To: API Lubricants Group
Cc: Lubricants Group Mailing List
API

<u>Technical Report 1533 "Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice"</u>

On December 15, 2022, Lubricants Group (LSG) received a Technical Report (TR) from the Lubricants Sustainability Work Group entitled "Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice". The Lubricants Sustainability Work Group had completed their work and offered the final draft of API TR1533 Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice and presented it for a Lubricants Group ballot review.

After discussion, the Lubricants Group received a motion to issue a 60-day Ballot to Review and Accept API TR1533 Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice. The Motion was Seconded and Carried by a unanimous Vote of the present LG Members

A copy of API TR1533 "Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice" is included in the Ballot as Attachment 1.

Lubricants Life Cycle Assessment and Carbon Footprinting –

Methodology and Best Practice

API TECHNICAL REPORT TR1533

FIRST EDITION, OCTOBER 2022

American Petroleum Institute

Lubricants Group Members should use the API Ballot System to cast their vote and make comments. The Ballot Link is: http://Ballots.api.org. The Lubricants Group Member votes will be counted, and all received comments reviewed and considered to finalize and accept API TR1533 "Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice".

Non-Lubricants Group Members may comment using the API Ballot system. The Ballot Link is: http://Ballots.api.org .

This Ballot will close on February 17, 2022. All votes and/or comments on the API TR1533 “Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice” must be received by that date. API TR1533 “Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice” will be issued with an Affirmative Vote.

Attachment 1

API TR1533

“Lubricants Life Cycle Assessment and Carbon Footprinting

Methodology and Best Practice”

Lubricants Life Cycle Assessment and Carbon Footprinting – Methodology and Best Practice

API TECHNICAL REPORT 1533
FIRST EDITION, October 2022

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1. Introduction, Purpose, Scope, and Definitions

Life cycle assessment (LCA) and carbon footprints of products (CFP) are established methodologies used to quantify the environmental performance of products, processes or services, and are increasingly being used as a basis for environmental decision making along the supply chain. While LCA includes multiple impact categories in the assessment, CFP focusses specifically on the impact category of "climate change", which is associated with greenhouse gas (GHG) emissions/removals.

Both LCA (International Organization for Standardization, 2006) (International Organization for Standardization, 2006) and CFP (International Organization for Standardization, 2018) depend on functional methods for which there are international standards that set principles, requirements and guidelines for carrying out such studies. Despite these standards, choices are still left with the practitioner performing the study regarding for example: setting the boundaries of the system, allocation of impacts between co-products or recycled products, selecting metrics used to estimate impacts, choosing the sources of data. These choices can have significant impacts on the outcome of a performed assessment and alignment on these choices is needed to allow for fair comparison of results from different studies.

This need for alignment is the motivation to create a common LCA and CFP framework for lubricant products within the API Lubricants Sustainability Group. This collaboration was formed through the cooperation of API members with the intention of providing guidance via this Technical Report (TR).

The purpose of this document is to define terminology and to identify and capture best practices for life cycle assessment (LCA) and carbon footprinting of lubricants[1] (Figure 1; definition of life cycle). The overall aim is to promote harmonization and consistency in the application of LCA and carbon footprinting across the lubricants industry. While many concepts discussed in this Technical Report will be generally applicable to both LCA and CFP assessments, more detailed discussion in this version of the document are often focused on CFP assessments, driven by strong interest in the industry in the topic.

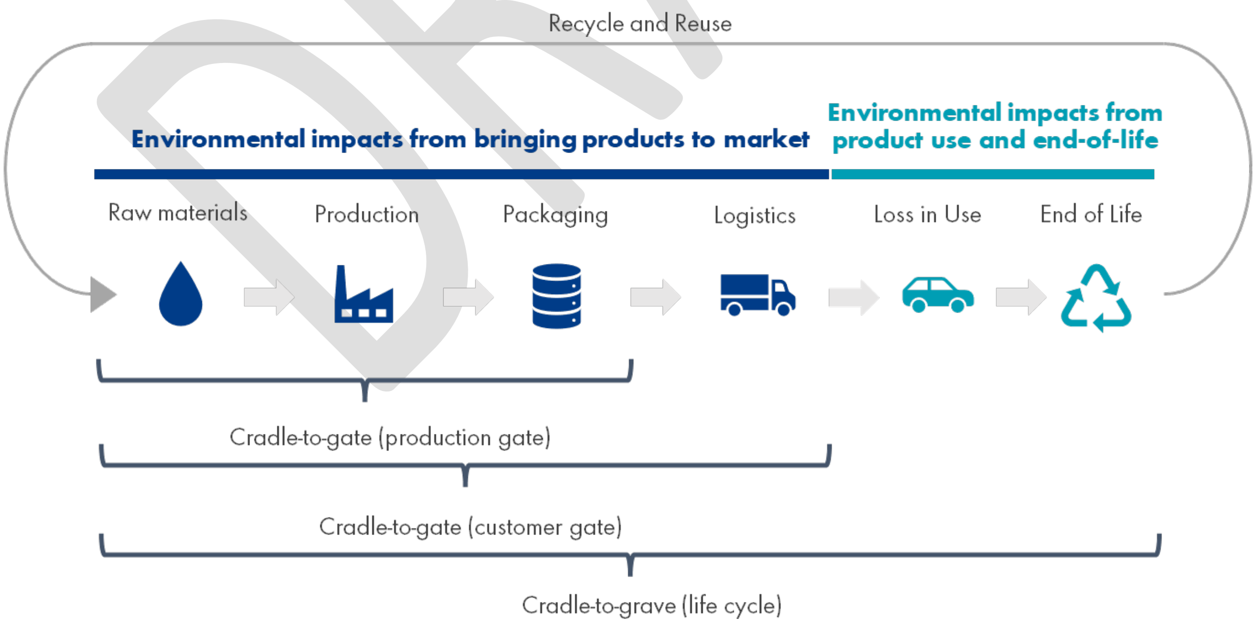


Figure 1: Overview of the key stages of the lubricant life cycle

[1] "Lubricant" is defined in section 3.1 and for the purposes of this Technical Report encompasses "lubricants and specialty products".

This best practice document is not intended to be as prescriptive and detailed as product category rules (PCR). However, it could serve as the foundation for such definitions at a later date.

Lubricants for various application areas, that are consistent with the definition of a "lubricant" as provided in section 3.1 and where sufficient data is available to describe the life cycle stages outlined in Figure 1, are part of the scope for this Technical Report. The applicability of the methodology in this Technical Report to a specific case in hand can ultimately be decided by the practitioner executing the study. Examples of lubricants include, but are not limited to the following:

- Engine oils (both light and heavy duty)
- Driveline fluids
- Greases
- Other industrial type fluids e.g., thermal management, hydraulic fluids, gear oils.

This Technical Report defines the carbon footprint of product (CFP) for a lubricant product on a life cycle (Figure 1) or cradle-to-grave basis. Therefore, to generate the CFP, the absolute GHG emission and removals at each stage of the life cycle are summed up (Figure 2) and converted to CO_2 equivalent (CO_2e). To generate a partial CFP, e.g., on a cradle-to-gate basis, the respective, absolute GHG emissions and removals at the applicable life cycle stages are summed up and converted to CO_2e.

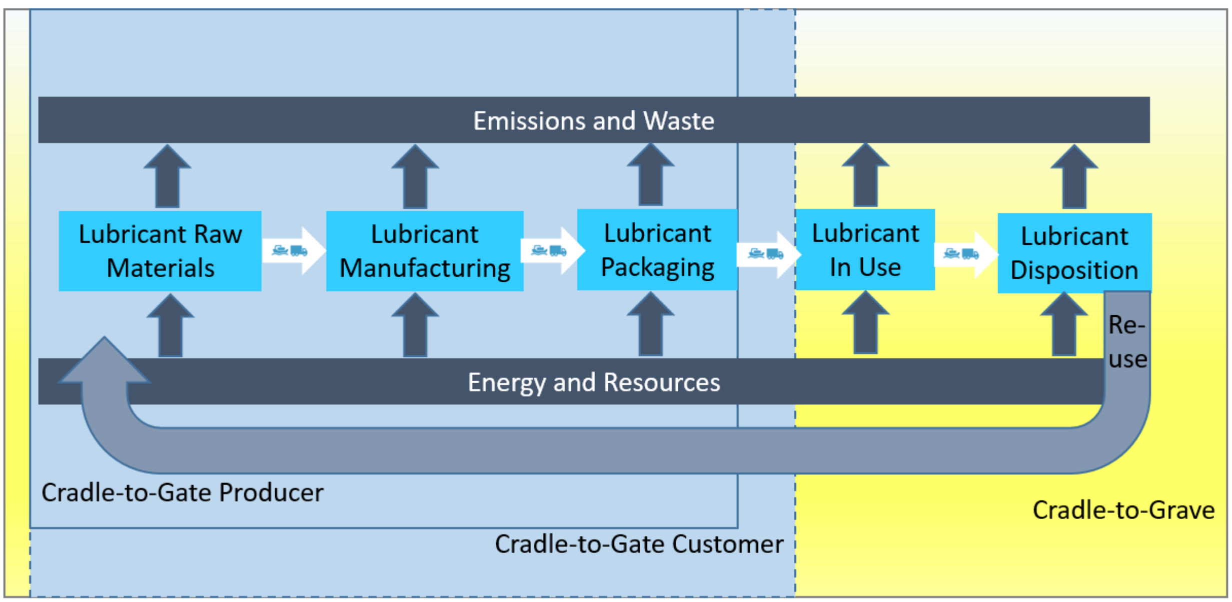


Figure 2: Definition of scopes for carbon footprint of product (CFP) assessments.

With focus on the carbon content of the lubricant itself, Figure 3 examines potential losses of the lubricant to the environment after the production (after cradle-to-customer-gate) and until final disposition in more detail. These potential losses should be accounted for and included in the assessment if a cradle-to-grave scope of the CFP is intended to be covered.

