Product Category Rules for Starch Industry Products

Version 2.1

November 2021

Date of expiration: 31 November 2025

This PCR 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 the Starch Industry to be fully compliant with the PEF method, and the process of developing a PEFCR has not been followed. This document is thus no official PEFCR. Therefore, the current document is referred to as PCR, not PEFCR. We aim to be as much PEF compliant as possible, indicate where there are deviations from the PEF method and justify why. Studies performed according to this PCR are not compliant with PEF and are referred to as LCA studies.

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1. INTRODUCTION

This PCR is largely based on the document *Suggestions for updating the Product Environmental Footprint (PEF) method* (Zampori and Pant, 2019), but is not fully compliant. The process of developing a PEFCR has not been followed. Studies performed according to this PCR are therefore not compliant to PEF. Italic text in this PCR has been taken over from Zampori and Pant (2019), only terminology has been adjusted if needed[1].

The Product Environmental Footprint (PEF) method provides detailed and comprehensive technical rules on how to conduct PEF studies that are more reproducible, consistent, robust, verifiable and comparable. Results of PEF studies are the basis for the provision of EF information and they may be used in a diverse number of potential fields of applications, including in-house management and participation in voluntary or mandatory programmes.

For all requirements not specified in this PCR the user of the PCR shall refer to the documents this PCR is in conformance with (see section 2.4).

Terminology: shall, should and may

This PCR uses precise terminology to indicate the requirements, the recommendations and options that could be chosen when an LCA study is conducted.

- *The term "shall" is used to indicate what is required in order for a LCA study to be in conformance with this PCR.*
- *The term "should" is used to indicate a recommendation rather than a requirement. Any deviation from a "should" requirement has to be justified when developing the LCA study and made transparent.*
- *The term "may" is used to indicate an option that is permissible. Whenever options are available, the LCA study shall include adequate argumentation to justify the chosen option.*

A list with acronyms and definitions is available in Annex 1.

2. GENERAL INFORMATION ABOUT THE PCR

2.1. COMMISSIONER

This PCR has been commissioned by the European Starch Industry Association, Starch Europe. It is developed by the Flemish institute for technological research (VITO) and is based on a participatory process which included consultation with the members of Starch Europe. Starch Europe members constitute more than 95% of EU starch production.

2.2. GEOGRAPHIC VALIDITY

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

Each LCA study shall identify its geographical validity listing all the countries where the product object of the LCA 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] Due to not being an official PEFCR, terminology has been adjusted when referring to this document: PEFCR is replaced by PCR, PEF study by LCA study and PEF profile by environmental profile.

2.3. LANGUAGE

The PCR is written in English. The original in English supersedes translated versions in case of conflicts.

2.4. CONFORMANCE TO OTHER DOCUMENTS

This PCR has been prepared in conformance with the following documents (in prevailing order):

- *Product Environmental Footprint (PEF) method*

This PCR is, as much as possible, based on the document *Suggestions for updating the Product Environmental Footprint (PEF) method* (Zampori and Pant, 2019). However, it is not fully compliant with the PEF method and the process of developing a PEFCR has not been followed. This document is thus no official PEFCR.

3. PCR SCOPE

3.1. PRODUCT CLASSIFICATION

The scope of this PCR are products of the starch industry. More specifically, the CPA codes for the following products in class "Starches and starch products" (CPA 10.62) are included in this PCR:

- Starches; wheat gluten; dextrins and other modified starches (CPA 10.62.11) excluding inulin[2]
- Glucose and glucose syrup; fructose and fructose syrup; invert sugar; sugars and sugar syrups n.e.c. (CPA 10.62.13)
- Maize oil (CPA 10.62.14)
- Residues of starch manufacture and similar residues (CPA 10.62.20)

Additionally, some products that fall under other CPA codes are included:

- Bran, part of CPA 10.61.40 (Bran, sharps and other residues from the working of cereals)
- Sorbitol[3] (D-glucitol), diols and polyhydric alcohols[4], all part of CPA 20.14.23 (Diols, polyalcohols, cyclical alcohols and derivatives thereof)
- Potable alcohol and broth, part of CPA 20.14.74 (Undenatured ethyl alcohol of alcoholic, strength by volume of ≥ 80%)

The underlying LCA-study referred to in this PCR includes all products from the starch industry listed in Table *1*. Please note that rice, barley and peas are not included in the scope of this PCR as too few datasets on products from these raw materials were available for the underlying LCA-study. Nevertheless, there are no methodological differences to be expected compared to the other raw materials included.

Table 1: Overview of products included in the scope of this PCR and their application

From wheat	*Application*	From maize	*Application*	From potatoes	*Application*
(Loose) Bran (as such, after grinding)	*FE*	Steep liquor	*FE, I*	Potato proteins	*FE*

[2] Inulin (prodcom code 10.62.11.30) is not covered by this PCR.
[3] Sorbitol or D-glucitol, prodcom code 20.14.23.33
[4] Diols and polyhydric alcohols (excluding ethylene glycol and propylene glycol, D-glucitol), prodcom code 20.14.23.39

Dry wheat feed (bran and solubles mixed, then dried) – pelletilised or not	*FE*	Dry corn feed (steep liquor mixed with fibres, then dried)	*FE*	Fruit juice	*FE, I*
Dry (solubilised or not) gluten	*FO, FE*	Wet corn fibres	*FE*	Concentrated fruit juice	*FE*
Wet solubilised gluten	*FO, FE*	Dry germs	*FO, FE*	Wet pulp	*FE*
Liquid solubles (as such, after evaporation)	*FE*	Oil	*FO*	Dry pulp (fibres)	*FE*
Wheat germs	*FO, FE, I*	Dry proteins	*FE*		
Liquid glucose (including hydrolysates, fructose and glucose syrups)					*FO, I*
Dry crystallized dextrose					*FO, FE*
Maltodextrin					*FO*
Liquid sorbitol					*FO, I*
Dry sorbitol					*FO, I*
Unfermented special polyols					*FO, I*
Native and lightly modified starches					*FO, FE, I*
Modified starch excluding dextrins (e.g. esters and ethers)					*FO, FE, I*
Dextrins					*FO, I*
Potable alcohol					*FO*
Broth (co-product from potable alcohol)					*FE*

(FO = Food, FE = Feed, I = Industrial)

The starch industry products are used in a wide range of applications, including food (e.g. drinks, sweets, soups, bread), feed (e.g. pet food, cattle feed, aquafeed) and other industries (e.g. paper, textiles, plastics, pharmaceuticals). The performance depends on the specific product and application.

3.2. Representative product

The representative product is a virtual starch industry product, composed of all products covered by this PCR (Table 2). Its composition is based on weighted average quantities (mass) of European sales to end user industries. Sales data is collected for Starch Europe by PricewaterhouseCoopers (PwC). Data for 2019 are used, as sales did not vary much over the last years. For some products no sales data are available. Some of these are estimated from literature (i.e. sorbitol, polyols, alcohol). For others, quantities of some co-products produced from a process are known, thus quantities of the other co-products from the same process could be estimated from the share of the outputs as collected for the LCA. The share of the different products is calculated as the share of the dry substance mass of the product within the total dry substance mass of all sold products.

Table 2: Composition of the representative product

From wheat	Share (% DS)	From maize	Share (% DS)	From potatoes	Share (% DS)
(Loose) Bran (as such, after grinding)	1,5%	Steep liquor	0,6%	Potato proteins	0,2%
Dry wheat feed (bran and solubles mixed, then dried) – pelletilised or not	6,8%	Dry corn feed (steep liquor mixed with fibres, then dried)	6,5%	Fruit juice	0,01%
Dry (solubilised or not) gluten	2,4%	Wet corn fibres	1,0%	Concentrated fruit juice	0,3%
Wet solubilised gluten	0,3%	Dry germs	1,9%	Wet pulp	0,4%
Liquid solubles (as such, after evaporation)	1,9%	Oil	0,5%	Dry pulp (fibres)	0,1%
Wheat germs	0,01%	Dry proteins	2,0%		
Liquid glucose (including hydrolysates, fructose and glucose syrups)					25%
Dry crystallized dextrose					3,6%
Maltodextrin					2,6%
Liquid sorbitol					1,8%
Dry sorbitol					1,5%
Unfermented special polyols					1,2%
Native and lightly modified starches					19%
Modified starch excluding dextrins (e.g. esters and ethers)					11%
Dextrins					1,5%
Potable alcohol					4,6%
Broth (co-product from potable alcohol)					1,8%

The third-party report of the LCA study of the representative product and individual starch industry products is available upon request to Starch Europe or Starch Europe members.

3.3. Functional unit and reference flow

The products of the starch industry fulfil multiple functions (Table 1) 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. sweeten, improve colour, add nutrients, enhance flavour, improve consistency, add strength, bind, stabilize). Even for one specific starch industry product, different applications exist. Therefore, the functional unit should be considered as a declared unit (identical to the reference flow[5]) 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[6] (FU) is "1 tonne DS (dry substance) of starch industry product delivered at the customers' entry gate".

The functional unit is expressed as dry substance mass, to avoid that differences in impact of the same product arise due to a different water content.

Table 3 contains average factors to convert dry substance mass to total mass.

[5] The reference flow is the amount of product needed to fulfil the defined functional unit.
[6] This is a declared unit rather than a functional unit, but the term "functional unit" is kept for consistency reasons.

Table 3: Conversion factors from dry substance to total mass

From wheat	ton DS/ton product	From maize	ton DS/ton product	From potatoes	ton DS/ton product
(Lose) Bran (as such, after grinding)	0.88	Steep liquor	0.47	Potato proteins	0.91
Dry wheat feed (bran and solubles mixed, then dried) – pelletilised or not	0.87	Dry corn feed (steep liquor mixed with fibres, then dried)	0.89	Fruit juice	0.03
Dry (solubilised or not) gluten	0.94	Wet corn fibres	0.40	Concentrated fruit juice	0.49
Wet solubilised gluten	0.39	Dry germs	0.94	Wet pulp	0.17
Liquid solubles (as such, after evaporation)	0.20	Oil	1.00[7]	Dry pulp (fibres)	0.90
Wheat germs	0.86	Dry proteins	0.90		
Liquid glucose (including hydrolysates, fructose and glucose syrups)					0.76
Dry crystallized dextrose					0.92
Maltodextrin					0.97
Liquid sorbitol					0.70
Dry sorbitol					1.00
Unfermented special polyols					1.00
Native and lightly modified starches					0.85
Modified starch excluding dextrins (e.g. esters and ethers)					0.84
Dextrins					0.87
Potable alcohol					1.00[7]
Broth (co-product from potable alcohol)					0.27

3.4. System boundary

The system boundaries are split up in various figures due to the large number of products and processes included. Figure 1 shows the system boundary diagram for starch slurry and co-products from wheat. Starch slurry and co-products from maize are shown in Figure 2. Figure 3 presents the system boundaries for starch slurry and co-products from potatoes. In a next step, the starch slurry from the three crops is further processed to different products. Figure 4 shows the further processing to liquid glucose, liquid/dry sorbitol, unfermented special polyols, maltodextrins and dry crystallized dextrose. Figure 5 presents the process to produce native starch and dextrins. The system boundary diagram for modified starch (excluding dextrins) is shown in Figure 6. Figure 7 presents the system boundary diagram for potable alcohol and co-product broth. In all system boundary diagrams, grey life cycle steps (further processing by other industries, distribution of the final products, use and end of life) are excluded from the system boundaries. The system boundaries include processes that are currently used by the European starch industry. However, not every company performs all processes and produces all products. Including a process in the system boundaries is only mandatory when it actually occurs.

[7] For oil and potable alcohol, results are expressed as the actual mass, not the DS mass.

