BASF Methodology for Product Carbon Footprint Calculation

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Index

Document Change Control / History ... *3*

1. Introduction ... *4*

2. Methodological principles and requirements according to ISO 14067:2018 ... *4*

2.1 Definition of declared unit ... **4**

2.2 Product System ... **4**

2.3 System boundary ... **5**

2.4 Data requirements ... **6**

2.4.1 The data needs matrix ... 6
2.4.2 Data quality requirements of primary data collection ... 7
2.4.3 Selection of secondary data and use of proxy data ... 8
2.4.4 Reporting on secondary or background data ... 8
2.4.5 Modelling of waste and wastewater ... 9

2.5 Cut-off criteria ... **9**

2.6 Allocation ... **10**

2.6.1 Multi-output Allocation ... 10
2.6.2 End-of-Life Allocation ... 11

2.7 LCIA methodology ... **12**

2.7.1 Fossil removals ... 13
2.7.2 Biogenic carbon in product and biogenic removals ... 13

2.8 Sensitivity analysis and quality checks of results ... **13**

2.8.1 Quick checklist ... 13

2.9 Reporting requirements ... **14**

Annex A Glossary ... *15*

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1. Introduction

This document is meant as a technical guidance to help other companies and LCA analysts. It outlines BASF's own methodology to calculate cradle-to-gate product carbon footprints. BASF's Product Carbon Footprint calculation tool (SCOTT), currently in use at BASF, and brought into the market via partnering software companies, adheres to this document.

Such methodology is based on ISO14067:2018 for carbon footprint of products, which builds on the principles and requirements of the ISO standards 14040:2006 and 14044:2006 for life cycle assessment. Other LCA-related guidance documents such as WBCSD Chemicals[1] or PlasticsEurope[2] have been followed when making decision about allocation schemes

2. Methodological principles and requirements

2.1 Definition of declared unit

The declared unit for which the PCF of a product system is calculated shall be 1 kg of unpackaged product at factory gate, regardless of its state (solid, liquid, gas), as its specific density is considered. The declared unit shall not include transport emissions to customer premises

2.2 Product System

The product system of the cradle-to-gate PCF is the sum of GHG emissions, expressed as CO_2 equivalents, from the extraction of the resources up to production of the final product. It shall include all product related direct GHG emissions, including removals, from Scopes 1, 2 and 3 upstream (Figure 1).

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[1] WBCSD Chemicals 2013, Life Cycle Metrics for Chemical Products: A guideline by the chemical sector to assess and report on the environmental footprint of products, based on life cycle assessment.

[2] PlasticsEurope recommendation on steam cracker allocation, Life Cycle and Sustainability working group of PlasticsEurope, 2017.

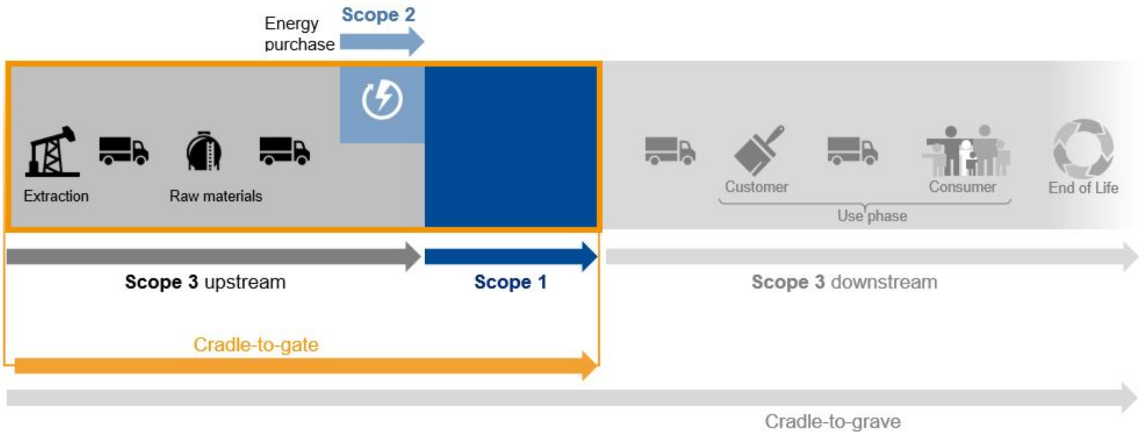

Figure 1 System boundary definition according to GHG Protocol

Scope 1 direct CO_2e emissions result from production processes that are owned or controlled by the reporting company. They arise from e.g.,

- emissions from chemical reactions,
- emissions stemming from waste treatment w/o energy use (e.g., flares),
- emissions from fuel and residues incineration in process plants.