This Technical Report provides general methodological recommendations in section 4, while more detailed considerations along the stages of the life cycle are covered in section 5. The life cycle stages falling into the cradle-to-customer-gate scope are covered in section 5.1 - 5.4. To complete the cradle-to-grave scope, sections 5.5 and sections 5.6 cover the "use" and "End-of-Life" life cycle stages respectively in more detail.

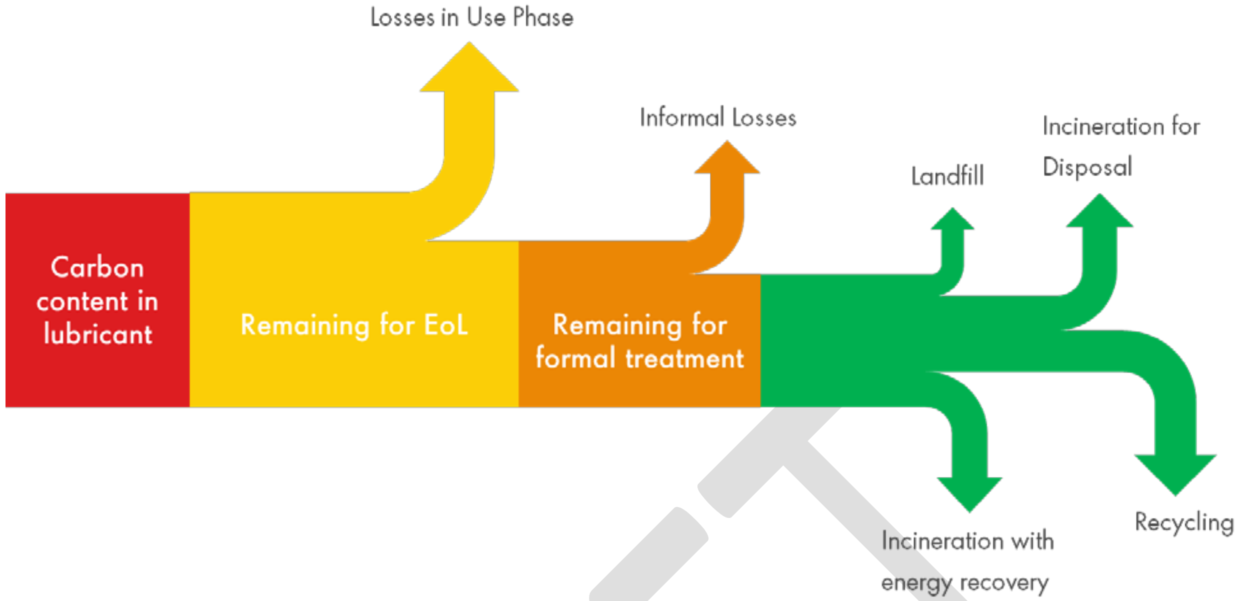


Figure 3: Tracing carbon content through the "in use" and "End-of-Life" stages of the life cycle.

While the cradle-to-grave scope includes losses in the "use" stage (e.g., partial combustion of lubricant during use), certain "in use benefits" should stand separately, in addition to the carbon footprint (CFP). "In use benefits", also referred to as "avoided emissions" or "comparative emissions" rely on a relative comparison between two scenarios, one where the product exists and one where it is replaced by a reference product or functionally relevant baseline. (World Resources Institute, 2019) "Avoided emissions" are discussed briefly in section 6 of this Technical Report and could involve calculations that assess the following:

- Avoided emissions from extension of the oil drain interval (ODI), thereby reducing the volume of lubricant required across the lifetime of the application.
- Avoided emissions during the use of the lubricant product, through fuel economy due to efficiency improvements, thereby reducing the volume of fuel required to travel a certain distance or operate for a certain period of time.

Such calculations of avoided emissions are of strong industry interest but are also complex matters. Future updates to this Technical Report may include a more comprehensive treatment of these topics.

2. Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

For application of life cycle assessment:

ISO 14040, *Environmental management – Life cycle assessment – Principles and framework*

ISO 14044, *Environmental management – Life cycle assessment – Requirements and guidelines*

In addition to the above, for application to product carbon footprinting:

ISO 14067, *Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification*

ISO 14021, Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling)

ISO 14071, Environmental management — Life cycle assessment — Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006

GHG Protocol – *Product Life Cycle Accounting and Reporting Standard*

PAS 2050, *Specification for the assessment of the life cycle greenhouse gas emissions of goods and services*

3. Terms, Definitions, Acronyms, and Abbreviations

3.1. Terms and Definitions

For the purposes of this document, the following terms and definitions apply. Please note: Quoted materials are presented in italics below.

Additive Package
Combination of additive components that provide targeted lubricant performance.

Note 1 to entry: Further information on additives can be found in section 5.1.2.

Avoided Emissions
Based on a relative comparison between two scenarios, one where the product exists and one where it is replaced by a reference/functionally equivalent baseline product, it can be shown that the former leads to reduced emissions.

Note 1 to entry: A high level discussion on the topic of "avoided emissions" is provided in section 6.

Biogenic Carbon
Carbon derived from biomass

[Source ISO 14067:2018 Section 3.1.7.2]

Note 1 to entry: For biogenic carbon in lubricants see section 4.8.

Biomass
Material of biological origin, excluding material embedded in geological formations and material transformed to fossilized material

Note 1 to entry: Biomass includes organic material (both living and dead), e.g., trees, crops, grasses, tree litter, algae, animals, manure and waste of biological origin.

Note 2 to entry: In this document, biomass excludes peat.

[Source ISO 14067:2018 Section 3.1.7.1]

Blends
Mixing of different components to meet a specific ratio in composition is referred to as a blend.

Carbon Content
Carbon contained in the molecules that make up the lubricant product.

Carbon Dioxide Equivalent (CO_2e)
Unit for comparing the radiative forcing of a GHG to that of carbon dioxide.

[Source: ISO 14067:2018 Section 3.1.2.2]

Note 1 to entry: For a lubricant, the mass of applicable GHGs is converted into CO_2 equivalents by multiplying the mass of the GHG by the corresponding Global Warming Potential over a 100-year timeframe (GWP-100).

Carbon Footprint of a Product
Sum of 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.

[Source: ISO 14067:2018 section 3.1.1.1]

Note 1 to entry: A definition of a carbon footprint for a lubricant on a cradle-to-grave basis is provided in section 1.

Carbon Neutral
“Carbon neutral” refers to a product (as a product system) that has a “carbon footprint” of zero or a product with a “carbon footprint” that has been offset.

In relation to a product, “carbon neutral” requires that all the GHG emissions from all stages of the product life cycle, and within the specified product system, have been reduced, removed or accounted for through a system of offsets or credits, or by other means.

[Source ISO 14021:2016 Section 7.17.3.1 & 7.17.3.2]

Circular Economy
The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible.

[Source: (European Parliament, 2022)]

Cradle-to-Gate
All upstream stages until either the production gate or customer gate. The former includes the following life cycle stages: raw materials, production, packaging (if applicable). The latter definition includes the logistics to the customer gate into the scope definition.

Cradle-to-Grave
All stages of the lubricant life cycle (Figure 1) are included in this scope, typically covering the following: raw materials, production, packaging, logistics, in use and End-of-Life.

Comparative Assertion
Environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.

[Source ISO 14044:2006 Section 3.6]

Comparative Emissions
Difference in emissions, based on a relative comparison between two scenarios, one where the product exists and one where it is replaced by a reference/functionally relevant baseline product.

Note 1 to entry: A high level discussion on the topic is provided in section 6.

Components
A lubricant will typically be blended from different constituent parts (e.g., base oil and additives), such parts are referred to as components.

Critical Review
Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment.

Note 1 to entry: The principles are described in ISO 14040:2006, 4.1.

Note 2 to entry: The requirements are described in ISO14044:2006, 6.

[Source ISO 14044:2006 Section 3.45]

Cut-Off Criteria
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.

[Source ISO 14044:2006 Section 3.18]

Note 1 to entry: Information on cut-off criteria as they pertain to lubricants are in section 4.5.

Direct Land Use Change (dLUC)
Change in the human use of land within the relevant boundary

Note 1 to entry: In this document, the relevant boundary is the boundary of the system under study.

Note 2 to entry: Land use change happens when there is a change in the "land-use category" as defined by the IPCC (e.g., from forest land to cropland).

[Source ISO 14067:2018 Section 3.1.7.5]

Embedded Carbon
See definition of "carbon content".

End-of-Life
Final stage in the life cycle of a product.

Environmental Impact
Change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's environmental aspects.

[Source ISO 14001:2015 Section 3.2.4]

Environmental Aspect
Element of an organization's activities or products or services that interacts or can interact with the environment

Note 1 to entry: An environmental aspect can cause (an) environmental impact(s). A significant environmental aspect is one that has or can have one or more significant environmental impact(s).

Note 2 to entry: Significant environmental aspects are determined by the organization applying one or more criteria.

[Source ISO 14001:2015 Section 3.2.2]

Feedstock
Raw materials entering a process of refinement or synthesis step.

Note 1 to entry: For lubricants examples could be: Used lubricant entering a re-refinement process or naphtha being converted via synthesis to an additive component.

Fuel Economy
Coefficient relating distance travelled by a vehicle with the amount of fuel consumed.

Global Warming Potential (GWP)
Index, based on radiative properties of GHGs, measuring the radiative forcing following a pulse emission of a unit mass of a given GHG in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide (CO_2)

[Source ISO 14067:2018 Section 3.1.2.4]

Note 1 to entry: For lubricants the GWPs over 100-year horizon as published by the IPCC should be used for conversation to CO_2 equivalent.

Greenhouse Gas (GHG)
Gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds.

