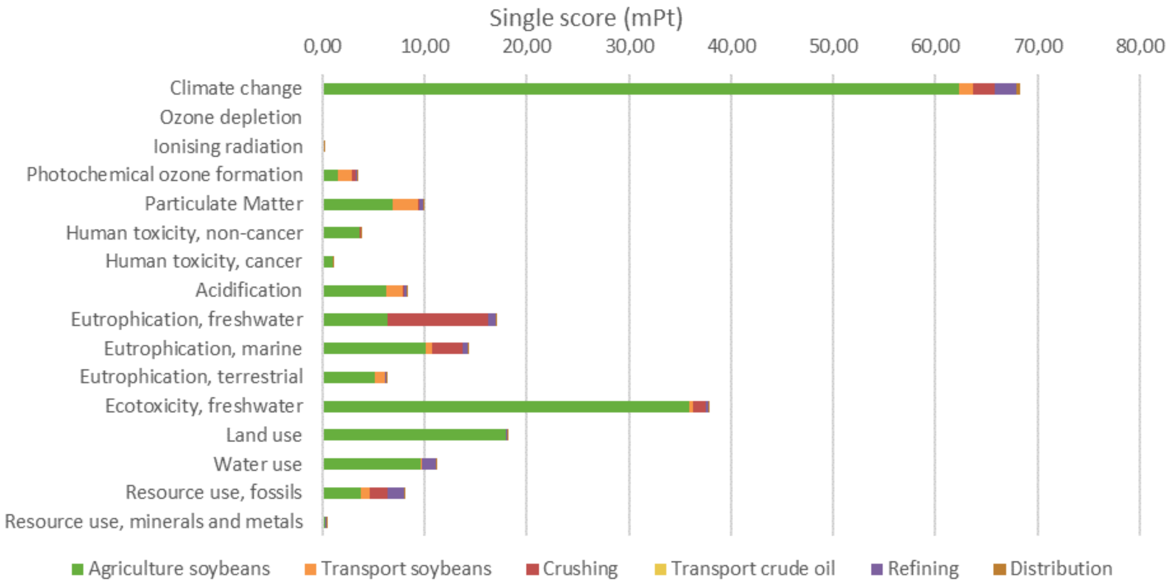

Figure 98: Weighted environmental profile of 1 tonne soap stock from soybeans

2.3. PRODUCTS FROM SUNFLOWER SEEDS

Figure 99: Weighted environmental profile of 1 tonne crude oil from sunflower seeds

Figure 100: Weighted environmental profile of 1 tonne meal from sunflower seeds

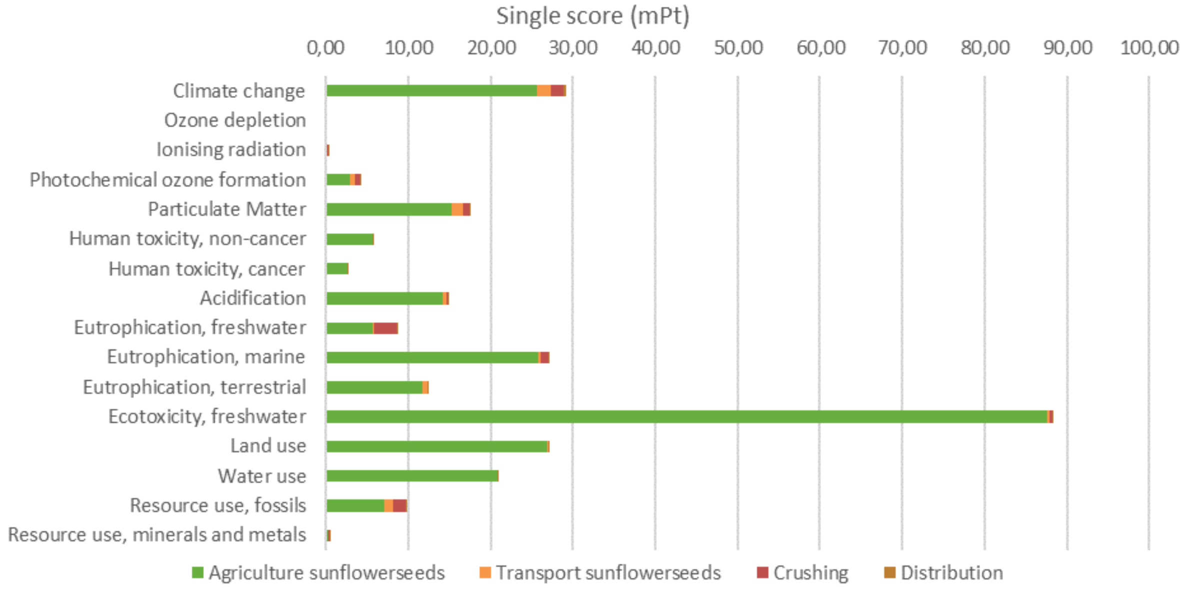

Figure 101: Weighted environmental profile of 1 tonne lecithin from sunflower seeds

Figure 102: Weighted environmental profile of 1 tonne husks from sunflower seeds

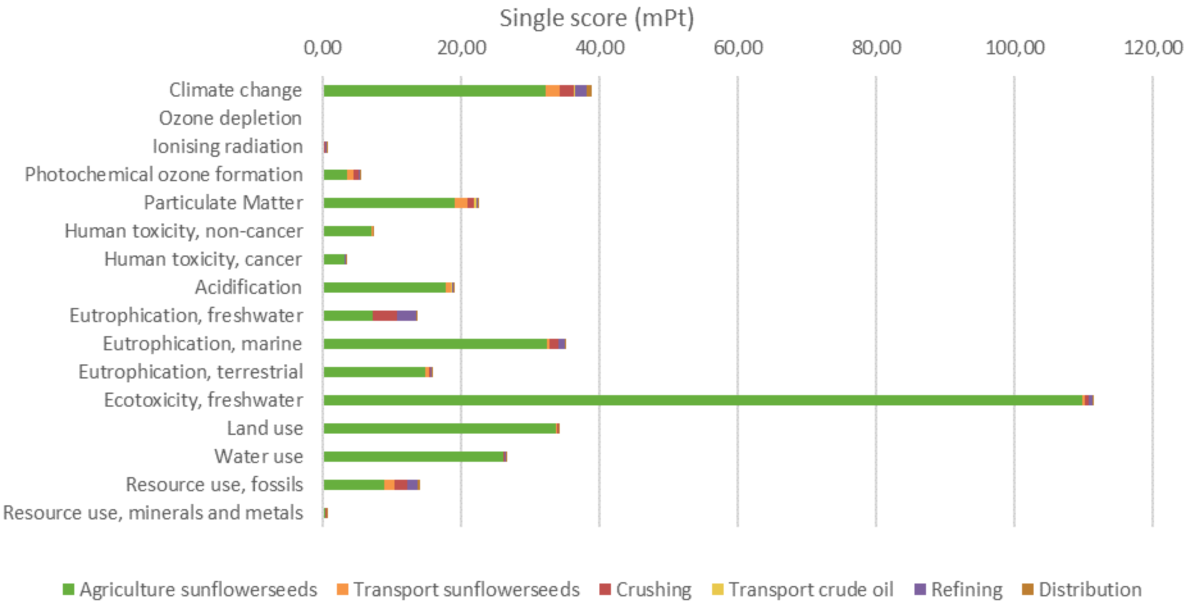

Figure 103: Weighted environmental profile of 1 tonne refined oil from sunflower seeds