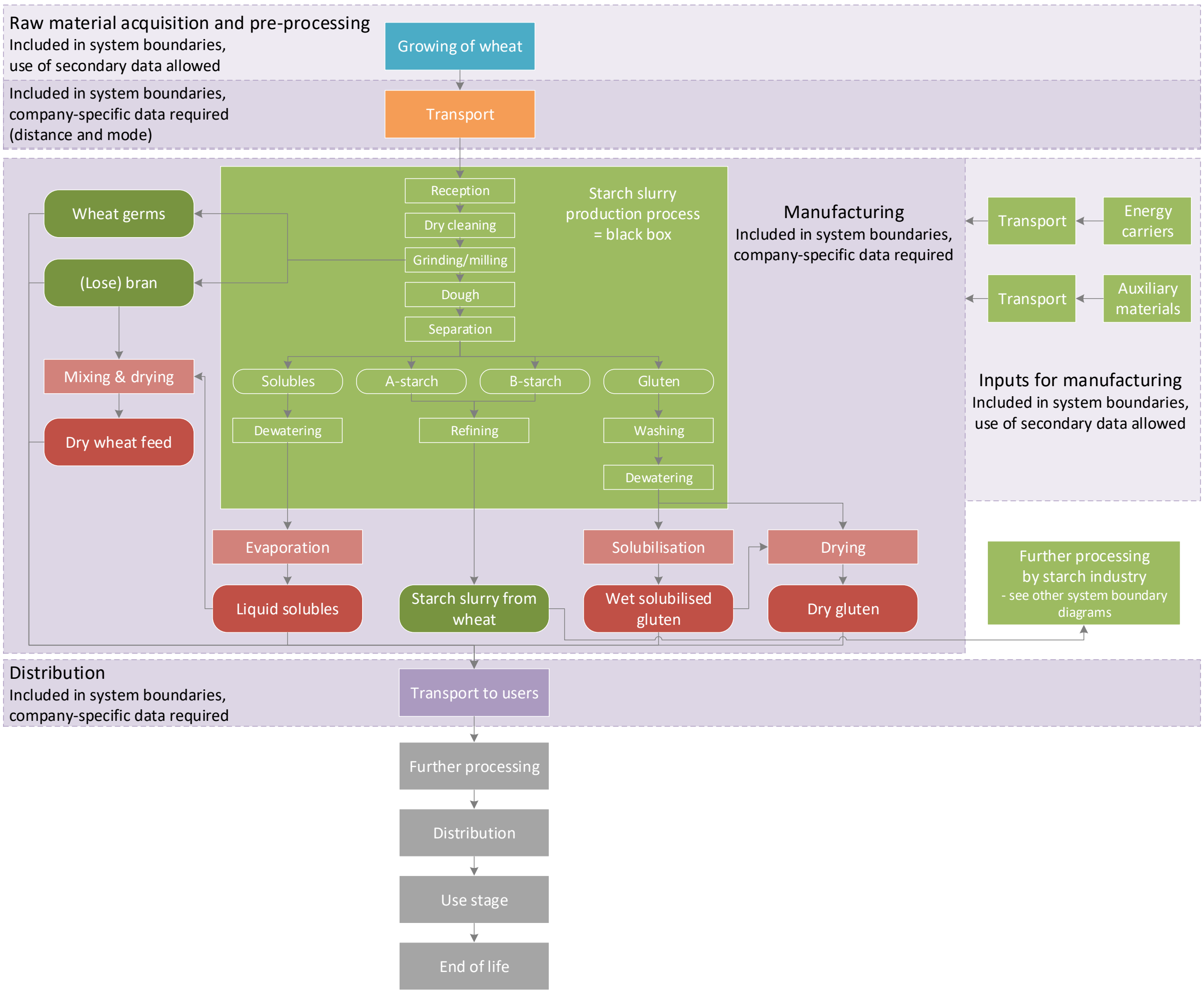

Figure 1: System boundary diagram for starch slurry and co-products from wheat

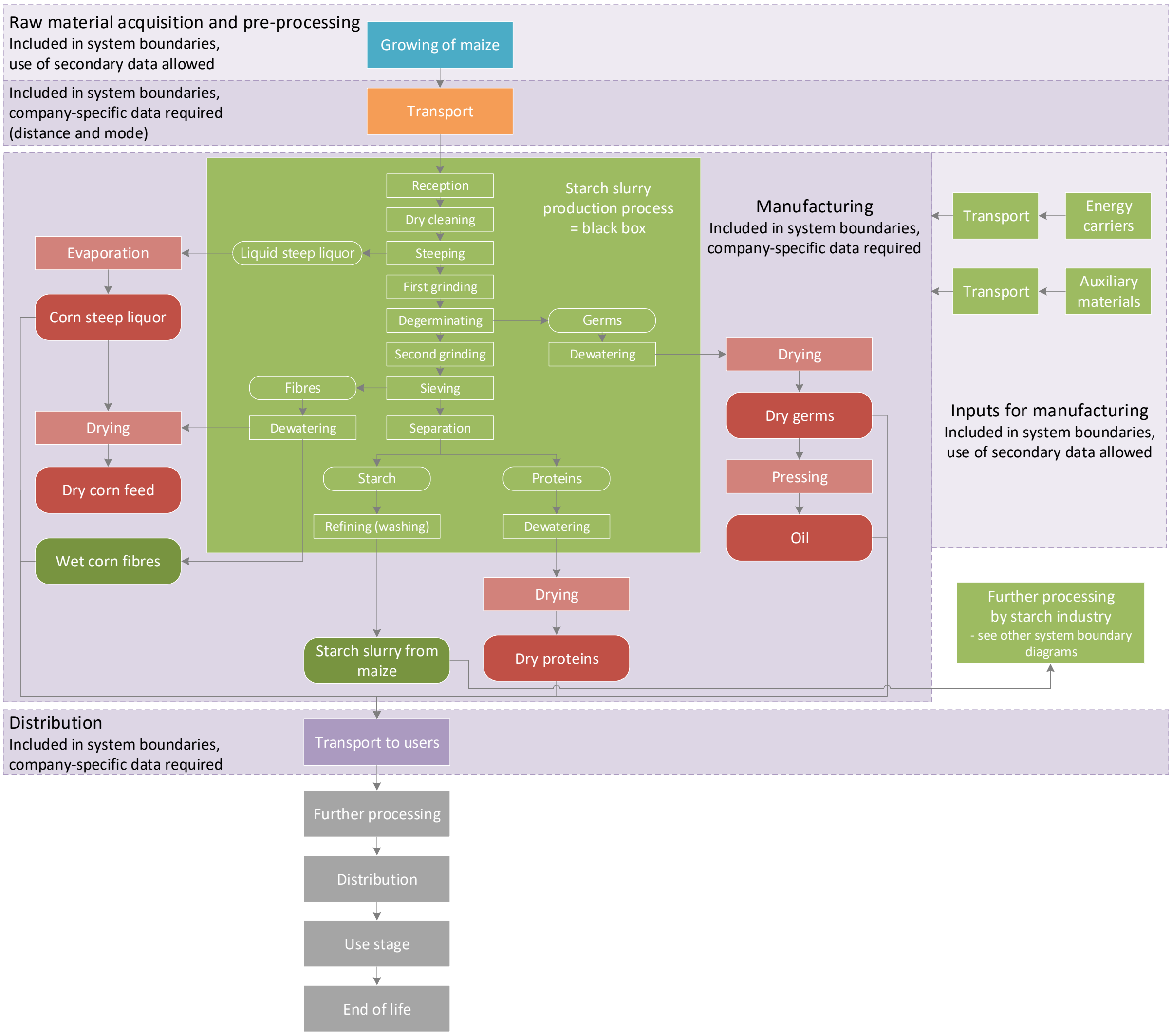

Figure 2: System boundary diagram for starch slurry and co-products from maize

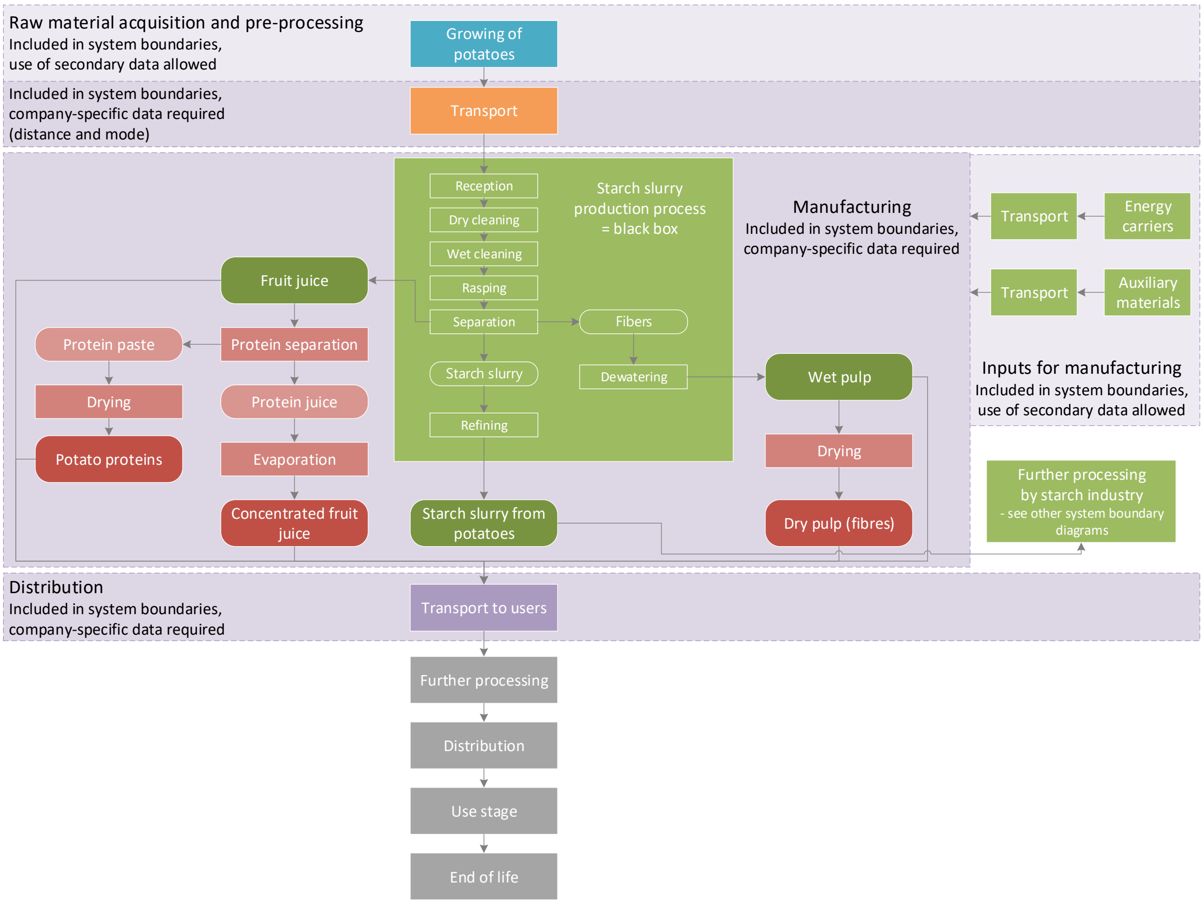

Figure 3: System boundary diagram for starch slurry and co-products from potatoes

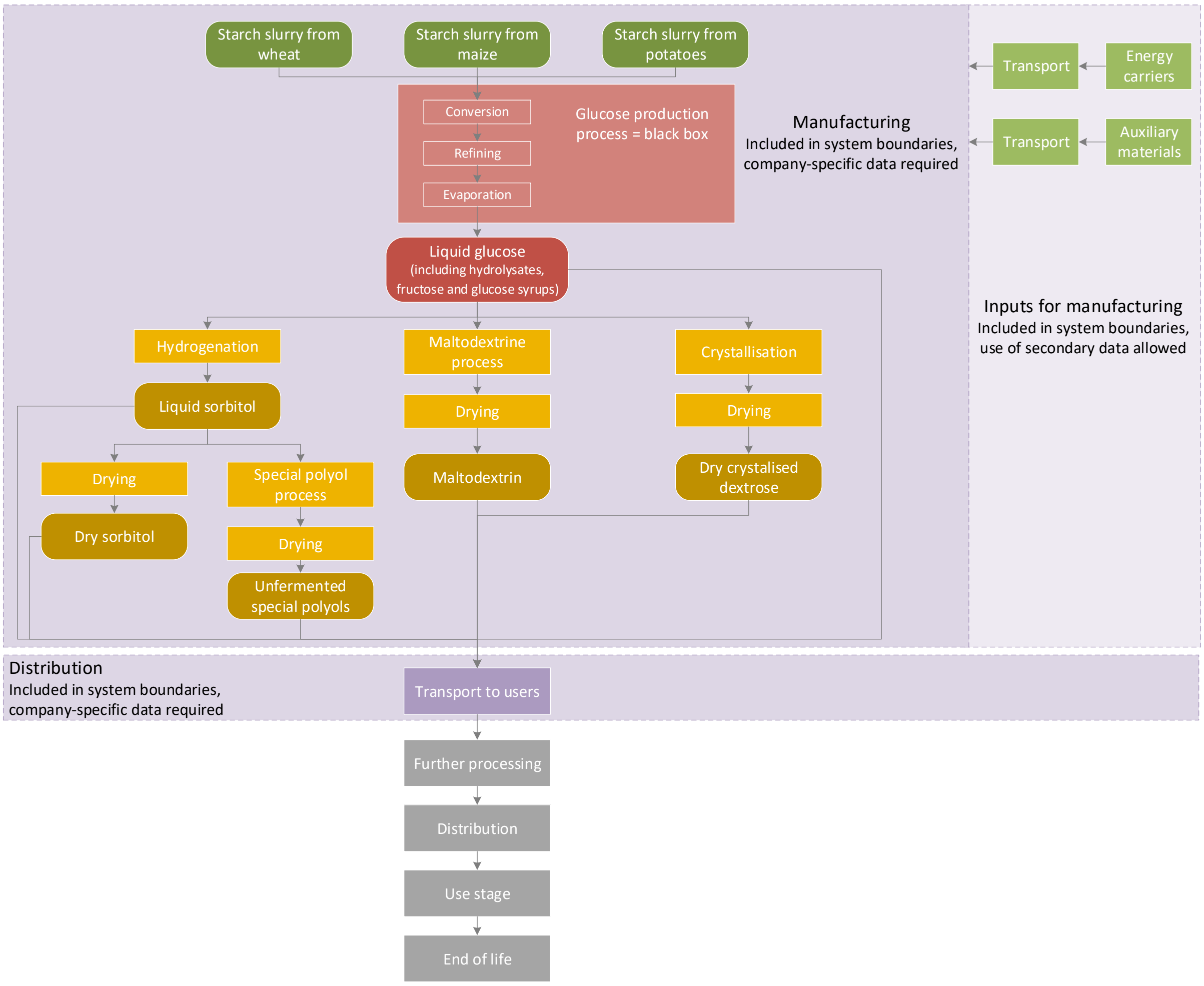

Figure 4: System boundary diagram for liquid glucose, liquid/dry sorbitol, unfermented special polyols, maltodextrins and dry crystallized dextrose

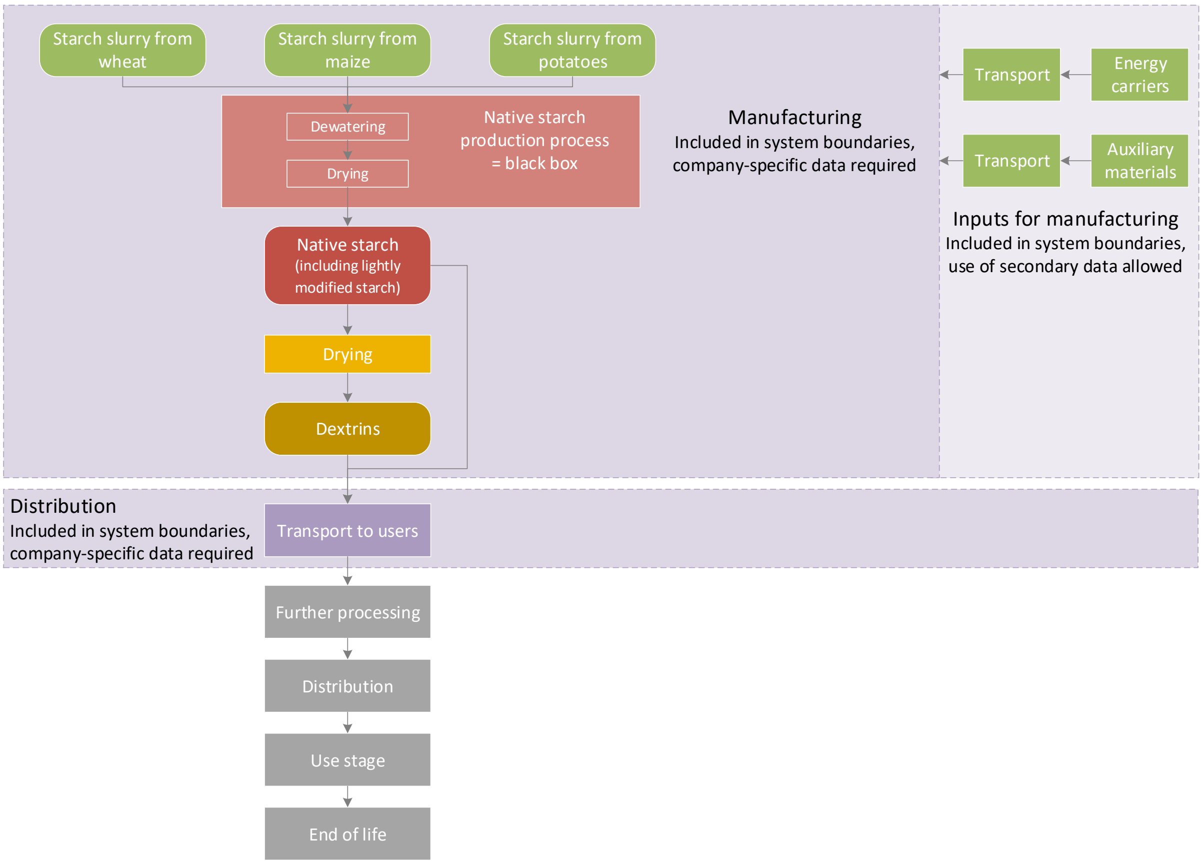

Figure 5: System boundary diagram for native starch and dextrins

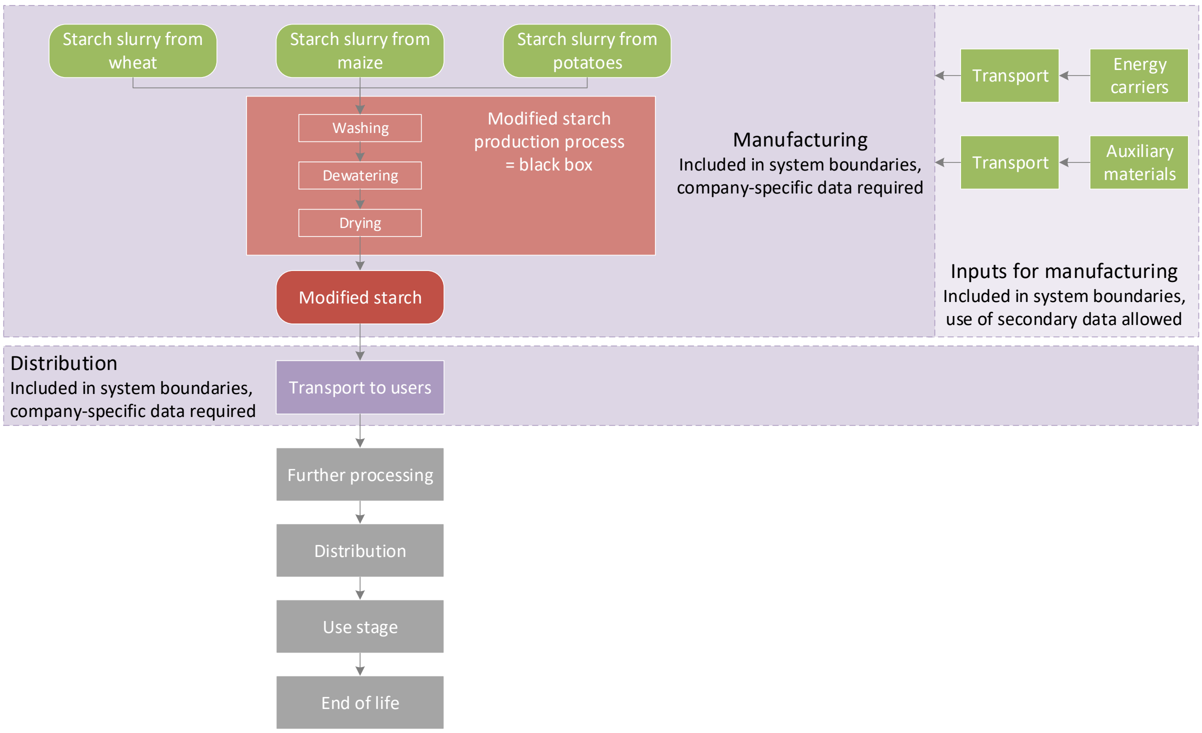

Figure 6: System boundary diagram for modified starch (excluding dextrins)

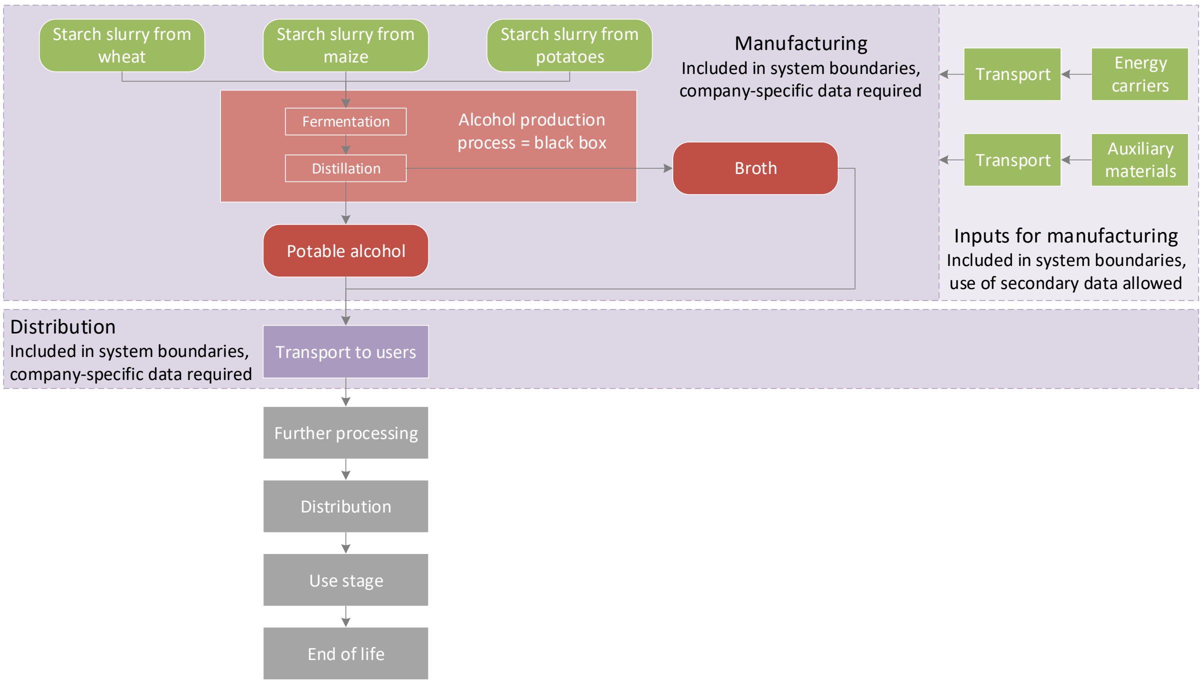

Figure 7: System boundary diagram for potable alcohol and co-product broth

The following life cycle stages and processes shall be included in the system boundary:

Table 4: Life cycle stages

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 wheat, maize and potatoes 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.
Raw material acquisition and pre-processing: transportation	Transport of raw materials from the field to the starch production plants.
Manufacturing	All relevant processes, starting with the reception of the raw materials need to be included. Depending on the specific starch industry product, these processes can be: reception, dry cleaning, wet cleaning, rasping, steeping, degerminating, grinding/flour milling, dough, separation, sieving, dewatering, washing, refining, mixing & drying, evaporation, drying, solubilizing, pressing, protein separation, conversion, hydrogenation, special polyol process, maltodextrin process, crystallization, fermentation and distillation. 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. The manufacturing stage can be subdivided into the processes shown in the system boundary diagrams above. This allows to allocate environmental impacts of a process only to the products coming out of this process and to better identify environmental hotspots.
Distribution	Transportation from the starch production facility to the customers.

According to this PCR, the following processes may be excluded based on the cut-off rule: capital goods for the manufacturing processes of the starch industry, packaging of starch industry products, packaging of incoming auxiliary materials, storage at warehouses, resources and tools for logistic operations at the starch plants and process waste (except wastewater, which needs to be included). *No additional cut-off is allowed.*

Each LCA study done in accordance with this PCR shall provide in the LCA study a diagram (or table) *indicating the activities falling in situation 1, 2 or 3 of the data needs matrix.*

3.5. LIST OF EF IMPACT CATEGORIES

Each LCA study carried out in compliance with this PCR shall calculate the environmental profile including all EF impact categories listed in Table 5.

Table 5: List of the impact categories to be used to calculate the environmental profile

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 (CTU_h)*	*CTUh*	*USEtox model 2.1 (Fankte et al, 2017)*
Human toxicity, non-cancer	*Comparative Toxic Unit for humans (CTU_h)*	*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 (CTU_e)*	*CTUe*	*USEtox model 2.1 (Fankte et al, 2017)*
Land use	• *Soil quality index[8]* • *Biotic production* • *Erosion resistance* • *Mechanical filtration*	• *Dimensionless (pt)* • *Kg biotic production* • *kg soil* • *m3 water*	*Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)*

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

EF impact category	Impact Category indicator	Unit	Characterization model
	• *Groundwater replenishment*	• *m3 groundwater*	
Water use	*User deprivation potential (deprivation- weighted water consumption)*	*m^3 world eq*	*Available WAter REmaining (AWARE) as recommended by UNEP, 2016*
Resource use[9], 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*

The full list of normalization factors and weighting factors are available in Annex 2 - List of EF normalisation factors and weighting factors.

The full list of characterization factors is available at this link: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml. EF reference package 3.0 shall be used. If the Agri-footprint® database (Paassen et al., 2019) is used for agricultural production[10], the EF 3.0 method needs to be made compatible to the nomenclature of this database. 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 needs to be 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. It needs to be noted that this modified method is not EF compliant anymore.

3.6. ADDITIONAL TECHNICAL INFORMATION

The biogenic carbon content at factory gate (physical content) shall be reported.

3.7. ADDITIONAL ENVIRONMENTAL INFORMATION

Biodiversity is considered as relevant for this PCR.

Currently, no method is available that fully captures the impact of products on biodiversity. The ReCiPe Endpoint method gives an indication of the potential loss of species and can be easily applied, as it is available in common LCA software. Users of this PCR shall thus calculate impacts on biodiversity with ReCiPe 2016 Endpoint (H) and report the result (species.yr) as additional information.

3.8. LIMITATIONS

Even if carried out in accordance with this PCR, a LCA study will have some limitations. These are described in the following paragraphs.

3.8.1. COMPARISONS AND COMPARATIVE ASSERTIONS

This PCR is for intermediate products and is thus not meant for comparative assertions, which should always be made considering the function of the product. At the level of the declared unit of this PCR, only products with the same characteristics can be compared (e.g. liquid glucose from wheat versus

[9] 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.