Scope 2 CO_2e emissions result from the generation of purchased energy such as electricity and steam.

Scope 3 upstream CO_2e emissions result e.g., from the use of purchased raw materials and indirect emissions due to the generation and extraction of fuels consumed by the product-processing plants.

2.3 System boundary

In the cradle-to-gate PCF calculation the emissions from the following activities shall be included and excluded, respectively as described in Table 2-1.

*Table 2-1 System boundary of cradle-to-gate product system**

Included	Excluded
✓ Raw materials (incl. catalysts that are consumed in the reaction) and fuels	× Packaging
✓ Energy consumption	× Outbound transports
✓ Utilities	× Capital goods / infrastructure / including catalysts that are re-generated / recovered

✓ Manufacturing	× Non-production-related products[3]
✓ Inbound transportation	× Employee commuting / business travel
✓ Site-to-site transportation	
✓ Treatment of process waste	
✓ Wastewater treatment	

**for definition of terms see glossary*

2.4 Data requirements

2.4.1 The data needs matrix

The requirements for use of primary (company-specific) or secondary data (Scope 2 and Scope 3) for GHG emissions depend on the level of influence the company has on the process[4] and are as follows.

The following three cases are distinguished in the data needs matrix (Table 2-2):

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

Table 2-2 Data needs matrix

		Data requirements
Situation 1: process run by the company	**Scope 1**	Collect primary (company-specific) data for both, activity data and direct emissions, via a bottom-up approach (by unit-process) and for each site. This includes own production plants, power plants, transport activities, waste, and wastewater treatment. For transportation activities use high quality CO_2e emission factors, in this case fleet specific.

[3] Non-production-related procurement (often called indirect procurement) consists of purchased goods and services that are not integral to the company's products but are instead used to enable operations. Non-production-related procurement may include capital goods, such as furniture, office equipment, and computers. Source: GHG Protocol Corporate Value Chain Standard.
[4] A set of interrelated or interacting activities that transforms or transports a product. Source: GHG Protocol Corporate Value Chain Standard.

Situation 2: process not run by the company but with access to company-specific information	**Scope 2**	Data sources for Scope 2 emissions should be supplier-specific (also referred to as market-based emission factors[5]) from energy suppliers for the reference period (Note: The Scope 3 upstream emissions for the fuels that go into the energy production have to be added as well, in order to arrive at a complete cradle-to-gate PCF of the purchased energy. For renewable energy sources, the Scope 3 upstream emissions may be neglected if they are insignificant and thus fall under the cut-off criteria.
	Scope 3	Use a supplier-specific PCF for raw materials or fuels. The quality of the supplier-specific PCF has to be evaluated and checked for appropriateness according to the GHG Protocol Product Standard or ISO 14067:2018.
Situation 3: process not run by the company and without access to company-specific information	**Scope 2**	Use location-based factors for external energy supply.
	Scope 3	Among available data, use PCF values that are most representative and specific to the geography and technology used to produce the raw materials, utilities and fuels. The below hierarchy for raw materials, utilities and fuels shall be applied: 1. Most recent and valid association data (e.g., Plastics Europe) 2. Most recent quality secondary database (Sphera / GaBi, Ecoinvent, CM Database, others)[6] 3. Proxies or estimations For transportation activities use high quality CO_2e emission factors from EcoTransIT or Sphera/GaBi.

2.4.2 Data quality requirements of primary data collection

Minimum criteria on data quality of primary data collection and all processes related to Scope 1 operations are shown in Table 2-3.

[5] The purchase and use of green electricity can be considered in the market-based emission factor provided that the criteria in ISO 14067:2018, Chapter 6.4.9.4.4 are met.

[6] Source of secondary database is to be disclosed in the PCF report. Since BASF uses secondary data predominantly from Sphera/GaBi, we recommend that our suppliers also use Sphera/GaBi PCF data in their PCF calculations due to consistency reasons.

