Methodology for Product Carbon Footprint Calculations for Lubricants and other Specialties

Contents

1 Intention of methodology document

There is an increasing request from customers of the lubricants industry to supply product carbon footprints (PCF), also named carbon footprint of a product (CFP), of lubricants and other specialties. For these customers, transparent and coherent PCFs are important for identifying and ultimately reducing GHG emissions across the value chain of lubricants. However, different methodologies and assumptions for calculating PCFs widen the spread and variability of PCFs. Furthermore, PCF calculations are perceived as time-consuming and costly, hindering their broad calculation across value chains. To address these points, the Union of the European Lubricants Industry (UEIL) and the Technical Association of the European Lubricants Industry (ATIEL) have developed a cradle-to-gate methodology document, which is fully aligned with ISO Standard 14067:2018 and the GHG Protocol Product Standard (GHG PPS) to provide consistent guidance for the lubricants industry and their stakeholders when conducting product carbon footprint calculations for lubricants and associated specialties. By this means, this methodology document aims to provide guidance to lubricants and other specialties product sectors, facilitating a more consistent implementation of existing PCF methodologies. By adopting a standardized approach, this document helps minimize the spread and variability of PCFs resulting from inconsistent methodology choices. It also serves as a starting point for all companies to calculate comparable PCF values.

The following definitions apply in understanding how to implement this methodology in accordance with ISO International Standards:

- The term "shall" indicates what is required for a PCF to be compliant with this methodology.
- The term "should" indicates a recommendation rather than a requirement. Any deviation from a "should" recommendation must be justified by the party conducting the study and made transparent.
- The term "may" indicates an option that is permissible.
- The term "can" is used to indicate that something is possible, for example, that an organization or individual is able to do something.

2 Goal and scope definition for PCF calculation

This chapter provides an overview of the goal and scope of this methodological framework for PCF calculations. Section 2.1 outlines the goal definition and Section 2.2. describes the scope of the PCF calculations according to this methodological framework.

2.1 Goal for PCF calculation

The intended application of this methodological framework is to harmonize PCF calculations of lubricants and other specialties based on ISO 14067:2018 and the GHG PPS. The reason for providing this methodology document is to move towards achieving alignment in the lubricants industry, resulting in transparency, comparability, and acceptability of PCF calculations for their stakeholders. Furthermore, it shall facilitate management decisions and serve as standardized guidance on measuring and reducing GHG emissions. The intended audience is internal and external stakeholders globally, being, for instance:

- Customers and users
- Suppliers
- Lubricant industry
- Legislators
- Investors
- LCA/PCF auditors and practitioners
- Internal stakeholders

Although comparative assertions can be supported, as per Annex B of ISO 14067:2018, the methodology and the calculated PCF results alone are not intended to be used in comprehensive comparative assertions. Comparative carbon footprint communication (not to compare with comparative assertions!) may be done in accordance with ISO 14026:2018, as stated in Annex B of ISO 14067:2018. The methodology and its implementation should be reviewed by a third party, for instance according to ISO 14071:2014, to ensure credibility and enhanced understanding. If the aim is to do a specific PCF comparative assertion, we recommend performing a critical review according to ISO 14071:2014 and additional guidance as per ISO 14026:2018. Additionally, disclosing results to the general public is not advisable unless a third party; has verified the data, the applied calculation methodology, and the results by following ISO 14071:2014.

Suppliers to the lubricant industry can also have links to other industries, such as the base oil and fine chemical industries and will be asked to supply PCFs for their products to enable the calculations by the lubricant industry. Therefore, this methodology accepts PCFs that have been calculated based on other methodologies according to their latest version for a cradle-to-gate system boundary in the following hierarchy, as illustrated in Figure 1:

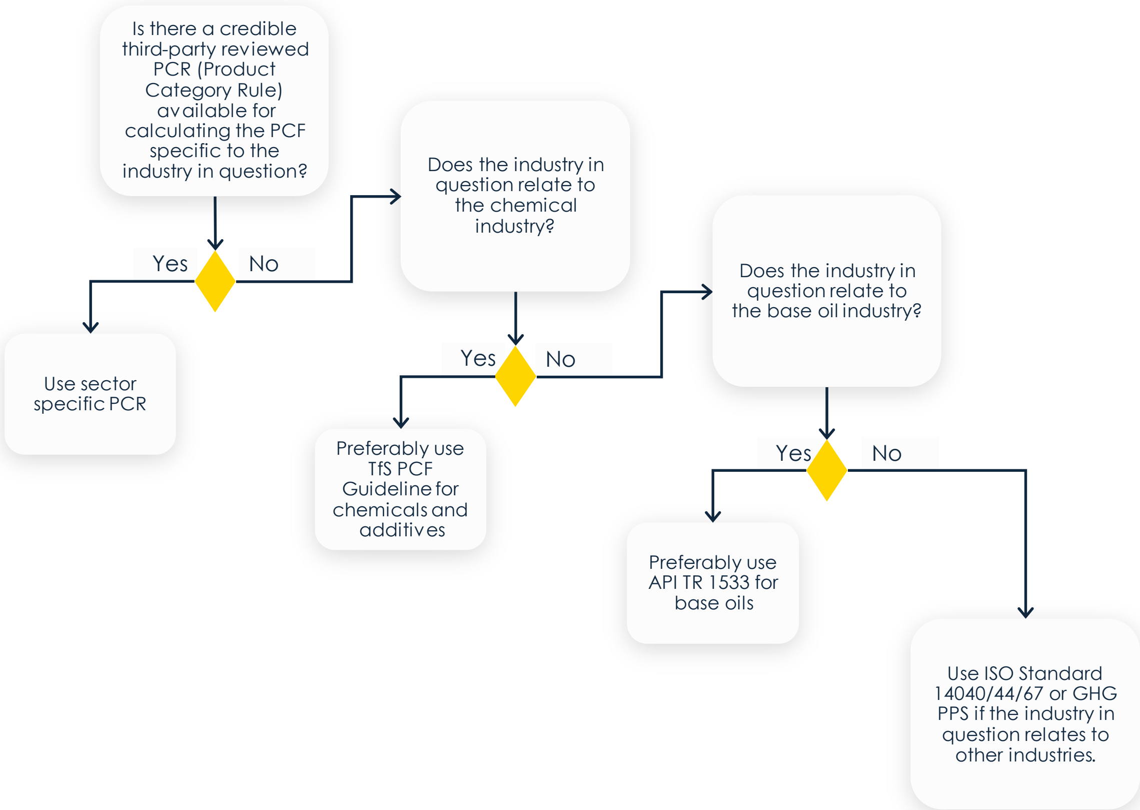


Figure 1: Hierarchical acceptance of methodologies from other industries that supply lubricant manufacturers.

The hierarchical acceptance is listed more descriptively in the following:

1. Credible third-party review Product category rules (PCR) developed on sector-specific/industry-specific guidelines based on ISO 14000 series, e.g. Plastics Europe.
2. TfS PCF Guideline Sector Specific (preferred guideline for the chemical and additive industry)
3. API TR 1533 Sector Specific Guideline (preferred guideline for the base oil industry)
4. ISO 14040/44/67 standard [ISO 14067: 2006], [ISO 14044:2006], [ISO 14067: 2018] and GHG PPS.

If PCFs are supplied to the lubricant industry, the additional reporting requirements according to Section 6.1 are requested. The data shall be limited to the scope and product system as defined in this methodology document (cf. Section 2.2.2. cradle-to-(inbound)-gate). For example, the additional reporting requirements apply, if the

PCF delivered to the lubricant manufacturer is based on an alternative methodology because it e.g. originates from a different industry.

2.2 Scope for PCF calculation

The scope for PCF calculation includes the definition of the declared unit and the reference flow (cf. Section 2.2.1). Moreover, the considered product system is defined (cf. Section 2.2.2), including the defined system boundaries (cf. Section 2.2.3).

2.2.1 Declared unit and reference flow

The declared unit is the production of 1 kg of unpacked lubricant or other specialty at the factory outbound gate. Likewise, the reference flow is defined as 1 kg of unpacked lubricant or other specialty at the factory outbound gate[1].

An example of the declared unit could be the production of 1 kg of unpacked automotive engine oil (SAE 0W-20) at the outbound factory gate of the lubricant manufacturer.

The lubricants or other specialties for which this methodology applies can be, for instance, grouped into:

- Automotive Engine Oils
- Automotive Transmission and Gear Oils
- Automotive Antifreeze and Coolants
- Industrial Gear Oils
- Hydraulic Oils
- Compressor Fluids
- Anticorrosion Fluids
- Metalworking Fluids
- Marine Lubricants
- Greases and Pastes
- Thermal Fluids
- Bio-based lubricants
- Food-grade lubricants
- Textile lubricants

[1] Note: Internal calculation through, e.g. ERP systems might require a change of magnitude of unit (e.g. change of unit to tons) to avoid losing accuracy.