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

liquid glucose with the same technical characteristics from maize). LCA studies based on this PCR could be used by customers of the starch industry to calculate environmental footprints of their 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 LCA studies that are combined.

Not all impact assessment methods listed in section 3.5 are equally robust. This should be taken into account in the interpretation of the LCA results, prior to the weighting.

3.8.2. DATA GAPS AND PROXIES

Data gaps on company-specific data
The following data gaps on the company-specific data to be collected are most frequently encountered by companies.

- Dust emissions to air: If data on dust emissions to air are not available, the default values, provided in the accompanying excel file '*PCR for starch industry products_2.1 - Life cycle inventory'* may be used.
- Capital goods: Often companies lack data on the capital goods. They can however be excluded from the life cycle inventory as their impact on each of the impact categories is below 3% cut-off (see section).
- Packaging non-bulk chemicals: Often companies lack data on the packaging of chemicals. They can however be excluded from the life cycle inventory as their impact on each of the impact categories is below 3% cut-off (see section).

List of processes excluded from the PCR
The following processes are excluded from the PCR due to missing dataset and shall not be filled in by the user of the PCR:

- None

List of processes for which the user shall apply ILCD-EL compliant proxies:

- Agricultural processes are to be modelled with the datasets from Agri-footprint® 5.0 database (Paassen et al., 2019).

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

4.1. MOST RELEVANT EF IMPACT CATEGORIES

The most relevant impact categories for the product category in scope of this PCR are the following:

1. *Ecotoxicity, freshwater*
2. *Climate change*
3. *Resource use, fossils*
4. *Eutrophication, marine*
5. *Particulate Matter*
6. *Acidification*
7. *Eutrophication, terrestrial*

4.2. MOST RELEVANT LIFE CYCLE STAGES

The most relevant life cycle stages for the product category in scope of this PCR are the following:

- *Raw material acquisition and pre-processing: agriculture*
- *Manufacturing*
- *Distribution*

4.3. MOST RELEVANT PROCESSES

The most relevant processes for the product category in scope of this PCR are the following shown in the Table below. Life cycle stages are abbreviated as:

- A: Raw material acquisition and pre-processing: agriculture
- T: Raw material acquisition and pre-processing: transportation
- M: Manufacturing
- D: Distribution

Table 6: List of the most relevant processes

Impact category	***Processes***
Ecotoxicity, freshwater	Insecticide emissions, at farm/RER (A)
	Insecticide emissions, at farm/GLO (A)
Climate change	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 (M)
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)
	Wheat grain, at farm/FR Economic (A)
	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)
	Energy, from diesel burned in machinery/RER Economic (A)
	Electricity from natural gas {FR} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)
	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), at plant/RER Economic (A)
	Maize, at farm/FR Economic (A)
	Ammonia, as 100% NH3 (NPK 82-0-0), at plant/RER Economic (A)
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, EU-27 S System - Copied from ELCD (A)
	Electricity from natural gas {IT} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
	Wheat grain, at farm/DE Economic (A)
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, FR S System - Copied from ELCD (A)
	Electricity from natural gas {NL} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (T)
	Maize, at farm/IT Economic (A)

[11] This EF database record has been adapted: the fuel input has been added and the load factor was set to 50%.

Impact category	*Processes*
	Residual grid mix {PL} | AC, technology mix | consumption mix, to consumer | 1kV - 60kV | LCI result (M)
	Electricity from natural gas {ES} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), at plant/RER Economic (A)
	Electricity from natural gas {DE} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
	Maize, at farm/UA Economic (A)
Resource use, fossils	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 (M)
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)
	Diesel, from crude oil, consumption mix, at refinery, 200 ppm sulphur EU-15 S System - Copied from ELCD (A)
	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)
	Electricity from natural gas {FR} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
	Natural gas, from onshore and offshore prod. incl. pipeline and LNG transport, consumption mix, EU-27 S System - Copied from ELCD (A)
	Residual grid mix {FR} | AC, technology mix | consumption mix, to consumer | 1kV - 60kV | LCI result (M)
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, EU-27 S System - Copied from ELCD (A)
	Electricity from natural gas {IT} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, FR S System - Copied from ELCD (A)
	Electricity from natural gas {NL} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)
Eutrophication, marine	Wheat grain, at farm/FR Economic (A)
	Maize, at farm/FR Economic (A)
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)
	Wheat grain, at farm/DE Economic (A)
	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)
	Maize, at farm/IT Economic (A)
	Wheat grain, at farm/LT Economic (A)
	Wheat grain, at farm/PL Economic (A)
	Maize, at farm/HU Economic (A)
	Maize, at farm/BG Economic (A)
	Maize, at farm/UA Economic (A)
	Wheat grain, at farm/BE Economic (A)
	Maize, at farm/SK Economic (A)
	Potatoes, at farm/DE Economic (A)
	Wheat grain, at farm/IT Economic (A)

Impact category	*Processes*
	Energy, from diesel burned in machinery/RER Economic (A)
Particulate Matter	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)
	Wheat grain, at farm/FR Economic (A)
	Maize, at farm/FR Economic (A)
	Energy, from diesel burned in machinery/RER Economic (A)
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)
	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), at plant/RER Economic (A)
	Wheat grain, at farm/DE Economic (A)
	Maize, at farm/IT Economic (A)
	Native starch production process (M)
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)
	Wheat grain, at farm/BE Economic (A)
	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 (M)
	Wheat grain, at farm/IT Economic (A)
	Wheat grain, at farm/PL Economic (A)
	Potatoes, at farm/NL Economic (A)
	Potatoes, at farm/DE Economic (A)
	Wheat grain, at farm/LT Economic (A)
	Maize, at farm/SK Economic (A)
	Maize, at farm/UA Economic (A)
	Wheat grain, at farm/CZ Economic (A)
	Maize, at farm/HU Economic (A)
Acidification	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)
	Wheat grain, at farm/FR Economic (A)
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)
	Maize, at farm/FR Economic (A)
	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), at plant/RER Economic (A)
	Wheat grain, at farm/DE Economic (A)
	Maize, at farm/IT Economic (A)
	Energy, from diesel burned in machinery/RER Economic (A)
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)
	Wheat grain, at farm/BE Economic (A)
	Wheat grain, at farm/IT Economic (A)
	Wheat grain, at farm/PL Economic (A)
	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 (M)
	Potatoes, at farm/NL Economic (A)
	Potatoes, at farm/DE Economic (A)
	Wheat grain, at farm/LT Economic (A)
Eutrophication, terrestrial	Wheat grain, at farm/FR Economic (A)
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)

Impact category	Processes
	Transoceanic ship, containers {GLO}	heavy fuel oil driven, cargo	consumption mix, to consumer	27.500 dwt payload capacity, ocean going	LCI result (D)
	Maize, at farm/FR Economic (A)
	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), at plant/RER Economic (A)
	Energy, from diesel burned in machinery/RER Economic (A)
	Wheat grain, at farm/DE Economic (A)
	Maize, at farm/IT Economic (A)
	Wheat grain, at farm/BE Economic (A)
	Wheat grain, at farm/IT Economic (A)
	Wheat grain, at farm/PL Economic (A)
	Potatoes, at farm/NL Economic (A)
	Potatoes, at farm/DE Economic (A)
	Diesel mix at filling station {EU-27}	from crude oil and bio components	consumption mix, at filling station	7.23 wt.% bio components	LCI result (D)
	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 (M)

4.4. MOST RELEVANT DIRECT ELEMENTARY FLOWS

The most relevant direct elementary flows for the product category in scope of this PCR are the following:

Table 7: List of the most relevant elementary flows

Impact category	Processes	Most relevant elementary flows[12]
Ecotoxicity, freshwater	Insecticide emissions, at farm/RER (A)	Lambda-cyhalothrin to water, Chlorpyrifos to water, Bifenthrin to water
	Insecticide emissions, at farm/GLO (A)	
Climate change	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 (M)	Carbon dioxide, fossil to air
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3}	diesel driven, Euro 4, cargo	consumption mix, to consumer	more than 32t gross weight / 24,7t payload capacity	Unit process, single operation[11] (D)	Carbon dioxide, fossil to air
	Wheat grain, at farm/FR Economic (A)	Dinitrogen monoxide to air Carbon dioxide, fossil to air Carbon dioxide, land transformation to air
	Transoceanic ship, containers {GLO}	heavy fuel oil driven, cargo	consumption mix, to consumer	27.500 dwt payload capacity, ocean going	LCI result (D)	Carbon dioxide, fossil to air
	Energy, from diesel burned in machinery/RER Economic (A)	Carbon dioxide, fossil to air
	Electricity from natural gas {FR}	AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning	production mix, at power plant	1kV - 60kV	LCI result (M)	Carbon dioxide, fossil to air
	Diesel mix at filling station {EU-27}	from crude oil and bio components	consumption mix, at filling station	7.23 wt.% bio components	LCI result (D)	Carbon dioxide, fossil to air Methane, fossil to air

[12] According to Zampori and Pant (2019), this should be the most relevant direct elementary flows only. However, as the EF database contains aggregated datasets, it is not possible to distinguish between direct and indirect elementary flows.

Impact category	*Processes*	*Most relevant elementary flows*[12]
	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), at plant/RER Economic (A)	Dinitrogen monoxide to air
	Maize, at farm/FR Economic (A)	Dinitrogen monoxide to air Carbon dioxide, fossil to air
	Ammonia, as 100% NH3 (NPK 82-0-0), at plant/RER Economic (A)	Carbon dioxide, fossil to air Carbon dioxide to air
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, EU-27 S System - Copied from ELCD (A)	Carbon dioxide to air
	Electricity from natural gas {IT} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)	Carbon dioxide, fossil to air
	Wheat grain, at farm/DE Economic (A)	Dinitrogen monoxide to air Carbon dioxide, fossil to air
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, FR S System - Copied from ELCD (A)	Carbon dioxide to air
	Electricity from natural gas {NL} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)	Carbon dioxide, fossil to air
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (T)	Carbon dioxide, fossil to air
	Maize, at farm/IT Economic (A)	Dinitrogen monoxide to air Carbon dioxide, fossil to air Carbon dioxide to air
	Residual grid mix {PL} | AC, technology mix | consumption mix, to consumer | 1kV - 60kV | LCI result (M)	Carbon dioxide, fossil to air
	Electricity from natural gas {ES} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)	Carbon dioxide, fossil to air
	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), at plant/RER Economic (A)	Carbon dioxide to air
	Electricity from natural gas {DE} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)	Carbon dioxide, fossil to air
	Maize, at farm/UA Economic (A)	Dinitrogen monoxide to air Carbon dioxide, fossil to air Carbon dioxide, land transformation to air
Resource use, fossils	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 (M)	Energy, from gas, natural
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)	Energy, from oil
	Diesel, from crude oil, consumption mix, at refinery, 200 ppm sulphur EU-15 S System - Copied from ELCD (A)	Energy, from oil
	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)	Energy, from oil
	Electricity from natural gas {FR} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)	Energy, from gas, natural

Impact category	***Processes***	***Most relevant elementary flows[12]***
	Natural gas, from onshore and offshore prod. incl. pipeline and LNG transport, consumption mix, EU-27 S System - Copied from ELCD (A)	Energy, from gas, natural
	Residual grid mix {FR} | AC, technology mix | consumption mix, to consumer | 1kV - 60kV | LCI result (M)	Energy, from uranium
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, EU-27 S System - Copied from ELCD (A)	Energy, from gas, natural
	Electricity from natural gas {IT} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)	Energy, from gas, natural
	Process steam from natural gas, heat plant, consumption mix, at plant, MJ, FR S System - Copied from ELCD (A)	Energy, from gas, natural
	Electricity from natural gas {NL} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result (M)	Energy, from gas, natural
Eutrophication, marine	Wheat grain, at farm/FR Economic (A)	Nitrate to water
	Maize, at farm/FR Economic (A)	Nitrate to water
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)	Nitrogen monoxide to air Nitrogen dioxide to air
	Wheat grain, at farm/DE Economic (A)	Nitrate to water
	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)	Nitrogen dioxide to air
	Maize, at farm/IT Economic (A)	Nitrate to water
	Wheat grain, at farm/LT Economic (A)	Nitrate to water
	Wheat grain, at farm/PL Economic (A)	Nitrate to water
	Maize, at farm/HU Economic (A)	Nitrate to water
	Maize, at farm/BG Economic (A)	Nitrate to water
	Maize, at farm/UA Economic (A)	Nitrate to water
	Wheat grain, at farm/BE Economic (A)	Nitrate to water
	Maize, at farm/SK Economic (A)	Nitrate to water
	Potatoes, at farm/DE Economic (A)	Nitrate to water
	Wheat grain, at farm/IT Economic (A)	Nitrate to water
	Energy, from diesel burned in machinery/RER Economic (A)	Nitrogen oxides to air
Particulate Matter	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)	Particulates, < 2.5 um to air Sulfur dioxide to air
	Wheat grain, at farm/FR Economic (A)	Ammonia to air
	Maize, at farm/FR Economic (A)	Ammonia to air
	Energy, from diesel burned in machinery/RER Economic (A)	Particulates, < 2.5 um to air
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)	Particulates, < 2.5 um to air Nitrogen monoxide to air Sulfur dioxide to air
	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), at plant/RER Economic (A)	Ammonia to air
	Wheat grain, at farm/DE Economic (A)	Ammonia to air
	Maize, at farm/IT Economic (A)	Ammonia to air
	Native starch production process (M)	Particulates, < 2.5 um to air

Impact category	*Processes*	*Most relevant elementary flows[12]*
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)	Sulfur dioxide to air Particulates, < 2.5 um to air Ammonia to air
	Wheat grain, at farm/BE Economic (A)	Ammonia to air
	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 (M)	Particulates, < 2.5 um to air Sulfur dioxide to air
	Wheat grain, at farm/IT Economic (A)	Ammonia to air
	Wheat grain, at farm/PL Economic (A)	Ammonia to air
	Potatoes, at farm/NL Economic (A)	Ammonia to air
	Potatoes, at farm/DE Economic (A)	Ammonia to air Particulates, < 2.5 um to air
	Wheat grain, at farm/LT Economic (A)	Ammonia to air Particulates, < 2.5 um to air
	Maize, at farm/SK Economic (A)	Ammonia to air
	Maize, at farm/UA Economic (A)	Ammonia to air Particulates, < 2.5 um to air
	Wheat grain, at farm/CZ Economic (A)	Ammonia to air
	Maize, at farm/HU Economic (A)	Ammonia to air Particulates, < 2.5 um to air
Acidification	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)	Sulfur dioxide to air Nitrogen dioxide to air
	Wheat grain, at farm/FR Economic (A)	Ammonia to air
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)	Nitrogen monoxide to air Nitrogen dioxide to air
	Maize, at farm/FR Economic (A)	Ammonia to air
	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), at plant/RER Economic (A)	Ammonia to air
	Wheat grain, at farm/DE Economic (A)	Ammonia to air
	Maize, at farm/IT Economic (A)	Ammonia to air
	Energy, from diesel burned in machinery/RER Economic (A)	
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)	Sulfur dioxide to air Nitrogen dioxide to air
	Wheat grain, at farm/BE Economic (A)	Ammonia to air
	Wheat grain, at farm/IT Economic (A)	Ammonia to air
	Wheat grain, at farm/PL Economic (A)	Ammonia to air
	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 (M)	Nitrogen dioxide to air Sulfur dioxide to air
	Potatoes, at farm/NL Economic (A)	Ammonia to air
	Potatoes, at farm/DE Economic (A)	Ammonia to air
	Wheat grain, at farm/LT Economic (A)	Ammonia to air
Eutrophication, terrestrial	Wheat grain, at farm/FR Economic (A)	Ammonia to air
	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation[11] (D)	Nitrogen monoxide to air Nitrogen dioxide to air

Impact category	*Processes*	*Most relevant elementary flows*[12]
	Transoceanic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27.500 dwt payload capacity, ocean going | LCI result (D)	Nitrogen dioxide to air
	Maize, at farm/FR Economic (A)	Ammonia to air
	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), at plant/RER Economic (A)	Ammonia to air
	Energy, from diesel burned in machinery/RER Economic (A)	Nitrogen oxides to air
	Wheat grain, at farm/DE Economic (A)	Ammonia to air
	Maize, at farm/IT Economic (A)	Ammonia to air
	Wheat grain, at farm/BE Economic (A)	Ammonia to air
	Wheat grain, at farm/IT Economic (A)	Ammonia to air
	Wheat grain, at farm/PL Economic (A)	Ammonia to air
	Potatoes, at farm/NL Economic (A)	Ammonia to air
	Potatoes, at farm/DE Economic (A)	Ammonia to air
	Diesel mix at filling station {EU-27} | from crude oil and bio components | consumption mix, at filling station | 7.23 wt.% bio components | LCI result (D)	Nitrogen dioxide to air Ammonia to air
	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 (M)	Nitrogen dioxide to air

5. LIFE CYCLE INVENTORY

Sampling is allowed for the collection of primary data. The sampling procedure is described in Annex 4. *In case sampling is needed, it shall be conducted as specified in this PCR. However, sampling is not mandatory and any user of this PCR may decide to collect the data from all the plants or farms, without performing any sampling.*

5.1. LIST OF MANDATORY COMPANY-SPECIFIC DATA

It is mandatory to use company-specific data for:

- the types and quantities of agricultural products;
- the transportation of the agricultural products to the starch production plants;
- the manufacturing processes of the starch industry;
- the distribution of the starch industry products to customers.

Raw material acquisition and pre-processing: agriculture

Company-specific quantities and geographic origins shall be used for the agricultural products. The excel file *"PCR for starch industry products_2.1 - Life cycle inventory"* contains a list of company specific activity data to be collected. It also contains the default amounts used to model the representative product and the average starch industry products with.

Raw material acquisition and pre-processing: transportation

Transport of raw materials from the field to the starch production plants shall be modelled with company-specific transport modes and distances. Again, the excel file *"PCR for starch industry products_2.1 - Life cycle inventory"* contains a list of company specific activity data to be collected.

Manufacturing

Using company-specific data (i.e. activity data and direct elementary flows) is mandatory for the processes of the starch industry. These processes depend on the specific starch industry product and include reception, dry cleaning, wet cleaning, rasping, steeping, degerminating, grinding/milling, dough, separation, sieving, dewatering, washing, refining, mixing & drying, evaporation, drying, solubilising, pressing, protein separation, conversion, hydrogenation, special polyol process, maltodextrin process, crystallization, fermentation, distillation.

It is not always possible to collect data for each of these processes separately. Therefore, it is allowed to collect activity data and direct elementary flows for various processes together that are considered as a 'black box' that cannot be subdivided further.

In the following paragraphs, processes are grouped as in section 3.4 (System boundary):

- starch slurry and co-products from wheat;
- starch slurry and co-products from maize;
- starch slurry and co-products from potatoes;
- liquid glucose, liquid/dry sorbitol, unfermented special polyols, maltodextrins and dry crystallized dextrose from starch slurry;
- native starch and dextrins from starch slurry;
- modified starch (excluding dextrins);
- potable alcohol and co-product broth from starch slurry and other raw materials.

For each process (or group of processes considered as a black-box), company-specific types and quantities of all input flows (energy, water, auxiliary materials) and output flows (products, wastewater, dust emissions[13]) need to be collected.

Production of starch slurry and co-products from wheat

When producing starch slurry from wheat, several co-products are produced as well (bran, dry wheat feed, dry gluten, wet solubilised gluten, liquid solubles and wheat germs). Starch slurry, wheat germs and (lose) bran come out of the main process step as such while the other co-products (liquid solubles, dry wheat feed, wet solubilized gluten and dry wheat gluten) each require one or more additional steps. This is presented graphically in the system boundary diagrams in section 3.4.