Table 2-3 Data quality requirements on primary data (Scope 1)

Data Quality Criteria	Requirement
Geographical representativeness	Primary data from all sites relevant for the product under study.
Technological representativeness	Specific (actual) technology from the production plants for product under study.
Temporal representativeness	The primary data considered • refers to the most recent annual administration period, • is not older than 3 years, • covers at least 12 calendar months to avoid seasonal changes.
Consistency	A minimum of consistency and justification will have to be ensured by checking for 15% deviation from the previous year's primary data. In case of a bigger deviation, a justifying comment must be provided by the practitioners.
Completeness	See cut-off criteria (chapter 2.5).
Reliability	Data based on measurements of actual and site-specific internal production data.
Precision	Measured/calculated and internally verified, plausibility checked by (internal) reviewer.

2.4.3 Selection of secondary data and use of proxy data

The below hierarchy for the selection of secondary data for Scope 3 processes shall be applied:

1. If the production origin (region or country) of the supplied raw material and fuel is known choose a regional or country-specific production mix.
2. If the production origin is not known choose a regional or country-specific consumption mix based on the location of your tier-1 supplier.
3. If there is no regional or country-specific dataset available choose the same raw material or fuel from another country or region which is the most appropriate in terms of GHG emissions.
4. If the specific raw material or fuel is not available choose an appropriate proxy e.g., a chemical substance from the same chemical group.

2.4.4 Reporting on secondary or background data

Secondary or background data concern processes outside the operational control of the company. The source of secondary data must be specified in the report. The extent to which secondary data is used should be specified in relation to all Scope 2 and Scope 3 GHG emissions by CO_2 equivalents.

As part of the quality check, the most relevant contributions of LCIs regarding their plausibility should be assessed and reported in the study report, including at minimum year of publication, database source and version.

2.4.5 Modelling of waste and wastewater

For modelling the GHG impact from waste and wastewater treatment, appropriate generic LCI datasets from LCA databases may be used.

As approximation, specific emission factors can be used. They should be calculated by considering the following:

GHG emissions from waste treatment

- Waste for material recovery: see chapter 2.6.2 (if the recommended cut-off approach is applied, no GHG emissions are to be allocated)
- Waste for energy recovery:
    - 100% conversion to CO_2e based on carbon content
    - CO_2e credit for heat production may be considered
    - CO_2e from fuel needed for combustion process may be considered
- Waste to underground landfill: no GHG emissions to be allocated
- Waste to surface landfill: 100% conversion to CO_2e based on carbon content
- Waste to incineration:
    - 100% conversion to CO_2e based on carbon content
    - CO_2e from fuel needed for combustion process may be considered

GHG emissions from wastewater treatment

- If the Total Organic Carbon (TOC) load of your processes is known:
    - 100% conversion to CO_2e based on carbon content
    - Utilities for treatment of wastewater and sludge incineration included

2.5 Cut-off criteria

The LCI data collection shall aim for completeness – a closed mass and energy balance – and avoid cut-offs altogether. Where quantitative data are available, they shall be included. However, no undue effort should be spent on developing data of negligible significance concerning GHG emissions.

Cut-offs may become necessary in cases where no data are available, where elementary flows are very small (below quantification limit), or where the level of effort required to close data gaps and to achieve an acceptable result becomes prohibitive.

1. In cases where no matching life cycle inventories are available to represent a raw material or where processes and elementary flows are very small (below quantification limit), proxy data shall be used based on conservative assumptions regarding GHG emissions.
2. Include all material inputs that have a cumulative total of at least 99% of the total mass inputs to the unit process.

3. Include all energy inputs that have a cumulative total of at least 99% of total energy inputs to the unit process.
4. If precious metal containing catalysts are used as an input of chemical reactions, they shall be considered in the PCF calculation, even if their input is <=1%. The PCF calculation of the product resulting out of such a chemical reaction, should at minimum consider the loss of catalyst with PCF equal to the virgin material, to ensure the correct PCF calculation. If known, the efforts of the recycling of the catalysts should be considered in addition.

2.6 Allocation

The application of allocation rules significantly determines the results. Special attention should therefore be paid to the multi-output allocation.