- Turbine Oils
- Transformer Oils
- Gas Engine Oils
- Paper Machine Oils
- Transformer fluids
- Dielectric fluids

Additional functions shall be reported in the documentation but shall not be considered in the PCF calculation. Examples of additional functions are:

- Cooling ability
- Corrosion Protection
- Cleaning abilities
- Renewable content
- Biodegradability
- Service life

2.2.2 Product system

The product system comprises the life cycle stages from cradle-to-(outbound)-gate, resulting in a partial PCF calculation. This product system covers the raw material extraction and manufacturing up to and including the product manufacturing, as well as internal storage and transport by the lubricant manufacturer. By this means, "gate" indicates the lubricant manufacturer's outbound gate. Figure 2 shows the typical product life cycle stages of a lubricant or other specialty. Note, that the depicted product life cycle stages are general descriptions and might include more detailed product life stages. A cradle-to-grave approach comprising all life cycle stages is out of scope for this methodology.

Acknowledging that there are lubricant manufacturers containing several life cycle stages within their company operations, e.g. integrated companies, the inbound gate of the lubricant manufacturer might be situated before the actual manufacturing life cycle stage phase of a lubricant or other specialty. For example, the lubricant manufacturer could contain the refining and processing of raw materials or even the raw material acquisition itself, thus comprising all life cycle stages from cradle-to-(outbound)-gate within the lubricant manufacturer company's (inbound)-gate-to (outbound)-gate (cf. Figure 2). An example product system of a typical lubricant manufacturer only containing the manufacturing part as a life cycle stage is provided in Figure 3.

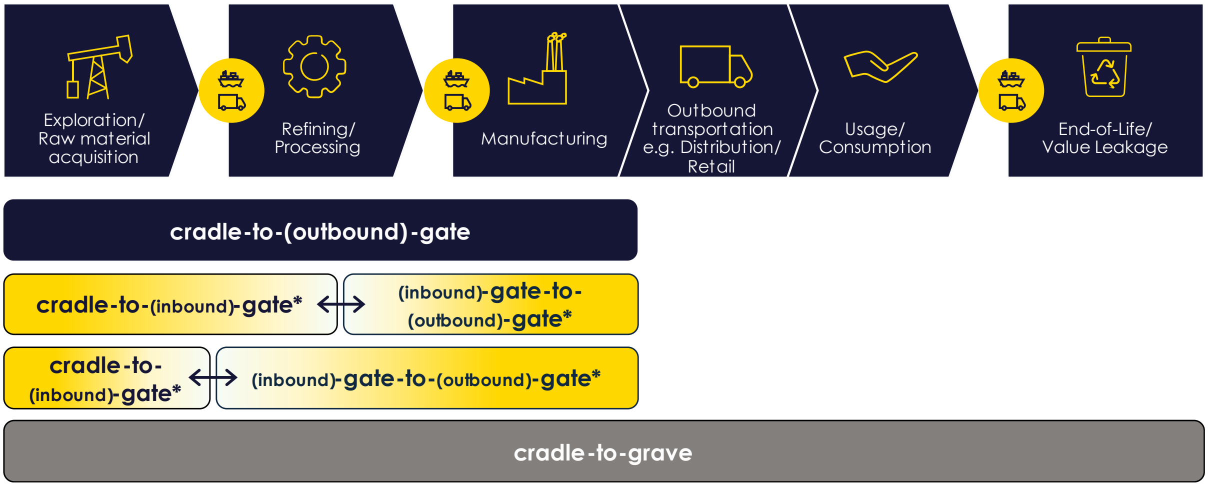


Figure 2: Schematic overview of the product life cycle of a lubricant or other specialty. * (inbound)-gate-to-(outbound)-gate might contain more life cycle stages, up to the raw material acquisition phase, e.g. for integrated companies.

The cradle-to-(outbound)-gate (partial) PCF includes the following emission sources (cf. Figure 2):

- The cradle-to-(inbound)-gate scope includes all GHG emissions resulting from the production, transport, and packaging of purchased raw materials required for the manufacturing of the product described by the reference flow.
- For the assessment of the emissions resulting from (inbound)-gate-to-(outbound)-gate activities, the lubricant manufacturer collects internally related primary data individually for each operational site and calculates the gate-to-gate GHG emission based on these data:
    - (inbound)-gate-to-(outbound)-gate:
        - summarizing all gate-to-gate GHG emissions originating from operations (production, storage and transport) in the plants producing or storing the product.
        - summarizing all GHG emissions resulting from the production of energy purchased by the lubricant manufacturer energy purchases.
        - summarizing indirect emissions, directly related to (inbound)-gate-to-(outbound)-gate activities.

The GHG Protocol "Scope" terminology is widely used for Corporate Carbon (CCF) reporting and is applied and known in the industry. Therefore, an example for a product system of stereotypical lubricant manufacturers including the Scope terminology is provided to enhance the understanding (cf. Figure 3).

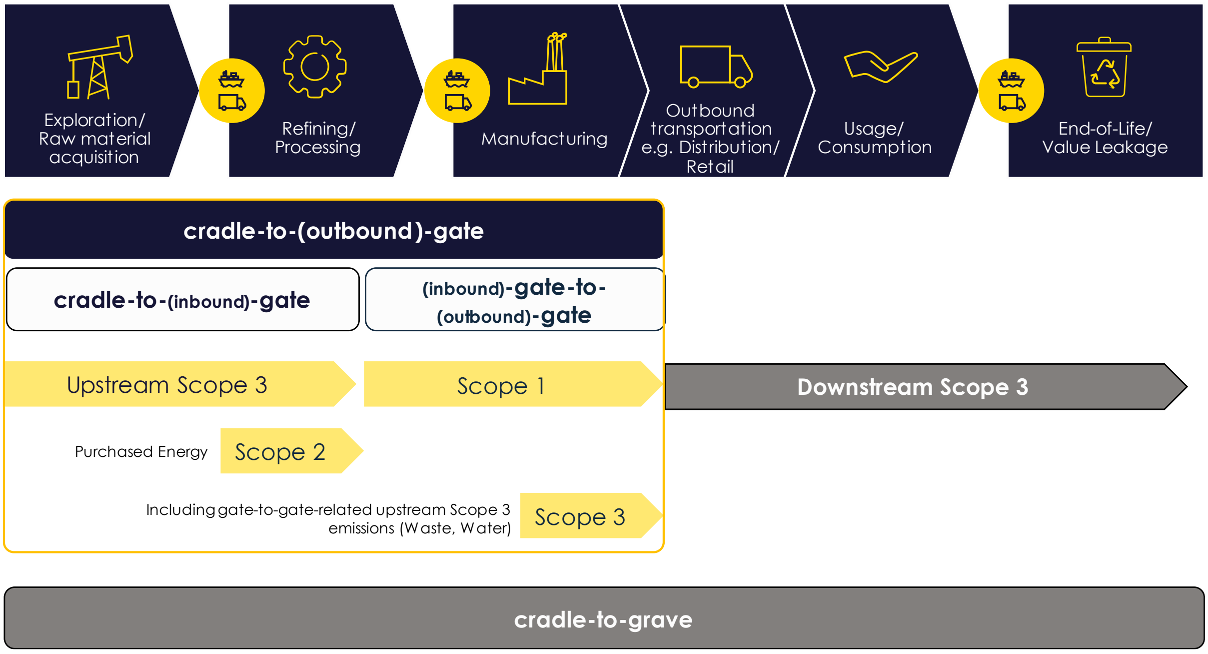


Figure 3: Schematic overview of the lubricant manufacturers product system

The cradle-to-gate (partial) PCF includes the following emission sources (cf. Figure 3):

- Upstream scope 3 within the cradle-to-(inbound)-gate scope: summarizing all upstream GHG emissions resulting from the production, transport and packaging of purchased raw materials needed to meet the defined reference flow of the product (cf. Section 2.2.3).
- For the assessment of the emissions resulting from (inbound)-gate-to-(outbound)-gate activities, the lubricant manufacturer collects internally related primary data individually for each manufacturing-site and calculates the gate-to-gate based on these data:
    - Scope 1 within the (inbound)-gate-to-(outbound)-gate: summarizing all gate-to-gate GHG emissions originating from operations (production, storage and transport) in the plants producing or storing the product.

      Examples: direct emissions from the combustion of fuels, process emissions and leakages, such as air-conditioning systems, or methane leakages from a gas pipe (cf. Section 2.2.3).
    - Scope 2 directly related to (inbound)-gate-to-(outbound)-gate activities: summarizing all GHG emissions resulting from the production of energy purchased by the lubricant manufacturer.

      Examples: externally produced steam and electricity (cf. Section 2.2.3).

- Scope 3 indirect emissions, directly related to (inbound)-gate-to-(outbound)-gate activities; excluding the emissions from the lubricant itself.

  Examples: water consumption and wastewater treatment, upstream energy-related emissions or waste generation by the lubricant manufacturer (cf. Section 2.2.3).