Table 8 and *Table 9* summarize the input and output flows that are related to the production process of starch slurry from wheat including the default datasets used for calculating the environmental impacts. This main process step is needed for each of the products produced from wheat and the data used are presented in *Table 8* and Table 9. All data for the additional process steps needed to finalize some of the co-products are presented in the accompanying excel file *"PCR for starch industry products_2.1 - Life cycle inventory"*. The tables below (and the excel file) list the inputs and outputs encountered in the LCA of the representative product. If other inputs or outputs are encountered (e.g. different chemicals, another type of energy etc.), these also need to be included.

[13] Most emissions to air from the starch industry are energy-related, however, dust emissions from manufacturing processes also can have a relevant environmental impact. Therefore, it is necessary to include emissions of particulates < 2.5 um. If only data on total dust emissions are available, the particulates < 2.5 um can be estimated as 50% of total dust emissions.

Table 8: Data collection requirements for production[14] of starch slurry, loose bran and germs from wheat

Requirements for data collection purposes			**Requirements for modelling purposes**								**Remarks**
Activity data to be collected	*Specific requirements*	*Unit of measure*	*Dataset source (i.e. node)*	*Default dataset to be used*	*UUID*	*TiR*	*TeR*	*GeR*	*P*	*DQR*	
Inputs:											
Sodium bisulphite	1-year data	tonne	Ecoinvent	Sodium hydrogen sulphite production {RER} | technology mix | production mix, at plant | 100% active substance | LCI result	8559b1de-51ab-430e-93b8-295759b853fe	1	2	1	2	1,5	/
Sodium hydroxide	1-year data	tonne	Ecoinvent	Sodium hydroxide production {RER} | technology mix | production mix, at plant | 100% active substance | LCI result	2ba49ead-4683-4671-bded-d52b80215e9e	2	1	1	2	1,5	/
Enzymes	1-year data	tonne	Ecoinvent	Enzymes production {RER} | technology mix | production mix, at plant | 100% active substance | LCI result	c2ec381a-5480-45e3-a5e9-10e13152f2fd	1	1	1	2	1,3	/
Other auxiliary materials	1-year data	tonne	Ecoinvent	*confidential*	*confidential*	not available, aggregation of multiple confidential raw materials					/
Tap water	1-year data	tonne	Sphera	Tap water {EU-28+3} | technology mix | at user | per kg water | LCI result	212b8494-a769-4c2e-8d82-9a6ef61baad7	2	2	2,4	2	2,1	/
Electricity - from grid (*country*)	1-year data	kWh	Sphera	Residual grid mix {*country*}| AC, technology mix| consumption mix, to consumer |1 kV- 60 kV| LCI result	*depending on country*	2	1	1	1	1,3	To be adapted depending on the country.
Electricity - from CHP (*country*)	1-year data	kWh	Sphera	Electricity from natural gas {*country*} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning |	*depending on country*	2	1	1	1	1,3	To be adapted depending on the country.

[14] Black-box process including reception, dry cleaning, grinding/milling, dough, separation, dewatering, refining and washing.

				production mix, at power plant | 1 kV - 60 kV | LCI result							
Electricity - from CHP on biogas (*country*)	1-year data	kWh	Sphera	Electricity from biogas {*country*} | AC, mix of direct and CHP, technology mix regarding firing and flue gas cleaning | production mix, at power plant | 1kV - 60kV | LCI result	*depending on country*	1	2	1	2	1,5	To be adapted depending on the country. Proxy for electricity from CHP on biogas/
Steam - from CHP	1-year data	kWh	Sphera	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	2	1	1	2	1,5	Proxy for steam from CHP
Steam - from CHP on biogas	1-year data	kWh	Sphera	Process steam from biogas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 90% efficiency | LCI result	aadf67e1-9e2b-4da3-96f9-786c63e10d10	1	3	1	2	1,8	Proxy for steam from CHP on biogas
Steam - from natural gas boiler	1-year data	kWh	Sphera	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	2	1	1	2	1,5	Proxy for steam from natural gas boiler
Steam – from biogas boiler	1-year data	kWh	Sphera	Process steam from biogas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 90% efficiency | LCI result	aadf67e1-9e2b-4da3-96f9-786c63e10d10	1	3	1	2	1,8	Proxy for steam from biogas boiler
Steam – from wood boiler	1-year data	kWh	Sphera	Process steam from biomass (solid) 90% {EU-27} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 90% efficiency | LCI result	6f053940-bbe1-44e9-8a74-b8a2e5a6f91e	2	2	1	2	1,8	Proxy for steam from wood boiler
Steam - from fuel oil	1-year data	kWh	Sphera	Thermal energy from light fuel oil (LFO) {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 100% efficiency | LCI result	e7510ad9-4bfa-4113-94b0-426e5f430c98	Not evaluated					Proxy for steam from fuel oil, adjusted to 90%

											efficiency by dividing by 0.9
Geothermal hot water	1-year data	kWh	Sphera	Electricity from geothermal {IT}|, AC, CHP, technology mix | production mix, at power plant | 1 kV - 60 kV | LCI result	4639f269-d45d-4b3b-a848-d0f046888ac7	Not evaluated					Proxy for geothermal hot water
Natural gas	1-year data	kWh	Sphera	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	2	1	1	2	1,5	Proxy for heat from natural gas
Transport of bulk auxiliary materials – truck	1-year data	tkm	Sphera	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation	938d5ba6-17e4-4f0d-bef0-481608681f57	1	1	1	2	1,3	Adapted: the fuel input has been added and the load factor was set to 50%.
Transport of non-bulk auxiliary materials – truck	1-year data	tkm	Sphera	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32t gross weight / 24,7t payload capacity | Unit process, single operation	938d5ba6-17e4-4f0d-bef0-481608681f57	1	1	1	2	1,3	Adapted: the fuel input has been added and the load factor was set to 64%.
Outputs:											
Waste water wheat starch production	1-year data	tonne	Sphera	Treatment of effluents from maize starch production {EU-28+EFTA} | waste water treatment including sludge treatment | production mix, at plant | 1m3 of waste water treated | LCI result	72603325-62ca-4580-9b5b-e2a6fe847e4e	Not evaluated					Proxy for waste water treatment of wheat starch production

Table 9: Direct elementary flow collection requirements for production of starch slurry, lose bran and germs from wheat

Emissions/resources	Elementary flow	UUID	Frequency of measurement	Default measurement method[15]	Remarks
Resources					
Ground water (country)	Water, well, (country)	Not applicable	1-year measurement	No default method…	
Surface water (country)	Water, river (country)	Not applicable	1-year measurement	No default method	
Emissions			_		
Particulate matter	Particlates, < 2.5 µm	Not applicable	Company specific	No default method	If dust, TSP or PM 10 available, assume 50% is PM 2.5

For the data collection requirements for the additional processing steps 'production of liquid solubles (evaporation)', 'production of dry wheat feed (mixing & drying)', 'production of wet solubilised gluten (solubilisation)' and 'production of dry wheat gluten (drying)', we refer to the excel file *"PCR for starch industry products_2.1 - Life cycle inventory"* which *contains a list of company specific activity data and elementary flows to be collected.*

Production of starch slurry and co-products from maize

When producing starch slurry from maize, several co-products are produced as well (steep liquor, dry corn feed, wet corn fibres, dry germs, oil and dry proteins). Starch slurry and wet corn fibres come out of the main process step as such while the other co-products (corn steep liquor, dry corn feed, dry proteins, dry germs and oil) each require one or more additional steps to be finalized. This is presented graphically in the system boundary diagrams in section 3.4.

The input and output flows that are related to the production process of starch slurry from maize and the additional steps to finalize co-products including the default datasets used for calculating the environmental impacts are provided in the excel file *"PCR for starch industry products_2.1 - Life cycle inventory"*. The main process step 'starch slurry from maize' is needed for each of the products. For some co-products, additional process steps are needed. The life cycle inventory and default datasets are available in the excel file. It concerns the production process steps 'production of dry germs (drying)', 'production of oil (pressing)', 'production of dry proteins (drying)', 'production of corn steep liquor (evaporation)', 'production of dry corn feed (drying)'.

Production of starch slurry and co-products from potatoes

When producing starch slurry from potatoes, a number of co-products are produced as well (potato proteins, fruit juice, concentrated fruit juice, wet pulp and dry pulp). Starch slurry, wet pulp and fruit juice come out of the main process step as such while the co-products potato proteins, concentrated fruit juice and dry pulp (fibres) each require one or more additional steps to be finalized. This is presented graphically in the system boundary diagrams in section 3.4.

[15] Unless specific measurement methods are foreseen in a country-specific legislation

The input and output flows that are related to the production process of starch slurry from potatoes and the additional steps to finalize co-products including the default datasets used for calculating the environmental impacts are provided in the excel file *"PCR for starch industry products_2.1 - Life cycle inventory"*. The main process step 'starch slurry from potatoes' is needed for each of the co-products. All data for the additional process steps needed to finalize some of the co-products are as well presented in the excel file. It concerns the processes 'production of dry pulp (fibres) (drying)', 'production of protein paste and juice (protein separation)', 'production of potato proteins (drying)', production of concentrated fruit juice (evaporation).

Production of liquid glucose, sorbitol, unfermented special polyols, maltodextrins and dextrose

Liquid glucose and co-products are produced from starch slurry from wheat, maize or potatoes through a number of process steps. The first process step produces liquid glucose. The other reference products (liquid and dry sorbitol, unfermented special polyols, maltodextrins and dextrose) all start from liquid glucose and require one or more additional process steps to be produced. This is presented graphically in the system boundary diagrams in section 3.4.

The input and output flows that are related to the production process of liquid glucose and the additional process steps to produce the other reference products including the default datasets used for calculating the environmental impacts are provided in the excel file *"PCR for starch industry products_2.1 - Life cycle inventory"*. The main process step to produce liquid glucose is needed for each of the products. All data for the additional process steps needed to produce all products besides liquid glucose are also presented in the excel file. It concerns the processes for 'production of liquid sorbitol (hydrogenation)', 'production of dry sorbitol (drying)', 'production of special polyols (special polyol process and drying)', 'production of maltodextrin (maltodextrin process and drying)', production of dry crystallized dextrose (crystallisation and drying)'.

Production of native starch and dextrins

Native starches (including lightly modified starches) and dextrins are produced from starch slurry from wheat, maize or potatoes through a number of process steps. The first process step produces native starch including lightly modified starch. Dextrin production starts from native starch and requires an additional drying step and chemicals. This is presented graphically in the system boundary diagrams in section 3.4.

The input and output flows that are related to the production process of native starch and the additional drying step to produce the dextrins including the default datasets used for calculating the environmental impacts are provided in the excel file "*PCR for starch industry products_2.1 - Life cycle inventory"*. The main process step to produce native starch is needed for dextrins as well. All data for the additional drying step needed to produce dextrins are also presented in the excel file.

Production of modified starch (excluding dextrins)

Modified starch (excluding dextrins) is produced from starch slurry from wheat, maize or potatoes through a number of process steps, which are aggregated into one black-box process. This is presented graphically in the system boundary diagrams in section 3.4.

The input and output flows that are related to the production process of modified starch including the default datasets used for calculating the environmental impacts are provided in the excel file "*PCR for starch industry products_2.1 - Life cycle inventory"*.

Production of potable alcohol and co-product broth

Potable alcohol can be produced from different input materials including starch slurry from wheat, maize or potatoes through a number of process steps. These process steps are combined into one black-box process, for which the impacts need to be allocated over potable alcohol and the co-product broth. This is presented graphically in the system boundary diagrams in section 3.4.

The input and output flows that are related to the production process of potable alcohol and broth including the default datasets used for calculating the environmental impacts are provided in the excel file "*PCR for starch industry products_2.1 - Life cycle inventory*".

Distribution

Transportation of products from the starch production facility to the customers shall be modelled with company-specific transport modes and distances.

See excel file named "PCR for starch industry products_2.1 - Life cycle inventory" for the list of all company-specific data to be collected.

5.2. List of processes expected to be run by the company

There are no further processes expected to be run by the company in addition to those listed as mandatory company-specific data.

5.3. Data quality requirements

The data quality of each dataset and the total LCA study shall be calculated and reported. The calculation of the DQR shall be based on the following formula with four criteria:

$$DQR = \frac{TeR+GeR+TiR+P}{4}$$ *[Equation B.1]*

where TeR is technological representativeness, GeR is geographical representativeness, TiR is time representativeness, and P is precision. The representativeness (technological, geographical and time-related) characterises to what degree the processes and products selected are depicting the system analysed, while the precision indicates the way the data is derived and related level of uncertainty.

The next chapters provide tables with the criteria to be used for the semi-quantitative assessment of each criterion.

5.3.1. Company-specific datasets

The DQR shall be calculated at the level-1 disaggregation, before any aggregation of sub- processes or elementary flows is performed. The DQR of company-specific datasets shall be calculated as following:

1. *Select the most relevant activity data and direct elementary flows: most relevant activity data are the ones linked to sub-processes (i.e. secondary datasets) that account for at least 80% of the total environmental impact of the company-specific dataset, listing them from the most contributing to the least contributing one. Most relevant direct elementary flows are defined as those direct elementary flows contributing cumulatively at least with 80% to the total impact of the direct elementary flows.*
2. *Calculate the DQR criteria TeR, TiR, GeR and P for each most relevant activity data and each most relevant direct elementary flow. The values of each criterion shall be assigned based on Table 10.*
    a. *Each most relevant direct elementary flow consists of the amount and elementary flow naming (e.g. 40 g carbon dioxide). For each most relevant elementary flow, the user of the PCR shall evaluate the 4 DQR criteria named Te_{R-EF}, Ti_{R-EF}, G_{R-EF}, P_{EF}. For example,*

the user of the PCR shall evaluate the timing of the flow measured, for which technology the flow was measured and in which geographical area.

b. *For each most relevant activity data, the 4 DQR criteria shall be evaluated (named Ti_{R-AD}, P_{AD}, G_{r-AD}, T_{er-AD}) by the user of the PCR.*

c. *Considering that the data for the mandatory processes shall be company- specific, the score of P cannot be higher than 3, while the score for TiR, TeR, and GR cannot be higher than 2 (The DQR score shall be ≤1.5).*

3. *Calculate the environmental contribution of each most relevant activity data (through linking to the appropriate sub-process) and direct elementary flow to the total sum of the environmental impact of all most-relevant activity data and direct elementary flows, in % (weighted, using all EF impact categories). For example, the newly developed dataset has only two most relevant activity data, contributing in total to 80% of the total environmental impact of the dataset:*

- *Activity data 1 carries 30% of the total dataset environmental impact. The contribution of this process to the total of 80% is 37.5% (the latter is the weight to be used).*
- *Activity data 2 carries 50% of the total dataset environmental impact. The contribution of this process to the total of 80% is 62.5% (the latter is the weight to be used).*

4. *Calculate the TeR, TiR, GeR and P criteria of the newly developed dataset as the weighted average of each criteria of the most relevant activity data and direct elementary flows. The weight is the relative contribution (in %) of each most relevant activity data and direct elementary flow calculated in step 3.*

5. *The user of the PCR shall calculate the total DQR of the newly developed dataset using Equation B.2, where $\overline{Te_R}$, $\overline{Ge_R}$, $\overline{Ti_R}$ and $\overline{P}$, are the weighted average calculated as specified in point (4).*

$$DQR = \frac{\overline{Te_R}+\overline{Ge_R}+\overline{Ti_R}+\overline{P}}{4}$$

[Equation B.2]

Table 10: How to assess the value of the DQR criteria for datasets with company-specific information

Rating	**P_{EF} and P_{AD}**	**Ti_{R-EF} and Ti_{R-AD}**	**Te_{R-EF} and Te_{R-AD}**	**G_{R-EF} and G_{R-AD}**
1	Measured/calculated <u>and</u> externally verified	The data refers to the most recent annual administration period with respect to the EF report publication date, not considering exceptional years[16]	The elementary flows and the activity data reflect exactly the technology of the newly developed dataset	The activity data and elementary flows reflects the exact geography where the process modelled in the newly created dataset takes place
2	Measured/calculated and internally verified, plausibility checked by reviewer	The data refers to maximum 2 annual administration periods with respect to the EF report publication date, not considering exceptional years	The elementary flows and the activity data is a proxy of the technology of the newly developed dataset	The activity data and elementary flows) partly reflects the geography where the process modelled in the newly created dataset takes place

[16] If the previous year was not representative due to an exceptional event (e.g. COVID-19), it may be chosen to use data from the year before without having to lower the TiR.

3	Measured/calculated/literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	The data refers to maximum three annual administration periods with respect to the EF report publication date, not considering exceptional years	Not applicable	Not applicable
4-5	Not applicable	Not applicable	Not applicable	Not applicable

$\mathbf{P}_{EF}$: Precision for elementary flows; $\mathbf{P}_{AD}$: Precision for activity data; $\mathbf{Ti}_{R\text{-}EF}$: Time Representativeness for elementary flows; $\mathbf{Ti}_{R\text{-}AD}$: Time representativeness for activity data; $\mathbf{Te}_{R\text{-}EF}$: Technology representativeness for elementary flows; $\mathbf{Te}_{R\text{-}AD}$: Technology representativeness for activity data**;** $\mathbf{G}_{R\text{-}EF}$: Geographical representativeness for elementary flows; $\mathbf{G}_{R\text{-}AD}$**:** Geographical representativeness for activity data.

5.4. Data needs matrix (DNM)

All processes required to model the product and outside the list of mandatory company-specific data (listed in section 5.1) shall be evaluated using the Data Needs Matrix (see Table 11). The user of the PCR shall apply the DNM to evaluate which data is needed and shall be used within the modelling of its PEF, depending on the level of influence the user of the PCR (company) has on the specific process. The following three cases are found in the DNM and are explained below:

1. ***Situation 1:** the process is run by the company applying the PCR;*
2. ***Situation 2:** the process is not run by the company applying the PCR but the company has access to (company-)specific information;*
3. ***Situation 3:** the process is not run by the company applying the PCR and this company does not have access to (company-)specific information.*

*Table 11: Data Needs Matrix (DNM)[17]. *Disaggregated datasets shall be used.*

		Most relevant process	Other process
Situation 1: process run by the company using the PEFCR	Option 1	Provide company-specific data (as requested in the PCR) and create a company-specific dataset, in aggregated form (DQR≤1.5) Calculate the DQR values (for each criterion + total)	
	Option 2		Use default secondary dataset in PCR, in aggregated form (DQR≤3.0) Use the default DQR values
Situation 2: process <u>not</u> run by the company using the PCR but with access to company-specific information	Option 1	Provide company-specific data (as requested in the PCR) and create a company-specific dataset, in aggregated form (DQR≤1.5) Calculate the DQR values (for each criterion + total)	
	Option 2	Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤3.0)*	

[17] The options described in the DNM are not listed in order of preference.

		Re-evaluate the DQR criteria within the product specific context	
	Option 3		Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤4.0)* Use the default DQR values.
Situation 3: process <u>not</u> run by the company using the PCR and without access to company-specific information	Option 1	Use default secondary data set in aggregated form (DQR≤3.0) Re-evaluate the DQR criteria within the product specific context	
	Option 2		Use default secondary data set in aggregated form (DQR≤4.0) Use the default DQR values

5.4.1. PROCESSES IN SITUATION 1

For each process in situation 1 there are two possible options:

- *The process is in the list of most relevant processes as specified in the PCR or is not in the list of most relevant process, but still the company wants to provide company- specific data (option 1);*
- *The process is not in the list of most relevant processes and the company prefers to use a secondary dataset (option 2).*

Situation 1/Option 1

For all processes run by the company and where the user of the PCR applies company- specific data. The DQR of the newly developed dataset shall be evaluated as described in section 5.3.1.

Situation 1/Option 2

For the non-most relevant processes only, if the user of the PCR decides to model the process without collecting company-specific data, then the user shall use the secondary dataset listed in the PCR together with its default DQR values listed here.