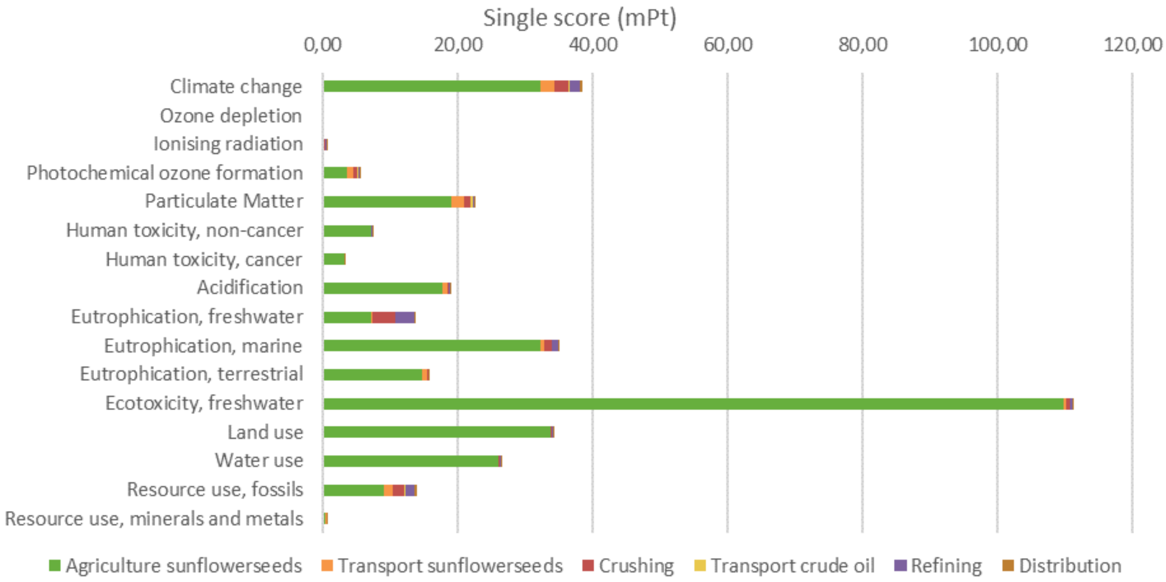

Figure 104: Weighted environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from sunflower seeds

2.4. PRODUCTS FROM MAIZE GERMS

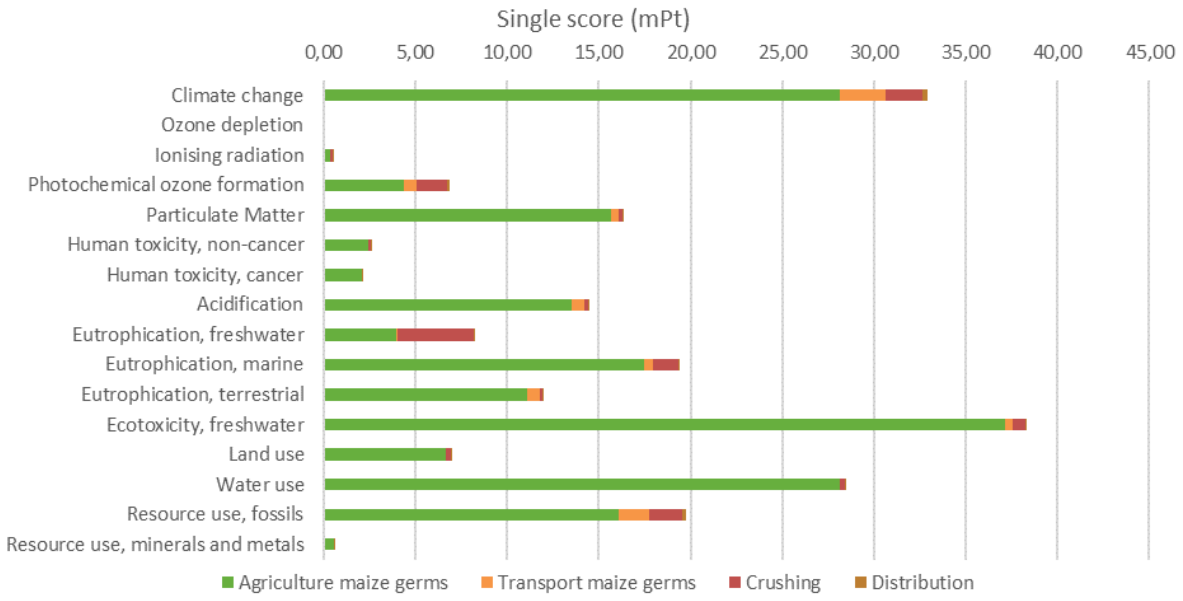

Figure 105: Weighted environmental profile of 1 tonne crude oil from maize germs

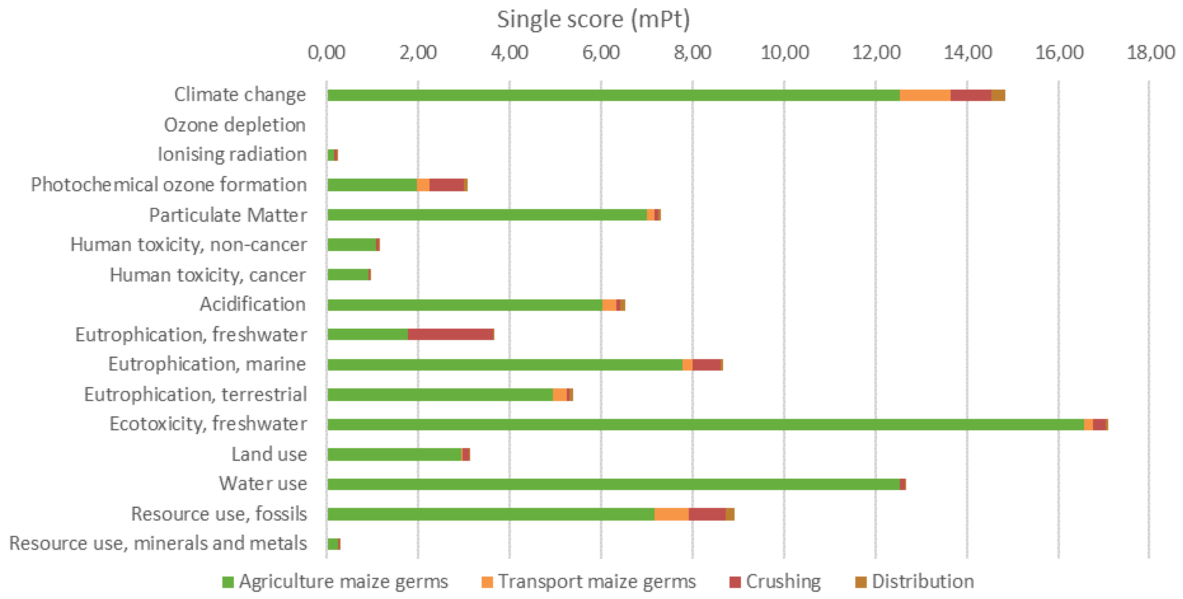

Figure 106: Weighted environmental profile of 1 tonne meal from maize germs

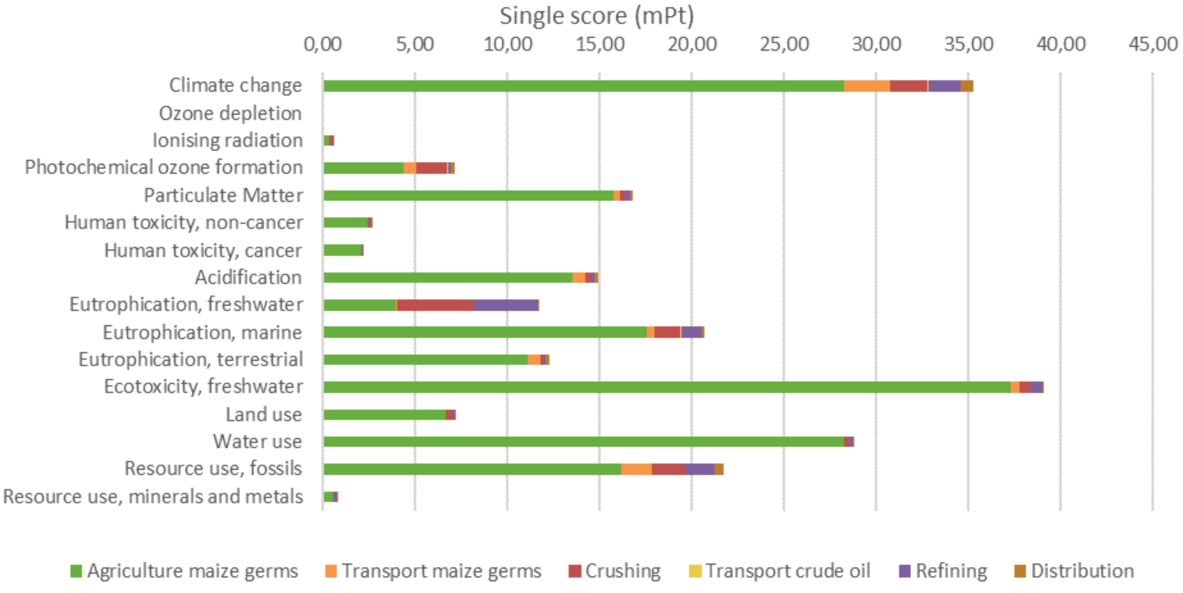

Figure 107: Weighted environmental profile of 1 tonne refined oil from maize germs