2.2.3 System boundary

The PCF assessment includes only those processes, material flows and energy flows within the system boundaries. The relevant life cycle stages in this PCF methodology document shall be selected according to the cradle-to-gate approach. Table 1 provides an overview of the specific elements that are included and excluded in this scope.

Table 1: Included and excluded activities as defined in the system boundary.

Included (if not excluded due to cut-off criteria)	Excluded
Production-related raw materials	Production of capital goods
Fuel and energy-related utilities (electricity, steam, natural gas, biomethane, oil, etc.)	Business travel or employee commuting
Direct emissions from manufacturing	Services such as engineering or infrastructure services, R&D activities
Other utilities consumed (process water, inert gas, etc.)	Downstream transportation
Treatment of waste and wastewater	Downstream packaging
Upstream transportation	
Upstream packaging	

The system boundary of the PCF calculation methodology is a cradle-to-gate PCF, comprising all extraction, manufacturing, upstream transportation and upstream packaging processes until the product leaves the (outbound) lubricant manufacturer's gate. It should be noted that typically the major impact of a lubricant originates from the raw materials used to produce the lubricant or other specialty. However, it is important to also assess all emission sources to ensure a full picture of the PCF. Emissions that occur during the use and disposal of the product are not included in a cradle-to-gate calculation, see Figure 2.

The following activities shall be included in cradle-to-lubricant manufacturer's outbound gate PCF calculation: Upstream-emissions of production-related raw materials including small contributors by mass if their specific carbon footprint is high, e.g. catalysts containing precious metals like platinum (cf. Section 3.2). Direct and indirect GHG emissions related to the product's production processes and utilities such as fuel and energy consumption (such as, but not limited to electricity, external heat, steam, natural gas, biomethane and oil) shall be included. This also includes upstream

GHG emissions resulting from the generation of electricity, steam, heating and cooling by the energy provider. Moreover, other utilities such as process water, excess steam, cooling water, demineralized water, or inert gases shall be included, as well as the treatment of waste and wastewater.

Also, upstream transportation shall be taken into account which consists of the upstream transportation up to the lubricant manufacturer gate, as well as inbound transportation within the lubricant manufacturer (site-to-site transportation/(inbound)-gate-to-(outbound)-gate). Similar to upstream transportation, upstream packaging shall be included, which takes the inbound packaging up to the lubricant manufacturer gate. Note that depending on the cut-off criteria the cut-off can still be applied to the included parts of the system boundary.

The PCF calculations shall exclude activities as described in Table 1. The reasons for the exclusion of activities are described in the following:

- Services such as engineering or infrastructure services and R&D activities, as well as the production of investment goods, business travel and employee commuting shall be excluded from the system boundaries of PCF calculations because these activities are not directly linked to the production activities of the respective lubricant or other specialty.
- Downstream transportation, outside the lubricant manufacturer, as well as downstream packaging shall be excluded from the PCF calculation. Downstream transportation is not considered, because the lubricant manufacturer delivers its products to different customers in different locations. This would lead to the contradiction of transparency aspects defined in the goal of this methodology. The same reasoning applies to the exclusion of downstream packaging. The lubricant manufacturer delivers products in different packaging sizes or bulk, resulting in a lack of transparency and comparability. Thus, it is recommended to calculate downstream packaging and downstream transportation depending on the customer requests of the lubricant manufacturer and report it separately.

Although this methodology describes the PCF calculation of an unpacked product at the manufacturer's outbound gate, users of this methodology can expand on this methodology and, outside this methodology, calculate the PCF of a packed and even delivered product.

3 Life Cycle Inventory for PCF calculation

This chapter provides an overview of the life cycle inventory which describes the compilation and quantification of inputs and outputs of a product system over its life cycle. Section 3.1 describes the data collection and validation steps that need to be performed. Based on the collected data, cut-off rules shall be applied (cf. Section 3.2) and multifunctionality problems shall be solved according to defined allocation procedures (cf. Section 3.3). Additionally, specific modeling principles for the calculation of waste and wastewater treatment, as well as recycling are described in Section 3.4.

3.1 Data requirements

This section describes the data collection and validation steps that need to be performed. Section 3.1.1 provides an overview of the principles governing data collection. It includes a description of the flows that take place within the product system, as well as the differentiation between the foreground system and the background system. In addition, an explanation of different data categories is provided. Section 3.1.2 outlines the data quality requirements used to evaluate the quality of the collected data. Section 3.1.3 offers a description of how to assess the total data quality rating of the resulting PCF.

3.1.1 Data collection principles

The data collection for the PCF calculation is crucial for ensuring the accuracy and completeness of LCA results. Therefore, the data sources of the collected data shall be reported during the PCF assessment. Note that the data collection shall consider all data within the defined system boundary (cf. Section 2.2).

In general, two types of input and output flows need to be collected: elementary flows and technology flows (cf. Figure 4). Elementary flows are material or energy flows entering or leaving the product system. Elementary flows are drawn/released from/into the environment without previous or subsequent human transformation, e.g. GHG emissions, natural gas, etc. Technology flows are all products, energy, waste and material flows that are exchanged between processes within the system boundary.

As an example, Figure 4 illustrates a stereotypical production process of a lubricant manufacturer within the defined system boundary (cf. Section 2.2): In the foreground system, at the lubricant manufacturer's production site, all processes that are under the control of the lubricant manufacturer are presented [2]. These can be simplified and summarized into the raw material storage, intra-site material handling, including

[2] Note: The foreground system might change for lubricant manufacturers that have operations before the manufacturing life cycle stage, cf. Section 2.2.2. Thus, processes as raw material acquisition might fall under the foreground system.

transport and the blending and storage of the actual production process of blending (also involving the management of waste such as flushing oil and product waste), which are accounted for in the foreground system. These processes are linked with their representing technology flows. In contrast, the background system consists of all processes that the lubricant manufacturer does not directly control, such as the production of electricity, fuel, thermal energy and raw materials. This also includes the exploration, production and inbound transportation of raw materials to the lubricant manufacturer. Note that the background system contains as well only cradle-to-gate data.

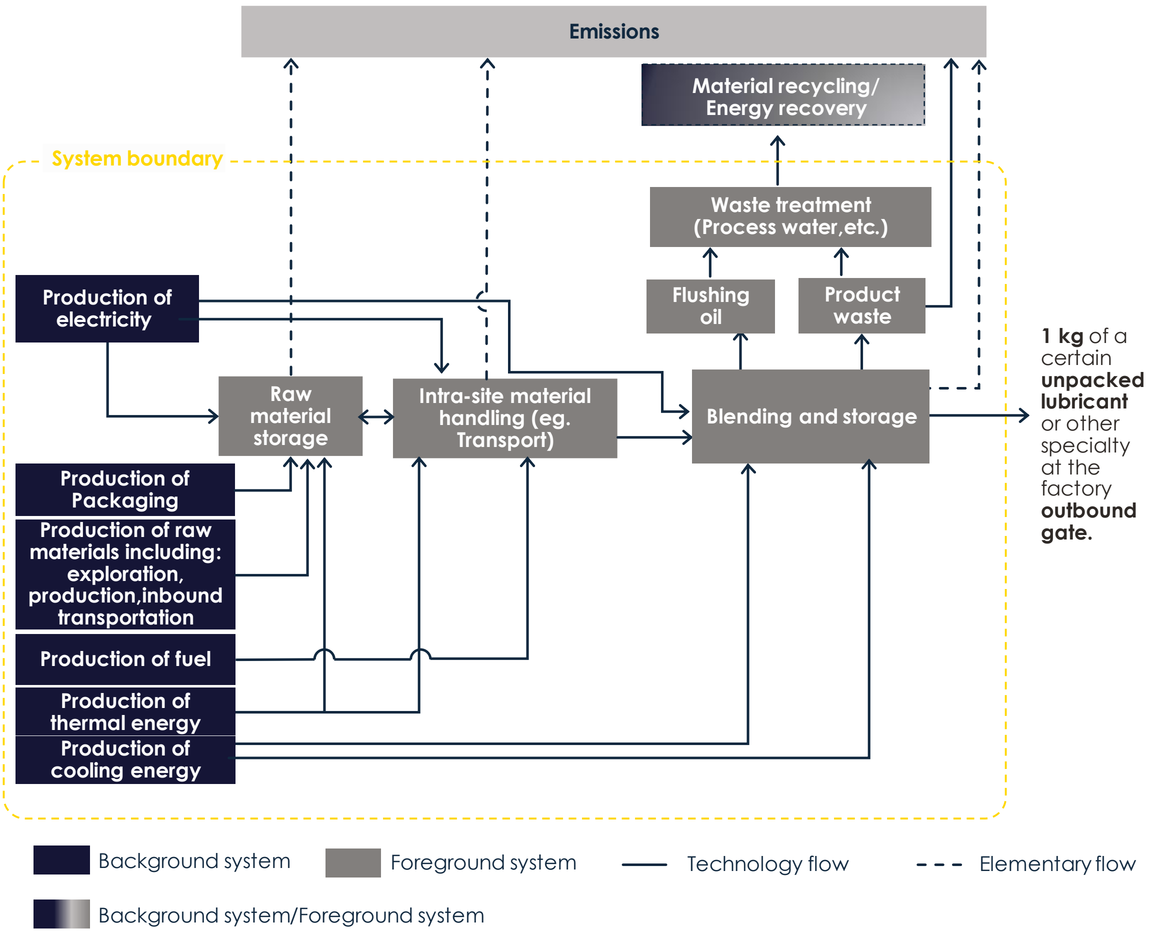


Figure 4: Illustrative process flow sheet of a lubricant manufacturer.