If the default dataset to be used for the process is not listed in the PCR, the user of the PCR shall take the DQR values from the metadata of the original dataset.

5.4.2. PROCESSES IN SITUATION 2

When a process is not run by the user of the CR, but there is access to company-specific data, then there are three possible options:

- *The user of the PCR has access to extensive supplier-specific information and wants to create a new EF compliant dataset (Option 1);*
- *The company has some supplier-specific information and want to make some minimum changes (Option 2);*

- *The process is not in the list of most relevant processes and the company wants to make some minimum changes (option 3).*

Situation 2/Option 1

For all processes not run by the company and where the user of the PCR applies company- specific data, the DQR of the newly developed dataset shall be evaluated as described in section 5.3.1.

Situation 2/Option 2

The user of the PCR shall use company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets, starting from the default secondary dataset provided in the PCR.

Please note that the PCR lists all dataset names together with the UUID of their aggregated dataset. For this situation, the disaggregated version of the dataset is required.

The user of the CR shall make the DQR context-specific by re-evaluating TeR and TiR using the table Table 12. The criteria GeR shall be lowered by 30%[18] and the criteria P shall keep the original value.

Situation 2/Option 3

The user of the PCR shall apply company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets, starting from the default secondary dataset provided in the PCR.

Please note that the PCR lists all dataset names together with the UUID of their aggregated dataset. For this situation, the disaggregated version of the dataset is required.

In this case, the user of the PCR shall use the default DQR values. If the default dataset to be used for the process is not listed in the PCR, the user of the PCR shall take the DQR values from the original dataset.

Table 12: How to assess the value of the DQR criteria when secondary datasets are used.

	TiR	***TeR***	***GeR***
1	*The EF report publication date happens within the time validity of the dataset*	*The technology used in the EF study is exactly the same as the one in scope of the dataset*	*The process modelled in the EF study takes place in the country the dataset is valid for*
2	*The EF report publication date happens not later than 2 years beyond the time validity of the dataset*	*The technologies used in the EF study is included in the mix of technologies in scope of the dataset*	*The process modelled in the EF study takes place in the geographical region (e.g. Europe) the dataset is valid for*
3	*The EF report publication date happens not later than 4 years beyond the time validity of the dataset*	*The technologies used in the EF study are only partly included in the scope of the dataset*	*The process modelled in the EF study takes place in one of the geographical regions the dataset is valid for*

[18] In situation 2, option 2 it is proposed to lower the parameter GeR by 30% in order to incentivise the use of company-specific information and reward the efforts of the company in increasing the geographic representativeness of a secondary dataset through the substitution of the electricity mixes and of the distance and means of transportation.

4	*The EF report publication date happens not later than 6 years beyond the time validity of the dataset*	*The technologies used in the EF study are similar to those included in the scope of the dataset*	*The process modelled in the EF study takes place in a country that is not included in the geographical region(s) the dataset is valid for, but sufficient similarities are estimated based on expert judgement.*
5	*The EF report publication date happens later than 6 years after the time validity of the dataset*	*The technologies used in the EF study are different from those included in the scope of the dataset*	*The process modelled in the EF study takes place in a different country than the one the dataset is valid for*

5.4.3. PROCESSES IN SITUATION 3

If a process is not run by the company using the PCR and the company does not have access to company-specific data, there are two possible options:

It is in the list of most relevant processes (situation 3, option 1);

It is not in the list of most relevant processes (situation 3, option 2).

Situation 3/Option 1

In this case, the user of the PCR shall make the DQR values of the dataset used context- specific by re-evaluating TeR, TiR and GeR, using the table(s) provided. The criteria P shall keep the original value.

Situation 3/Option 2

For the non-most relevant processes, the user of the PCR shall apply the corresponding secondary dataset listed in the PCR together with its DQR values.

If the default dataset to be used for the process is not listed in the PCR, the user of the PCR shall take the DQR values from the original dataset.

5.5. WHICH DATASETS TO USE?

This PCR lists the secondary datasets to be applied by the user of the PCR. Whenever a dataset needed to calculate the environmental profile is not among those listed in this PCR, then the user shall choose between the following options (in hierarchical order):

- *Use an EF compliant dataset available on one of the nodes of the Life Cycle Data Network http://eplca.jrc.ec.europa.eu/LCDN/.*
- *Use an EF compliant dataset available in a free or commercial source.*
- *Use another EF compliant dataset considered to be a good proxy. In such case this information shall be included in the "limitations" section of the LCA report.*
- *Use an ILCD entry level (EL) compliant dataset. These datasets shall be included in the "limitations" section of the LCA report.* [19]
- If no EF compliant or ILCD-EL compliant proxy is available, a dataset or proxy from another source shall be used. In this case, the EF 3.0 method needs to be made compatible to the nomenclature of this database by adding additional flows if necessary. These datasets shall be included in the "limitations" section of the LCA report. [20]

[19] This option is only PEF-compliant if a maximum of 10% of the total environmental impact is derived from ILCD-EL compliant datasets (calculated cumulatively from lowest to largest contribution to the total environmental profile).
[20] This option is not PEF-compliant.

5.6. HOW TO CALCULATE THE AVERAGE DQR OF THE STUDY

To calculate the average DQR of the LCA study, the user of the PCR shall calculate separately the TeR, TiR, GeR and P for the LCA study as the weighted average of all most relevant processes, based on their relative environmental contribution to the total single overall score. The calculation rules explained in section 4.6.5.8 of the PEF method shall be used.

5.7. ALLOCATION RULES

Systems involving multi-functionality of processes shall be modelled in accordance with the decision hierarchy provided in the PEF method (section 4.5). When allocation cannot be avoided, the allocation rules listed in Table 13 shall be applied.

Table 13: Allocation rules

Process	***Allocation rule***	***Modelling instructions***	***Allocation factor***
Agricultural processes	Economic allocation	The price of the different outputs averaged over five years shall be used to allocate impacts of the agricultural production processes.	As available in the economic allocation library of the Agri-footprint® database (Paassen et al., 2019). If primary data are used to model agricultural production, economic allocation shall be performed as described in the LEAP Guideline (FAO, 2016).
Starch industry processes	Physical allocation based on dry substance mass	The DS mass of the different outputs shall be used to allocate impacts of the black-box production processes.	The mass of each output depends on the exact production process and differs per starch plant. Company-specific allocation factors shall thus be used[21].

Many production processes in the starch industry are complex and may be considered as 'black box' processes delivering multiple output products. The PEF method (Zampori and Pant, 2019, page 81) provides a decision hierarchy for the modelling of systems involving multi-functionality of processes. In short, the decision hierarchy (PEF method, Zampori and Pant, 2019) is as follows: (1) Subdivision or system expansion; (2) Allocation based on a relevant underlying physical relationship; (3) Allocation based on some other relationship.

When performing a study on a specific starch industry product according to this PCR, allocation can usually not be avoided through subdivision or system expansion. Subdivision/disaggregation can (and should) be done up to a certain level, as some processes can be attributed to one product only. However, many production processes in the starch industry are complex and may be considered as a 'black box' that cannot be subdivided further (see system boundary diagrams in section 3.4). System expansion is not useful either, as the goal of the LCA is to determine the environmental impacts per co-product, to allow companies that use only one specific starch industry product to use the results as an input for the LCA of their products. When subdivision or system expansion is not possible,

[21] Using company-specific allocation factors is not PEF-compliant, but it is the best option for the manufacturing of starch products due to the large variety of possible co-products.

allocation should be done based on a relevant underlying physical relationship. For the starch industry products, mass allocation (dry substance) should be applied. Mass allocation was chosen because:

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

5.8. ELECTRICITY MODELLING

The following electricity mix shall be used in hierarchical order:

1. *Supplier-specific electricity product shall be used if for a country there is a 100% tracking system in place, or if:*
    a. *available, and*
    b. *the set of minimum criteria to ensure the contractual instruments are reliable is met.*
2. *The supplier-specific total electricity mix shall be used if:*
    a. *available, and*
    b. *the set of minimum criteria to ensure the contractual instruments are reliable is met.*
3. *The 'country-specific residual grid mix, consumption mix' shall be used. Country-specific means the country in which the life cycle stage or activity occurs. This may be an EU country or non-EU country. The residual grid mix prevents double counting with the use of supplier-specific electricity mixes in (a) and (b).*
4. *As a last option, the average EU residual grid mix, consumption mix (EU-28 +EFTA), or region representative residual grid mix, consumption mix, shall be used.*

The environmental integrity of the use of supplier-specific electricity mix depends on ensuring that contractual instruments (for tracking) ***reliably and uniquely convey claims to consumers****. Without this, the study lacks the accuracy and consistency necessary to drive product/ corporate electricity procurement decisions and accurate consumer (buyer of electricity) claims. Therefore, a set of* ***minimum criteria*** *that relate to the integrity of the contractual instruments as reliable conveyers of environmental footprint information has been identified. They represent the minimum features necessary to use supplier-specific mix within PEF studies.*

<u>Set of minimum criteria to ensure contractual instruments from suppliers</u>

A supplier-specific electricity product/ mix may only be used if the user of the PCR ensures that the contractual instrument meets the criteria specified below. If contractual instruments do not meet the criteria, then country-specific residual electricity consumption-mix shall be used in the modelling.

The list of criteria below is based on the criteria of the GHG Protocol Scope 2 Guidance – An amendment to the GHG Protocol Corporate Standard – Mary Sotos – World Resource Institute. A contractual instrument used for electricity modelling shall:

Criterion 1 – Convey attributes

- *Convey the energy type mix associated with the unit of electricity produced.*

- *The energy type mix shall be calculated based on delivered electricity, incorporating certificates sourced and retired (obtained or acquired or withdrawn) on behalf of its customers. Electricity from facilities for which the attributes have been sold off (via contracts or certificates) shall be characterized as having the environmental attributes of the country residual consumption mix where the facility is located.*

Criterion 2 – Be a unique claim

- *Be the only instruments that carry the environmental attribute claim associated with that quantity of electricity generated.*
- *Be tracked and redeemed, retired, or cancelled by or on behalf of the company (e.g. by an audit of contracts, third party certification, or may be handled automatically through other disclosure registries, systems, or mechanisms).*

Criterion 3 – Be as close as possible to the period to which the contractual instrument is applied

Modelling 'country-specific residual grid mix, consumption mix':

Datasets for residual grid mix, consumption mix, per energy type, per country and per voltage are made available by data providers.

If no suitable dataset is available, the following approach should be used:

Determine the country consumption mix (e.g. X% of MWh produced with hydro energy, Y% of MWh produced with coal power plant) and combine them with LCI datasets per energy type and country/region (e.g. LCI dataset for the production of 1MWh hydro energy in Switzerland):

- *Activity data related to non-EU country consumption mix per detailed energy type shall be determined based on:*
    - *Domestic production mix per production technologies;*
    - *Import quantity and from which neighbouring countries;*
    - *Transmission losses;*
    - *Distribution losses;*
    - *Type of fuel supply (share of resources used, by import and / or domestic supply).*
      These data may be found in the publications of the International Energy Agency (IEA (www.iea.org).
- *Available LCI datasets per fuel technologies. The LCI datasets available are generally specific to a country or a region in terms of:*
    - *fuel supply (share of resources used, by import and/ or domestic supply);*
    - *energy carrier properties (e.g. element and energy contents);*
    - *technology standards of power plants regarding efficiency, firing technology, flue-gas desulphurisation, NOx removal and de-dusting.*

If the consumed electricity comes from more than one electricity mix, each mix source shall be used in terms of its proportion in the total kWh consumed. For example, if a fraction of this total kWh consumed is coming from a specific supplier a supplier-specific electricity mix shall be used for this part. See below for on-site electricity use.

A specific electricity type may be allocated to one specific product in the following conditions:

1. *If the production (and related electricity consumption) of a product occurs in a separate site (building), the energy type physical related to this separated site may be used.*

2. *If the production (and related electricity consumption) of a product occurs in a shared space with specific energy metering or purchase records or electricity bills, the product- specific information (measure, record, bill) may be used.*
3. *If all the products produced in the specific plant are supplied with a publicly available LCA study, the company wanting to make the claim shall make all LCA studies available. The allocation rule applied shall be described in the LCA study, consistently applied in all LCA studies connected to the site and verified. An example is the 100% allocation of a greener electricity mix to a specific product.*

When a product is produced in different locations, the ratios of production between EU countries/regions shall be reflected in the electricity modelling. Where such data are not available, the average EU mix (EU-28 +EFTA), or region representative mix, shall be used.

<u>On-site electricity generation:</u>

If on-site electricity production is equal to the site own consumption, two situations apply:

- *No contractual instruments have been sold to a third party: the own electricity mix (combined with LCI datasets) shall be modelled.*
- *Contractual instruments have been sold to a third party: the 'country-specific residual grid mix, consumption mix' (combined with LCI datasets) shall be used.*

If electricity is produced in excess of the amount consumed on-site within the defined system boundary and is sold to, for example, the electricity grid, this system may be seen as a multifunctional situation. The system will provide two functions (e.g. product + electricity) and the following rules shall be followed:

- *If possible, apply subdivision. Subdivision applies both to separate electricity productions or to a common electricity production where you may allocate based on electricity amounts the upstream and direct emissions to your own consumption and to the share you sell out of your company (e.g. if a company has a windmill on its production site and exports 30% of the produced electricity, emissions related to 70% of produced electricity should be accounted in the LCA study).*
- *If not possible, direct substitution shall be used. The country-specific residual consumption electricity mix shall be used as substitution[22].*
- *Subdivision is considered as not possible when upstream impacts or direct emissions are closely related to the product itself.*

5.9. CLIMATE CHANGE MODELLING

The impact category 'climate change' shall be modelled considering three sub-categories:

1. ***Climate change – fossil**: This sub-category includes emissions from peat and calcination/carbonation of limestone. The emission flows ending with '(fossil)' (e.g., 'carbon dioxide (fossil)' and 'methane (fossil)') shall be used, if available.*

2. ***Climate change – biogenic**: This sub-category covers carbon emissions to air (CO_2, CO and CH_4) originating from the oxidation and/or reduction of biomass by means of its transformation or degradation (e.g. combustion, digestion, composting, landfilling) and CO_2 uptake from the atmosphere through photosynthesis during biomass growth*

[22] For some countries, this option is a best case rather than a worst case.

– i.e. corresponding to the carbon content of products, biofuels or aboveground plant residues, such as litter and dead wood. Carbon exchanges from native forests[23] *shall be modelled under sub-category 3 (incl. connected soil emissions, derived products, residues). The emission flows ending with '(biogenic)' shall be used.*
A simplified modelling approach shall be used when modelling foreground emissions.
Only the emission 'methane (biogenic)' is modelled, while no further biogenic emissions and uptakes from atmosphere are included. If methane emissions can be both fossil or biogenic, the release of biogenic methane shall be modelled first and then the remaining fossil methane.

The biogenic carbon content at factory gate (physical content and allocated content) shall be reported as 'additional technical information'.

3. ***Climate change – land use and land use change****: This sub-category accounts for carbon uptakes and emissions (CO_2, CO and CH_4) originating from carbon stock changes caused by land use change and land use. This sub-category includes biogenic carbon exchanges from deforestation, road construction or other soil activities (including soil carbon emissions). For native forests, all related CO_2 emissions are included and modelled under this sub-category (including connected soil emissions, products derived from native forest*[24] *and residues), while their CO2 uptake is excluded. The emission flows ending with '(land use change)' shall be used.*

   For land use change, all carbon emissions and removals shall be modelled following the modelling guidelines of PAS 2050:2011 (BSI 2011) and the supplementary document PAS2050-1:2012 (BSI 2012) for horticultural products. PAS 2050:2011 (BSI 2011): "Large emissions of GHGs can result as a consequence of land use change. Removals as a direct result of land use change (and not as a result of long- term management practices) do not usually occur, although it is recognized that this could happen in specific circumstances. Examples of direct land use change are the conversion of land used for growing crops to industrial use or conversion from forestland to cropland. All forms of land use change that result in emissions or removals are to be included. Indirect land use change refers to such conversions of land use as a consequence of changes in land use elsewhere. While GHG emissions also arise from indirect land use change, the methods and data requirements for calculating these emissions are not fully developed. Therefore, the assessment of emissions arising from indirect land use change is not included.

   The GHG emissions and removals arising from direct land use change shall be assessed for any input to the life cycle of a product originating from that land and shall be included in the assessment of GHG emissions. The emissions arising from the product shall be assessed on the basis of the default land use change values provided in PAS 2050:2011 Annex C, unless better data is available. For countries and land use changes not included in this annex, the emissions arising from the product shall be assessed using the included GHG emissions and removals occurring as a result of direct land use change in accordance with the relevant sections of the IPCC (2006). The assessment of the impact of land use change shall include all direct land use change occurring not more than 20 years, or a single harvest period, prior to undertaking the assessment (whichever is the longer). The total GHG emissions and removals arising from direct land use change over the period shall be included in the quantification of GHG emissions of products arising from this land on the basis of equal allocation to each year of the period[25]*.*

[23] Native forests – represents native or long-term, non-degraded forests. Definition adapted from table 8 in Annex V C(2010)3751 to Directive 2009/28/EC.
[24] Following the instantaneous oxidation approach in IPCC 2013 (Chapter 2).
[25] In case of variability of production over the years, a mass allocation should be applied.

1. Where it can be demonstrated that the land use change occurred more than 20 years prior to the assessment being carried out, no emissions from land use change should be included in the assessment.
2. Where the timing of land use change cannot be demonstrated to be more than 20 years, or a single harvest period, prior to making the assessment (whichever is the longer), it shall be assumed that the land use change occurred on 1 January of either:
    - *the earliest year in which it can be demonstrated that the land use change had occurred; or*
    - *on 1 January of the year in which the assessment of GHG emissions and removals is being carried out.*

The following hierarchy shall apply when determining the GHG emissions and removals arising from land use change occurring not more than 20 years or a single harvest period, prior to making the assessment (whichever is the longer):
1. where the country of production is known and the previous land use is known, the GHG emissions and removals arising from land use change shall be those resulting from the change in land use from the previous land use to the current land use in that country (additional guidelines on the calculations can be found in PAS 2050- 1:2012);
2. where the country of production is known, but the former land use is not known, the GHG emissions arising from land use change shall be the estimate of average emissions from the land use change for that crop in that country (additional guidelines on the calculations can be found in PAS 2050-1:2012);
3. where neither the country of production nor the former land use is known, the GHG emissions arising from land use change shall be the weighted average of the average land use change emissions of that commodity in the countries in which it is grown.

Knowledge of the prior land use can be demonstrated using a number of sources of information, such as satellite imagery and land survey data. Where records are not available, local knowledge of prior land use can be used. Countries in which a crop is grown can be determined from import statistics, and a cut-off threshold of not less than 90% of the weight of imports may be applied. Data sources, location and timing of land use change associated with inputs to products shall be reported."

Soil carbon storage shall not be modelled, calculated and reported as additional environmental information.

The sum of the three sub-categories shall be reported.

The sub-category 'Climate change-biogenic' shall be reported separately.

The sub-category 'Climate change-land use and land transformation' shall be reported separately[26].

Credits associated with temporary and permanent carbon storage and/or delayed emissions shall not be considered in the calculation of the climate change indicator. This means that all emissions and removals shall be accounted for as emitted "now" and there is no discounting of emissions over time (in line with ISO 14067:2018).

[26] Even though for the contribution of 'climate change – biogenic' and 'climate change - land use and land use change' to climate change is less than 5% for the representative product, it is requested to report the sub-categories separately. The reason is that the contribution of 'climate change - land use and land use change' is more than 5% for two products (bran and wheat germs).