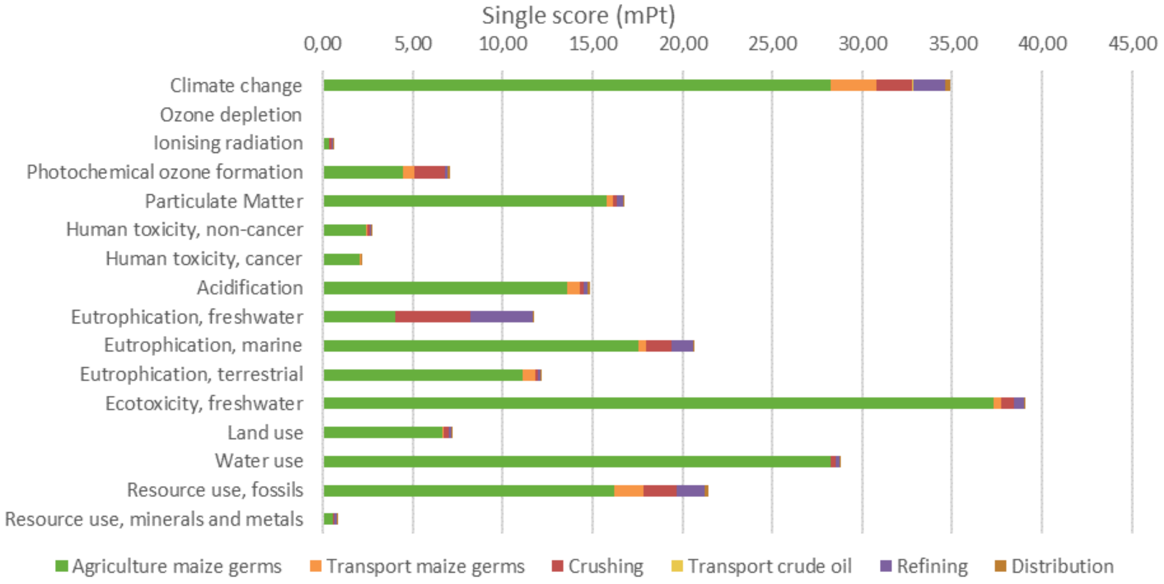

Figure 108: Weighted environmental profile of 1 tonne acid oil or deodistillates from maize germs

2.5. PRODUCTS FROM PALM

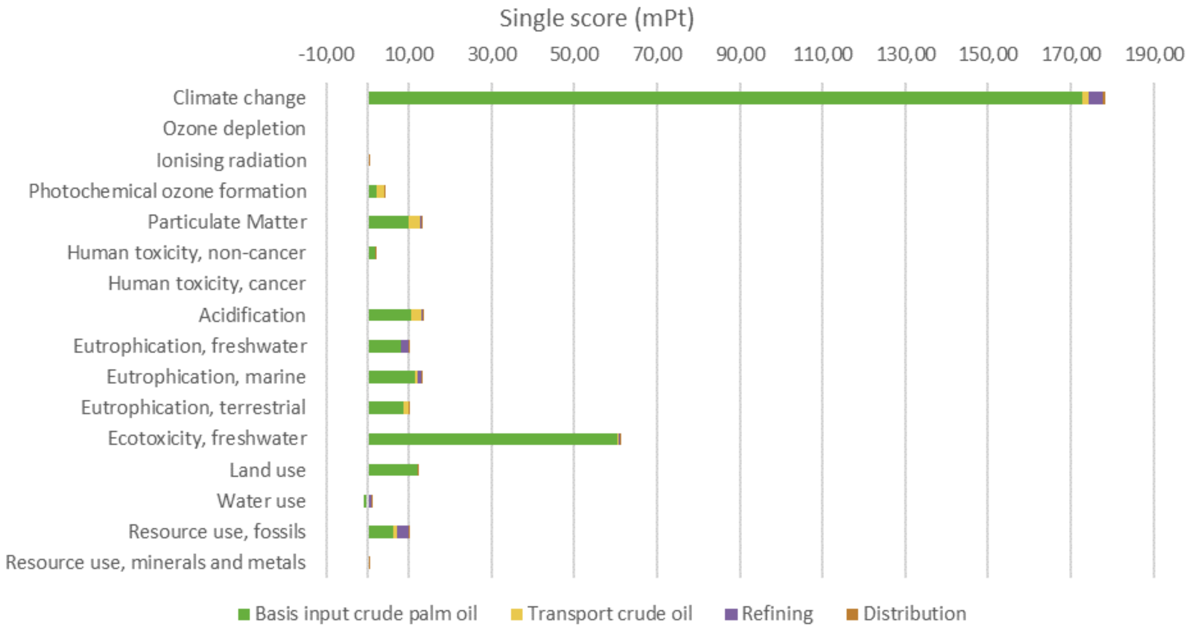

Figure 109: Weighted environmental profile of 1 tonne refined oil from palm

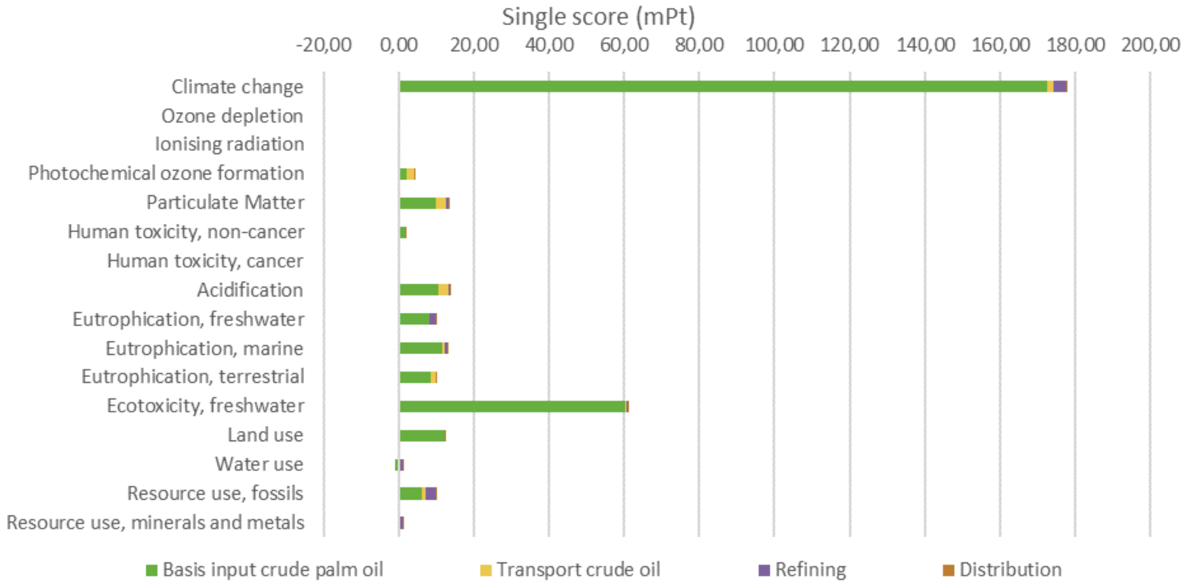

Figure 110: Weighted environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from palm