When collecting foreground and background data, several categories of data exist. These data categories represent (1) primary data, (2) specific secondary data, (3) proxy data and (4) estimated data.

When choosing data categories to represent the foreground or background data, the data quality requirements shall be assessed (cf. Section 3.1.2) and those data categories shall be selected for the PCF calculation with the highest data quality, for instance, based on the data quality rating (cf. Section 3.1.3) if not stated otherwise.

Primary Data:

Primary data refers to company-specific data obtained from processes within the life cycle of the product being studied or within a different but comparable product system (cf. Section 3.1.2 for data quality) and that are directly measured, collected, or calculated by the specific company. Primary data shall be collected to quantify the input and output flows in the foreground system of the lubricant manufacturers' production system (cf. Figure 4).

The data is gathered for all processes that are either owned or controlled by the reporting company. Measured data shall be collected over a period of one year, e.g. data from ERP systems. For non-continuous or irregular production years, e.g. pandemic years, recessions, etc., production data shall be averaged for a longer period of up to three production years for use in a PCF calculation. The collected data and thereof calculated PCF shall be validated by e.g. checking against other data sources, (cf. Section 5). Primary data used in the PCF calculation shall be as recent as practicable and not older than five years related to the PCF's reference year.

Specific Secondary Data:

Specific secondary data may include supplier-specific and technology-specific data that is derived from detailed data at the plant or site level, as well as market reports, patents, industry averages, or literature studies. Commonly, specific secondary data are sourced from third-party database providers such as Carbon Minds, Ecoinvent, Sphera or other suitable database providers. Specific secondary data should be independently reviewed for increased reliability and data quality rating. Specific secondary data can have the same or sometimes even higher data quality rating than primary data and vice versa. Depending on the process of data generation and sources, data quality can vary for both data sources. Thus, specific secondary data as well as primary data should be evaluated and checked for plausibility, as per GHG PPS.

For specific secondary data used in PCF calculation, the most recent activity data and LCIs should be considered. The reference year of the specific secondary data should not be older than 10 years related to the PCF's reference year. If the specific secondary data is older, more recent proxies should be used instead. For instance, if a lubricant manufacturer intends to use a specific secondary dataset from 2005 as a representative of raw material to calculate a PCF for the year 2020, it is recommended to use proxy data from at least 2010 or a more recent dataset instead.

Data gaps may arise when insufficient primary or specific secondary data is available to represent a particular process in a product's life cycle. In this case, data gaps should be filled with proxy data or, as a last resort, estimated data.

Proxy data:

Proxy data refer to primary or specific secondary data that reflect similar processes or products and can serve as a substitute or approximation. For instance, no primary or specific secondary data exists for PAO 6. However, specific secondary data for PAO 2 and PAO 40 as secondary data or supporting literature exists to support a study. As no data is available for PAO 6, specific secondary data for PAO 2 is used as proxy data for PAO 6.

Estimated data:

When no primary data, specific secondary data, or proxy data is available, the significance of the data missing in the data gap shall be evaluated. According to the cut-off criteria (cf. Section 3.2), missing data can be then cut-off from the product system if the significance of the missing data falls under the cut-off threshold. If the data gap is significant, a careful estimation shall be made, considering the knowledge of the missing data and any relevant information. A conservative approach should be applied by, e.g. selecting the value at the top of the potential range. Estimated data shall be replaced as soon as possible by primary or secondary data in the update of the PCF.

PCF:

PCFs should be regularly calculated to monitor progress. The validity period for PCFs is up to 5 years unless there are major production process or formulation changes (if the new PCF is expected to increase by over 20% compared to the original PCF). After 5 years, PCFs shall be recalculated. An internal review process for PCFs should be initiated prematurely, e.g. after 3 years may be suitable. The PCF calculation should always disclose the reference year and date of calculation/publication, as they determine the time boundary of the PCF value.

3.1.2 Data quality requirements

In the data collection phase, the lubricant manufacturer shall assess the quality of their data. This can be achieved by utilizing data quality indicators to evaluate activity data, emission factors and/or direct emissions data. A detailed description of the data quality indicators is shown in Table 2. For each indicator, three quality levels exist, where level 1 represents the highest data quality and level 3 the lowest.

Table 2: Description of data quality indicators.

Indicator	Description	Relation to data quality
Technological representative-ness	Chemicals can be manufactured through various production technologies utilizing different reaction pathways and plant designs. Hence, relevant data from actual production plants should be utilized for the studied product.	Lubricant manufacturers should select data that are technologically specific.
Temporal representative-ness	The degree to which the data reflects the actual time (e.g., year) or age of the activity.	Lubricant manufacturers should select data that are temporally specific.
Geographical representative-ness	Production chains of chemicals vary across regions. Therefore, datasets that accurately reflect the relevant population in terms of geography should be utilized.	Lubricant manufacturers select data that are geographically specific.
Completeness	Completeness includes the percentage of locations and processes for which data is available and used out of the total number that relate to a specific activity. Completeness also addresses seasonal and other normal fluctuations in data.	Lubricant manufacturers should select data that are complete.
Reliability	More reliable results are achieved when data is obtained from measurements of production data specific to the site and detailed modeling. On the other hand, simplified process calculations and assumptions result in less reliable data sets.	Lubricant manufacturers should select data that are reliable.

Table 3 shows the definitions for each indicator and data quality level.

Table 3: Data quality indicators (DQI) and their data quality levels.

Data quality indicator (DQI)	1	2	3 (default)
Technological representative-ness (TeR)	Same technology: All relevant production technologies are considered for the main product and raw materials.	Similar technology: The production technology used to model up to 50% of the raw materials is industrially relevant/similar but not the predominant market technology.	Different or unknown technology: Production of the main product or one or more major raw materials is based on a technology that is known not to be representative.
Temporal representative-ness (TiR)	Representativeness has been checked and confirmed from the reporting year.	Representativeness has been checked and confirmed within the last 5 years. Minor changes are known, but the dataset is still considered to be partly representative.	Data for substantial parts of the production chain is known to be outdated. Data is older than 5 years.
Geographical representative-ness (GeR)	Data correspond to the country average or state of the production location. No region specific averages such as EU, EMEA, or Asia are used to represent a specific state or country.	Data correspond to a similar area or region using region-specific averages, such as the EU average.	Data correspond to the global average or an unknown area.
Completeness (C)	Data collected for all relevant sites and processes within one year that have been measured at a high level of detail. In case of irregular production years, data is collected within up to three years.	Data collected for less than 50 % of sites or processes within one year, or data collected for more than 50% of sites or processes within less than one year. In case of irregular production years data is collected for less than 50% of sites or processes within three years, or for more than 50% of sites or processes within less than three years.	Data collected for less than 50% of sites or processes within less than one year or unknown. In case of irregular production years, data is collected for less than 50% of sites or processes within less than three years.

Reliability (R)	The activity data is fully based on measurements at relevant production sites. The results have been verified.	Activity data is partly based on assumptions, such as simplified process calculations or non-verified assumptions.	The activity data is based on non-qualified estimates.

3.1.3 The data quality rating (DQR)

In addition to assessing the data quality, the total data quality rating (DQR) of the PCF may be calculated and reported. The DQR aims at providing quantitative information on the overall quality of the data used and the resulting PCF. The DQR of a PCF for a lubricant or other specialty is formed by considering the data qualities of the unit process itself and the upstream value chain.

The DQR of the unit processes in the foreground system is based on the five data quality criteria (cf. Section 3.1.2), as specified in the formula below:

$$\mathrm{DQR}_{\mathrm{unit\ process}} = \frac{\mathrm{TeR} + \mathrm{GeR} + \mathrm{TiR} + \mathrm{C} + \mathrm{R}}{5}$$

Subsequently, the total DQR, meaning from cradle-to-(outbound)-gate, of a PCF is calculated from the sum of the PCF-based shares of the individual DQRs of the inputs and the unit process itself, as specified in the formula below:

$$\mathrm{DQR}_{\mathrm{total}} = \frac{\sum_{\mathrm{i}}(\mathrm{DQR}_{\mathrm{input\ i}} \cdot \mathrm{PCF}_{\mathrm{input\ i}} \cdot \mathrm{ConsumptionAmount}_{\mathrm{input\ i}})}{\mathrm{PCF}_{\mathrm{total}}} + \frac{\mathrm{DQR}_{\mathrm{unit\ process}} \cdot \mathrm{PCF}_{\mathrm{unit\ process}}}{\mathrm{PCF}_{\mathrm{total}}}$$

An example of the DQR calculation is shown in the following Table 4. Assuming a lubricant product has two inputs, for instance, one raw material input and one utility input, the information on the consumption amount, PCF and total DQR of both inputs need to be collected individually. Moreover, the PCF of the unit process operated by the lubricant manufacturer, as well as the DQR of the unit process need to be assessed. An example for this data collection is given in Table 4. In the next step, by inserting the collected data into the formula, the total DQR of the lubricant's PCF is calculated as shown in the formula below.