5.10. Modelling of end of life and recycled content

This is mainly relevant for the packaging of starch products. Most of the starch industry products are not packed, and the impact of packaging of the representative product was very low (below cut-off and can be excluded). Nevertheless, if for a specific product packaging is believed to be important, it may be included.

Overall, this should be modelled and reported at the life cycle stage where the waste occurs. This section provides rules on how to model the end of life of packaging as well as the recycled content.

The Circular Footprint Formula (CFF) is used to model the end of life of products as well as the recycled content and is a combination of "material + energy + disposal", i.e.:

Material

$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy $(1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$

Disposal $(1 - R_2 - R_3) \times E_D$

With the following parameters
A: *allocation factor of burdens and credits between supplier and user of recycled materials.*
B: *allocation factor of energy recovery processes. It applies both to burdens and credits. It shall be set to zero for all PEF studies.*
Qs_{in}: *quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.*
Qs_{out}: *quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.*
Q_p: *quality of the primary material, i.e. quality of the virgin material.*
R_1: *it is the proportion of material in the input to the production that has been recycled from a previous system.*
R_2: *it is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R_2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R_2 shall be measured at the output of the recycling plant. R_2 shall be set to zero for the starch products packaging waste, as the use phase is not included. R_2 shall also be set to zero in case the CFF formula is used for a starch product itself (e.g. if used in paper production), as the end of life of the product shall not be accounted for.*
R_3: *it is the proportion of the material in the product that is used for energy recovery at EoL. R_3 shall be set to zero for the starch products packaging waste, as the use phase is not included. R_3 shall also be set to zero in case the CFF formula is used for a starch product itself (e.g. if used in paper production), as the end of life of the product shall not be accounted for.*
$E_{recycled}$ (E_{rec}): *specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.*
$E_{recyclingEoL}$ (E_{recEoL}): *specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.*
E_V: *specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.*
E^*_V: *specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.*
E_{ER}: *specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.).*
$E_{SE,heat}$ and $E_{SE,elec}$: *specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.*

***E_D:** specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery. E_D shall be set to zero for the starch products packaging waste, as the use phase is not included. E_D shall also be set to zero in case the CFF formula is used for a starch product itself (e.g. if used in paper production), as the end of life of the product shall not be accounted for.*
***$X_{ER,heat}$ and $X_{ER,elec}$:** the efficiency of the energy recovery process for both heat and electricity.*
***LHV:** lower heating value of the material in the product that is used for energy recovery.*

Annex C of the PEF method provides default:

- A values. *If an application-specific or material-specific A value is not available, the A value shall be set equal to 0.5.*
- Quality ratios (Qsin, Qsout/Qp)
- R_1 values. *They shall be set to 0% when no application-specific data is available.*
- R_2 values

<u>Modelling recycled content (applicable for packaging only)</u>

The following part of the Circular Footprint Formula is used to model the recycled content:

$$(1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{Sin}}{Q_p}\right)$$

The R_1 values applied shall be supply-chain specific or default as provided in Annex C of the PEF method, in relation with the DNM. Material-specific values based on supply market statistics are not accepted as a proxy and therefore shall not be used.

When using supply-chain specific R_1 values other than 0, traceability throughout the supply chain is necessary. The following guidelines shall be followed when using supply-chain specific R_1 values:

- *The supplier information (through e.g., statement of conformity or delivery note) shall be maintained during all stages of production and delivery at the converter;*
- *Once the material is delivered to the converter for production of the end products, the converter shall handle information through their regular administrative procedures;*
- *The converter for production of the end products claiming recycled content shall demonstrate through its management system the [%] of recycled input material into the respective end product(s).*
- *The latter demonstration shall be transferred upon request to the user of the end product. In case an environmental profile is calculated and reported, this shall be stated as additional technical information of the environmental profile.*
- *Company-owned traceability systems may be applied as long as they cover the general guidelines outlined above.*

6. LIFE CYCLE STAGES

6.1. RAW MATERIAL ACQUISITION AND PRE-PROCESSING

This life cycle stage consists of the cultivation of plant-based ingredients and of the transportation of crops to Starch companies. Company specific activity data are mandatory for these processes, however, the background data will consist of secondary data. Secondary datasets on plant cultivation shall be taken from the Agri-footprint® 5.0 database – economic allocation (Paassen et al., 2019). Secondary datasets on transportation shall be taken from the EF database. The default datasets,

amounts per FU and DQR are provided in the excel file *"PCR for starch industry products_2.1 - Life cycle inventory"*.
Packaging of starch industry products shall be modelled as part of the raw material acquisition stage of the life cycle[27]. Packaging of the starch industry products may be excluded according to this PCR based on the cut-off rule.

For the different ingredients transported from supplier to factory, the user of the PCR needs data on (i) transport mode, (ii) distance per transport mode, (iii) utilisation ratios for truck transport and (iv) empty return modelling for truck transport.

The user of the PCR shall always check the utilisation ratio applied in the default dataset and adapt it accordingly.

The user of the PCR shall report the DQR values (for each criterion + total) for all the datasets used.

6.2. AGRICULTURAL MODELLING

Agri-footprint® 5.0 economic allocation (Paassen et al., 2019) appears to comply to all modelling guidelines of the PEF method. 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)."

Handling multi-functional processes: The rules described in the LEAP guidelines shall be followed: 'Environmental performance of animal feeds supply chains (pages 36-43), FAO 2015, available at http://www.fao.org/partnerships/leap/publications/en/'.

Use of crop type specific and country-, region- or climate-specific data for yield, water and land use, land use change, fertiliser (artificial and organic) amount (N, P amount) and pesticide amount (per active ingredient), per hectare per year, if available.

Cultivation data shall be collected over a period of time sufficient to provide an average assessment of the life cycle inventory associated with the inputs and outputs of cultivation that will offset fluctuations due to seasonal differences:

- *For annual crops, an assessment period of at least three years shall be used (to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests and diseases, etc.). Where data covering a three-year period is not available i.e. due to starting up a new production system (e.g. new greenhouse, newly cleared land, shift to another crop), the assessment may be conducted over a shorter period, but shall be not less than 1 year. Crops/plants grown in greenhouses shall be considered as annual crops/plants, unless the cultivation cycle is significantly shorter than a year and another crop is cultivated consecutively within that year. Tomatoes, peppers and other crops which are cultivated and harvested over a longer period through the year are considered as annual crops.*
- *For crops that are grown and harvested in less than one year (e.g. lettuce produced in 2 to 4 months) data shall be gathered in relation to the specific time period for production of a single crop, from at least three recent consecutive cycles. Averaging over three years may best be done by first gathering annual data and calculating the life cycle inventory per year and then determining the three years average.*

[27] LCA studies including packaging and more specifically reusable packaging from third party operated pools shall provide reuse rates. LCA studies with company-owned packaging pools shall calculate the reuse rate by using supply-chain-specific data only. The raw material consumption of reusable packaging shall be calculated by dividing the actual weight of the packaging by the reuse rate.

Pesticide emissions shall be modelled as specific active ingredients. As a default approach, pesticides applied on the field shall be modelled as 90% emitted to the agricultural soil compartment, 9% emitted to air and 1% emitted to water.

Fertiliser (and manure) emissions shall be differentiated per fertilizer type and cover as a minimum:

- *NH_3, to air (from N-fertiliser application)*
- *N_2O, to air (direct and indirect) (from N-fertiliser application)*
- *CO_2, to air (from lime, urea and urea-compounds application)*
- *NO_3, to water unspecified (leaching from N-fertiliser application)*
- *PO_4, to water unspecified or freshwater (leaching and run-off of soluble phosphate from P-fertiliser application)*
- *P, to water unspecified or freshwater (soil particles containing phosphorous, from P- fertiliser application).*

The LCI for P emissions should be modelled as the amount of P emitted to water after run-off and the emission compartment 'water' shall be used. When this amount is not available, the LCI may be modelled as the amount of P applied on the agricultural field (through manure or fertilisers) and the emission compartment 'soil' shall be used. In this case, the run-off from soil to water is part of the impact assessment method.

The LCI for N emissions shall be modelled as the amount of emissions after it leaves the field (soil) and ending up in the different air and water compartments per amount of fertilisers applied. N emissions to soil shall not be modelled. The nitrogen emissions shall be calculated from nitrogen applications of the farmer on the field and excluding external sources (e.g. rain deposition).

For Nitrogen-based fertilisers, the Tier 1 emissions factors of Table 2-4 of IPCC 2006 shall be used, as reproduced in Table 14, except when better data is available. In case better data is available, a more comprehensive nitrogen field model may be used in the LCA study, provided (i) it covers at least the emissions requested above, (ii) nitrogen shall be balanced in inputs and outputs and (iii) it shall be described in a transparent way.

Table 14: Parameters to be used when modelling nitrogen emission in soil

Emission	***Compartment***	***Value to be applied***
N_2O (synthetic fertiliser and manure; direct and indirect)	*Air*	*0.022 kg N_2O/ kg N fertilizer applied*
NH_3 (synthetic fertiliser)	*Air*	*kg NH_3= kg N * FracGASF= 1*0.1* (17/14) =* *0.12 kg NH_3/ kg N fertilizer applied*
NH_3 (manure)	*Air*	*kg NH_3= kg N*FracGASF= 1*0.2* (17/14) =* *0.24 kg NH_3/ kg N manure applied*
NO_3^- (synthetic fertiliser andmanure)	*Water*	*kg NO_3^-= kg N*FracLEACH = 1*0.3*(62/14) =* *1.33 kg NO_3^-/ kg N applied*
P based fertilisers	*Water*	*0.05 kg P/ kg P applied*

FracGASF: fraction of synthetic fertiliser N applied to soils that volatilises as NH_3 and NO_x.
FracLEACH: fraction of synthetic fertiliser and manure lost to leaching and runoff as NO_3-.

Heavy metal emissions from field inputs shall be modelled as emission to soil and/or leaching or erosion to water. The inventory to water shall specify the oxidation state of the metal (e.g., Cr^{+3}, Cr^{+6}). As crops assimilate part of the heavy metal emissions during their cultivation, clarification is needed on how to model crops that act as a sink. The following modelling approach shall be used:

- *The final fate of the heavy metals elementary flows are not further considered within the system boundary: the inventory does not account for the final emissions of the heavy metals and therefore shall not account for the uptake of heavy metals by the crop[28]. For example, heavy metals in agricultural crops cultivated for human consumption end up in the plant. Within the EF context human consumption is not modelled, the final fate is not further modelled and the plant acts as a heavy metal sink. Therefore, the uptake of heavy metals by the crop shall not be modelled.*

Methane emissions from rice cultivation shall be included on basis of IPCC 2006 calculation rules.

Drained peat soils shall include carbon dioxide emissions on the basis of a model that relates the drainage levels to annual carbon oxidation.

The following activities shall be included:

- *Input of seed material (kg/ha)*
- *Input of lime (kg $CaCO_3$/ha, type)*
- *Input of fertilisers and pesticides (kg/ha)*
- *Input N from crop residues that stay on the field or are burned (kg residue + N content/ha)*
- *Input of irrigation water*
- *Land use and land use change*
- *Emissions to air, water and soil*
- *Crop yield (kg/ha)*
- *Drying and storage of products*
- *Field operations through total fuel consumption and machine production, transports to/ from the field and energy for irrigation.*

6.3. MANUFACTURING

The processes taking place in this life cycle stage are:

- PRODUCTION OF STARCH SLURRY AND CO-PRODUCTS FROM WHEAT;
- PRODUCTION OF STARCH SLURRY AND CO-PRODUCTS FROM MAIZE;
- PRODUCTION OF STARCH SLURRY AND CO-PRODUCTS FROM POTATOES
- PRODUCTION OF LIQUID GLUCOSE, LIQUID/DRY SORBITOL, UNFERMENTED SPECIAL POLYOLS, MALTODEXTRINS AND DRY CRYSTALLIZED DEXTROSE
- PRODUCTION OF NATIVE STARCH AND DEXTRINS
- PRODUCTION OF MODIFIED STARCH (EXCLUDING DEXTRINS)
- PRODUCTION OF POTABLE ALCOHOL AND BROTH

[28] The Agri-footprint® 5.0 database does take uptake into account. It is however not possible to change this in the dataset. This issue will be solved, once the EF database is made publicly available.

The default datasets, amounts per FU and DQR are provided in the excel file "PCR for starch industry products_2.1 - Life cycle inventory".

According to this PCR, the following processes may be excluded based on the cut-off rule: capital goods for the manufacturing processes of the starch industry, packaging of incoming auxiliary materials[29], storage at warehouses, resources and tools for logistic operations at the starch plants and process waste (except wastewater, which needs to be included). No additional cut-off is allowed.

The user of the PCR shall report the DQR values (for each criterion + total) for all the datasets used.

The waste of products used during the manufacturing shall be included in the modelling.

6.4. DISTRIBUTION STAGE

Transport from factory to final client (including consumer transport) shall be modelled within this life cycle stage. The final client is defined as the food producer, feed producer or other industry that uses the product of the starch industry in their production processes.

In case supply-chain-specific information is available for one or several transport parameters, they may be applied following the Data Needs Matrix.

Because of the high relevance of distribution in the total environmental impact of starch products, collecting of company specific data is mandatory for the distribution stage. Care shall be taken about the application of a factor to correct for the dry substance (FU is expressed per tonne dry substance).

The user of the PCR shall report the DQR values (for each criterion + total) for all the datasets used.

The default transport data used to calculate the sector average environmental profiles are provided in Table 15. Distances are taken from Zampori and Pant (2019), the division between national, intra EU and extra EU has been calculated based on production, import, export and EU trade data from Eurostat.

Table 15: Default distribution data

National distribution	**16% * 12000 km by truck (>32 t, EURO4)**
Intra EU distribution	60% * 3500 km by truck (>32 t, EURO4)
Extra EU distribution	20% * 1000 km by truck (> 32t, EURO4) and 18000 km by transoceanic container ship

The waste of products during distribution and retail shall be included in the modelling.

A default loss rate of 2% shall be applied. This is the default loss rate for grain products mentioned in Annex F of Zampori and Pant (2019).

7. LCA RESULTS

7.1. REPRESENTATIVE PRODUCT

The representative product is a virtual starch industry product, composed of all products covered by this PCR (see section 3.2). This is not a benchmark and cannot be used for comparison, as comparing at the level of intermediate products shall not be done without considering the function. However, the results give an indication of the order of magnitude to expect. Characterised, normalised and weighted results are provided in the tables below.

Table 16: Characterised results for the representative product (virtual starch industry product)

[29] LCA studies including packaging and more specifically reusable packaging shall account for the additional energy and resource used for cleaning, repairing or refilling.

Impact category	Unit	Total life cycle	Total excl. distribution
Climate change, total	kg CO_2 eq	1,3E+03	9,9E+02
Climate change - fossil		1,3E+03	9,6E+02
Climate change - biogenic		2,1E+00	1,6E+00
Climate change – land use and land use change		3,4E+01	3,2E+01
Ozone depletion	kg CFC-11 eq	3,5E-05	3,5E-05
Particulate matter	disease incidence	1,0E-04	7,3E-05
Ionising radiation, human health	kBq U^{235} eq	7,5E+01	7,4E+01
Photochemical ozone formation, human health	kg NMVOC eq	5,1E+00	1,6E+00
Acidification	mol H+ eq	1,3E+01	9,0E+00
Eutrophication, terrestrial	mol N eq	5,5E+01	3,9E+01
Eutrophication, freshwater	kg P eq	1,7E-01	1,6E-01
Eutrophication, marine	kg N eq	1,2E+01	1,1E+01
Human toxicity, cancer	CTUh	9,3E-07	8,7E-07
Human toxicity, non-cancer	CTUh	3,4E-05	3,2E-05
Ecotoxicity	CTUe	8,3E+04	7,9E+04
Land use	Dimensionless (pt)	7,9E+04	7,7E+04
Water use	m^3 world eq	1,3E+03	1,3E+03
Resource use, minerals and metals	kg Sb eq	3,8E-04	3,6E-04
Resource use, fossils	MJ	1,6E+04	1,2E+04

Table 17: Normalised results for the representative product (virtual starch industry product)

Impact category	Total life cycle	Total excl. distribution
Climate change, total	1,7E-01	1,2E-01
Climate change - fossil	1,6E-01	1,2E-01
Climate change - biogenic	2,6E-04	2,0E-04
Climate change – land use and land use change	4,2E-03	4,0E-03
Ozone depletion	6,6E-04	6,6E-04
Particulate matter	1,7E-01	1,2E-01
Ionising radiation, human health	1,8E-02	1,8E-02
Photochemical ozone formation, human health	1,2E-01	4,0E-02
Acidification	2,4E-01	1,6E-01
Eutrophication, terrestrial	3,1E-01	2,2E-01
Eutrophication, freshwater	1,0E-01	1,9E+00
Eutrophication, marine	6,2E-01	5,5E-01
Human toxicity, cancer	5,5E-02	5,2E-02
Human toxicity, non-cancer	1,5E-01	1,4E-01
Ecotoxicity	1,9E+00	1,9E+00
Land use	9,6E-02	9,4E-02

Water use	1,2E-01	1,2E-01
Resource use, minerals and metals	6,0E-03	5,6E-03
Resource use, fossils	2,5E-01	1,8E-01

Table 18: Weighted results for the representative product (virtual starch industry product), in mPt

Impact category	**Total life cycle**	**Total excl. distribution**
Climate change, total	3,5E+01	1,5E+02
Climate change - fossil	3,4E+01	2,5E+01
Climate change - biogenic	5,6E-02	4,3E-02
Climate change – land use and land use change	8,9E-01	8,4E-01
Ozone depletion	4,1E-02	4,1E-02
Particulate matter	1,5E+01	1,1E+01
Ionising radiation, human health	8,9E-01	8,8E-01
Photochemical ozone formation, human health	6,0E+00	1,9E+00
Acidification	1,5E+01	1,0E+01
Eutrophication, terrestrial	1,2E+01	8,1E+00
Eutrophication, freshwater	2,9E+00	2,8E+00
Eutrophication, marine	1,8E+01	1,6E+01
Human toxicity, cancer	1,2E+00	1,1E+00
Human toxicity, non-cancer	2,7E+00	2,5E+00
Ecotoxicity	3,7E+01	3,6E+01
Land use	7,6E+00	7,5E+00
Water use	1,0E+01	9,9E+00
Resource use, minerals and metals	4,5E-01	4,2E-01
Resource use, fossils	2,1E+01	1,5E+01
Total	**1,9E+02**	**1,5E+02**

7.2. ENVIRONMENTAL PROFILE

The user of the PCR shall calculate the environmental profile of its product in compliance with all requirements included in this PCR. The following information shall be included in the LCA report:

- *full life cycle inventory;*
- *characterised results in absolute values, for all impact categories (as a table);*
- *normalised results in absolute values, for all impact categories (as a table);*
- *weighted result in absolute values, for all impact categories (as a table);*
- *the aggregated single overall score in absolute values.*

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ANNEXES

ANNEX 1 – ACRONYMS AND DEFINITIONS

Acronyms

AF	allocation factor
AR	allocation ratio
B2B	business to business
B2C	business to consumer
BoC	bill of components
BoM	bill of materials
BSI	British Standards Institution
CF	characterization factor
CFCs	Chlorofluorocarbons
CFF	Circular Footprint Formula
CPA	Classification of Products by Activity
DC	distribution centre
DMI	dry matter intake
DNM	Data Needs Matrix
DQR	Data Quality Rating
EC	European Commission
EF	Environmental Footprint
EI	environmental impact
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management Systems
EoL	End of life
EPD	Environmental Product Declaration
FU	functional unit
GE	gross energy intake
GHG	greenhouse gas
GR	geographical representativeness
GRI	Global Reporting Initiative
GWP	global warming potential
ILCD	International Reference Life Cycle Data System
ILCD-EL	International Reference Life Cycle Data System – Entry Level
IPCC	Intergovernmental Panel on Climate Change
ISIC	international standard industrial classification
ISO	International Organisation for Standardisation
IUCN	International Union for Conservation of Nature and Natural Resources
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCDN	Life Cycle Data Network
LCI	life cycle inventory
LCIA	life cycle impact assessment
LCT	life cycle thinking
LT	lifetime
NACE	Nomenclature Générale des Activités Economiques dans les Communautés Européennes
NDA	non-disclosure agreement
NGO	non-governmental organisation

NMVOC	non-methane volatile compounds
P	precision
PAS	Publicly Available Specification
PCR	Product Category Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PEF-RP	PEF study of the representative product
RF	reference flow
RP	representative product
SB	system boundary
SMRS	sustainability measurement & reporting system
SS	supporting study
TeR	technological representativeness
TiR time	representativeness
TS	Technical Secretariat
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

Definitions

Activity data - This term refers to information which is associated with processes while modelling Life Cycle Inventories (LCI). The aggregated LCI results of the process chains that represent the activities of a process are each multiplied by the corresponding activity data[30] and then combined to derive the environmental footprint associated with that process. Examples of activity data include quantity of kilowatt-hours of electricity used, quantity of fuel used, output of a process (e.g. waste), number of hours equipment is operated, distance travelled, floor area of a building, etc. Synonym of "non-elementary flow.