2.6.1 Multi-output Allocation

When multi-output allocation becomes necessary during the data collection phase, a consistent allocation approach for all possible (material and energetically) types of co-products used following a decision hierarchy shall be applied:

1. Allocation methods in line with published and accepted product category rules (PCR) of analogous processes shall be applied where available, e.g., PlasticsEurope. See Table 2-4.
2. Co-products which are only used in energy recovery shall be treated by system expansion and substitution.
3. Carbon dioxide that is captured and used as input in another process is not considered as allocatable co-product.
4. If all co-products are gases and include hydrogen with a share > 1%, volume allocation shall be applied.
5. Following the guidance of the WBCSD Chemicals[7], the ratio of the economic value of co-products is a criterion to decide between physical allocation and economic allocation. If the ratio is equal or less than five (5), then mass allocation shall be applied, otherwise economic allocation shall be applied. Economic allocation factors shall be calculated from average prices over multiple years to average out fluctuations.[8]
6. If the share of a co-product is very small (in mass or volume <=1%), it shall be skipped in decision about the allocation method.
7. If similar technical processes with the same by-products (same chemical entity, share > 1 % to be relevant) are assigned different allocation approaches according to the above scheme, these may both be set to mass allocation.

[7] WBCSD Chemicals 2013, Life Cycle Metrics for Chemical Products: A guideline by the chemical sector to assess and report on the environmental footprint of products, based on life cycle assessment.
[8] BASF calculates this ratio from production cost data averaged over several years to reduce fluctuations.

Table 2-4 Examples of product systems using a PCR to allocate co-products

Product system	Allocation approach	Standard/Rationale followed
Steam crackers	Specific mass allocation. Products are categorized in intended and co-products. Energy demands and emissions are allocated by mass to intended products. Feedstocks are allocated by mass to all intended and by-products.	PlasticsEurope steam cracker allocation paper[9]
C12-14 Fatty alcohols (oleo), methyl esters, refined oils, and crude oils from oil palm, refined- and crude oils from Coconut	Mass	ERASM[10]
Toluene diisocyanate (TDI), Methylene diphenyl diisocyanate (MDI)	Stoichiometric	ISOPA[11]
Chlorine (chlor-alkali process)	Dry matter	Euro Chlor[12]

2.6.2 End-of-Life Allocation

End-of-Life allocation generally follows the requirements of ISO 14044, section 4.3.4.3. Such allocation approaches address the question of how to assign impacts from virgin production processes to material that is recycled and used in future product systems.

Two main approaches are commonly used in LCA studies to account for end-of-life recycling and recycled content.

- Cut-off approach (also known as 100:0 or recycled content approach) – burdens or credits associated with material from previous or subsequent life cycles are not considered i.e., are “cut-off”. Therefore, scrap input to the production process is considered to be free of burdens but, equally, no credit is received for scrap available for recycling at end-of-life. This approach rewards the use of recycled content but does not reward end of life recycling.
- Substitution approach (also known as 0:100, closed-loop approximation, recyclability substitution or end of life approach) – this approach is based on

[9] PlasticsEurope recommendation on steam cracker allocation, Life Cycle and Sustainability working group of PlasticsEurope, 2017.
[10] ERASM SLE (2014). Surfactant Life Cycle and Ecofootprinting Project; updating the life cycle inventories for commercial surfactant production. Final Report for ERASM (www.erasm.org), 186 p.
[11] Toluene Diisocyanate (TDI) & Methylenediphenyl Diisocyanate (MDI) ISOPA, Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers, 202.1
[12] An Eco-profile and Environmental Product Declaration of the European Chlor-Alkali Industry, Chlorine (The chlor--alkali process), Euro Chlor, 2013.

the perspective that material that is recycled into secondary material at end of life will substitute for an equivalent amount of virgin material. Hence a credit is given to account for this material substitution. However, this also means that burdens equivalent to this credit should be assigned to scrap used as an input to the production process, with the overall result that the impact of recycled granulate is the same as the impact of virgin material. This approach rewards end of life recycling but does not reward the use of recycled content.

Other approaches cover, e.g., the Circular Footprint Formula[13] or the Umbrella Formula + or Integrated Formula[14].

When end-of-life allocation becomes necessary during the data collection phase, an allocation approach in line with published and accepted category rules of analogous processes shall be applied where available. If this is not the case, we recommend using the cut-off approach.

Chemical Recycling Systems: All burdens from the point of origin of the waste and the recycling process to generate a new feedstock (collection, transports, sorting, recycling operation, pyrolysis) need to be taken into account in the uptaking system. As a consequence, the waste is not considered as burden-free. Consequently, the uptaking system can receive a credit for saving the burdens, that otherwise have been created in end-of-life options like incineration.