Note 1 to entry: For a lubricant, at a minimum the following GHGs should be considered: CO_2, CH_4 and N_2O. For a list of GHGs, see the latest IPCC Assessment Report. (International Panel for Climate Change, 2021)

Note 2 to entry: *Water vapour and ozone, which are anthropogenic as well as natural GHGs, are not included in the CFP and partial CFP.*

Note 3 to entry: *The focus of this document is limited to long-lived GHGs and it therefore excludes climate effects due to changes in surface reflectivity (albedo) and short-lived radiative forcing agents (e.g., black carbon and aerosols)*

[Source: ISO 14067:2018 Section 3.1.2.1]

Greenhouse Gas Emissions
Release of GHG into the atmosphere

[Source ISO 14067:2018 Section 3.1.2.5]

Greenhouse Gas Emission Factor
Coefficient relating activity data with the GHG emission.

[Source: ISO 14067:2018 Section 3.1.2.7]

Indirect Land Use Change (iLUC)
Change in the use of land which is a consequence of direct land use change, but which occurs outside the relevant boundary

Note 1 to entry: In this document, the relevant boundary is the boundary of the system under study.

Note 2 to entry: Land use change happens when there is a change in the "land-use category" as defined by the IPCC (e.g., from forest land to cropland).

[Source ISO 14067:2018 Section 3.1.7.6]

Informal Losses
Used oil entering informal treatment channels.

Note 1 on entry: Further details on formal and informal used oil treatment in section 5.6.1.

Life Cycle Assessment (LCA)
Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

[Source ISO 14067:2018 Section 3.1.4.3]

Lubricant
A product that is capable of reducing friction, adhesion, heat, wear or corrosion when applied to a surface or introduced between two surfaces in relative motion, or is capable of transmitting mechanical power.

[Source: (Joint Research Centre & European Comission's science and knowledge service, 2017)]

Non-Energy Product
Lubricants are not intended to be combusted for energy production and hence is defined as a non-energy product.[2]

[2] It is acknowledged, that in two stroke applications the lubricant will inevitably be combusted, but this is not its main intended function.

Oil Drain Interval
Interval between the instances when most of the lubricant in an application is changed (excluding top ups). This can be measured in distance (e.g., km or miles) or time (e.g., hours of operation).

Partial Carbon Footprint of a Product
Sum of GHG emissions and GHG removals of one or more selected process(es) in a product system, expressed as CO_2 equivalents and based on the selected stages or processes within the life cycle.

[Source: ISO 14067:2018 section 3.1.1.2]

Note 1 to entry: An example of a partial carbon footprint of a lubricant would be a cradle-to-gate footprint.

Primary Data
Quantified value of a process or an activity obtained from a direct measurement or a calculation based on direct measurements.

Note 1 to entry: Primary data need not necessarily originate from the product system under study because primary data might relate to a different but comparable product system to that being studied.

Note 2 to entry: Primary data can include GHG emission factors and/or GHG activity data (defined in ISO 14064-1:2006, 2.11).

[Source ISO 14067:2018 Section 3.1.6.1]

Note 3 to entry: For further details on data sources for lubricants, see section 4.6.

Raw Materials
Primary or secondary material that is used to produce a product.

Note 1 to entry: Secondary material includes recycled material.

[Source ISO 14044:2006 Section 3.15]

Re-Refined Base Oil
Lubricant base stock derived in part or completely from used oil via refinery processes.

Scope 1 Emissions
Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment.

[Source GHG Protocol – A Corporate Accounting and Reporting Standard – Chapter 4]

Scope 2 Emissions
Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.

[Source GHG Protocol – A Corporate Accounting and Reporting Standard – Chapter 4]

Note to entry: Scope 2 emissions as used in this technical report also includes imported steam.

Secondary Data
Data which do not fulfil the requirements for primary data.

[Source ISO 14067:2018 Section 3.1.6.3]

Note 1 on entry: For further details on data sources, see section 4.6.

Sensitivity Analysis
Systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study.

[Source ISO 14044:2006 Section 3.31]

Value Chain
A series of consecutive steps that are needed to create a finished product. At each step of the chain value is added.

3.2. Acronyms and Abbreviations

For the purposes of this document, the following acronyms and abbreviations apply.

Term	Definition
API	American Petroleum Institute
ATIEL	Technical Association of the European Lubricants Industry
BO	Base Oil
CC	Complete Combustion (all embedded carbon released as CO_2).
CD	Combustion for Disposal
CFP	Carbon Footprint of Product
CHP	Combined Heat and Power
CHR	Combustion with Heat Recovery
DEFRA	Department for Environment, Food & Rural Affairs
dLUC	Direct Land Use Change
EF	Emission Factor
EoL	End-of-Life
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GLEC	Global Logistics Emissions Council
GWP	Global Warming Potential
HDPE	High Density Polyethylene
IBC	Intermediate Bulk Containers
ICCA	International Council of Chemical Associations
iLUC	Indirect Land Use Change
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
LBP	Lubricant Blend Plant
MF	Mass Fraction
ODI	Oil Drain Interval
PAS	Publicly Available Standard
REDII	Renewable Energy Directive
RRBO	Re-Refined Base Oil

TR	Technical Report
TfS	Together for Sustainability
USDA	US Department of Agriculture
VGO	Vacuum Gas Oil
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute
WtW	Well-to-Wheel
Wt%	Weight Percent

4. Methodology Recommendations for LCA of Lubricants

4.1. Goal of the Assessment

The overall goal of the application of this Technical Report to the life cycle assessment (LCA) of lubricants is to promote that a common methodology is applied across industry when, for example, defining the carbon footprint of product (CFP) for the lubricant in question. It will outline industry best practice, where the selected international standard allows for methodological choices to be made.

The following international standards and industry guidelines are applicable in this Technical Report:

International standards:

ISO 14040:2006, *Environmental management – Life cycle assessment – Principles and framework*

ISO 14044:2006, *Environmental management – Life cycle assessment – Requirements and guidelines*

ISO 14067:2018, *Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification*

Industry agreed guidelines and national standards:

GHG protocol – *Product Life Cycle Accounting and Reporting Standard*

PAS 2050:2011, *Specification for the assessment of the life cycle greenhouse gas emissions of goods and services*

The focus of this Technical Report is on definition of the CFP and therefore is on "climate change" as a single impact category. There is an acknowledgement that focus and optimization of a single impact category can lead to greater impacts in other environmental aspects. Such trade-offs can be identified and the LCA expanded with additional impact categories, where applicable, to obtain a more complete picture of the overall environmental impact of the product.

Output from calculations according to the above standards and performed in accordance with the best practice defined in this Technical Report could be used to demonstrate "Carbon Neutrality" according to the standard listed below.[3] Further specifications on demonstration of "carbon neutrality" are detailed in the standard below and this application is beyond the scope of this Technical Report:

PAS 2060:2014, Specification for the demonstration of carbon neutrality

4.2. Functional and Declared Unit

In line with section 4.2.3.2 of ISO14044:2006, the functional or declared unit defines the quantification of

[3] Currently in preparation: ISO 14068, *Greenhouse gas management and related activities – Carbon neutrality*

the identified functions (performance characteristics) of the product. A functional or declared unit will always be required as it provides a reference to which all inputs and outputs of the analyzed system are related. Based on the functional or declared unit, the associated reference flow is determined.

The functional or declared unit for lubricants according to this Technical Report is the performance characteristic relative to its mass (per kg of lubricant) or volume (per liter/US gallon of lubricant). The latter unit is of interest, as lubricants are often sold on a volumetric basis. Using the product specific density, the two units can be readily inter-converted.

The examples below show the recommendations for the functional and declared unit in the application to a CFP or partial CFP assessment:

- Example 1: The functional unit for a CFP is the life cycle GHG emissions of a lubricant (expressed in CO_2 equivalent) relative to the lubricant mass:
    - Functional unit: Cradle-to-grave emissions in kg CO_2e/kg of lubricant
- Example 2: For partial CFPs (e.g., for an intermediate material sold on cradle-to-gate basis), the declared unit is the GHG emissions (expressed in CO_2 equivalent), included according to the applicable scope, and expressed relative to the lubricant mass.
    - Declared unit: Cradle-to-gate emissions in kg CO_2e/kg of lubricant

While the above provides the recommendations for the functional and declared units for lubricants, the final choice of unit employed will depend on the goal and scope of the study. For some studies, it may be determined that the functional or declared unit is more appropriately determined based on, for example, the lifetime of the engine or a certain distance travelled. Similarly, it is acknowledged, that for other applications (e.g. avoided emissions from extension in lubricant lifetime), like the ones discussed in section 6 of this Technical Report, other units might be more applicable (e.g. number of years in a specific lubricant use profile or the amount of work performed e.g. amount of metal processed, etc.). These could be reached via conversions from the functional units and declared units outlined above.

4.3. System Boundary

In order to determine the environmental impacts of a lubricant, all relevant stages of the lubricant life cycle shall be included in the assessment. An overview of the life cycle stages applicable to a generic lubricant are shown in Figure 1, containing the six main life cycle stages: raw materials, production, packaging, logistics, use and End-of-Life.

While the illustration in Figure 1 shows a primarily linear progression through the life cycle stages towards the End-of-Life stage, characteristics of the circular economy are becoming increasingly important. For example, re-refined base oils (RRBO) are shown as a waste product from the End-of-Life stage feeding back into the “raw material” stage of the life cycle.

An overview of the life cycle stages applicable to lubricant production is shown in Figure 1. Applicable system boundaries can be drawn according to the following scopes:

- Cradle-to-grave: All stages of the lubricant life cycle are included in this scope and this represents the basis of the definition of the functional unit (section 4.2).
- Cradle-to-gate-customer: All upstream stages to the lubricant life cycle until the customer entrance gate is reached. This includes logistics from the lubricant producer to the customer.
- Cradle-to-gate-producer: All upstream stages of the lubricant life cycle until the production exit gate is reached. This excludes logistics of the lubricant to the respective customer.