2.6. PRODUCTS FROM PALM KERNEL

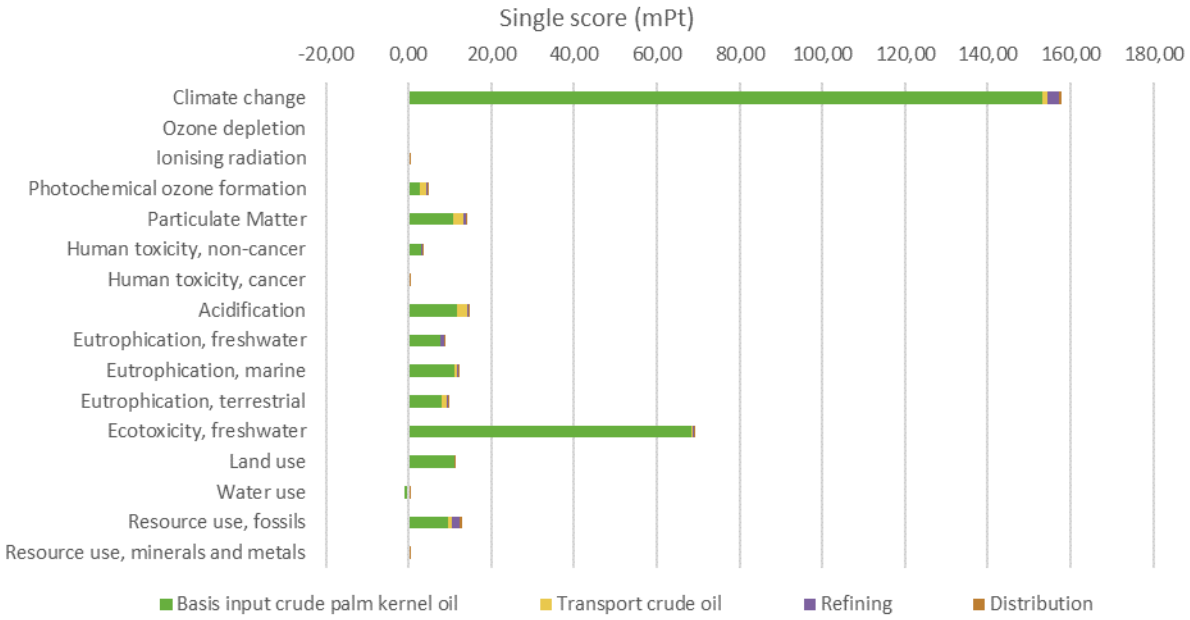

Figure 111: Weighted environmental profile of 1 tonne refined oil from palm kernel

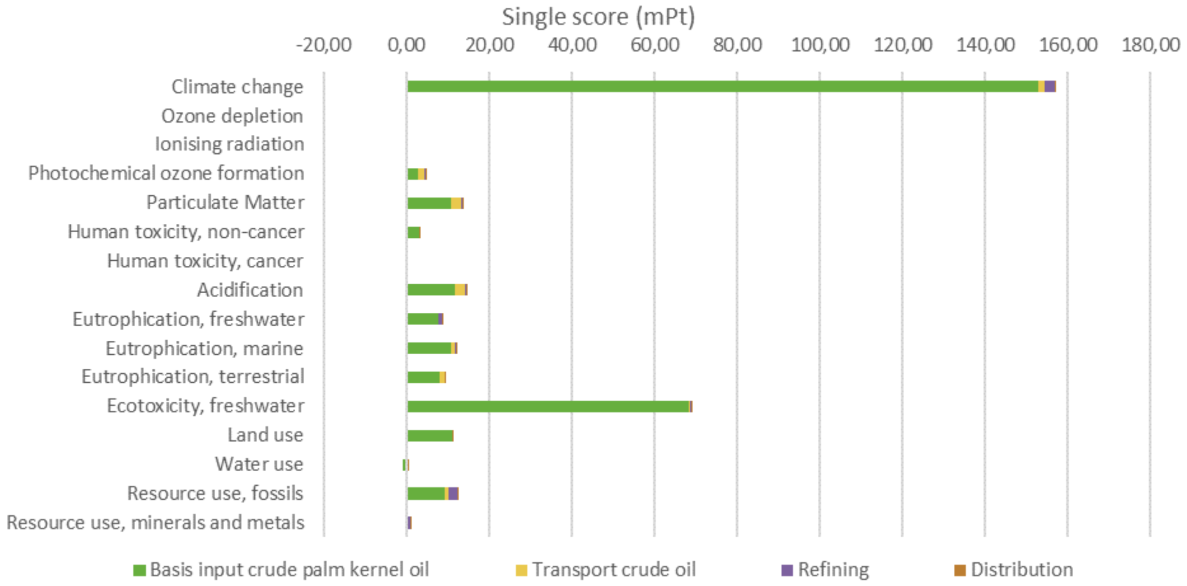

Figure 112: Weighted environmental profile of 1 tonne fatty acid distillates from palm kernel

2.7. PRODUCTS FROM COCONUT

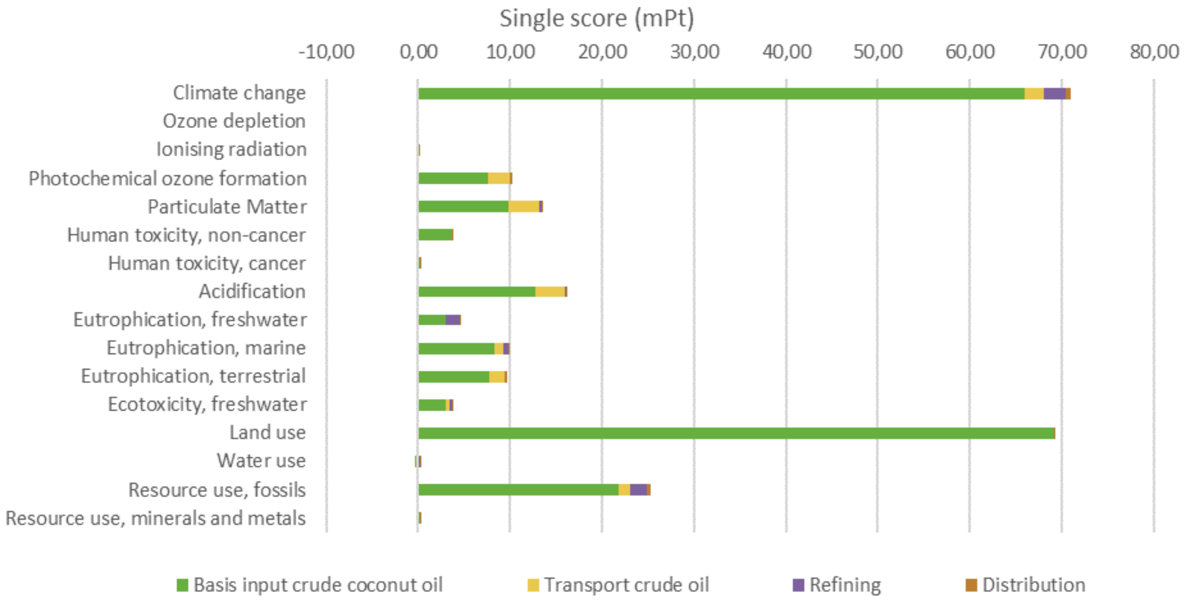

Figure 113: Weighted environmental profile of 1 tonne refined oil from coconut

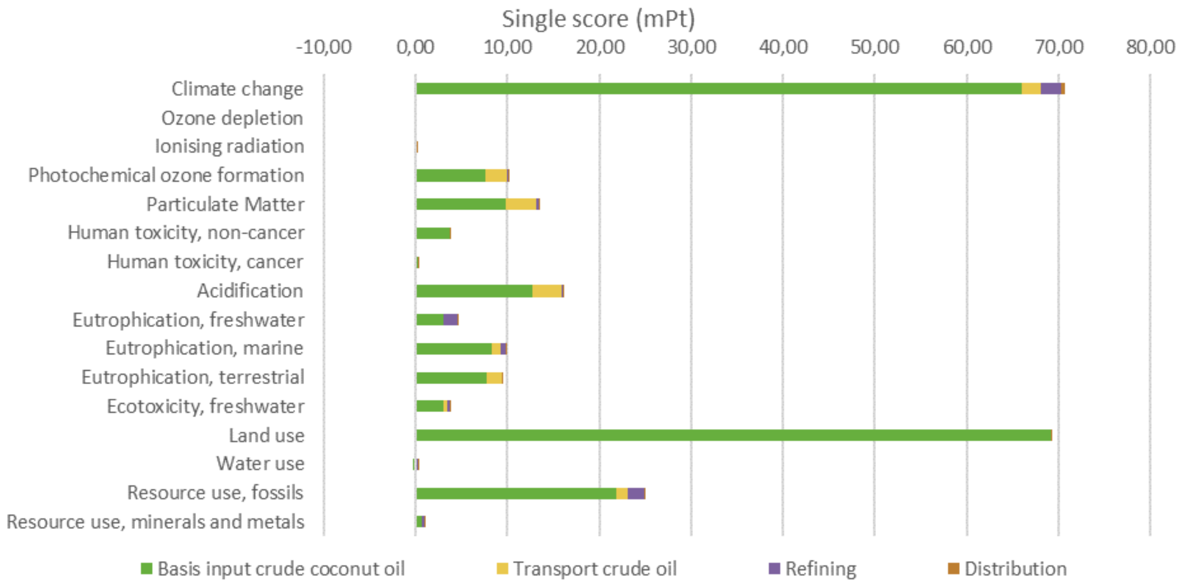

Figure 114: Weighted environmental profile of 1 tonne acid oil, deodistillates or fatty acid distillates from coconut