Acidification - EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of NOx, NH_3 and SOx lead to releases of hydrogen ions (H+) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

Additional environmental information - Environmental information outside the EF impact categories that is calculated and communicated alongside PEF results.

Additional technical information - Non-environmental information that is calculated and communicated alongside LCA results.

Aggregated dataset - Complete or partial life cycle of a product system that next to the elementary flows (and possibly not relevant amounts of waste flows and radioactive wastes) lists in the input/output list exclusively the product(s) of the process as reference flow(s), but no other goods or services. Aggregated datasets are also called "LCI results" datasets. The aggregated dataset may have been aggregated horizontally and/or vertically.

Allocation - An approach to solving multi-functionality problems. It refers to "partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14040:2006).

Application specific - It refers to the generic aspect of the specific application in which a material is used. For example, the average recycling rate of PET in bottles.

Attributional - Refers to process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects.

Average Data - Refers to a production-weighted average of specific data.

Background processes - Refers to those processes in the product life cycle for which no direct access to information is possible. For example, most of the upstream life-cycle processes and generally all processes further downstream will be considered part of the background processes.

Benchmark - A standard or point of reference against which any comparison may be made. In the context of PEF, the term 'benchmark' refers to the average environmental performance of the representative product sold in the EU market.

Bill of materials - A bill of materials or product structure (sometimes bill of material, BOM or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture the product in scope of the PEF study. In some sectors it is equivalent to the bill of components.

Business to Business (B2B) - Describes transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

Business to Consumers (B2C) - Describes transactions between business and consumers, such as between retailers and consumers. According to ISO 14025:2006, a consumer is defined as "an

[30] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011).

individual member of the general public purchasing or using goods, property or services for private purposes".

Characterisation - Calculation of the magnitude of the contribution of each classified input/output to their respective EF impact categories, and aggregation of contributions within each category. This requires a linear multiplication of the inventory data with characterisation factors for each substance and EF impact category of concern. For example, with respect to the EF impact category "climate change", CO_2 is chosen as the reference substance and kg CO_2-equivalents as the reference unit.

Characterisation factor - Factor derived from a characterisation model which is applied to convert an assigned life cycle inventory result to the common unit of the EF impact category indicator (based on ISO 14040:2006).

Classification - Assigning the material/energy inputs and outputs tabulated in the life cycle inventory to EF impact categories according to each substance's potential to contribute to each of the EF impact categories considered.

Climate change - All inputs or outputs that result in greenhouse gas emissions. The consequences include increased average global temperatures and sudden regional climatic changes. Climate change is an impact affecting the environment on a global scale.

Co-function - Any of two or more functions resulting from the same unit process or product system.

Commissioner of the EF study - Organisation (or group of organisations) that finances the EF study in accordance with the PEF method and the relevant PEFCR, if available (definition adapted from ISO 14071/2014, point 3.4).

Company-specific data - It refers to directly measured or collected data from one or multiple facilities (site-specific data) that are representative for the activities of the company. It is synonymous to "primary data". To determine the level of representativeness a sampling procedure may be applied.

Company-specific dataset - It refers to a dataset (disaggregated or aggregated) compiled with company-specific data. In most cases the activity data is company-specific while the underlying sub-processes are datasets derived from background databases.

Comparative Assertion - An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category) (adapted from ISO 14044:2006).

Comparison - A comparison, not including a comparative assertion, (graphic or otherwise) of two or more products based on the results of a PEF study and supporting PEFCRs.

Co-product - Any of two or more products resulting from the same unit process or product system (ISO 14040:2006).

Cradle to Gate - A partial product supply chain, from the extraction of raw materials (cradle) up to the manufacturer's "gate". The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Cradle to Grave - A product's life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle.

Critical review - Process intended to ensure consistency between a PEFCR and the principles and requirements of the PEF method.

Data Quality - Characteristics of data that relate to their ability to satisfy stated requirements (ISO 14040:2006). Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.

Data Quality Rating (DQR) - Semi-quantitative assessment of the quality criteria of a dataset based on Technological representativeness, Geographical representativeness, Time-related representativeness, and Precision. The data quality shall be considered as the quality of the dataset as documented.

Delayed emissions - Emissions that are released over time, e.g. through long use or final disposal stages, versus a single emission at time t.

Direct elementary flows (also named elementary flows) - All output emissions and input resource use that arise directly in the context of a process. Examples are emissions from a chemical process, or fugitive emissions from a boiler directly onsite.

Direct land use change (dLUC) - The transformation from one land use type into another, which takes place in a unique land area and does not lead to a change in another system.

Directly attributable - Refers to a process, activity or impact occurring within the defined system boundary.

Disaggregation - The process that breaks down an aggregated dataset into smaller unit process datasets (horizontal or vertical). The disaggregation may help making data more specific. The process of disaggregation should never compromise or threat to compromise the quality and consistency of the original aggregated dataset

Downstream - Occurring along a product supply chain after the point of referral.

Ecotoxicity, freshwater - Environmental footprint impact category that addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Ecotoxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.

EF communication vehicles - It includes all the possible ways that may be used to communicate the results of the EF study to the stakeholders (e.g. labels, environmental product declarations, green claims, websites, infographics, etc.).

EF compliant dataset - Dataset developed in compliance with the EF requirements provided at http://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml.

Electricity tracking - Electricity tracking is the process of assigning electricity generation attributes to electricity consumption.

Elementary flows - In the life cycle inventory, elementary flows include “material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation” (ISO 14040, 3.12). Elementary flows include, for example, resources taken from nature or emissions into air, water, soil that are directly linked to the characterisation factors of the EF impact categories.

Environmental aspect - Element of an organisation’s activities or products or services that interacts or can interact with the environment (ISO 14001:2015).

Environmental Footprint (EF) Impact Assessment - Phase of the PEF analysis aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product (based on ISO 14044:2006). The impact assessment methods provide impact characterisation factors for elementary flows in order to aggregate the impact to obtain a limited number of midpoint indicators.

Environmental Footprint (EF) Impact Assessment method - Protocol for quantitative translation of life cycle inventory data into contributions to an environmental impact of concern.

Environmental Footprint (EF) Impact Category - Class of resource use or environmental impact to which the life cycle inventory data are related.

Environmental Footprint (EF) impact category indicator - Quantifiable representation of an EF impact category (based on ISO 14000:2006).

Environmental impact - Any change to the environment, whether adverse or beneficial, that wholly or partially results from an organisation's activities, products or services (EMAS regulation).

Environmental mechanism - System of physical, chemical and biological processes for a given EF impact category linking the life cycle inventory results to EF category indicators (based on ISO 14040:2006).

Eutrophication - Nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure expressed as the oxygen required for the degradation of dead biomass. Three EF impact categories are used to assess the impacts due to eutrophication: Eutrophication, terrestrial; Eutrophication, freshwater; Eutrophication, marine.

External Communication - Communication to any interested party other than the commissioner or the practitioner of the study.

Extrapolated Data - Refers to data from a given process that is used to represent a similar process for which data is not available, on the assumption that it is reasonably representative.

Flow diagram - Schematic representation of the flows occurring during one or more process stages within the life cycle of the product being assessed.

Foreground elementary flows - Direct elementary flows (emissions and resources) for which access to primary data (or company-specific information) is available.

Foreground Processes - Refer to those processes in the product life cycle for which direct access to information is available. For example, the producer's site and other processes operated by the producer or its contractors (e.g. goods transport, head-office services, etc.) belong to the foreground processes.

Functional unit - The functional unit defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions "what?", "how much?", "how well?", and "for how long?".

Gate to Gate - A partial product supply chain that includes only the processes carried out on a product within a specific organisation or site.

Gate to Grave - A partial product supply chain that includes only the distribution, storage, use, and disposal or recycling stages.

Global warming potential - Capacity of a greenhouse gas to influence radiative forcing, expressed in terms of a reference substance (for example, CO2-equivalent units) and specified time horizon **(**e.g. GWP 20, GWP 100, GWP 500, for 20, 100, and 500 years respectively)**.** It relates to the capacity to influence changes in the global average surfaceair temperature and subsequent change in various climate parameters and their effects, such as storm frequency and intensity, rainfall intensity and frequency of flooding, etc.

Horizontal averaging - it is the action of aggregating multiple unit process datasets or aggregated process datasets in which each provides the same reference flow in order to create a new process dataset (UN Environment, 2011).

Human toxicity - cancer - EF impact category that accounts for adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to cancer.

Human toxicity - non cancer - EF impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to noncancer effects that are not caused by particulate matter/respiratory inorganics or ionising radiation.

Independent external expert - Competent person, not employed in a full-time or parttime role by the commissioner of the EF study or the user of the EF method, and not involved in defining the scope or conducting the EF study (adapted from ISO 14071/2014, point 3.2).

Indirect land use change (iLUC) - It occurs when a demand for a certain land use leads to changes, outside the system boundary, i.e. in other land use types. These indirect effects may be mainly assessed by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale.

Input flows - Product, material or energy flow that enters a unit process. Products and materials include raw materials, intermediate products and co-products (ISO 14040:2006).

Intermediate product - Output form a unit process that is input to other unit processes that require further transformation within the system (ISO 14040:2006). An intermediate product is a product that requires further processing before it is saleable to the final consumer.

Ionising radiation, human health - EF impact category that accounts for the adverse health effects on human health caused by radioactive releases.

Land use - EF impact category related to use (occupation) and conversion (transformation) of land area by activities such as agriculture, forestry, roads, housing, mining, etc. Land occupation considers the effects of the land use, the amount of area involved and the duration of its occupation (changes in quality multiplied by area and duration). Land transformation considers the extent of changes in land properties and the area affected (changes in quality multiplied by the area).

Lead verifier - Verifier taking part in a verification team with additional responsibilities compared to the other verifiers in the team.

Life cycle - Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal (ISO 14040:2006).

Life cycle approach - Takes into consideration the spectrum of resource flows and environmental interventions associated with a product from a supply-chain perspective, including all stages from raw material acquisition through processing, distribution, use, and end of life processes, and all relevant related environmental impacts (instead of focusing on a single issue).

Life cycle Assessment (LCA) - Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040:2006).

Life cycle impact assessment (LCIA) - Phase of life cycle assessment that aims at understanding and evaluating the magnitude and significance of the potential environmental impacts for a system throughout the life cycle (ISO 14040:2006). The LCIA methods used provide impact characterisation factors for elementary flows to in order to aggregate the impact to obtain a limited number of midpoint and/or damage indicators.

Life cycle inventory (LCI) - The combined set of exchanges of elementary, waste and product flows in a LCI dataset.

Life cycle inventory (LCI) dataset - A document or file with life cycle information of a specified product or other reference (e.g., site, process), covering descriptive metadata and quantitative life cycle inventory. A LCI dataset could be a unit process dataset, partially aggregated or an aggregated dataset.

Loading rate - Ratio of actual load to the full load or capacity (e.g. mass or volume) that a vehicle carries per trip.

Material-specific - It refers to a generic aspect of a material. For example, the recycling rate of PET.

Multi-functionality - If a process or facility provides more than one function, i.e. it delivers several goods and/or services ("co-products"), then it is “multifunctional”. In these situations, all inputs and emissions linked to the process will be partitioned between the product of interest and the other co-products according to clearly stated procedures.

Non-elementary (or complex) flows - In the life cycle inventory, non-elementary flows include all the inputs (e.g. electricity, materials, transport processes) and outputs (e.g. waste, co-products) in a system that need further modelling efforts to be transformed into elementary flows. Synonym of activity data.

Normalisation - After the characterisation step, normalisation is the step in which the life cycle impact assessment results are multiplied 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. When displaying the normalised life cycle impact assessment results of the different impact topics next to each other, it becomes evident which impact categories are affected most and least by the analysed system. Normalised life cycle impact assessment results reflect only the contribution of the analysed system to the total impact potential, not the severity/relevance of the respective total impact. Normalised results are dimensionless, but not additive.

Output flows - Product, material or energy flow that leaves a unit process. Products and materials include raw materials, intermediate products, co-products and releases (ISO 14040:2006).

Ozone depletion - EF impact category that accounts for the degradation of stratospheric ozone due to emissions of ozone-depleting substances, for example long-lived chlorine and bromine containing gases (e.g. CFCs, HCFCs, Halons).

Partially disaggregated dataset - A dataset with a LCI that contains elementary flows and activity data, and that only in combination with its complementing underlying datasets yield a complete aggregated LCI data set.

Partially disaggregated dataset at level-1 - A partially disaggregated dataset at level- 1 contains elementary flows and activity data of one level down in the supply chain, while all complementing underlying datasets are in their aggregated form.

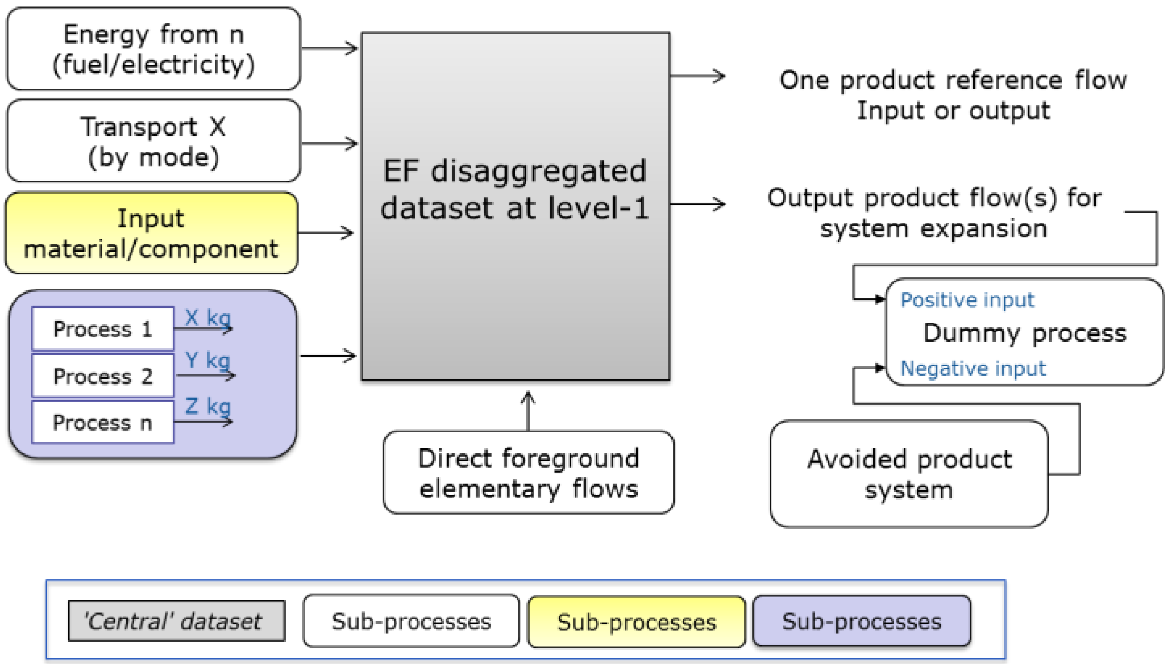

Figure 8: Example of dataset partially disaggregated at Level-1

Particulate Matter - EF impact category that accounts for the adverse health effects on human health caused by emissions of Particulate Matter (PM) and its precursors (NOx, SOx, NH_3).

PEFCR supporting study - PEF study based on a draft PEFCR. It is used to confirm the decisions taken in the draft PEFCR before the final PEFCR is released.

PEF profile - The quantified results of a PEF study. It includes the quantification of the impacts for the various impact categories and the additional environmental information considered necessary to report.

PEF report - Document that summarises the results of the PEF study.

PEF study of the representative product (PEF-RP) - PEF study carried out on the representative product(s) and intended to identify the most relevant life cycle stages, processes, elementary flows, impact categories and any other major requirements needed for the definition of the benchmark for the product category/ sub-categories in scope of the PEFCR.

PEF study - Term used to identify the totality of actions needed to calculate the PEF results. It includes the modelling, the data collection, and the analysis of the results. It excludes the PEF report and the verification of the PEF study and report.

Photochemical ozone formation - EF impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight. High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials through reaction with organic materials.

Population - Any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study.

Primary data[31] - This term refers to data from specific processes within the supply chain of the user of the PEF method or user of the PEFCR. Such data may take the form of activity data, or foreground

[31] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011).

elementary flows (life cycle inventory). Primary data are site-specific, company-specific (if multiple sites for the same product) or supply chain specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the user of the PEF method or user of the PEFCR. In this method, primary data is synonym of "company-specific data" or "supply-chain specific data".

Product - Any goods or services (ISO 14040:2006).

Product category - Group of products (or services) that can fulfil equivalent functions (ISO 14025:2006).

Product Category Rules (PCRs) - Set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories (ISO 14025:2006).

Product Environmental Footprint Category Rules (PEFCRs) - Product category specific, life cycle based rules that complement general methodological guidance for PEF studies by providing further specification at the level of a specific product category. PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the PEF method. Only the PEFCRs listed on the European Commission website (http://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm) are recognised as in line with this method.

Product flow - Products entering from or leaving to another product system (ISO 14040:2006).

Product system - Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product (ISO 14040:2006).

Raw material - Primary or secondary material that is used to produce a product (ISO 14040:2006).

Reference flow - Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit (based on ISO 14040:2006).

Releases - Emissions to air and discharges to water and soil (ISO 14040:2006).

Representative product (model) - The RP may be a real or a virtual (non-existing) product. The virtual product should be calculated based on average European market salesweighted characteristics of all existing technologies/materials covered by the product category or sub-category. Other weighting sets may be used, if justified, for example weighted average based on mass (ton of material) or weighted average based on product units (pieces).

Representative sample - A representative sample with respect to one or more variables is a sample in which the distribution of these variables is exactly the same (or similar) as in the population from which the sample is a subset.

Resource use, fossil - EF impact category that addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).

Resource use, minerals and metals - EF impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals).

Sample - A sample is a subset containing the characteristics of a larger population. Samples are used in statistical testing when population sizes are too large for the test to include all possible members or observations. A sample should represent the whole population and not reflect bias toward a specific attribute.

Secondary data[32] - It refers to data not from a specific process within the supply-chain of the company performing a PEF study. This refers to data that is not directly collected, measured, or estimated by the company, but sourced from a third party LCI database or other sources. Secondary data includes industry average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and may also be based on financial data, and contain proxy data, and other generic data. Primary data that go through a horizontal aggregation step are considered as secondary data.