Note: Other scopes can also be defined (e.g. Gate-to-gate). If such scopes are selected, these should be clearly defined as part of the documentation, to ensure that it is transparent what is included in the system boundary.

In line with section 6.3.4.1 of ISO 14067:2018, exclusions from the scope as defined by the system boundary, e.g., by exclusion of certain life cycle stages shall be clearly stated and reason for such exclusions explained. Such exclusions should be justified in accordance with the materiality threshold e.g., as defined in the cut-off criteria (see section 4.5 for details). Transparency in the documentation of the system boundary and possible exclusions is of crucial importance. This ensures the user of the assessment has knowledge of the exact scope and environmental impacts considered to determine how the assessment meets their need for information.

More detailed considerations of the system boundary, where applicable, e.g., application of the cut off approach for certain used lubricant fates during the End-of-Life, are included in section 5 of this document.

4.4. Allocation Approaches

As defined in section 4.3.4.2 of ISO 14044:2006 and section 6.4.6.2 of ISO14067:2018 there is a hierarchy proposed regarding allocation approaches, which shall be applied to LCAs and CFPs for lubricants. The hierarchy as outline in ISO14067:2018 reads as follows:

a) *Step 1: Wherever possible, allocation should be avoided by*
   a. *dividing the unit process to be allocated into two or more sub-processes separately and collecting the input and output data related to these sub-processes, or*
   b. *expanding the product system to include the additional functions related to the co-products.*

b) *Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them.*

c) *Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and the 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 economic value of the products*

This hierarchy, as it shall be applied to LCAs and CFPs for lubricants, is outlined below:

1. Step 1: Wherever possible, allocation should be avoided.
2. Step 2: Components that are used in lubricants are often the product of processes that cannot be subdivided and hence allocation becomes necessary. In such cases allocation on physical properties is recommended. For non-energy products like components intended for blending in the lubricant, the physical allocation shall be performed on mass basis. An example of this type of allocation is the production of base oils from a refinery.
3. Step 3: Should allocation on physical properties not be possible another relationship should be established between the product and co-products from the process. Economic value of the products is an example of such a relationship.

It should be acknowledged, as the components going into lubricants are often products of larger refinery or chemical production processes, such scenarios can lead to a mixture of allocation approaches (e.g., allocation on energy content basis when the primary products of upstream processes are energy products and allocation on mass basis when primary products are non-energy products). In such cases the allocation approach selected shall be clearly documented to make this apparent and mixing allocation approaches should be avoided wherever possible.

For more details on allocation at End-of-Life for used/waste oil, please see section 5.6.1 of this document. Where applicable, in line with the cut off criteria defined in section 4.5, waste generated during raw material production processes should also be accounted for. A future version of this document intends to provide further guidance on this topic.

The topic of allocation is complex, with multiple possible approaches outlined in the above hierarchy. However, when setting out with a new assessment and allocation cannot be avoided, the allocation approach must be validated and transparently documented if deviating from the outline hierarchy. Some specific examples of allocations applied in LCAs and CFPs for lubricants, can be found in sections 4.4.1 to 4.4.3.

4.4.1. **Allocation of Utilities**

Many manufacturing plants do not have individual meters (sub-metering) at the production units. If installation of sub-metering is not possible, allocation is required in order to assign utilities, such as electricity consumption, steam consumption, etc., to specific production units, batches and products.

This Technical Report proposes allocation of utilities for lubricant products as follows:

- Where limited difference is estimated in the utility consumption per output of product (e.g., per tonne product) for the different production units and products, allocation should be based on mass. For example, this may be the case where the only activities of the site are those of formulating finished lubricant.
- Where the utility consumption per output of product is estimated to show a difference greater than 20% for the different production units and products, allocation should be based on expert judgement. For example, this may be the case where the lubricant manufacturing site produces both components and blends, or an additive manufacturing site produces different components that have significantly varying energy requirements.

4.4.2. **Allocation of Onsite Combined Heat and Power**

For onsite combined heat and power (CHP), the allocation of the environmental impacts of the unit to electricity and heat respectively should be based on the efficiency method as outlined in the WRI/WBCSD GHG Protocol document "Allocation of GHG Emissions from Combined Heat and Power (CHP) Plant". (WRI and WBCSD, 2006)
Section 8.5 of PAS2050:2011 also provides guidance on potential allocation approaches for CHPs as well as EN15316-4-5:2017.

4.4.3. **Allocation of Multi-Output Processes for Non Base Oils**

In addition to the main product being produced, some additive production processes also generate co-products. The product and co-products, may vary considerably, both in terms of their composition, their quality, and their economic value. To allocate the environmental burdens between the product and co-products, this Technical Report proposes to follow the guidance provided in the Together for Sustainability (TfS) Product Carbon Footprint guideline document. (Together for Sustainability, 2022) The TfS methodology was developed for the chemicals industry and aligns well with the methodology described in this Technical Report. On introduction of cradle-to-(Additive supplier)-gate figures (which have been derived in accordance with the TfS) into assessments in accordance with this Technical Report, attention should be paid that allocation is aligned with the hierarchy outline in section 4.4.

4.5. Materiality Thresholds and Cut Off Criteria

General considerations regarding cut-off criteria from section 6.3.4.3 of ISO 14067:2018 and section 4.2.3.3.3 of ISO 14044:2006 should be consulted by the practitioner when defining the materiality threshold and cut-off criteria for the specific study under consideration. Such thresholds should be tested for appropriateness to the goal and scope of the evaluation using expert judgement. A suggested starting point for setting materiality thresholds on a mass basis could include:

- No more than 2% contribution to individual components (e.g., by life cycle stage) to the overall environmental impact(s)
- No more than 5% contribution cumulatively across multiple components to the overall environmental impact(s)

As per section 4.2.3.3.3 of ISO 14044:2006 other cut-off criteria on energy and environmental significance could be considered as well if deemed appropriate. It is common that activities not directly related to the production of a lubricant are cut off such as: capital goods/installations and other non-production related overhead, cleaning and research & development.

Application of cut-off criteria can be particularly challenging, when faced with missing data, as it can be difficult to judge if the missing contribution is distorting the results of the lubricant under investigation. The topic of missing data is discussed further in section 4.7 of this Technical Report.

Attention is drawn to one of the general principles of LCA as defined in section 4.1 of ISO 14040:2006, that an iterative approach should be applied – meaning that the view on certain inputs falling above or below the defined cut-off criteria could change over time as better information becomes available. Any exclusions made should be transparently documented.

4.6. Data Collection and Hierarchy of Data Sources

In line with industry standards like section 6.3.5 of ISO 14067:2018 a hierarchy approach should be applied on the selection of data sources to be used to calculate the LCA or CFP for lubricants. Overall, the preference as per this Technical Report is to use primary data, where it is obtainable with reasonable effort. Focus should be on using primary data at least for the value chain segments in which the preparer participates (Scope 1 & 2 emissions) and collection of primary data for upstream processes should be requested.

Although expert judgment is required to assess the inclusion of any individual datasets into the calculation for the LCA or CFP for lubricants, a hierarchy as follows could be applied to guide such inclusion:

1. Primary data that are site-specific
2. Primary data from a different but representative product system (e.g. through average across different sites as per Note 2 section 6.3.5 of ISO14067:2018)
3. Secondary data for the process under investigation
4. Secondary data from proxy processes or estimates

Specific aspects, broken down by stages of the lubricant life cycle, on the collection of primary data will be captured in section 5 of this Technical Report.

Where no primary data are available, secondary data should be used from the following sources:

- Data for representative process from recognized LCA databases/software
- Data for representative process from published scientific literature
- Data for representative process from published industry sources

Where no secondary data for a representative process can be identified, proxy values should be used from the data sources identified above. Such proxy values can be derived from the following:

- Use of similar production processes
- Tracing the upstream supply chain to raw materials to estimate contributions from required production steps.

On progression down the hierarchy as outlined above, the uncertainty in the estimate will likely increase. Hence a conservative approach, consistent with general GHG accounting principles (GHG Protocol, 2005), should be applied for selecting data from a scenario where a range of values is available from different sources. Great care should be applied on the data selection, to ensure that the LCA or CFP for lubricant is not underestimated, conservativeness in selection of values from a range (e.g., selection of top of the range estimate) can lead to a higher CFP value overall. An iterative approach will drive the selection of data sources towards the use of primary data, improving data quality, reducing uncertainty and removing the need for conservativeness in the estimates of secondary data over time.

Frequently for calculations of LCAs and CFPs for lubricants, data will be needed for components from upstream in the supply chain (e.g., raw materials being used in a chemical process). In such cases, to ensure consistency, data should be developed in accordance with the guidance provided in this Technical Report (e.g., use of applicable standards, allocation approaches and external independent assurance). If the data cannot be supplied in accordance with this guidance, great care should be taken in possible conclusions drawn from the study and limitations should be clearly documented.

4.7. Data Quality Assessment and Treatment of Missing Data

Performing an internal quality control on the data used for the assessment, based on the professional judgment of the preparer, is highly recommended by this document. Qualitative data quality scores, although subjective at times, could be used to assess and, if consistently applied, to improve data quality over time.

Data quality should assess the following five data quality indicators, defined in line with the GHG Protocol guidelines (GHG Protocol, 2011):

- Technological representativeness: the degree to which the data reflect the actual technology(ies) used in the process
- Geographical representativeness: the degree to which the data reflects actual geographic location of the processes within the inventory boundary (e.g., country or site)
- Temporal representativeness: the degree to which the data reflect the actual time (e.g., year) or age of the process
- Completeness: the degree to which the data are statistically representative of the process sites
- Reliability: the degree to which the sources, data collection methods, and verification procedures used to obtain the data are dependable

Owing to the still comparatively new application of LCA to lubricant products, there may be examples where data is not available within the life cycle stage under investigation. An example is that lubricants can often be comprised of a complex mixture of varied chemistries, the challenge of missing data can be encountered for components comprising the lubricant. If such a gap in the data is encountered, it is recommended to use the hierarchy approach listed in section 4.6 to attempt to close the gap. The final stage in the outline hierarchy would be to select proxy values (e.g., from applicable LCA databases) guided by the professional judgement of the practitioner, to bridge the gap in the missing data. For all treatment of missing data, the conservativeness in approach should be applied as outlined in section 4.6.