ANNEX III – RESULTS SENSITIVITY ANALYSIS

1. PRODUCTS FROM RAPESEED

		meal					crude oil					refined oil			
		energy/ energy	mass/ energy	economic/ energy	energy/ mass	energy/ economic	energy/ energy	mass/ energy	economic/ energy	energy/ mass	energy/ economic	energy/ energy	mass/ energy	economic/ energy	energy/ mass
Climate change	kg CO2 eq	8,35E+02	7,64E+02	9,68E+02	1,27E+03	6,42E+02	1,86E+03	1,70E+03	2,15E+03	1,27E+03	2,12E+03	2,22E+03	2,04E+03	2,56E+03	1,53E+03
Ozone depletion	kg CFC11 eq	2,77E-06	2,54E-06	3,30E-06	4,24E-06	2,12E-06	6,22E-06	5,70E-06	7,40E-06	4,24E-06	7,11E-06	8,59E-06	7,98E-06	9,95E-06	6,25E-06
Ionising radiation	kBq U-235 eq	9,12E+00	8,74E+00	9,98E+00	1,39E+01	6,99E+00	2,04E+01	1,95E+01	2,23E+01	1,39E+01	2,33E+01	2,54E+01	2,44E+01	2,76E+01	1,77E+01
Photochemical ozone formation	kg NMVOC eq	1,93E+00	1,84E+00	2,11E+00	2,92E+00	1,50E+00	4,25E+00	4,04E+00	4,65E+00	2,92E+00	4,85E+00	5,08E+00	4,84E+00	5,55E+00	3,52E+00
Particulate matter	disease inc.	7,97E-05	7,28E-05	9,22E-05	1,22E-04	6,11E-05	1,78E-04	1,63E-04	2,06E-04	1,22E-04	2,04E-04	2,08E-04	1,90E-04	2,40E-04	1,41E-04
Human toxicity, non-cancer	CTUh	4,44E-05	3,99E-05	5,25E-05	6,79E-05	3,40E-05	9,95E-05	8,93E-05	1,18E-04	6,79E-05	1,14E-04	1,15E-04	1,04E-04	1,36E-04	7,82E-05
Human toxicity, cancer	CTUh	1,17E-06	1,05E-06	1,39E-06	1,79E-06	8,99E-07	2,63E-06	2,36E-06	3,11E-06	1,79E-06	3,00E-06	3,05E-06	2,73E-06	3,60E-06	2,06E-06
Acidification	mol H+ eq	9,88E+00	8,93E+00	1,16E+01	1,51E+01	7,58E+00	2,21E+01	1,99E+01	2,59E+01	1,51E+01	2,52E+01	2,57E+01	2,32E+01	3,01E+01	1,74E+01
Eutrophication, freshwater	kg P eq	5,58E-01	5,39E-01	5,91E-01	8,53E-01	4,27E-01	1,25E+00	1,21E+00	1,33E+00	8,53E-01	1,43E+00	1,69E+00	1,64E+00	1,77E+00	1,22E+00
Eutrophication, marine	kg N eq	1,23E+01	1,11E+01	1,42E+01	1,87E+01	9,39E+00	2,74E+01	2,49E+01	3,19E+01	1,87E+01	3,13E+01	3,26E+01	2,97E+01	3,77E+01	2,23E+01
Eutrophication, terrestrial	mol N eq	4,41E+01	3,98E+01	5,16E+01	6,71E+01	3,38E+01	9,83E+01	8,87E+01	1,15E+02	6,71E+01	1,12E+02	1,14E+02	1,03E+02	1,34E+02	7,75E+01
Ecotoxicity, freshwater - part 1	CTUe	4,56E+04	4,10E+04	5,35E+04	6,96E+04	3,49E+04	1,02E+05	9,19E+04	1,20E+05	6,96E+04	1,17E+05	1,19E+05	1,07E+05	1,40E+05	8,09E+04
Ecotoxicity, freshwater - part 2	CTUe	5,87E+04	5,25E+04	6,95E+04	8,97E+04	4,49E+04	1,32E+05	1,18E+05	1,56E+05	8,97E+04	1,50E+05	1,52E+05	1,36E+05	1,80E+05	1,03E+05
Land use	Pt	1,01E+05	9,03E+04	1,20E+05	1,54E+05	7,72E+04	2,26E+05	2,02E+05	2,68E+05	1,54E+05	2,58E+05	2,61E+05	2,34E+05	3,09E+05	1,76E+05
Water use	m3 depriv.	2,74E+01	2,63E+01	2,97E+01	4,17E+01	2,11E+01	6,09E+01	5,83E+01	6,61E+01	4,17E+01	6,95E+01	8,63E+01	8,33E+01	9,22E+01	6,35E+01
Resource use, fossils	MJ	4,73E+03	4,53E+03	5,36E+03	7,14E+03	3,66E+03	1,04E+04	9,95E+03	1,18E+04	7,14E+03	1,19E+04	1,32E+04	1,27E+04	1,48E+04	9,35E+03
Resource use, minerals and metals	kg Sb eq	1,20E-04	1,09E-04	1,41E-04	1,83E-04	9,21E-05	2,68E-04	2,43E-04	3,14E-04	1,83E-04	3,06E-04	4,03E-04	3,74E-04	4,55E-04	3,02E-04
Climate change - Fossil	kg CO2 eq	5,92E+02	5,46E+02	6,78E+02	8,98E+02	4,56E+02	1,31E+03	1,21E+03	1,51E+03	8,98E+02	1,50E+03	1,59E+03	1,47E+03	1,81E+03	1,10E+03
Climate change - Biogenic	kg CO2 eq	1,16E-01	1,16E-01	1,16E-01	1,67E-01	9,40E-02	2,35E-01	2,35E-01	2,35E-01	1,67E-01	2,66E-01	5,47E-01	5,47E-01	5,47E-01	4,64E-01
Climate change - Land Use and LU C	kg CO2 eq	2,43E+02	2,18E+02	2,89E+02	3,72E+02	1,86E+02	5,46E+02	4,88E+02	6,49E+02	3,72E+02	6,23E+02	6,29E+02	5,63E+02	7,48E+02	4,25E+02