2.7 LCIA methodology

The characterization method focuses on greenhouse gas emissions. The impact of greenhouse gas emissions – such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) is assessed over a fixed period of 100 years according to the Bern model[15]. The PCF, expressed in kg CO_2 equivalents, reflects the climate change impact of air emissions of greenhouse gases (GHGs). Increased GHGs in the troposphere result in warming of the earth's surface.

The climate change category considers that different gases have different climate change impacts on global warming. The total impact is described in CO_2 equivalents.

[13] Zampori, L. and Pant, R., *Suggestions for updating the Product Environmental Footprint (PEF) method*, EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 00654-1, doi:10.2760/424613, JRC11

[14] https://maki-consulting.com/wp-content/uploads/2016/09/Umbrella-formula_incl._reformulated_Integrated_formula_improved_Wolf_Sep2016-3.pdf

[15] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

The PCF shall be calculated considering all six Kyoto gases (Carbon dioxide “CO_2”, Methane “CH_4”, Nitrous oxide “N_2O”, Hydrofluorocarbons “HFCs”, Perfluorocarbons “PFCs”, Sulphur hexafluoride “SF_6”), plus NF_3, measured by mass and converted into CO_2 equivalents using the 100-year global warming potential (GWP) coefficients of the 2013 IPCC 5th Assessment Report with climate carbon feedbacks. This includes CO_2 from land use and land use change.

For example, the correct characterization methods in Sphera’s Product Sustainability Solution (GaBi) are called

- *IPCC AR5 GWP100, excl biogenic carbon, incl Land Use Change, no norm/weight*
- and *IPCC AR5 GWP100, incl. biogenic carbon, incl Land Use Change, no norm/weight*.

In other LCA Software tools the names can differ from that but shall contain the same characterization factors.

2.7.1 Fossil removals

Fossil removals shall be included in the PCF calculation. The net result of fossil GHG emissions and removals shall be documented.

2.7.2 Biogenic carbon in product and biogenic removals

The biogenic emissions and removals shall be considered in the PCF quantification and reported separately from the PCF excluding biogenic emissions and removals. Additionally, the biogenic carbon content of the product shall be reported. Biogenic carbon balance should be closed.

2.8 Sensitivity analysis and quality checks of results

Sensitivity analyses with different modelling choices (e.g., another dataset for a raw material, another allocation method for the foreground product system) should be performed in order to test the robustness of the result.

Validation of the resulting PCF of a product should be obtained by experts, such as technology experts, controllers, plant managers, site managers, and LCA experts.

2.8.1 Quick checklist

The following short checklist shall help the LCA practitioner to validate the PCF.

- Check the overall mass balance (includes raw material inputs, product outputs, wastes as well as emissions into air and water)
- Check the elementary balance by doing a stochiometric calculation
- Check if on-stage direct emissions are realistic, e.g., by carbon balance
- Check utility consumption (plausible?)
- Check allocation factors (in line with chapter 2.6.1?)
- Check the appropriateness of the secondary datasets selected for Scope 3:

- Check if technology represented in the LCI is the appropriate.
  - Check if the application of proxies is appropriate.
  - If supplier data is available replace dataset.
- CO_2e benchmark against own calculations, same product from other sites/plants companies, existing LCA data, LCIs from other third-party databases.
- Check why there are significant deviations to LCA benchmark data

2.8.2 Reporting requirements

As a minimum requirement the results of the PCF calculation (including and excludding biogenic emissions and removals) along with the following information must be reported:

- Name of the producer
- Name of the product
- Location of production
- Declared unit
- System boundaries
- Sources of secondary data
- Time-related scope
- Geographical scope
- Technological scope
- Allocation (for multi-output define if allocation or system expansion is used; if allocation, define if specific PCR or used allocation approach)
- LCIA method used