As per the guidance provided in section 4.5 and others, and in accordance with the professional judgment of the practitioner, should any exclusions be made, these should be transparently documented.

4.8. Biogenic Carbon in Products

Biogenic carbon generated from the consumption of CO_2 during photosynthesis should be considered to be temporarily sequestered in intermediate components intended for blending into the finished lubricant products and ultimately in the finished lubricant itself. In line with ISO 14067:2018 section 6.4.9.3 and section 3.3 of the GHG protocol (Product Life Cycle Accounting and Reporting standard) GHG emissions and removals from biogenic and fossil sources should be reported separately to allow for tracing of biogenic content to the End-of-Life stage. This is particularly important for interfaces in the lubricant supply chain, where data is passed from intermediate component suppliers to downstream actors. In addition, in a cradle-to-gate analysis, the temporarily sequestered CO_2 in the form of biogenic carbon can be subtracted from the total $kgCO_2e/kg$ product and documented separately as a net result. In a cradle-to-grave analysis, the biogenic credit can be used to balance any biogenic CO_2 emissions from the re-release of sequestered carbon - as a result there is no net contribution of the biogenic CO_2 emissions to the CFP.

Biogenic carbon in intermediate components or finished lubricants can be assessed by a combination of ASTM D-6866 and Total Organic Carbon analysis or by the application of mass-balance. A description of the mass-balance approach is contained in section 5.4.2 of ISO22095:2020. (International Organization for Standardization, 2020) ASTM D-6866 measures the %carbon present in a sample which is renewable. ASTM D6866 is a requirement for USDA bio-preferred and other renewable carbon certifications. (United States Department of Agriculture, 2022) Total carbon percent of the intermediate component or finished lubricants can be measured to determine $kgCO_2e/kg$ product (product can be either intermediate component or finished lubricant) benefit from the biogenic carbon. For this a total organic carbon analysis should be performed to determine the wt% carbon present in the product such as ASTM D5291, DIN13137 or equivalent.

The data from ASTM D6866 and Total Organic Carbon analysis can be used to calculate the quantity of temporarily sequestered kgCO_2e/kg as biogenic carbon in the intermediate component or finished lubricant. Formulas for calculating the contributions from biogenic and fossil carbon respectively are provided below:

Attributed to biogenic carbon (Biogenic carbon for Cradle-to-gate & End-of-Life combustion emissions):

CO_2ekg/kg product = (%total carbon * %biogenic carbon) * (mw_{CO2}/mw_C)

Attributed to fossil carbon (Fossil carbon for Cradle-to-gate & End-of-Life combustion emissions):

CO_2ekg/kg product = (%total carbon * (1-%biogenic carbon)) * (mw_{CO2}/mw_C)

Where:

%total carbon: Fraction of mass of carbon relative to total mass (e.g., 0.8 for 80% carbon content)

%biogenic carbon: Fraction of total embedded carbon that is of biogenic origin.

mw_{CO2}: molecular weight of carbon dioxide (CO_2)

mw_C: molecular weight of carbon (C)

Confirmation of biogenic content in the final lubricant using primary data is preferred, while tracing of biogenic content, which is established through experimental data in a component used in a blend is permissible, if no major losses of the biocomponent during blending is assured.[4] For primarily fossil-carbon- based lubricants, please see section 5.5 for further details on End-of-Life combustion emission factors. For production of components where the biogenic carbon is only a fraction of the total carbon, a mass balance approach can be taken. The CFP of the biogenic carbon fraction should be calculated in accordance with ISO14067, or equivalent, and applied into production mass-balance carbon accounting. Independent certification of this mass-balance approach, if applied, should be obtained. Secondary data on bioliquid feedstocks can be found in REDII Annex V and Annex VI. (European Parliament, 2018)

In line with ISO 14067:2018 section 6.4.9.2, for biomass-derived components, emissions produced in the production of the biomass should be included in the evaluation, including, but not limited to, cultivation, production and harvesting of biomass. For feedstock derived from such biomass, emissions of interest furthermore consist of fuel used, the extraction or cultivation of raw materials, annualized emissions from land-use change, processing to target feedstock, and emissions used in transportation.

To account for land use change impacts within the last decades[5], where the biogenic carbon was sourced from should be accounted for in gate-to-grave and cradle-to-gate LCIA and CFP studies. In accordance with ISO 14067:2018 section 6.4.9.5 direct land use change (dLUC) should be accounted for using site-specific studies. When a site-specific study is not available, use of internationally recognized methods such as IPCC Guidelines for National Greenhouse Gas Inventories and PAS 2050:2011 section 5.6 is appropriate. (International Panel for Climate Change, 2006) dLUC accounting should be included and documented separately in the CFP.

The international community does not currently have agreement on how to fully account for indirect land use change (iLUC) impacts on LCIA and CFP studies. Once international agreement has been reached inclusion of iLUC should be considered in CFP studies.

4.9. Sensitivity Analysis

In line with section 4.3.3.4 of ISO 14044:2006, it is recommended to perform a sensitivity analysis to understand the main contributors from the input parameters to the overall study. Keeping the iterative approach for LCA (e.g., section 4.3 of ISO 14040:2006) in mind, such sensitivity analysis can help to identify focus areas for further improvement and helps to test the assumptions that underpin the overall

[4] Care needs to be used, not to apply experimental methods to lubricants with components, that have had biogenic content established using a mass-balance chain of custody approach (ISO 22095:2020), as measured content might not reflect assigned content.

[5] As per ISO14067 section 6.4.9.5: The IPCC tier 1 period of 20 years is frequently used.

evaluation. This directs the practitioner towards improvement of parameters, which are likely to have the biggest impact on the overall outcome of the study.

Below are some examples of potential sensitivity analysis that could be considered:

- Variations in EFs for feedstocks – e.g., if secondary data sources used, exploration of different data sources should be considered to gauge the impact on the overall outcome of the assessment.
- Explore regional variation e.g., probing the influence of raw material sourcing from different regions and associated variation in EFs on the overall outcome of the assessment.

4.10. External, Independent Assurance

Verification of compliance of the undertaken calculation with the applicable standards listed in section 4.1 of this document by an independent verification body is recommended.

This can for example be in form of a critical review of the model in accordance with ISO 14071:2014 (International Organization for Standardization, 2014), or other external verification of the methodology and calculators against the standard selected. If a comparative assertion is being sought (e.g., direct comparison of two products in the marketplace), with intention for disclosure to the public, such a critical review or external verification is mandatory according to section 4.2.3.7 in ISO 14044:2006.

Verification bodies that are used should be accredited to carry out such verification exercises. An example would be that the external verifier maintains a management system that meets accreditation requirements for the international standard of ISO14065:2013.

5. Considerations by Life Cycle Stage

The section below provides more detailed aspects to consider when applying LCA methodology to carbon footprint of products (CFP) calculations. This is structured according to the stages of the lubricant life cycle as defined in Figure 1 and is intended to provide practical advice on the application of the methodology (e.g., types of parameters to include in the assessment for this life cycle stage). Publicly available data sources that could aid in the application of the guidance provided organized by life cycle stage can be found in Annex A.

5.1. Raw Materials

Raw materials make up an important contribution to the LCA and CFP of the product and have been subdivided into two main groups here: 1.) Base oils & Re-refined base oils {API Groups I-V} 2.) Additives. Lubricants are typically blended from these components (or can be made up of a single component), and for a LCA and CFP for a finished lubricant the product specific formulation should be used in order to determine a mass fraction weighting of the contribution by the individual components making up the lubricant.

5.1.1. Base Oils

Guidance on what data to collect to determine the contribution to the LCA and CFP by the base oil has been grouped by base stock: Group I-III and Group IV &V respectively. (American Petroleum Institute, 2015)

5.1.1.1. Base Oils and Re-Refined Base Oils (API Groups I-III)

To determine the contribution to the finished lubricant CFP from the base oil (BO; API groups I-III) on a cradle-to-refinery-gate basis, primary data from a representative asset on mass flow and energy consumption & type should ideally be used for the basis of the assessment.

Although not an exhaustive list, the following items would be important to consider when gathering data to determine the component contribution from the base oil (BO) or re-refined BO:

1a. For Base oil - Crude oil intake data. The crude oil slate can be used to determine the fraction of crude from different regions/countries, which could be paired with applicable GHG emission factors (EF). The EF by crude types should include at least production and extraction, surface processing, and transport to the refinery inlet. On a country level such EF have e.g., been published by Masnadi et al. (Masnadi, et al., 2018) but comparable data sources with a similar level or granularity or field level emission factors could also be used, if available.

1b. For Re-refined base oil - Used oil intake data. For re-refined base oil, the used oil intake data includes the acquisition and processing of used oil into the system, transportation of used oil to terminals and re-refinery via truck, rail, and barge, as well as the acquisition of chemical, energy and fuel inputs to the re-refinery's pre-processing that may be performed at the terminal and/or re-refinery level. As per guidance in section 5.6.1, the cut-off approach is applied and used lubricant enters the re-refinement process without upstream emissions (treatment as waste material). For any feedstock not purely based on used and recycled oil (e.g., co-feeding with virgin vacuum gas oil (VGO)), data sources listed in 1a need to be consulted to account for crude oil intake and associated upstream emissions.