2. PRODUCTS FROM SOYBEANS

		meal					crude oil					refined oil			
		energy/ energy	mass/ energy	economic/ energy	energy/ mass	energy/ economic	energy/ energy	mass/ energy	economic/ energy	energy/ mass	energy/ economic	energy/ energy	mass/ energy	economic/ energy	energy/ mass
Climate change	kg CO2 eq	1,89E+03	1,80E+03	2,31E+03	2,38E+03	1,91E+03	4,23E+03	4,02E+03	5,18E+03	2,38E+03	4,20E+03	4,38E+03	4,17E+03	5,33E+03	2,51E+03
Ozone depletion	kg CFC11 eq	3,60E-06	3,57E-06	3,98E-06	4,52E-06	3,63E-06	8,06E-06	8,00E-06	8,92E-06	4,52E-06	8,00E-06	1,04E-05	1,03E-05	1,13E-05	6,80E-06
Ionising radiation	kBq U-235 eq	6,92E+00	6,87E+00	7,54E+00	8,69E+00	6,99E+00	1,55E+01	1,53E+01	1,69E+01	8,69E+00	1,53E+01	2,38E+01	2,37E+01	2,52E+01	1,69E+01
Photochemical ozone formation	kg NMVOC eq	2,15E+00	2,13E+00	2,26E+00	2,68E+00	2,17E+00	4,73E+00	4,69E+00	4,98E+00	2,68E+00	4,69E+00	5,04E+00	5,00E+00	5,29E+00	2,97E+00
Particulate matter	disease inc.	4,69E-05	4,61E-05	5,09E-05	5,89E-05	4,74E-05	1,05E-04	1,03E-04	1,14E-04	5,89E-05	1,04E-04	1,10E-04	1,08E-04	1,19E-04	6,31E-05
Human toxicity, non-cancer	CTUh	3,48E-05	3,35E-05	4,05E-05	4,37E-05	3,52E-05	7,79E-05	7,49E-05	9,07E-05	4,37E-05	7,73E-05	7,96E-05	7,67E-05	9,25E-05	4,51E-05
Human toxicity, cancer	CTUh	5,91E-07	5,67E-07	6,93E-07	7,42E-07	5,97E-07	1,32E-06	1,27E-06	1,55E-06	7,42E-07	1,31E-06	1,37E-06	1,31E-06	1,59E-06	7,79E-07
Acidification	mol H+ eq	5,40E+00	5,30E+00	5,90E+00	6,77E+00	5,46E+00	1,20E+01	1,18E+01	1,31E+01	6,77E+00	1,19E+01	1,25E+01	1,23E+01	1,36E+01	7,22E+00
Eutrophication, freshwater	kg P eq	6,91E-01	6,79E-01	7,44E-01	8,69E-01	6,99E-01	1,55E+00	1,52E+00	1,67E+00	8,69E-01	1,54E+00	1,63E+00	1,60E+00	1,75E+00	9,41E-01
Eutrophication, marine	kg N eq	6,79E+00	6,66E+00	7,32E+00	8,52E+00	6,86E+00	1,52E+01	1,49E+01	1,64E+01	8,52E+00	1,51E+01	1,57E+01	1,54E+01	1,69E+01	8,97E+00
Eutrophication, terrestrial	mol N eq	2,22E+01	2,18E+01	2,44E+01	2,78E+01	2,25E+01	4,94E+01	4,83E+01	5,42E+01	2,78E+01	4,90E+01	5,11E+01	5,00E+01	5,58E+01	2,93E+01
Ecotoxicity, freshwater - part 1	CTUe	2,82E+04	2,68E+04	3,42E+04	3,55E+04	2,85E+04	6,32E+04	6,01E+04	7,66E+04	3,55E+04	6,27E+04	6,41E+04	6,10E+04	7,75E+04	3,61E+04
Ecotoxicity, freshwater - part 2	CTUe	3,39E+04	3,20E+04	4,20E+04	4,26E+04	3,43E+04	7,60E+04	7,18E+04	9,42E+04	4,26E+04	7,54E+04	7,60E+04	7,18E+04	9,42E+04	4,23E+04
Land use	Pt	1,38E+05	1,35E+05	1,55E+05	1,74E+05	1,40E+05	3,10E+05	3,02E+05	3,46E+05	1,74E+05	3,08E+05	3,11E+05	3,03E+05	3,48E+05	1,74E+05
Water use	m3 depriv.	9,82E+02	9,66E+02	1,05E+03	1,23E+03	9,93E+02	2,20E+03	2,17E+03	2,35E+03	1,23E+03	2,18E+03	2,49E+03	2,45E+03	2,64E+03	1,51E+03
Resource use, fossils	MJ	3,84E+03	3,88E+03	4,28E+03	4,78E+03	3,88E+03	8,41E+03	8,50E+03	9,39E+03	4,78E+03	8,34E+03	1,07E+04	1,08E+04	1,17E+04	7,05E+03
Resource use, minerals and meta	kg Sb eq	1,45E-04	1,41E-04	1,63E-04	1,82E-04	1,47E-04	3,25E-04	3,16E-04	3,64E-04	1,82E-04	3,22E-04	5,67E-04	5,59E-04	6,07E-04	4,22E-04
Climate change - Fossil	kg CO2 eq	3,89E+02	3,83E+02	4,24E+02	4,86E+02	3,93E+02	8,58E+02	8,45E+02	9,37E+02	4,86E+02	8,51E+02	1,01E+03	9,97E+02	1,09E+03	6,33E+02
Climate change - Biogenic	kg CO2 eq	5,32E-02	5,32E-02	5,32E-02	6,16E-02	5,36E-02	9,36E-02	9,36E-02	9,36E-02	6,16E-02	9,30E-02	2,89E-01	2,89E-01	2,89E-01	2,55E-01
Climate change - Land Use and LU	kg CO2 eq	1,50E+03	1,41E+03	1,89E+03	1,89E+03	1,52E+03	3,37E+03	3,17E+03	4,24E+03	1,89E+03	3,35E+03	3,37E+03	3,17E+03	4,24E+03	1,87E+03

3. PRODUCTS FROM SUNFLOWER

		meal					crude oil					refined oil			
		energy/ energy	mass/ energy	economic / energy	energy/ mass	energy/ economic	energy/ energy	mass/ energy	economic/ energy	energy/ mass	energy/ economic	energy/ energy	mass/ energy	economic/ energy	energy/ mass
Climate change	kg CO2 eq	6,24E+02	6,25E+02	6,26E+02	9,59E+02	4,95E+02	1,38E+03	1,39E+03	1,39E+03	9,59E+02	1,56E+03	1,49E+03	1,50E+03	1,50E+03	1,06E+03
Ozone depletion	kg CFC11 eq	4,30E-06	4,33E-06	4,34E-06	6,65E-06	3,40E-06	9,64E-06	9,70E-06	9,74E-06	6,65E-06	1,09E-05	1,11E-05	1,12E-05	1,12E-05	8,08E-06
Ionising radiation	kBq U-235 eq	1,46E+01	1,46E+01	1,47E+01	2,26E+01	1,15E+01	3,27E+01	3,28E+01	3,28E+01	2,26E+01	3,69E+01	4,09E+01	4,10E+01	4,11E+01	3,06E+01
Photochemical ozone formation	kg NMVOC eq	1,99E+00	1,99E+00	1,99E+00	3,04E+00	1,58E+00	4,37E+00	4,38E+00	4,38E+00	3,04E+00	4,93E+00	4,75E+00	4,76E+00	4,76E+00	3,39E+00
Particulate matter	disease inc.	6,40E-05	6,41E-05	6,41E-05	9,89E-05	5,06E-05	1,43E-04	1,43E-04	1,43E-04	9,89E-05	1,62E-04	1,50E-04	1,50E-04	1,50E-04	1,05E-04
Human toxicity, non-cancer	CTUh	3,96E-05	3,96E-05	3,96E-05	6,13E-05	3,13E-05	8,88E-05	8,88E-05	8,88E-05	6,13E-05	1,00E-04	9,13E-05	9,13E-05	9,13E-05	6,33E-05
Human toxicity, cancer	CTUh	1,13E-06	1,13E-06	1,13E-06	1,75E-06	8,92E-07	2,53E-06	2,53E-06	2,53E-06	1,75E-06	2,86E-06	2,59E-06	2,59E-06	2,59E-06	1,79E-06
Acidification	mol H+ eq	7,39E+00	7,39E+00	7,40E+00	1,14E+01	5,85E+00	1,65E+01	1,65E+01	1,65E+01	1,14E+01	1,86E+01	1,71E+01	1,71E+01	1,71E+01	1,19E+01
Eutrophication, freshwater	kg P eq	2,72E-01	2,72E-01	2,72E-01	4,21E-01	2,15E-01	6,10E-01	6,10E-01	6,10E-01	4,21E-01	6,90E-01	7,79E-01	7,79E-01	7,79E-01	5,86E-01
Eutrophication, marine	kg N eq	9,87E+00	9,87E+00	9,87E+00	1,53E+01	7,80E+00	2,21E+01	2,21E+01	2,21E+01	1,53E+01	2,50E+01	2,32E+01	2,32E+01	2,32E+01	1,62E+01
Eutrophication, terrestrial	mol N eq	3,29E+01	3,29E+01	3,29E+01	5,07E+01	2,61E+01	7,33E+01	7,33E+01	7,33E+01	5,07E+01	8,28E+01	7,59E+01	7,59E+01	7,59E+01	5,29E+01
Ecotoxicity, freshwater - part 1	CTUe	4,55E+04	4,55E+04	4,55E+04	7,03E+04	3,60E+04	1,02E+05	1,02E+05	1,02E+05	7,03E+04	1,15E+05	1,05E+05	1,05E+05	1,05E+05	7,28E+04
Ecotoxicity, freshwater - part 2	CTUe	6,25E+04	6,25E+04	6,25E+04	9,67E+04	4,93E+04	1,40E+05	1,40E+05	1,40E+05	9,67E+04	1,58E+05	1,43E+05	1,43E+05	1,43E+05	9,85E+04
Land use	Pt	1,54E+05	1,54E+05	1,54E+05	2,38E+05	1,21E+05	3,45E+05	3,45E+05	3,45E+05	2,38E+05	3,90E+05	3,52E+05	3,52E+05	3,52E+05	2,43E+05
Water use	m3 depriv.	1,55E+03	1,55E+03	1,55E+03	2,40E+03	1,22E+03	3,48E+03	3,48E+03	3,48E+03	2,40E+03	3,93E+03	3,57E+03	3,57E+03	3,57E+03	2,47E+03
Resource use, fossils	MJ	4,33E+03	4,40E+03	4,44E+03	6,61E+03	3,45E+03	9,51E+03	9,66E+03	9,75E+03	6,61E+03	1,07E+04	1,10E+04	1,12E+04	1,13E+04	8,10E+03
Resource use, minerals and metal	kg Sb eq	1,80E-04	1,80E-04	1,80E-04	2,78E-04	1,42E-04	4,02E-04	4,03E-04	4,03E-04	2,78E-04	4,55E-04	4,95E-04	4,95E-04	4,96E-04	3,68E-04
Climate change - Fossil	kg CO2 eq	5,50E+02	5,51E+02	5,52E+02	8,44E+02	4,37E+02	1,22E+03	1,22E+03	1,22E+03	8,44E+02	1,38E+03	1,32E+03	1,33E+03	1,33E+03	9,44E+02
Climate change - Biogenic	kg CO2 eq	9,35E-02	9,35E-02	9,35E-02	1,33E-01	7,82E-02	1,84E-01	1,84E-01	1,84E-01	1,33E-01	2,05E-01	2,52E-01	2,52E-01	2,52E-01	2,00E-01
Climate change - Land Use and LU	kg CO2 eq	7,39E+01	7,39E+01	7,39E+01	1,14E+02	5,84E+01	1,66E+02	1,66E+02	1,66E+02	1,14E+02	1,87E+02	1,69E+02	1,69E+02	1,69E+02	1,17E+02