Annex A Glossary

Acronym	Term	Definition
	Allocation	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 2006).
	Background data	See also secondary data. Data that concern processes outside the operational control of the company.
	Biogenic carbon content	Fraction of carbon derived from biomass in a product.
	Biogenic emissions	CO2 emissions from the combustion or biodegradation of biomass.
	Biogenic removals	The sequestration or absorption of GHG emissions from the atmosphere, which most typically occurs when CO2 is absorbed by biogenic materials during photosynthesis.
	Biomass	Material of biological origin excluding material embedded in geological formations and/or fossilized.
CO_2e	Carbon Dioxide Equivalent	Carbon dioxide equivalent, or CO_2e is a metric measure representing all greenhouse gases by converting them to the equivalent amount of CO_2.
	Consumption mix	This approach focuses on the domestic production and the imports taking place. These mixes can be dynamic for certain commodities (e.g., electricity) in the specific country/region.
	Cradle-to-gate	An assessment that includes part of the product's life cycle, including material acquisition through the production of the studied product and excluding the use or end-of-life stages. (WRI and WBCSD 2010)
	Cradle-to-grave	A cradle to grave assessment considers impacts at each stage of a product's life cycle, from the time natural resources are extracted from the ground and processed through each subsequent stage of manufacturing, transportation, product use, recycling, and ultimately, disposal. (Athena Institute & National Renewable Energy Laboratory draft 2010)
GWP	Global Warming Potential	GWP is a term used to describe the relative potency, molecule for molecule, of a greenhouse gas, taking account of how long it remains active in the atmosphere. The GWPs currently used are those calculated over 100 years. Carbon dioxide is taken as the gas of reference and given a 100-year GWP of 1.
GHG	Greenhouse Gases	Greenhouse gases constitute a group of gases contributing to global warming and climate change. The Kyoto Protocol, an environmental agreement adopted by many of the parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 1997 to

		curb global warming, nowadays covers seven greenhouse gases: • the non-fluorinated gases: o carbon dioxide (CO_2) o methane (CH_4) o nitrous oxide (N_2O) • the fluorinated gases: o hydrofluorocarbons (HFCs) o perfluorocarbons (PFCs) o Sulphur hexafluoride (SF_6) o nitrogen trifluoride (NF_3) Converting them to carbon dioxide (or CO_2) equivalents makes it possible to compare them and to determine their individual and total contributions to global warming.
ISO	International Organization for Standardization	
ISO 14067:2018	ISO standard on Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification	ISO 14067:2018 specifies principles, requirements and guidelines for the quantification and reporting of the carbon footprint of a product (CFP), in a manner consistent with International Standards on life cycle assessment (LCA) (ISO 14040 and ISO 14044).
LCA	Life Cycle Assessment	The compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle (ISO 1440:2006).
LCI	Life Cycle Inventory	The phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle (ISO 14040:2006).
LCIA	Life Cycle Impact Assessment	The phase of life cycle assessment 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 (ISO 14040:2006).
	Primary data	Sometimes also called activity data. Data that concern processes inside the operational control of the company or data from specific processes in the product life cycle.
PCF	Product Carbon Footprint	The Product Carbon Footprint is the most established method for determining the climate impact of a product, considering the total greenhouse gas (GHG) emissions caused to produce a product, expressed as carbon dioxide equivalent. The PCF can be assessed from cradle-to-gate (partial PCF) or from cradle-to-grave (total PCF).
PCR	Product Category Rules	Set of specific rules, requirements, and guidelines for developing Type III environmental declarations for one or more product categories. [ISO 14025:2006]
	Production mix	This approach focuses on the domestic production routes and technologies applied in the specific country/region and individually scaled according to the actual production volume of the respective production route. This mix is generally less dynamic.

	Removal	The sequestration or absorption of GHG emissions from the atmosphere, which most typically occurs when CO2 is absorbed by biogenic materials during photosynthesis.
	Primary data	Sometimes also called activity data.
	Scope 1 Emissions	Scope 1 emissions include GHG that arise from the combustion of fuels owned or controlled by the reporting organization.
	Scope 2 Emissions	Scope 2 emissions include GHG emissions that result from the consumption of purchased or acquired energy such as electricity, heating, cooling, and steam.
	Scope 3 Emissions	Scope 3 emissions include the remainder of indirect GHG emissions which cannot be categorized as energy-related emissions in Scope 2.
	Secondary data	See also background data. Data that concern processes outside the operational control of the company or process data that are not from specific processes in the product life cycle.
	System expansion	Expanding the product system to include the additional functions related to the co-products. System expansion is a method used to avoid co-product allocation.
	Utilities	The term “utilities” includes here: Electricity, process steam, excess steam, cooling water, demineralized water, process water, compressed air and nitrogen.