Table 4: Example values to calculate the total DQR of a PCF.

	Consumption Amount	PCF_{input}	$PCF_{unit\ process}$	$DQR_{input\ i}$	$DQR_{unit\ process}$
Input 1	0.5 kg/kg product	3 kg CO_{2eq}/kg		2.5	
Input 2	0.7 kg/kg product	4 kg CO_{2eq}/kg		1.2	
Unit process			1 kg CO_{2eq}/kg product		1.5

$$DQR_{total} = \frac{2.5 * 3\,\frac{\text{kg CO}_{2eq}}{\text{kg}} * 0.5\,\frac{\text{kg}}{\text{kg}_{product}} + 1.2 * 4\,\frac{\text{kg CO}_{2eq}}{\text{kg}} * 0.7\,\frac{\text{kg}}{\text{kg}_{product}}}{5.3\,\frac{\text{kg CO}_{2eq}}{\text{kg}_{product}}} + \frac{1.5 * 1\,\frac{\text{kg CO}_{2eq}}{\text{kg}_{product}}}{5.3\,\frac{\text{kg CO}_{2eq}}{\text{kg}_{product}}} = 1.62$$

Calculating the DQR can be difficult if the individual DQRs of the data used are not provided with the PCF data. To address this issue, a default DQR value of 3 (cf. Section 3.1.2) may be assigned to inputs. This approach represents a conservative calculation of the DQR.

When reporting DQRs, a qualitative explanation of the total data quality of the PCF should be provided alongside the quantitative DQR. This ensures that special cases are reflected, which may not be accounted for in the DQR calculation. For instance, if the dataset used to represent a unit process input has a high DQR but is used as a proxy by only reflecting a comparable unit process input and not the specific input is considered, this should be explained in the qualitative description of the PCF's total data quality.

3.2 Cut-offs

When calculating a PCF, it is necessary to include all processes, flows and activities that are linked to the product system as defined by the system boundary Table 1 (cf. Section 2.2.3). Nevertheless, the number of unlimited processes linked to the product system makes the collection of all data unfeasible, thus following the cut-off criteria shall be applied:

- At least 95% of all mass inputs (cumulatively) shall be included (>98% recommended).
- At least 95% of all energy inputs (cumulatively) shall be included (>98% recommended).
- Not more than 5% of the total PCF shall fall under cut-off criteria.
- When the impact of inputs on the total PCF is unclear, use estimated figures in a calculation to determine if a cut-off can be applied using an iterative approach.
- Materials with a high specific carbon footprint, e.g. catalysts containing precious metals like platinum, would likely not fall under the cut-off criteria as their contribution to the total PCF is typically higher than 5 %.

Where data is available, these should be included, even if a flow's contribution to the carbon footprint of a product is not relevant as per the above thresholds. Consider expert guesses, the global warming potentials of elementary flows and the studied region of the PCF calculation to quantify the relevance of an elementary flow.

3.3 Allocation

When evaluating the carbon footprint of products, the common issue of multifunctionality is encountered. Multifunctionality occurs when a process provides multiple functions. Multiple functions can be the production of multiple products, the treatment of multiple wastes, or the joint treatment of waste and subsequent production of a valuable product. This also includes separately produced products from a joint measurement of the utility consumption that cannot be traced back to the single production processes. To calculate product-specific carbon footprints for products from multifunctional processes, all inputs and outputs, such as raw material demands and exchanges, shall be allocated between the processes' functions.

Several methodological approaches exist for solving multifunctionality problems: subdivision, system expansion and allocation via physical or other underlying relationships. The selection of a specific allocation method can significantly influence the PCF. Thus, the ISO standards 14040/44/67 established a hierarchy among the different allocation methods to align the selection of allocation methods. *Figure 5* displays a decision tree that demonstrates the allocation hierarchy. The allocation hierarchy consists of four levels arranged in the order of preference: subdivision, system expansion, allocation via physical relationship and allocation via other criteria:

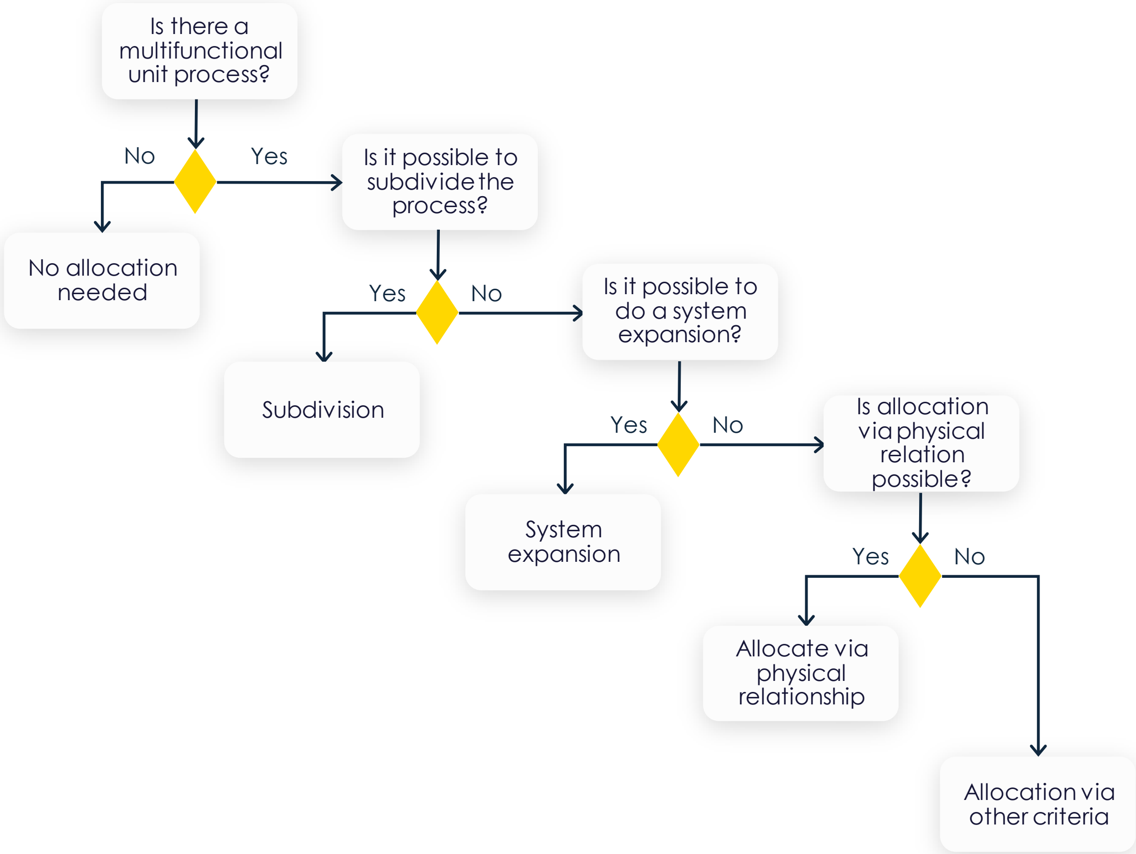


Figure 5: Allocation hierarchy according to ISO 14040/44 and ISO 14067:2018.

The first step is to identify whether a multifunctionality problem occurs in the process under study (cf. Figure 5). If no multifunctionality exists, all inputs and outputs of the process are attributed to the single function (e.g. to a product) of the process. If multifunctionality occurs, the allocation hierarchy shall be considered:

Level 1: Subdivision

If possible, allocation shall be avoided by examining if subdivision is applicable to the process under evaluation. Subdivision divides the unit process to be allocated into two or more technical sub-processes and collects the input and output data related to these sub-processes.

Often, subdivision is not feasible, because many processes cannot be subdivided into subprocesses. Thus, the multifunctionality shall be checked for system expansion, leading to the next level in the decision tree (cf. Figure 5).

Level 2: System expansion or system expansion via avoided burden

If subdivision is not feasible, system expansion shall be used to solve the multifunctionality problem. The system expansion approach expands the product system to include all functions of the process into the system boundaries.

Conversely, system expansion via avoided burden, which is also known as substitution, can be used to solve the multifunctionality problem. In the system expansion via the avoided burden approach, a credit is given for the joint provision of all functions that are not included in the declared unit. This credit is calculated by the avoided burden of the conventional processes that would have been used to provide the additional functions.