4. PRODUCTS FROM MAIZE

		meal				crude oil				refined oil			
		energy/ energy	mass/ energy	economic/ energy	energy/ mass	energy/ energy	mass/ energy	economic/ energy	energy/ mass	energy/ energy	mass/ energy	economic/ energy	energy/ mass
Climate change	kg CO2 eq	5,71E+02	5,60E+02	7,44E+02	8,51E+02	1,27E+03	1,24E+03	1,65E+03	8,51E+02	1,36E+03	1,33E+03	1,75E+03	9,40E+02
Ozone depletion	kg CFC11 eq	8,91E-06	8,71E-06	1,12E-05	1,34E-05	2,00E-05	1,95E-05	2,51E-05	1,34E-05	2,19E-05	2,14E-05	2,70E-05	1,53E-05
Ionising radiation	kBq U-235 eq	1,80E+01	1,77E+01	2,17E+01	2,70E+01	4,04E+01	3,97E+01	4,86E+01	2,70E+01	4,65E+01	4,58E+01	5,47E+01	3,31E+01
Photochemical ozone formation	kg NMVOC eq	2,63E+00	2,61E+00	2,99E+00	3,91E+00	5,81E+00	5,76E+00	6,63E+00	3,91E+00	6,08E+00	6,03E+00	6,91E+00	4,18E+00
Particulate matter	disease inc.	4,86E-05	4,69E-05	7,42E-05	7,27E-05	1,09E-04	1,05E-04	1,66E-04	7,27E-05	1,12E-04	1,08E-04	1,69E-04	7,57E-05
Human toxicity, non-cancer	CTUh	1,44E-05	1,38E-05	2,51E-05	2,16E-05	3,23E-05	3,07E-05	5,62E-05	2,16E-05	3,37E-05	3,21E-05	5,78E-05	2,30E-05
Human toxicity, cancer	CTUh	7,51E-07	7,15E-07	1,31E-06	1,13E-06	1,68E-06	1,60E-06	2,93E-06	1,13E-06	1,71E-06	1,63E-06	2,97E-06	1,15E-06
Acidification	mol H+ eq	5,84E+00	5,62E+00	9,34E+00	8,73E+00	1,30E+01	1,25E+01	2,08E+01	8,73E+00	1,34E+01	1,29E+01	2,13E+01	9,10E+00
Eutrophication, freshwater	kg P eq	2,09E-01	2,04E-01	2,92E-01	3,13E-01	4,68E-01	4,56E-01	6,54E-01	3,13E-01	6,72E-01	6,60E-01	8,58E-01	5,16E-01
Eutrophication, marine	kg N eq	5,73E+00	5,48E+00	9,56E+00	8,58E+00	1,28E+01	1,22E+01	2,14E+01	8,58E+00	1,37E+01	1,31E+01	2,23E+01	9,43E+00
Eutrophication, terrestrial	mol N eq	2,57E+01	2,47E+01	4,11E+01	3,84E+01	5,71E+01	5,49E+01	9,16E+01	3,84E+01	5,85E+01	5,63E+01	9,32E+01	3,97E+01
Ecotoxicity, freshwater - part 1	CTUe	1,68E+04	1,60E+04	2,95E+04	2,52E+04	3,76E+04	3,58E+04	6,59E+04	2,52E+04	3,92E+04	3,74E+04	6,76E+04	2,68E+04
Ecotoxicity, freshwater - part 2	CTUe	2,12E+04	2,01E+04	3,83E+04	3,18E+04	4,75E+04	4,50E+04	8,58E+04	3,18E+04	4,77E+04	4,53E+04	8,63E+04	3,20E+04
Land use	Pt	3,21E+04	3,05E+04	5,70E+04	4,82E+04	7,20E+04	6,84E+04	1,28E+05	4,82E+04	7,40E+04	7,04E+04	1,30E+05	5,01E+04
Water use	m3 depriv.	1,71E+03	1,62E+03	3,06E+03	2,56E+03	3,83E+03	3,63E+03	6,86E+03	2,56E+03	3,87E+03	3,67E+03	6,92E+03	2,60E+03
Resource use, fossils	MJ	6,98E+03	6,93E+03	8,27E+03	1,04E+04	1,54E+04	1,53E+04	1,83E+04	1,04E+04	1,70E+04	1,69E+04	1,99E+04	1,19E+04
Resource use, minerals and meta	kg Sb eq	2,27E-04	2,24E-04	2,69E-04	3,40E-04	5,07E-04	5,02E-04	6,02E-04	3,40E-04	6,40E-04	6,34E-04	7,34E-04	4,71E-04
Climate change - Fossil	kg CO2 eq	5,67E+02	5,56E+02	7,37E+02	8,44E+02	1,26E+03	1,23E+03	1,64E+03	8,44E+02	1,35E+03	1,32E+03	1,73E+03	9,33E+02
Climate change - Biogenic	kg CO2 eq	1,17E-01	1,17E-01	1,17E-01	1,65E-01	2,37E-01	2,37E-01	2,37E-01	1,65E-01	3,03E-01	3,03E-01	3,03E-01	2,32E-01
Climate change - Land Use and L	kg CO2 eq	4,22E+00	4,02E+00	7,28E+00	6,28E+00	9,35E+00	8,91E+00	1,62E+01	6,28E+00	9,58E+00	9,14E+00	1,65E+01	6,50E+00

5. PRODUCTS FROM PALM

		refined oil		
		energy/energy	mass/energy	economic/energy
Climate change	kg CO2 eq	6,86E+03	6,50E+03	7,04E+03
Ozone depletion	kg CFC11 eq	9,74E-06	9,39E-06	1,01E-05
Ionising radiation	kBq U-235 eq	1,79E+01	1,73E+01	1,84E+01
Photochemical ozone formation	kg NMVOC eq	3,73E+00	3,64E+00	3,80E+00
Particulate matter	disease inc.	8,78E-05	8,44E-05	8,99E-05
Human toxicity, non-cancer	CTUh	2,37E-05	2,25E-05	2,43E-05
Human toxicity, cancer	CTUh	1,16E-07	1,13E-07	1,19E-07
Acidification	mol H+ eq	1,22E+01	1,17E+01	1,25E+01
Eutrophication, freshwater	kg P eq	5,65E-01	5,40E-01	5,78E-01
Eutrophication, marine	kg N eq	8,62E+00	8,21E+00	8,82E+00
Eutrophication, terrestrial	mol N eq	4,86E+01	4,64E+01	4,98E+01
Ecotoxicity, freshwater - part 1	CTUe	5,84E+04	5,53E+04	5,99E+04
Ecotoxicity, freshwater - part 2	CTUe	7,77E+04	7,35E+04	7,98E+04
Land use	Pt	1,25E+05	1,19E+05	1,29E+05
Water use	m3 depriv.	3,95E+00	1,05E+01	1,05E+00
Resource use, fossils	MJ	8,01E+03	7,92E+03	8,44E+03
Resource use, minerals and metals	kg Sb eq	2,91E-04	2,85E-04	2,94E-04
Climate change - Fossil	kg CO2 eq	5,22E+03	4,96E+03	5,36E+03
Climate change - Biogenic	kg CO2 eq	9,41E+02	8,91E+02	9,67E+02
Climate change - Land Use and LU Change	kg CO2 eq	6,94E+02	6,57E+02	7,13E+02