1c. For feedstock with biogenic content **-** For BOs which contain biogenic carbon, both the biogenic carbon content (see section 4.8) and the carbon footprint associated with the production and transport must be considered. Please see section 4.8 for details in situations where sustainable material is co-fed to a refinery process, and the share of the share of such materials in the resulting BO needs to be accounted for, either directly or through means of mass-balance. (International Organization for Standardization, 2020)

2. Mass flow through the sub-units (Atmospheric distillation, vacuum distillation, solvent extraction, hydrotreater etc.) of the refinery. In alignment with allocation approach described in section 4.4 such mass flow data can be used to determine the mass fractions at each sub-unit, leading to the product of interest. The number of sub-units considered will vary with the refinery line up.
3. Energy consumption data, broken down by refinery sub-unit. This consumption data should include thermal energy sources (e.g., natural gas, fuel oil, etc.), electricity and steam. Also, any other energy consumption streams in line with the cut-off criteria defined as per section 4.5 should be considered. For steam production, data on the primary energy mix, efficiency and transfer losses should also be gathered to determine the associated emissions.

All data should be collected over a representative time period e.g., over a period of one year. If certain parameters are known to vary significantly year to year, e.g., significant variation of the crude diet occurs – in which case a longer time period might be warranted to determine a representative average crude intake to the refinery.

To ensure regional representation, based on the professional judgement of the practitioner, EFs representing the geography of the asset under investigation should be utilized during the assessment of the contribution to the CFP by the BO. Examples could include use of regional specific grid factors to assess emission attributable to electricity consumption at the site. In line with the life-cycle approach of this assessment, EF should also be selected with a life-cycle scope in mind (e.g., including upstream contributions).

In line with data collection approach as outlined in section 4.6, as data might not be available to this level of granularity for every BO stream at this point in time, in which case primary data from a representative asset should be used to determine carbon intensity ideally differentiated by API base stock categories (e.g. Group I, Group II, etc.) (American Petroleum Institute, 2015). In general, GHG intensity will increase with the degree of necessary processing to produce a certain type of base stock and in absence of site-specific data, this data should be adjusted for resulting uncertainty to be in line with the criteria of "conservativeness" as outlined in section 4.6.

The above information can be used to determine the cradle-to-refinery-gate contribution to the CFP for the BO. To estimate emissions associated with the transport of the BO to the refinery to the blender location, please refer to section 5.1.3.

5.1.1.2. Base Oils (API Groups IV & V)

Group IV and V base oils are those created by combining well defined raw materials into controlled chemical structures having predictable and tailored properties. Several examples are provided below, but are not limited to:

- Polymerization of Oligomers e.g., alpha olefins, butenes, glycols

- Esters e.g., Linear, branched and aromatic
- Other Synthetic fluids e.g., silicones, phosphate esters, alkylated aromatics, halogenated fluids

Group IV and V LCAs on a cradle to gate basis should include all relevant life cycle stages. These stages include: raw materials used, waste generated, energy flows and resources introduced or removed via the synthesis processes. Often with many commercial product processes other activities may need to be considered within boundaries. These activities may include on-site heating or storage, packaging and filling operations, as they are in scope of distributing a product to customers.

Synthetic base oil cradle to gate life cycle elements may include collection of some or all of the following data:

- Environmental burden inventory for the raw material feedstock(s). This accounting can include credits from raw materials having biogenic source origins (see Section 4.8) for tracing to the End-of-Life stage (section 5.6.1)
- In bound transport of the raw materials to the manufacturing facility (see Section 5.1.3)
- Mass flow through base oil chemical synthesis plant, to aid with environmental burden allocation to products, by-products in accordance with section 4.4. (Analogue to point 2 in section 5.1.1.1)
- Energy for both upstream production and consumption (fuels/electricity/steam) required for the base oil chemical synthesis. (Analogue to point 3 in section 5.1.1.1)
- Upstream burdens associated with resources and their wastes from products synthesis steps e.g., catalysts, solvents or neutralizing agents.
- Emissions from activities related to the product and associated within the manufacturing organization such as off-loading raw materials, storage, filling or packaging operations (see Section 5.3 and 5.6)
- Treatment for End-of-Life wastes e.g., synthesis by-products and / or raw material packaging (see section 5.6.2)

Guidance specific to data selection (section 4.6), cut off criteria (section 4.5), allocation (section 4.4) and independent assurances (section 4.10) for the production of synthetic base oils is suggested to be consistent with the details provided within this report. This also includes standard approaches for assessing the impact of packaging, handling, and transportation (see sections 5.1.3, 5.3 and 5.4) discussed elsewhere in this document.

5.1.2. Additives

5.1.2.1. Introduction to Additives

For a lubricant to meet the requirements of efficient operation and prolonged engine life, extended drain intervals etc., additives are added to base oils to produce the finished lubricant.

Additives are diverse materials and modern lubricants will contain a combination of them to meet the performance requirements demanded of the lubricant. The main classes of lubricant additives include: detergents, dispersants, antiwear compounds, antioxidants, corrosion inhibitors, antifoam, extreme pressure additives, friction modifiers, metal deactivators, pour point depressants, and viscosity modifiers. Their concentration in the finished lubricant will range from parts per million to percentages.

Individual additive components may be combined into so-called additive packages to ensure synergistic and adversarial effects of the additives in the finished lubricant are balanced. Additive packages and individual additives are then blended with base oils to form the finished lubricant.

5.1.2.2. Additive Manufacturing

Additive components are typically manufactured by chemical synthesis, in batch or continuous processes. The most common chemical reactions include condensation, neutralization, and reactions of olefins. After synthesizing the component, it is often purified by distillation and/or filtration. Additive raw materials can include but are not limited to: amines, metal oxides, metal salts, phosphorus compounds, sulfur compounds, silicones, olefins, alcohols, and long chain carboxylic acids. Generally, the carbon content which imparts oil solubility originates from crude oil, but some raw materials may originate from biogenic sources (See Section 4.8 regarding biogenic carbon).

Additive packages are generally made by simple blending of additive components.

The additive component or package may be diluted with base oil, esters or other hydrocarbon fluids for ease of handling (e.g., reduce viscosity).

Additives are transported to the finished oil formulator via pipeline or in bulk, totes, Intermediate Bulk Containers (IBCs), drums, or bags by road, rail, and sea.

5.1.2.3. Materiality of Additives

The potential materiality of the additive's CFP on the overall lubricant should be considered as a first step. Those additives that are added to a lubricant in the part per million range are unlikely to have a material impact on the lubricant overall CFP. See Section 4.5 for the discussion on materiality thresholds and cutoff criteria.

The optimal case is to have a specific cradle-to-gate CFP for each additive or additive package used in a lubricant, obtained through suppliers or from data sources as per hierarchy of data sources provided in section 4.6. The cradle-to-gate CFP must include all relevant life cycle stages, such as the extraction of raw materials (e.g., extraction, purification, and processing of metal ores to form the metal compounds that are used to make a metal-based additive), all intermediate stages of processing, additive production and transportation between upstream sites and inbound transportation to the additive manufacturing site. The preference is for independently reviewed/verified CFP, where available (See discussion in Section 4.10).

The standard approaches for assessing the impact of packaging, handling, and transportation discussed in Section 5.1.3, Inbound transport and packaging of raw materials should be followed.

5.1.3. Inbound Transport and Packaging for Raw Materials

To estimate the emission associated with transport of raw materials to the production location (LBP, section 5.2), the following data should be collected:

1. Mass of component transported
2. Distance the goods are transported over
3. Mode of transport utilized (road, rail, etc.) including fuel type, if available

Unless emissions data can be supplied by the logistics company (e.g., based on fuel consumption information), EFs for different modes of transport on a kg CO_2e/t.km basis can be sourced from a variety of public available sources e.g., the Global Logistics Emissions Council (GLEC) framework. (Smart Freight Centre, 2021)

For a more detailed discussion on transport/logistics emissions, please see section 5.4 of this TR.

Inbound packaging materials should be considered for raw materials; for details on potential emission factors by pack type, please refer to section 5.3.

More detailed considerations for inbound transport and packaging of base oils and additives respectively:

> Note 1: The formulation for most commercial lubricant formulations will consist principally of BOs and base stocks. Considering the prevalence of BOs, most LBPs will receive these components primarily in bulk form, conveyed by either tanker truck, railcar, barge and/or ship. However, some specialized and/or lower-consumption base stocks/base oils are received in smaller quantities, and in such cases drums and/or Intermediate Bulk Containers (IBCs) are frequently used.

Note 2: In comparison to BOs, additives may typically be received in smaller containers (e.g., pails); solids are frequently received packaged in bags (polymeric and paper bags are both common), with the bags in turn palletized. Similar to other packaging materials, the choice of pallet material (wood vs. plastic) may have sustainability implications. The supplier should be requested to provide a life cycle EF that considers the service life and recyclability of the pallet.

5.2. Production

Considerations of contribution to the CFP from the blending operations of the lubricant at the Lubricant Blending Plant (LBP) are discussed below.

To determine the contribution, the following type of data should be collected from the asset inventory:

- Consumption of thermal energy (e.g., natural gas, etc.)
- Consumption of imported electricity
- Consumption of imported steam
- Fuels consumed for onsite transports (unless included above)
- Waste lubricant from production and disposition of such waste (for oil disposal fates see section 5.6.1)
- Lubricant production volume
- If applicable, packaging and filling data should be collected.

All data should be collected over a representative time period e.g., over a period of one year.

More detailed considerations of aspects that can contribute to consumption of energy and therefore production of emissions at the LBP has been added to Annex D.

5.3. Packaging

To estimate the contribution from packaging to the overall product CFP, the packaging present at different stages of the life cycle should also be considered on a life cycle basis. The contribution on a cradle-to-gate basis is discussed in this section, while End-of-Life treatment of packaging is covered in section 5.6.2 – both these sections together cover the life cycle of the packaging material.

For the estimation of the cradle-to-gate contribution from primary packaging (packaging in direct contact with the lubricant), the following data should be gathered:

- Raw material type (e.g., plastic like HDPE, Steel)
- Raw material weight
- Nature of raw material (virgin or recycled)
- Packaging production process energy consumption (e.g., plastic blow molding)
- Thermal energy source used for packaging production
- Re-use of packaging materials (rewashing of IBCs) should be included.