To apply system expansion, it is necessary to identify such alternative processes that would have been operated in the absence of the product system being analyzed. An example where system expansion is often applied is in the case of energy co-production, where energy is co-produced in a process and not used internally in the process.

Level 3: Allocation via physical relationships

If system expansion cannot be applied, the allocation hierarchy indicates to allocate via physical relationships (cf. Figure 5). Where allocation cannot be avoided, the inputs and outputs of the system shall be partitioned between its different functions in a way that reflects the underlying physical relationships between them, i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system. A practical example of physical relationships could be the formulation of multiple lubricants or other specialties: The PCF of a raw material is only allocated to the formulation or other specialties which include the particular raw material.

Level 4: Allocation via other criteria

If allocation via physical relationships cannot be used for the allocation, allocation via other criteria should be applied, leading to the last level of the decision tree Figure 5.

Where physical relationships alone cannot be established or used as the basis for allocation, the inputs shall be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the e.g. mass, economic value, volume, etc. of the products.

According to this methodology, mass allocation shall be used in case of allocation via other criteria according to the allocation hierarchy. An example of mass allocation for calculating the PCF of a lubricant or other specialty can be: if a lubricant manufacturer cannot e.g., measure the individual energy consumption and waste generation of a single product in the dedicated blending unit, then the lubricant manufacturer can determine these data on the next higher available aggregation level, e.g. for the whole site where the product is produced and then allocate these flows to the individual product by referring the total flows to the total mass of products produced in this site. An exception to this general rule represents multi-output processes co-producing hydrogen, see latest TfS PCF Guideline: In this case, allocation based on the energy content shall be applied, except if one or more products have zero energy content, in which case allocation based on mass content is used.

In addition to these rules, this methodology acknowledges that some products within the lubricant manufacturer's value chain apply to other PCF methodologies, guidelines, or PCRs, as described in Section 2.1.

Thus, this methodology accepts other allocation principles that are in line with the hierarchy in Section 2.2. It is important to keep in mind that the allocation principle has a major impact on the PCF value, thus it shall be reported to and from the lubricant manufacturer as per Section 6.

3.4 Modeling of waste, wastewater and recycling

This section discusses how waste and wastewater treatment (cf. Section 3.4.1) as well as material recycling (cf. Section 3.4.2) shall be handled. A waste is any substance or object that the holder discards or intends to discard, e.g., per European Waste Framework Directive.

Herein, waste and wastewater are simplified by the term "waste".

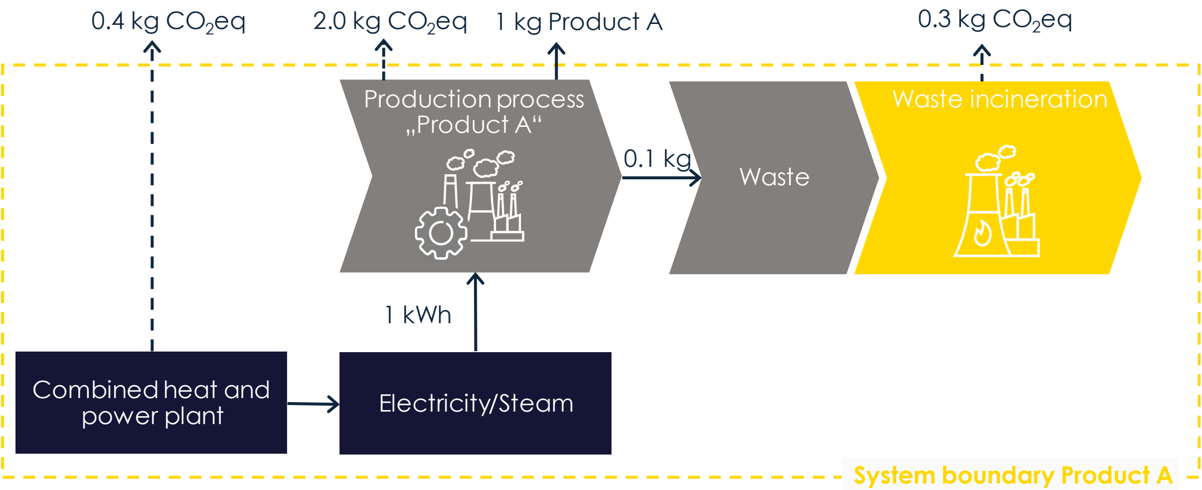
3.4.1 Waste treatment

In the following, this methodology presents how waste and wastewater treatment shall be handled depending on different scenarios:

- Scenario 1: waste treatment without energy recovery
- Scenario 2: waste treatment with energy recovery within the system boundary
- Scenario 3: waste treatment with energy recovery outside the system boundary

Scenario 1: Waste treatment without energy recovery

The simplest scenario is the waste from the lubricant manufacturing process of a lubricant or other specialty product which is incinerated without energy recovery. The GHG emissions of the incineration shall be fully allocated to the lubricant or other specialty, as shown in Figure 6.

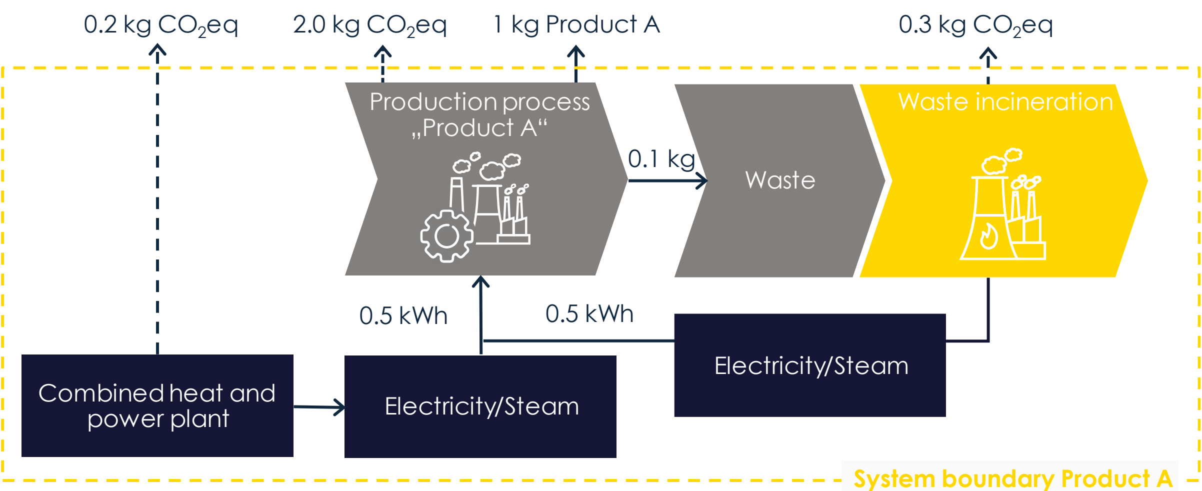


$$PCF_{\text{Product A}} = 2.0\,\frac{kg\ CO_2eq}{kg\ Product\ A} + 0.4\,\frac{kg\ CO_2eq}{kg\ Product\ A} + 0.3\,\frac{kg\ CO_2eq}{kg\ Product\ A} = 2.7\,\frac{kg\ CO_2eq}{kg\ Product\ A}$$

Figure 6: Waste treatment without energy recovery. Adapted from TfS PCF Guideline. All flows are scaled to the declared unit of the production of 1 kg Product A.

Scenario 2: Waste treatment with energy recovery within the system boundary

The second scenario is waste incineration with energy recovery within the system boundary. This can be the case when the product is incinerated with energy recovery on-site under operational control. The recovered energy is used solely in the production process of the product, so no allocation is necessary. All resulting GHG emissions from the process can be attributed to the product. An example is shown in Figure 7.