Sensitivity analysis - Systematic procedures for estimating the effects of the choices made regarding methods and data on the results of a PEF study (based on ISO 14040: 2006).

Site-specific data - It refers to directly measured or collected data from one facility (production site). It is synonymous to “primary data”.

Specific Data - Refers to directly measured or collected data representative of activities at a specific facility or set of facilities. Synonymous with “primary data.”

Subdivision - Subdivision refers to disaggregating multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. The process is investigated to see whether it may be subdivided. Where subdivision is possible, inventory data should be collected only for those unit processes directly attributable to the products/services of concern.

Sub-population - Any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study that constitutes a homogenous sub-set of the whole population. Synonymous with “stratum”.

Sub-processes - Those processes used to represent the activities of the level 1 processes (=building blocks). Sub-processes may be presented in their (partially) aggregated form (see Figure 1).

Sub-sample - A sample of a sub-population.

Supply chain - It refers to all of the upstream and downstream activities associated with the operations of the user of the PEF method, including the use of sold products by consumers and the end of life treatment of sold products after consumer use.

Supply chain specific - It refers to a specific aspect of the specific supply chain of a company. For example the recycled content value of an aluminium may produced by a specific company.

System boundary - Definition of aspects included or excluded from the study. For example, for a “cradle-to-grave” EF analysis, the system boundary includes all activities from the extraction of raw materials through the processing, distribution, storage, use, and disposal or recycling stages.

System boundary diagram - Graphic representation of the system boundary defined for the PEF study.

Temporary carbon storage - happens when a product reduces the GHGs in the atmosphere or creates negative emissions, by removing and storing carbon for a limited amount of time.

Type III environmental declaration - An environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information (ISO 14025:2006). The predetermined parameters are based on the ISO 14040 series of standards, which is made up of ISO 14040 and ISO 14044.

Uncertainty analysis - Procedure to assess the uncertainty in the results of a PEF study due to data variability and choice-related uncertainty.

Unit process - Smallest element considered in the LCI for which input and output data are quantified (based on ISO 14040:2006).

[32] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011)

Unit process, black box - Process chain or plant level unit process. This covers horizontally averaged unit processes across different sites. Covers also those multifunctional unit processes, where the different co-products undergo different processing steps within the black box, hence causing allocation problems for this dataset.

Unit process, single operation - Unit operation type unit process that cannot be further subdivided. Covers multi-functional processes of unit operation type.

Upstream - Occurring along the supply chain of purchased goods/ services prior to entering the system boundary.

User of the PEFCR - a stakeholder producing a PEF study based on a PEFCR.

User of the PEF method - a stakeholder producing a PEF study based on the PEF method.

User of the PEF results - a stakeholder using the PEF results for any internal or external purpose.

Verification - Conformity assessment process carried out by an environmental footprint verifier to demonstrate whether the PEF study has been carried out in compliance with the most updated version of the PEF method adopted by the Commission.

Validation - Confirmation by the environmental footprint verifier, that the information and data included in the PEF study, PEF report and the communication vehicles are reliable, credible and correct.

Validation statement - Conclusive document aggregating the conclusions from the verifiers or the verification team regarding the EF study. This document is mandatory and shall carry the electronic or handwritten signature of the verifier or, in case of a verification panel, of the lead verifier.

Verification report - Documentation of the verification process and findings, including detailed comments from the verifier(s), as well as the corresponding responses. This document is mandatory, but it may be confidential. The document shall carry the electronic or handwritten signature of the verifier, or in case of a verification panel, of the lead verifier.

Verification team - Team of verifiers that will perform the verification of the EF study, of the EF report and the EF communication vehicles.

Verifier - Independent external expert performing a verification of the EF study and eventually taking part in a verification team.

Vertical aggregation - Technical- or engineering-based aggregation refers to vertical aggregation of unit processes that are directly linked within a single facility or process train. Vertical aggregation involves combining unit process datasets (or aggregated process datasets) together linked by a flow (UN Environment, 2011).

Waste - Substances or objects which the holder intends or is required to dispose of (ISO 14040:2006).

Water use - It represents the relative available water remaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met. It assesses the potential of water deprivation, to either humans or ecosystems, building on the assumption that the less water remaining available per area, the more likely another user will be deprived (see also https://wulca-waterlca.org/aware/).

Weighting - Weighting is a step that supports the interpretation and communication of the results of the analysis. PEF results are 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 also summed across impact categories to obtain a single overall score.

ANNEX 2 – LIST OF EF NORMALISATION AND WEIGHTING FACTORS

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

The table below shows the list of normalisation and weighting factors that the user of the PCR shall apply.

Impact category	Unit	Normalisation factors (unit/person)	Weighting factors (%)
Climate change, total	kg CO2 eq	8,10E+03	21,06%
Ozone depletion	kg CFC-11 eq	5,36E-02	6,31%
Particulate matter	disease incidence	5,95E-04	8,96%
Ionising radiation, human health	kBq U^{235} eq	4,22E+03	5,01%
Photochemical ozone formation, human health	kg NMVOC eq	4,06E+01	4,78%
Acidification	mol H+ eq	5,56E+01	6,20%
Eutrophication, terrestrial	mol N eq	1,77E+02	3,71%
Eutrophication, freshwater	kg P eq	1,61E+00	2,80%
Eutrophication, marine	kg N eq	1,95E+01	2,96%
Human toxicity, cancer	CTUh	1,69E-05	2,13%
Human toxicity, non-cancer	CTUh	2,30E-04	1,84%
Ecotoxicity	CTUe	4,27E+04	1,92%
Land use	Dimensionless (pt)	8,19E+05	7,94%
Water use	m^3 world eq	1,15E+04	8,51%
Resource use, minerals and metals	kg Sb eq	6,36E-02	7,55%
Resource use, fossils	MJ	6,50E+04	8,32%

ANNEX 3 – LCA STUDY TEMPLATE

LCA Report

Starch industry product

Table of contents

Acronyms

[List in this section all the acronyms used in the LCA study. Those already included in the latest version of the PEF method shall be copied in their original form. The acronyms shall be provided in alphabetical order.]

Definitions

[List in this section all the definitions that are relevant for the LCA study. Those already included in the latest version of the PEF method shall be copied in their original form. The definitions shall be provided in alphabetical order.]

SUMMARY

[The summary shall include as a minimum the following elements:

- The goal and scope of the study, including relevant limitations and assumptions;
- A short description of the system boundary;
- Relevant statements about data quality,
- The main results of the LCIA: these shall be presented showing the results of all EF impact categories (characterized, normalized, weighted);
- A description of what has been achieved by the study, any recommendation made and conclusions drawn;

To the extent possible, the summary should be written with a non-technical audience in mind and should not be longer than 3-4 pages.]

GENERAL

[The information below should ideally be placed on the front-page of the study:

- Name of the product (including a photo),
- Product identification (e.g. model number),
- Product classification (CPA) based on the latest CPA list version available,
- Company presentation (name, geographic location),
- Date of publication of the LCA study (the date shall be written in extended format, e.g. 25 June 2015, to avoid confusion over the date format),
- Geographic validity of the LCA study (countries where the product is consumed/sold),
- Compliance with the PCR,
- Conformance to other documents,
- Name and affiliation of the verifier(s)]

GOAL OF THE STUDY

[Mandatory reporting elements include, as a minimum:

- Intended application(s);
- Reasons for carrying out the study;
- Target audience;
- Commissioner of the study;
- Methodological limitations;
- Identification of the verifier]

SCOPE OF THE STUDY

[The scope of the study shall identify the analysed system in detail and address the overall approach used to establish: i) functional unit and reference flow, ii) system boundary, iii) list of EF impact categories, iv) additional information (environmental and technical) iv) assumptions and limitations.]

Functional/declared unit and reference flow

[Provide the declared unit, as the functional unit cannot be defined (the product in scope is an intermediate product)

Provide reference flow]

System boundary

[This section shall include as a minimum:

- All life-cycle stages that are part of the product system. In case the naming of the default life cycle stages has changed, the user shall specify to which default life cycle stage it corresponds. Document and justify if life cycle stages were split and/or new ones were added.
- The main processes covered in each life cycle stage (details are in the LCI section 5). The co-products, co-products and waste streams of at least the foreground system shall be clearly identified.
- The reason for and potential significance of any exclusion.
- A system boundary diagram with the processes that are included and those excluded, highlight those activities which falls respectively under situation 1, 2, and 3 of the Data Needs Matrix, and highlight where company-specific data are used.]

Environmental Footprint impact categories

[Provide a table with the list of EF impact categories, units, and EF reference package used (see http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml for further details).

For climate change, specify if the results of the three sub-indicators are reported separately in the results section.]

Additional information

[Describe any additional environmental information and additional technical information included in the LCA study. Provide references and exact calculations rules adopted.

Explain if biodiversity is relevant/not relevant for the product in scope.

Additional technical information shall include the biogenic carbon content at factory gate (physical content and allocated content).

Assumptions and limitations

[Describe all limitations and assumptions. Provide list of data gaps, if any, and the way in which these gaps were filled. Provide list of proxy datasets used.]

LIFE CYCLE INVENTORY ANALYSIS

[This section shall describe the compilation of the Life Cycle Inventory (LCI) and include:

- Screening step, if performed,
- List and description of life cycle stages,
- Description of modelling choices,
- Description of allocation approaches applied,
- Description and documentation of data used and sources,
- Data quality requirements and rating]

Modelling choices

[Describe all modelling choices for the applicable aspects listed below (more can be added, when relevant):

- Agricultural production;
- Transport and logistics: all data used shall be provided in the report (e.g. transportation distance, payload etc.). If default scenarios were not used in the modelling, provide documentation of all specific data used;
- Capital goods: if capital goods are included, the LCA report shall include a clear and extensive explanation, reporting all assumptions made;
- Storage and retail;
- Electricity use;
- Sampling procedure (report if a sampling procedure was applied and indicate the approach taken);
- Greenhouse gas emissions and removals (report if a simplified approach was not used to model biogenic carbon flows);
- Offsets (if reported as additional environmental information).]

Handling multi-functional processes

[Describe the allocation rules used in the LCA study and how the modelling/calculations were made. Provide the list of all allocation factors used for each process and the detailed list of processes and datasets used, in case substitution is applied.]

Data collection

[This section shall include as a minimum:

- Description and documentation of all company-specific data collected:
  - list of processes covered by company-specific data indicating to which life cycle stage they belong;
  - list of resource use and emissions (i.e. direct elementary flows);
  - list of activity data used;
  - link to detailed bill of materials and/or ingredients, including substance names, units and quantities, including information on grades/ purities and other technically and/or environmentally relevant characterisation of these;
  - company-specific data collection/estimation/calculation procedures;
- List of all secondary datasets used (process name, UUID, dataset source (node on Life Cycle Data Network, data stock) and compliance with the EF reference package);
- Cut-off applied, if any;
- Sources of published literature;
- If a sensitivity analysis has been conducted, this shall be reported.]

Data quality requirements and rating

[Provide a table listing all processes and their situation according to the Data Needs Matrix (DNM).

Provide the DQR of the LCA study.]

IMPACT ASSESSMENT RESULTS

LCA results

[This section shall include as a minimum:

- Characterised results of all EF impact categories shall be calculated and reported as absolute values in the PEF report. The sub-categories 'climate change –fossil', 'climate change – biogenic' and 'climate change - land use and land use change', shall be reported separately if they show a contribution of more than 5% each to the total score of climate change);
- Normalised and weighted results as absolute values;
- Weighted results as single score]

Additional information

[This section shall include:

- Results of the additional environmental information;
- Results of the biodiversity assessment.]

INTERPRETING LCA RESULTS

[This section shall include as a minimum:

- Assessment of the robustness of the LCA study;
- List of most relevant impact categories, life cycle stages, processes and elementary flows (see tables below);
- Limitations and relationship of the EF results relative to the defined goal and scope of the LCA study,

- Conclusions, recommendations, limitations and improvement potentials)].

Item	At what level does relevance need to be identified?	Threshold
Most relevant impact categories	Normalised and weighted results	Impact categories cumulatively contributing at least **80%** of the total environmental impact
Most relevant life cycle stages	For each most relevant impact category	All life cycle stages contributing cumulatively more than **80%** to that impact category
Most relevant processes	For each most relevant impact category	All processes contributing cumulatively (along the entire life cycle) more than **80%** to that impact category, considering absolute values.
Most relevant elementary flows	For each most relevant process	All elementary flows contributing cumulatively at least to 80% to the total impact for each most relevant processes. If disaggregated data are available: for each most relevant process, all direct elementary flows contributing cumulatively at least to **80%** to that impact category (caused by the direct elementary flows only)

Example:

Most relevant impact category	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
IC 1		End of life		Process 1		el. flow 1	
						el. flow 2	
				Process 2		el. flow 2	
		Raw material acquisition and p.p.		Process 4		el. flow 1	
IC 2		Manufacturing		Process 1		el. flow 2	
						el. flow 3	
IC 3		Manufacturing		Process 1		el. flow 2	
						el. flow 3	

ANNEX I

[The Annex serves to document supporting elements to the main report which are of a more technical nature. It could include:

- Bibliographic references;
- Detailed life cycle inventory analysis;
- Detailed assessment of data quality: Provide i) Data Quality Rating per process in accordance with the PEF Method and ii) Data Quality Rating for the newly created datasets.]

ANNEX 4 – SAMPLING PROCEDURE

In some cases, a sampling procedure is needed to limit the data collection only to a representative sample of plants, farms etc. The user of the PCR shall (i) specify in the LCA report if sampling was applied, (ii) follow the requirements described in this section and (iii) indicate which approach was chosen.
Examples of cases when the sampling procedure may be needed are in case multiple production sites are involved in the production of the same product. E.g., in case the same raw material/input material comes from multiple sites or in case the same process is outsourced to more than one subcontractor/ supplier.
The representative sample shall be derived via a stratified sample, i.e. one that ensures that sub-populations (strata) of a given population are each adequately represented within the whole sample of a research study. Using a stratified sample allows to achieve greater precision than a simple random sample, provided that the sub-populations have been chosen so that the items of the same sub-population are as similar as possible in terms of the characteristics of interest. In addition, a stratified sample guarantees better coverage of the population[33].

The following procedure shall be applied in order to select a representative sample as a stratified sample:
(1) define the population;
(2) define homogeneous sub-populations (stratification);
(3) define the sub-samples at sub-population level;
(4) define the sample for the population starting from the definition of sub-samples at sub-population level.

1 How to define homogeneous sub-populations (stratification)

Stratification is the process of dividing members of the population into homogeneous subgroups (sub-populations) before sampling. The sub-populations should be mutually exclusive: every element in the population shall be assigned to only one sub-population.
Aspects at least to be taken into consideration in the identification of the sub-populations:

- Geographical distribution of sites;
- Technologies/ farming practices involved;
- Production capacity of the companies/ sites taken into consideration.

Additional aspects to be taken into consideration may be added.

The number of sub-populations shall be identified as:

$$Nsp=g*t*c$$

- Nsp: number of sub-populations
- g: number of countries in which the sites/plants/farms are located
- t: number of technologies/farming practices
- c: number of classes of capacity of companies

In case additional aspects are taken into account, the number of sub-populations is calculated using the formula just provided and multiplying the result with the numbers of classes identified for each additional aspect (e.g., those sites which have an environmental management or reporting systems in place).

[33] The researcher has control over the sub-populations that are included in the sample, whereas simple random sampling does not guarantee that sub-populations (strata) of a given population are each adequately represented within the final sample. However, one main disadvantage of stratified sampling is that it may be difficult to identify appropriate sub-populations for a population.

Example 1
Identify the number of sub-populations for the following population:
350 farmers located in the same region in Spain, all the farmers have more or less the same annual production and are characterized by the same harvestings techniques.

In this case:
g=1 : all the farmers are located in the same country
t=1 : all the framers are using the same harvesting techniques
c=1 : the capacity of the companies is almost the same (i.e. the have the same annual production)

$$Nsp=g*t*c=1*1*1=1$$

Only one sub-population may be identified that coincides with the population.

Example 2
350 farmers are distributed in three different countries (100 in Spain, 200 in France and 50 in Germany). There are two different harvesting techniques that are used that differ in a relevant way (Spain: 70 technique A, 30 technique B; France: 100 technique A, 100 technique B; Germany: 50 technique A). The capacity of the farmers in term of annual production varies between 10,000t and 100,000t. According to expert judgement/ relevant literature, it has been estimated that farmers with an annual production lower than 50,000t are completely different in terms of efficiency compared to the farmers with an annual production higher than 50,000t. Two classes of companies are defined based on the annual production: class 1, if production is lower than 50000 and class 2, if production if higher than 50,000. (Spain: 80 class 1, 20 class 2; France: 50 class 1, 150 class 2; Germany: 50 class 1).
Table 19 includes the details about the population.

Table 19: Identification of the sub-population for Example 2

Sub- population	**Country**		**Technology**		**Capacity**	
1	Spain	100	Technique A	70	Class 1	50
2	Spain		Technique A		Class 2	20
3	Spain		Technique B	30	Class 1	30
4	Spain		Technique B		Class 2	0
5	France	200	Technique A	100	Class 1	20
6	France		Technique A		Class 2	80
7	France		Technique B	100	Class 1	30
8	France		Technique B		Class 2	70
9	Germany	50	Technique A	50	Class 1	50
10	Germany		Technique A		Class 2	0
11	Germany		Technique B	0	Class 1	0
12	Germany		Technique B		Class 2	0

In this case:

g=3 : three countries
t=2 : two different harvesting techniques are identified
c=2 : two classes of production are identified

$$Nsp=g*t*c=3*2*2=12$$

It is possible to identify maximum 12 sub-populations that are summarized in Table 20:

Table 20: Summary of the sub-population for example 2

Sub- population	Country	Technology	Capacity	Number of companies in the sub- population
1	Spain	Technique A	Class 1	50
2	Spain	Technique A	Class 2	20
3	Spain	Technique B	Class 1	30
4	Spain	Technique B	Class 2	0
5	France	Technique A	Class 1	20
6	France	Technique A	Class 2	80
7	France	Technique B	Class 1	30
8	France	Technique B	Class 2	70
9	Germany	Technique A	Class 1	50
10	Germany	Technique A	Class 2	0
11	Germany	Technique B	Class 1	0
12	Germany	Technique B	Class 2	0

2 How to define sub-sample size at sub-population level

Once the sub-populations have been identified, for each sub-population the size of sample shall be calculated (the sub-sample size) based on the number of sites/farms/plants involved in the sub-population:
The required sub-sample size shall be calculated using the square root of the sub-population size.

$$n_{SS}=\sqrt{n_{SP}}$$

- n_{SS}: required sub-sample size
- n_{SP}: sub-population size

Example

Table 21: Example: how to calculate the number of companies in each sub-sample

Sub- population	Country	Technology	Capacity	Number of companies in the sub-population	Number of companies in the sample (sub- sample size, [n_{SS}])
1	Spain	Technique A	Class 1	50	7
2	Spain	Technique A	Class 2	20	5
3	Spain	Technique B	Class 1	30	6
4	Spain	Technique B	Class 2	0	0
5	France	Technique A	Class 1	20	5
6	France	Technique A	Class 2	80	9
7	France	Technique B	Class 1	30	6
8	France	Technique B	Class 2	70	8
9	Germany	Technique A	Class 1	50	7
10	Germany	Technique A	Class 2	0	0
11	Germany	Technique B	Class 1	0	0
12	Germany	Technique B	Class 2	0	0

3 How to define the sample for the population

The representative sample of the population corresponds to the sum of the sub-samples at sub-population level.

4 What to do in case rounding is necessary

In case rounding is necessary, the general rule used in mathematics shall be applied:

- If the number you are rounding is followed by 5, 6, 7, 8, or 9, round the number up.
- If the number you are rounding is followed by 0, 1, 2, 3, or 4, round the number down.