The data above can be used to select applicable emission factors for raw materials (e.g., kg CO_2e/kg of recycled HDPE; see section 4.6) in combination with the contribution from production (e.g., kg CO_2e/kWh of electricity/heat required) to estimate the contribution from fabrication. Inbound transport to the production facility and associated packaging material (packaging of packaging materials e.g., palleting, if applicable) should also be included. If a pre-calculated emission factor for a specific pack type from a secondary data source is to be used instead, the alignment of the assumptions for that emission factor should be tested against the collected data (e.g., are the raw material weights comparable).

Note1: Given that diverse packaging options are available and also may be different for the various life cycle stages, it is preferred to express emissions associated with packaging in the assessment documentation separately.

Note 2: The contribution from labelling should be evaluated in light of the cut off criteria (section 4.5). The label supplier could be approached for an EF accounting for: Offsite production of labels followed by transport of labels to the packaging site (e.g., LBP). If onsite spray-on application of labels is performed, associated energy consumption could already be included in the inventory gathered for the "production" stage (section 5.2).

Note 3: Specialty case of onsite packaging manufacturing: Rather than receiving smaller packages (e.g., 1qt or 1L bottles) from a package manufacturer, some LBPs implement on-site blow-molding operations to create the bottles on-site from polymeric resin. This will allow for direct collection of packaging production data, but care should be taken that associated production energy consumption is not also included in the inventory gathered for the "production" stage (section 5.2).

5.4. Logistics

This section covers the contribution to the LCA, and in terms of emission to the CFP, for distribution of the finished lubricant from the lubricant production gate to the customer gate. Although important to consider as an area for improvement, the contribution from logistics to the overall CFP, tends to be smaller, with exceptions for special circumstances of intercontinental import or air-freight transport.

To estimate the emission associated with transport portion of the life cycle of finished lubricants to the customer, the following data should be collected:

1. Mass of finished lubricant transported
2. Distance the goods are transported over (from/to location data)
3. Mode of transport utilized (road, rail, etc.) including fuel type, if available

EFs for different modes of transport on a kg CO_2e/t.km basis can be sourced from a variety of publicly available sources (Annex A). A recent example of a suitable data source could be the Global Logistics Emissions Council (GLEC) framework, which in turn e.g., references the EPA SmartWay as a data source for US heavy goods road transport (Smart Freight Centre, 2021).

It should be acknowledged that for different modes of transport (e.g., road, rail, etc.) there is a range of values available by transport types (e.g., different types of trucks for road transport), so guidance by the hauler or, if applicable, the logistics department, should be sought to select the most appropriate EF based on logistics fleet composition. It should be acknowledged that most of the transport for finished lubricant products will be via road transport, where EFs can be further differentiated by load factor and degree of empty running. Truck transport could include customer pick-up, in-house delivery fleets, and third-party hauling services.

More complex distribution patterns, which also vary over time, might require an approach of using averaged data over a representative time period (e.g., minimum of one year). This approach is more suitable for a product sold to a variety of customers, where tracing of individual transactions becomes prohibitively complex, with additional granularity only making a minor difference to the overall CFP.

Alternatively, if fuel consumption data is available from the hauler or if logistics is under operational control, and hence such primary data on fuel consumption is available for collection, this should be used for the estimation of the transport associated emissions, as this is usually a more accurate assessment. The fuel consumption data should be paired with Well-to-Wheel (WtW) emissions factors for the fuel types from recognized sources. (Environmental Protection Agency, 2022) (UK Department for Business, Energy & Industrial Strategy, 2022) (Smart Freight Centre, 2021) If hauler data is already supplied and converted to CO_2e, the data source for the EFs used for the conversion should be determined and calibrated against data sources quoted above (e.g. if the same EF scope is covered are values provided within 5%). As per the general guidance in section 4.6, in case there are gaps in the data those should be bridged with conservative estimates informed by the best available data.

While transport related emissions will be the main contribution to this life cycle stage, other activities could contribute additional emissions, and could be evaluated if sufficiently granular data is available:

- Warehousing at different stages of the value chain – conservatively estimated default values show that this is likely to be a small contribution to the logistics section. (Dobers, Ruediger, & Jarmer, 2019)
- If not reflected elsewhere (e.g., transport type EF or asset specific accounting), energy requirements for on and off-loading could be considered. Also, if applicable in special circumstances, where additional heat is required during transport (e.g., to maintain fluidity), an estimation should be performed to assess a potential contribution to the overall CFP.
- In light of the cut off criteria (4.5), the impact of product returns e.g., for repatriating non-conforming, adulterated, or past-expiry product should be evaluated.

5.5. In Use

The use stage is part of the life cycle where a lubricant is put into service, by an end consumer, based on its market design and function. The use stage begins when the end consumer takes possession of the lubricant. The use stage extends through a lubricant's useful life to the point of final disposition, reuse for a different function, recycling or energy recovery. Within the use stage contributions to GHG emissions from activities and energy consumed during lubricant use, are determined. The life cycle scope for the use stage, shall specify the user and lubricating environment along with the products use profile.

Factors that influence GHG emissions within the use stage include losses through combustion, volatility or leakage out of the lubricating environment. A lubricants use profile describes its typical performance under realistic conditions of use and contribution to the impact associated with these losses. The use profile for a lubricant should be determined with relevant data to the extent possible. When profile data are not available, estimations of a lubricant performance under realistic conditions, within the lubricating environment are acceptable.

Use Profile Data:

- Shall be documented and verifiable
- Based on function, market and intended use
- Obtained from: regulators, equipment manufacturers, relevant industry groups, academia or lubricant marketers, industry applicable qualified testing facilities
- If no method is established for use profile data, estimates or modeling may be used to define use profile features
- Estimates should be documented as such, by the organization carrying out the CFP and LCA study

With the fraction of lubricant lost (Figure 3) defined in the "profile data" (MF_{use} = mass fraction of lubricant lost at "in use" stage), the contribution to the CFP can be calculated. Unless other information is available, it shall be assessed that complete combustion takes place.

The contribution to CFP from the "in use" stage can be expressed with the formula below:

Contribution to CFP for "in use" stage = $MF_{use} \times EF_{CC}$

where:

A "mass fraction" (e.g., MF_{use}) is defined as a ratio of mass over total lubricant mass and is unitless.

MF_{use}: Mass fraction of lubricant lost in use based on "use profile data"

EF_{CC}: Complete combustion emission factor (all contained carbon released as CO_2)

The emission factor for complete combustion (EF_{CC}) assumes for all the carbon embedded in the product to be released as CO_2. Building on the formula provided in section 4.8, when the product is only based on fossil carbon, the emission factor can be estimated as follows:

EF_{CC}: kg CO_2 /kg product = (%total carbon) x (mw $_{CO2}$ / mw $_C$)

where

%total carbon: Fraction of mass of carbon relative to total mass (e.g., 0.8 for 80% carbon content)

mw $_{CO2}$: molecular weight of carbon dioxide (CO_2)

mw $_C$: molecular weight of carbon (C)

In alignment with section 4.8, for a product that is based on both biogenic carbon and fossil carbon, the emission factor to account for the fossil portion of the emissions can be estimated as follows (example of application of this formula provided in Annex B):

EF_{CC}: kg CO_2 /kg product = (%total carbon * (1-%biogenic carbon)) * (mw $_{CO2}$/mw $_C$)

Where:

%total carbon: Fraction of mass of carbon relative to total mass (e.g., 0.8 for 80% carbon content)

%biogenic carbon: Fraction of total embedded carbon that is of biogenic origin.

mw $_{CO2}$: molecular weight of carbon dioxide (CO_2)

mw $_C$: molecular weight of carbon (C)

Percentage of total carbon content (%total carbon) can be estimated using knowledge of the composition of the underlying lubricant product or alternatively can be experimentally determined through methods such as ASTM D5291, DIN13137 or equivalent.

Note: In absence of such direct figures, recognized secondary data sources have published complete combustion emission factors for used oil e.g. on the EPA GHG emission factors hub (Environmental Protection Agency, 2022) and by the UK Department for Business, Energy and Industrial strategy (formerly DEFRA) (UK Department for Business, Energy & Industrial Strategy, 2022). Further details on such secondary data sources can be found in Annex A.

Additional sources of emissions within the use stage that may apply include: energy associated with lubricant storage, distribution and wastes generated from maintenance activities such as lubricant flushing and or change over (see sections 5.4 and 5.6.1 in this context). When included in the life cycle study, these should be transparently documented with its associated activity.

5.6. End-of-Life

5.6.1. End-of-Life – Used Oil

The End-of-Life stage commences at the end of the lubricant's service life i.e., when the lubricant's useful life has been expended and it becomes used oil. Therefore, this section focuses specifically on the material that remains following the "in use" stage (section 5.5).

Note: For example, where 35% of the lubricant has been lost at the "in use" stage due to combustion and leakages, the remaining 65% of the lubricant still needs to be accounted for at the "End-of-Life" stage (Figure 3).

The used oil can go into two types of treatment channels:

1. A fraction that arrives at "formal" treatment channels and therefore the fate of the used oil can be traced.
2. A fraction that arrives at "informal" treatment channels, where the fate of the used lubricant is unknown due to untraceable disposal practices (e.g., combustion of used oil in space heaters at

workshops).

The fate of the used oil shall be accounted for, no matter the treatment channel. Due to the unknown nature of “informal” treatment channels, these shall be conservatively estimated in a way that all the embedded carbon is assumed to be released as CO_2 (via use of the “complete combustion emission factor” EF_{CC} defined in section 5.5). The volume of used oil entering “informal” treatment channels shall account for the difference in volume of used oil available after the “in use” stage and used oil arriving in traceable “formal” treatment channels.