6. PRODUCTS FROM PALM KERNEL

		refined oil		
		energy/energy	mass/energy	economic/energy
Climate change	kg CO2 eq	6,07E+03	5,88E+03	7,09E+03
Ozone depletion	kg CFC11 eq	1,09E-05	1,08E-05	1,23E-05
Ionising radiation	kBq U-235 eq	1,57E+01	1,56E+01	1,80E+01
Photochemical ozone formation	kg NMVOC ec	4,06E+00	3,91E+00	4,55E+00
Particulate matter	disease inc.	9,19E-05	8,81E-05	1,06E-04
Human toxicity, non-cancer	CTUh	4,10E-05	3,64E-05	5,08E-05
Human toxicity, cancer	CTUh	1,38E-07	1,29E-07	1,60E-07
Acidification	mol H+ eq	1,31E+01	1,25E+01	1,53E+01
Eutrophication, freshwater	kg P eq	4,97E-01	4,86E-01	5,70E-01
Eutrophication, marine	kg N eq	8,08E+00	7,87E+00	9,31E+00
Eutrophication, terrestrial	mol N eq	4,58E+01	4,45E+01	5,25E+01
Ecotoxicity, freshwater - part 1	CTUe	6,64E+04	6,44E+04	7,75E+04
Ecotoxicity, freshwater - part 2	CTUe	8,70E+04	8,49E+04	1,02E+05
Land use	Pt	1,16E+05	1,13E+05	1,35E+05
Water use	m3 depriv.	-7,93E+01	-7,62E+01	-9,91E+01
Resource use, fossils	MJ	1,00E+04	9,47E+03	1,21E+04
Resource use, minerals and metals	kg Sb eq	3,36E-04	3,34E-04	3,55E-04
Climate change - Fossil	kg CO2 eq	4,74E+03	4,59E+03	5,54E+03
Climate change - Biogenic	kg CO2 eq	9,04E+02	8,82E+02	1,05E+03
Climate change - Land Use and LU Change	kg CO2 eq	4,22E+02	4,11E+02	4,92E+02

7. PRODUCTS FROM COCONUT

		refined oil		
		energy/energy	mass/energy	economic/energy
Climate change	kg CO2 eq	2,73E+03	2,17E+03	3,57E+03
Ozone depletion	kg CFC11 eq	6,87E-06	5,66E-06	8,55E-06
Ionising radiation	kBq U-235 eq	1,21E+01	1,01E+01	1,50E+01
Photochemical ozone formation	kg NMVOC eq	8,69E+00	7,38E+00	1,04E+01
Particulate matter	disease inc.	9,03E-05	7,44E-05	1,18E-04
Human toxicity, non-cancer	CTUh	4,69E-05	3,57E-05	6,71E-05
Human toxicity, cancer	CTUh	2,06E-07	1,65E-07	2,75E-07
Acidification	mol H+ eq	1,46E+01	1,20E+01	1,91E+01
Eutrophication, freshwater	kg P eq	2,61E-01	2,27E-01	3,04E-01
Eutrophication, marine	kg N eq	6,59E+00	5,30E+00	8,77E+00
Eutrophication, terrestrial	mol N eq	4,60E+01	3,76E+01	5,93E+01
Ecotoxicity, freshwater - part 1	CTUe	6,87E+03	5,72E+03	8,74E+03
Ecotoxicity, freshwater - part 2	CTUe	1,75E+03	1,29E+03	2,66E+03
Land use	Pt	7,15E+05	5,17E+05	1,12E+06
Water use	m3 depriv.	-1,36E+01	-6,21E+00	-1,77E+01
Resource use, fossils	MJ	1,98E+04	1,61E+04	2,55E+04
Resource use, minerals and metals	kg Sb eq	2,32E-04	1,97E-04	2,93E-04
Climate change - Fossil	kg CO2 eq	2,50E+03	2,01E+03	3,21E+03
Climate change - Biogenic	kg CO2 eq	7,39E-02	7,39E-02	7,39E-02
Climate change - Land Use and LU Change	kg CO2 eq	2,28E+02	1,65E+02	3,59E+02

ANNEX IV: REVIEW STATEMENT

Critical Review Statement

PEF REPORT OF VEGETABLE OIL AND PROTEINMEAL INDUSTRY PRODUCTS

Commissioned by*:*	FEDIOL - European vegetable oil and proteinmeal industry association, Belgium
Prepared by:	VITO, Belgium
Reviewer:	Prof. Dr. Matthias Finkbeiner, Germany
References	PEFCR on vegetable oil and protein meal industry products Product Environmental Footprint (PEF) method including Zampori, L. and Pant, R., Suggestions for updating the Product Environmental Footprint (PEF) method, EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-00654-1, doi:10.2760/424613, JRC115959.

Scope of the Critical Review

The reviewer had the task to assess whether the report is consistent with the PEF method and the PEFCR on vegetable oil and protein meal industry products.
The review was performed concurrently to the study. This review statement is only valid for this report in its final version dated April 2022.

Outside the scope of this review were

- the verification of assumptions made for the types and properties of vegetable oil and proteinmeal products
- the underlying LCA model and
- the verification of individual LCI datasets

Review process

The review process was coordinated between FEDIOL, VITO and the reviewer. As a first step in the review process, the first draft of the goal and scope of the study was submitted to the reviewer on 24.08.2021. The reviewer provided 6 comments of general, technical and editorial nature to VITO and FEDIOL by 19.09.2021.

As a next step, VITO provided the first draft of the study report and responses to the review comments on 09.03.2022. The reviewer provided 49 comments of general, technical and editorial nature and sent them to the commissioner by 20.03.2022. A critical review meeting with VITO (web conference) was held on 28.03.2022 to address the comments that needed additional information or agreement on how they are supposed to be implemented. VITO provided a revised and final study report and documentation on the implementation of the review comments on 02.05.2022.

Most critical issues and several of the recommendations of the reviewer were addressed in this revision. Several reviewer comments intended to improve the scientific and technical validity of the study were not implemented as the PEF method prescribed a different approach or wording. The reviewer acknowledges the unrestricted access to all requested information as well as the open and constructive dialogue during the critical review process.

General evaluation

The scope of the study were the following products of the vegetable oil and proteinmeal industry:

- Crude oil and co-products from rapeseed
- Refined oil and co-products from rapeseeds
- Crude oil and co-products from soybeans
- Refined oil and co-products from soybeans
- Crude oil and co-products from sunflower seeds
- Refined oil and co-products from sunflower
- Crude oil and co-products from maize germs
- Refined oil and co-products from maize germs
- Refined oil and co-products from palm
- Refined oil and co-products from palm kernel
- Refined oil and co-products from coconut

FEDIOL members represent more than 85% of EU vegetable oil and proteinmeal production. In this study, thirteen FEDIOL member companies were involved, who participated in meetings and provided feedback on the draft documents. Ten member companies provided data for the life cycle assessment of the sector average products and representative product. The provided data are applicable to 33% of the EU vegetable oil sector.

The study was performed in a professional manner using the PEF method and PEFCR as baseline approaches. As transparently documented in the study report itself, the following aspects should be noted for a proper interpretation and for potential future updates of the study:

- This PEFCR is not fully compliant with the PEF method as the official process of developing a PEFCR has not been followed. Therefore, also this PEF report is not fully compliant with PEF either.

- Some data sources are not fully PEF compliant.
- The study did not include calculations of DQR scores as required by the PEF method and PEFCR.
- For some of the agricultural products, the environmental profile of production in different regions, different land use situations and different production technologies is quite heterogeneous. Therefore, the average results presented here may differ significantly from specific sources of the products.
- For some significant processes and emissions, the modelling requirements of the PEF method (e.g. the N-modelling in agriculture) and the choice of the datasets (e.g. choice of pesticides, waste water treatment) were quite decisive for the results. In that sense, some of the associated results might be more representative of the defined PEF modelling approach than for the products assessed.

Conclusion

The PEF report follows overall the Product Environmental Footprint (PEF) method and PEFCR on vegetable oil and protein meal industry products, while full compliance was not intended.

Matthias Finkbeiner

16th May 2022