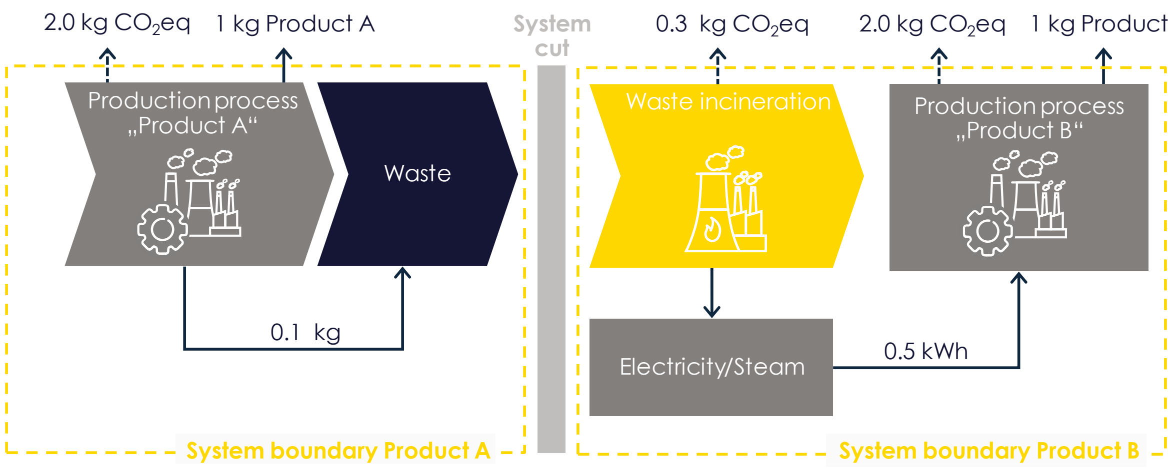
$$PCF_{\text{Product A}} = 2.0\,\frac{kg\ CO_2eq}{kg\ Product\ A} + 0.2\,\frac{kg\ CO_2eq}{kg\ Product\ A} + 0.3\,\frac{kg\ CO_2eq}{kg\ Product\ A} = 2.5\,\frac{kg\ CO_2eq}{kg\ Product\ A}$$

Figure 7: Waste incineration with energy recovery within the system boundary. Adapted from TfS PCF Guideline. All CO_2eq attributed to the product.

Scenario 3: Waste treatment with energy recovery outside the system boundary

In the case of waste treatment with energy recovery outside the system boundary, the cut-off approach shall be used to allocate the GHG emissions of the waste treatment. In the cut-off approach, a system cut is done after the waste has been generated by the lubricant manufacturer. The waste is incinerated outside of the defined system boundary and no emissions are allocated to the waste producer (lubricant manufacturer). The user that utilizes the recovered energy from the waste incineration process gets the emission accounted for in their production. An example of the cut-off approach is shown in Figure 8.

This PCF calculation methodology acknowledges that there are different approaches to handle waste treatment with energy recovery outside of the system boundary. However, to ensure more consistency, transparency and comparability of PCF calculations the cut-off approach should be used.



PCF Product A = 2.0 $\frac{kg\ CO_2eq}{kg\ Product\ A}$ = 2.0 $\frac{kg\ CO_2eq}{kg\ Product\ A}$

PCF Energy = 0.3 kg CO_2eq / 0.5 kWh = 0.6 $\frac{kg\ CO_2eq}{kWh}$

PCF Product B = 2.0 $\frac{kg\ CO_2eq}{kg\ Product\ B}$ + 0.3 $\frac{kg\ CO_2eq}{kg\ Product\ B}$ = 2.3 $\frac{kg\ CO_2eq}{kg\ Product\ B}$

Figure 8: Energy recovery from waste incineration with the application of the cut-off approach. Adapted from TfS PCF Guideline.

3.4.2 Recycling

Material recycling involves the extraction of secondary materials from waste, which can then be reused as raw materials in the manufacturing of various products[3]. If the recycling process and use of the obtained secondary material occurs inside the lubricant manufacturer's system boundary, there is no need for specific considerations and the GHG emissions of the recycling process should be accounted for in the PCF.

However, if the recycling process occurs outside of the lubricant manufacturer's system boundary, the following rules according to the cut-off approach shall be applied[4]:

- Preparatory steps and supporting activities, such as collection, transportation, sorting, dismantling, or shredding, shall be factored into the inventory results of the product system that generates the secondary product, as they have an impact on its overall carbon footprint, e.g. collection of used oil should be attributed to the re-refiner for the production of re-refined base oil.
- In the recycling process, the waste input is considered to be burden-free. This means that any burdens or credits associated with material from previous or subsequent life cycles are not taken into account and are "cut-off."
- The impact of the recycling process shall be added to the inventory results, thus influencing the PCF value of the product that uses the secondary material.
- For the product in scope the PCF of all burdens from preparatory steps and supporting activities, as well as the recycling process shall be reported.

[3] This methodology acknowledges PCFs calculated by the mass balance approach, as per ISO 22095 for sustainable material, such as biobased materials, recycled materials.

[4] Case study from IFEU/GEIR support the cut-off approach for an attributional LCA. There is an acknowledgment that the study also considered a consequential LCA. The reference is only intended to support the cut-off approach for an attributional LCA study.

4 Life Cycle Impact Assessment for PCF calculation

In the process of life cycle impact assessment (LCIA), all elementary flows are transformed into the environmental impact category of climate change by multiplying the elementary flows with the 100-year global warming potential (GWP 100) characterization factors. The most recent characterization factors of the Intergovernmental Panel on Climate Change (IPCC) shall be employed for the calculation of the product carbon footprint (PCF). Currently, the latest values available GWP 100 characterization factors are based on IPCC's Sixth Assessment Report (AR6). The characterization factors shall be extracted from Table 7.15 of Chapter 7 of the IPCC AR6 Climate Change 2021 Physical Science Basis. For substances that are not listed in Table 7.15, the characterization factors shall be extracted from Table 7.SM.7 in Chapter 7 Supplementary Materials of the AR6 Climate Change 2021 Physical Science Basis.

The outcome of the elementary flow conversion generates the PCF result, expressed in kg CO_2-equivalent per declared unit, representing all greenhouse gas emissions and removals throughout a product's considered life cycle stages. It should be noted that this methodology evaluates the life cycle stages of a lubricant manufacturer's products in a cradle-to-(outbound)-gate product system, resulting in a partial PCF.

According to ISO 14067:2018, partial PCFs shall take into account fossil and biogenic GHG emissions and removals, as well as GHG emissions and removals from direct land use change (dLUC) and aircraft GHG emissions. The aircraft GHG emissions may be neglected due to the minor significance of aircraft transportation in the value chain of lubricants or other specialties and therefore, the minor significance of aircraft GHG emissions to the total partial PCF. Furthermore, all summands shall be reported separately in the final report and not only the partial PCF. Consequently, the partial PCF result according to this methodology is summarized in the following Equation:

Sum of $PCF_{partial}$ = $PCF_{partial,fossil}$ + $PCF_{partial,biogenic}$ + $PCF_{partial,dLUC}$

- $PCF_{partial,fossil}$ including only fossil GHG emissions/removals in kg CO_{2e}/kg lubricant or other specialty.
- $PCF_{partial,biogenic}$ including only biogenic GHG emissions/removals in kg CO_{2e} /kg lubricant or other specialty.
- $PCF_{partial,dLUC}$ including only GHG emissions/removals occurring as a result of direct land use change (dLUC) in kg CO_{2e}/kg lubricant or other specialty.

According to ISO 14067:2018, the following characterization factors shall be applied to consider sources and sinks of biogenic and direct land use change greenhouse gas emissions:

- -1 kg CO_2eq./kg CO_2 for biogenic CO_2 uptake
- +1 kg CO_2eq./kg CO_2 for biogenic CO_2 emissions
- -1 kg CO_2eq./kg CO_2 for CO_2 stored in biomass stock or soil
- +1 kg CO_2eq./kg CO_2 for CO_2 released from biomass stock or soil

Additionally, to enable the calculation of biogenic greenhouse gas emissions in the subsequent downstream value chain, the biogenic carbon content (in kg C_{Bio} / kg product) and the total carbon content (TCC) (in kg C_{total} /kg product), are tracked throughout the product's value chain. The lubricant manufacturer shall report separately the biogenic carbon content and the TCC of the lubricant or other specialty. Furthermore, the recycled content should be stated as the mass percentage of recycled content per kg product.

4.1 Additional Reporting

If a company is taking actions to offset emissions related to a particular product, these compensation measures shall not be included in the calculation of the PCF. Additionally, the remaining GHG emission compensation measures can be reported separately. Herein, compensation or neutralization measures mean GHG related emission/removals in kg CO2eq/kg.

GHG emissions from electricity use should be calculated via the market-based approach.

5 Sensitivity analysis, quality checks and interpretation

The results of the PCF calculation can be analyzed in terms of the goal and scope definition by identifying key aspects of the PCF results using various techniques including:

Contribution analysis: aims to identify significant issues in the PCF results by examining individual life cycle stages, processes and key flows.

Completeness check: ensures that all relevant information and data requirements specified in the goal and scope of the PCF calculation are available and complete.

Consistency check: evaluates the consistency of assumptions, methods and data with the goal and scope of the PCF calculation.

Quality assessment: involves validating the collected data for the PCF calculation by checking against scientific laws, comparing with other data sources and assessing the suitability of secondary data in terms of technology and geography.

Sensitivity analysis: to ensure the results are robust, sensitivity analysis shall be conducted using various modeling choices, such as an alternative allocation method for the foreground product system.

With the sensitivity analysis, the PCF values will vary. For significant variations of PCF, for instance, due to remaining methodological choices or the choice of background datasets (cf. Section 3.1), the decisive change and the range by which the PCF is expected to change should be reported.

The following checklist can be used for LCA practitioners to validate the PCF:

- Verify the overall mass balance, including raw material inputs, product outputs, wastes and emissions into the air and water.
- Confirm the realism of on-stage direct emissions, such as by using carbon balance.
- Evaluate utility consumption for plausibility.
- Ensure allocation factors are in line with Section 3.3.
- Assess the appropriateness of secondary datasets selected for Scope 3. Check whether the technology represented in the LCI is appropriate, whether the application of proxies is appropriate and consider replacing the dataset with supplier data if available.
- Benchmark CO_2-equivalents against own calculations, the same product from other plants or sites, existing LCA data and LCIs from third-party databases.
- Investigate and determine the cause of significant deviations from LCA benchmark data.

6 Reporting requirements

To ensure consistent reporting and transparent PCF values, the following data shall be included in the report of the PCF:

- Company name and ID
- Product trade name
- Declared unit and reference flow
- Description of the life cycle stage under the study
- Total GHG emissions and removals representing the partial PCF ($PCF_{partial}$)
- Net fossil GHG emissions and removals ($PCF_{partial,fossil}$)
- Biogenic GHG emissions and removals ($PCF_{partial,biogenic}$)
- GHG emissions and removals occurring due to direct land use change ($PCF_{partial,dLUC}$)
- Biogenic carbon content of products
- Selected cut-off criteria and cut-offs
- Selected allocation procedures
- Description of data and data quality, according to Section 3.1.2. The reporting of the data quality rating (DQR) according to Section 3.1.3 may be reported in future
- Time period for which the PCF is representative (Year or start/end date if the time period is > one year. Include versions if revised within reference period)
- Technological description, e.g.: the blending of oil
- Geography: location or region of production for which the PCF is representative. Moreover, it shall be stated whether the PCF has been obtained by averaging the PCF across several individual production sites within the specific location or region.
- Optional additional reporting:
    - Total GHG emissions and removals of partial PCF ($PCF_{partial}$), fossil GHG emissions and removals ($PCF_{partial,fossil}$), biogenic GHG emissions and removals ($PCF_{partial,biogenic}$), GHG emissions and removals occurring due to direct land use change ($PCF_{partial,dLUC}$) for (1) outbound transportation and (2) outbound packaging of the lubricant manufacturer to their customers. Note that the cut-off criteria can still apply to the outbound transportation and outbound packaging of the lubricant manufacturer to their customers.
    - Report of remaining GHG emissions, if applicable (cf. Section 4.1)

6.1 Additional reporting requirements for suppliers

If the lubricant manufacturer receives raw material PCFs from a supplier, the following additional reporting requirements shall apply:

- If a methodology differs from this methodology for lubricants and other specialties, the alternative methodology adopted by the supplier shall be reported accurately at all times along with the PCF, so that the differences to this methodology are clear. The reported methodology shall be categorized according to the hierarchy listed in Section 2.1.
- Total GHG emissions and removals ($PCF_{partial}$), fossil GHG emissions and removals ($PCF_{partial,fossil}$), biogenic GHG emissions and removals ($PCF_{partial,biogenic}$), GHG emissions and removals occurring due to direct land use change ($PCF_{partial,dLUC}$) for (1) outbound transportation and (2) outbound packaging of the suppliers to the lubricant manufacturer, shall be already included in the raw material PCF from a supplier.

7 Sources and valid documents

This document explains the UEIL/ATIEL PCF calculation methodology for computing product carbon footprints from cradle-to-(outbound)-gate in compliance with ISO 14067:2018 and GHG Protocol Product Standard. The methodological options, along with their corresponding assumptions and limitations, are outlined in detail. Sources on which this document is based on:

- Actual version of ISO 14067 (ISO 14067:2018) Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification.
- The Greenhouse Gas Protocol. Product Life Cycle Accounting and Reporting Standard.
- Together for Sustainability – The Product Carbon footprint Guideline for the Chemical Industry – Version 2.0 – November 2022.
- API Technical Report 1533: Lubricants Life Cycle Assessment and Carbon Footprinting — Methodology and Best Practice, May 2023.
- Pathfinder Framework (PACT powered by WBCSD); GHG Protocol Product Standard [GHG Protocol Product Standard].
- Product Environmental Footprint Category rule (PEFCR) developed under the European Product Environmental Footprint initiative [EU PEF].
- ISO/TS 14071:2014: Environmental management — Life cycle assessment — Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006
- ISO 14026:2017: Environmental labels and declarations. Principles, requirements and guidelines for communication of footprint information

- IFEU/GEIR case study: Updated LCA for regeneration of waste oil to base oil – Final Report

8 Terms and Abbreviations

The following chapter lists the terms and abbreviations in Table 5 and Table 6, respectively.

Table 5 Terms and Explanations

Term	Explanation
Allocation	Practice of 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
Functional Unit	Quantified performance of a product system for use as a reference flow. (ISO 14040)
Base oil	Base oils are essential lubricant components derived from petroleum, synthetic sources, or renewable sources used to reduce friction and protect machinery.
CO_2 equivalents	Unit for comparing the radiative forcing of a GHG to that of carbon dioxide.
Cut off	Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study. (ISO14040)
Declared Unit	Quantity of a product for use as a reference unit in the quantification of a partial PCF. (ISO 14067:2018)
Gate-to-gate	Assessment scope which includes part of the product's life cycle limited to the production of the studied product and excluding the acquisition of materials, the use or end-of-life stages. (WBCSD)
Greenhouse Gas	Gases that contribute to the greenhouse effect by absorbing infrared radiation. Carbon dioxide and chlorofluorocarbons are examples of greenhouse gases.

GHG Emissions	Emissions from a process or system which release GHG into the atmosphere
GHG Protocol Product Standard	The Greenhouse Gas Protocol. Product Life Cycle Accounting and Reporting Standard
ISO 14067:2018	Standard that provides principles, requirements and guidelines for the quantification and communication of the carbon footprint of a product based on LCA principles.
Life Cycle Assessment	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. ISO 14040.
Life Cycle Impact Assessment	Evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product (ISO14040:2006)
Life Cycle Inventory	LCI is the data collection portion of LCA; a methodology step that involves creating an inventory of input and output flows for a product system.
Lubricants	A lubricant is a liquid or solid that lubricates surfaces to mainly reduce friction and wear but also to fulfill other functions such as cooling, corrosion protection or vibration damping.
Partial PCF	Method of calculating carbon emissions that accounts for the carbon footprint of each stage in the production process. It focuses on specific stages in the life cycle of a product or component and calculates the carbon emissions associated with them (such as cradle-to-gate, gate-to-gate, etc.).
Product carbon footprint	The sum of greenhouse gas (GHG) emissions and GHG removals in a product system expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change. (ISO 14067:2018)

Reference Flow	The measure of the outputs from processes in a given product system required to fulfill the function expressed by the functional unit or declared unit.
Scope 1 emissions	Direct GHG emissions or -equivalents (CO_{2e}) by the lubricant manufacturer (e.g., process emissions, heat production, GHG leakages, …) acc. to GHG-Protocol
Scope 2 emissions	Indirect GHG emissions or -equivalents (CO_{2e}) resulting from the generation of energy purchased by lubricant manufacturer (e.g., electricity, steam) acc. to GHG-Protocol.
Downstream Scope 3 emissions	Downstream emissions are the emissions related to customers, from selling goods and services to their distribution, use and end-of-life stages.
Upstream Scope 3 emissions	Indirect GHG emissions which originate upstream due to the use of raw materials purchased from suppliers as well as indirect GHG emissions due to the generation or extraction of fuels, but also other non-energy-related indirect GHG emissions caused by the operation such as Waste Generation, Water Consumption, Business Travel etc.).
Specialty	Herein, specialties are defined as products also produced and marketed by the lubricant industry, whereby the lubrication function plays a minor role and other functions, such as e.g., cleaning, cooling or heat transfer play a major role.
WBCSD chemical guidance	Guidance of the World Business Council for Sustainable Development for Accounting & Reporting Corporate GHG Emissions in the Chemical Sector Value Chain

Table 6: Abbreviations and Explanations

Abbreviation	Explanation
ATIEL	The Technical Association of the European Lubricants Industry
CCF	Corporate carbon footprint. Total amount of greenhouse gas emissions, measured in Carbon Dioxide Equivalents (CO_2eq).
C	Completeness
CO_2	Carbon Dioxide
CO_{2eq}	Carbon Dioxide Equivalents
DQR	Data Quality Rating
DQI	Data quality indicator
ERP	Enterprise Resource Planning
EU PEF	European Product Environmental Footprint initiative
GeR	Geographical representativeness
GEIR	European Grouping of the Regenerative Industry
GHG	Greenhouse Gas
GHG PPS	Greenhouse Gas Protocol Product Standard
IFEU	Institut für Energie- und Umweltforschung Heidelberg
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment

PAO	Polyalphaolefin
PCF	Product Carbon Footprint
R	Reliability
TeR	Technological representativeness
TiR	Temporal representativeness
TCC	Total carbon content
UEIL	Union of the European Lubricants Industry
WBCSD	World Business Council for Sustainable Development