Used oil arriving at “formal” treatment channels typically undergoes one of four fates:

1. Recycling of used oil (e.g., re-refining)
2. Combustion of used oil with heat recovery
3. Combustion of used oil for disposal (no heat recovery)
4. Landfill of used oil

The contribution to the End-of-Life stage from each of the four fates to the CFP is given by an applicable emission factor.

The overall contribution to the CFP from the “End-of-Life” stage can be expressed with the formula below:

$$\text{Contribution to CFP for “End-of-Life” stage} = MF_{EoL} \times F_{informal} \times EF_{CC} + MF_{EoL} \times F_{formal} \times (F_{recycle} \times EF_{recycle} + F_{CHR} \times EF_{CHR} + F_{CD} \times EF_{CD} + F_{landfill} \times EF_{landfill})$$

Where

$MF_{EoL} = 1 - MF_{use}$ (Embedded carbon in the product that remains after the “in use” stage)

$F_{informal} + F_{formal} = 1$ (MF_{EoL} is subdivided into informal and formal treatment channels)

$F_{recycle} + F_{CHR} + F_{CD} + F_{landfill} = 1$ (applies to lubricant waste undergoing formal waste treatment)

Terms definition:

A “mass fraction” (e.g., MF_{use}) is defined as a ratio of mass over total lubricant mass and is unitless.

MF_{use}: Mass fraction of lubricant lost in use based on “use profile data”

MF_{EoL}: Mass fraction of lubricant entering the End-of-Life stage.

A “fraction” (e.g., $F_{informal}$) is the ratio of mass entering a treatment channel over the combined mass that remains to be accounted for (e.g., total mass entering EoL stage). A fraction is unitless.

$F_{informal}$: Fraction of used oil entering informal treatment channels.

F_{formal}: Fraction of used oil entering formal treatment channels.

$F_{recycle}$: Formal fate – fraction of used oil undergoing recycling.

F_{CHR}: Formal fate – fraction of used oil undergoing combustion with heat recovery (CHR).

F_{CD}: Formal fate – fraction of used oil undergoing combustion for disposal (CD).

$F_{landfill}$: Formal fate – fraction of used oil being disposed in a landfill.

Emission factors will carry the unit of kg CO_2/kg.

EF_{CC}: Complete combustion emission factor (all embedded carbon released as CO_2).

$EF_{recycle}$: Emission factor for recycling of used oil.

EF_{CHR}: Emission factor for combustion of used oil with heat recovery.

EF_{CD}: Emission factor for combustion of used oil for disposal.

$EF_{landfill}$: Emission factor for disposal of used oil in landfill.

An overall formula, showing the combined contribution to the CFP from the "use" (section 5.5) and "End-of-Life" stages is provided in Annex B alongside examples for applications of this formula.

To estimate the GHG emissions associated with the End-of-Life stage according to the formula provided above, the following type of data are required:

- Split of used oil undergoing "informal" or "formal" End-of-Life treatments
- Split into four main used oil formal fates as defined above

Such data will vary regionally, and the factors selected should reflect this variation. Where available, country level data should be obtained to provide additional granularity over regional/global averages. Annex A provides potential data sources for such factors.

Note: For example, a recent report from the department of energy (DOE) provides insights for such parameters for the USA (US Department of Energy, 2020).

For used oil treatment fates, where downstream parties derive a benefit from the treatment approach (e.g., recycling of used oil), a cut-off approach shall be used. Therefore, the emissions associated with those used oil treatment fates will be outside the system boundary and carried by the beneficiary.

The four main formal fates of used lubricant and associated emission factors are discussed in more detail below:

1. Recycling of used oil:

   The used oil has been declared as destined for reclamation[6]/re-refinement and therefore recycling. Through application of the cut-off approach the used oil associated with this fate leaves the system boundary for the life cycle assessment of the lubricant product and the emissions shall be attributed to the system of the beneficiary from use of the recycled material (in this case the re-refiner). The point where the material destined for recycling leaves the system boundary is therefore the start point as the "raw material" for the re-refined base oil process as defined in section 5.1.1.1. It should be noted that the used oil carries no upstream emissions burden, which has already been fully accounted for in the "raw materials" stage contribution of the first life cycle of the lubricant product.[7]

   When the cut-off approach is applied the applicable emission factor for the CFP calculation for the life cycle of the current lubricant is $EF_{recycle}$ = 0 kg CO_2e/kg.

   Note: Application of the cut-off approach avoids double counting of the embedded carbon emissions, when the recycled material reaches the End-of-Life stage again having run through the life cycle as defined in Figure 1 for a second time.

2. Combustion of used oil with heat recovery:

   The used oil has been declared as destined for combustion, with the associated released energy being utilized (e.g., providing heat through combustion of the used oil in a cement kiln). Application of the cut-off approach, consistent with the approach for the recycling fate detailed above, means that the used oil leaves the system boundary for the life cycle assessment of the lubricant product and combustion related emissions shall be carried by the party benefitting from the use of the

[6] Reclamation: The used oil may be filtered, dewatered, and re-used as a lubricant. This definition encompasses applications when the used oil returns as a lubricant with minimal re-processing.

[7] If feedstock is supplemented with virgin VGO, the associated upstream emissions shall be accounted for, based on the mass fraction that the virgin VGO is contributing to the produced base oil.

released energy.

Depending on where the boundary is drawn, there may be transport related emissions that need to be accounted for (e.g., transport to the waste facility). If used oil collection is performed by the downstream beneficiary of the energy use, then the applicable emission factor is EF_{CHR} = 0 kg CO_2e/kg. This means emissions associated with the used lubricants transport and emissions from combustion of the lubricant are outside of the system boundary.

For consistency with the approach adopted for the recycling of used oil, adoption of the cut-off approach for this waste fate is the recommended route for this TR. However, potential alternative approaches, which are not recommended by the TR, can be found in Annex C.

3. Combustion of used oil for disposal (no heat recovery):

   The used oil has been declared as destined for combustion, but solely for the purpose of disposal of the waste and without use being made of the released energy (disposal by incineration). Hence, no other party is deriving a benefit from the disposal and therefore the emissions associated with the release of the embedded carbon are within the system boundary and part of the lubricant product life cycle.

   There might be transport related emissions that would need to be accounted for (e.g., transport to the waste facility), which can be evaluated based on the cut-off criteria (section 4.5). If used lubricants transport emissions are negligible, the associated emission factor would simplify to $EF_{CD} = EF_{CC}$.

4. Landfill of used oil:

   The used oil is disposed of in a landfill. Due to the unknown nature of the fate of the lubricant over a 100-year timeframe for such disposals, these should be conservatively estimated as all the contained carbon to be released as CO_2. Again, no other party is deriving a benefit from this type of disposal, therefore emissions associated with the release of the embedded carbon are within the system boundary and part of the lubricant product life cycle.

   There might be transport related emissions that would need to be accounted for (e.g., transport to the waste facility), which can be evaluated based on the cut off-criteria (section 4.5). If used oil transport emissions are negligible, the associated emission factor would simplify to $EF_{landfill} = EF_{CC}$.

5.6.2. End-of-Life – Packaging Materials

The End-of-Life stage for packaging commences when the associated lubricant product has been dispensed and the packaging material becomes a waste material. To ensure that the life cycle emissions for the packaging material are covered, this section needs to account for the emission that take place following the “cradle-to-gate” scope as defined in section 5.3. The End-of-Life contribution from packaging to the overall CFP is usually limited, due to the relatively low weight of packaging in relation to the packed material.

To calculate the End-of-Life contribution from primary packaging (packaging in direct contact with the lubricant), the following data are required:

- Weight of packaging, by raw material type
- Data on proportional disposition by country/region and waste material type into four main waste fates: Recycling, combustion with heat recovery, combustion without heat recovery and landfill.
- Emission factors by waste material type and waste fate (e.g., Polyethylene – incineration without energy recovery).

The approach selected for End-of-Life for packaging, should be consistent with the approach for used oil. Therefore, if the cut-off approach is used, the emission factors for the waste fates of “recycling” and “combustion with energy recovery” should be set to 0 kg CO_2e/kg, as the associated emissions are carried by the downstream beneficiary.

Note: Due to oil contamination, recycling of lubricant plastic bottles is only possible in a limited number of countries where legislation is in place to address this challenge. This should be taken into account when the waste fate splits by country/region are determined.

Additional contributions to this stage of the life cycle from transport of the waste to the waste disposal facility should be considered.

6. Applications of Outcome of Lubricant LCA

This section is intended to explore potential application areas of the outcome of LCA and CFP studies of lubricant products. Common applications for the potential benefits of lubricants may include: efficiencies obtained through service consisting of lower fuel or electricity use and less oil used over a given functional unit. As per section 1 of this document, this section is not intended as an exhaustive treatment of these topics, but to provide some examples with high-level guidance.

6.1. Avoided Emissions Through Fuel Economy Benefits

Avoided emissions are estimated based on a comparative study, in which a product solution in terms of its greenhouse gas (GHG) emissions impact is compared to an alternative product, that provides an equivalent function (reference solution or functionally relevant baseline). (World Resources Institute, 2019) If the product solution leads to overall lower GHG emissions in this comparison, the delta would be referred to as “avoided emissions”. Avoided emissions stand separately and in addition to the lubricant life cycle assessment and the defined CFP of the lubricant.

One example of such “avoided emissions”, which is applicable to lubricants, is emissions that are avoided due to fuel economy benefits offered by a lubricant product with a use profile differentiated by fuel consumed when compared to a functionally relevant baseline.

To estimate such “avoided emissions”, at a high level, four figures need to be compared with each other:

- The CFP of the lubricant product against the CFP of the functionally relevant baseline solution – The absolute emissions difference is determined by the volume requirement of the application. (Both CFPs should be determined in the same manner line with this TR**)**
- Comparison of fuel economy benefit afforded by the lubricant product in comparison to the fuel economy benefit afforded by the functionally relevant baseline solution – Difference in fuel not consumed is translated into avoided CO_2e emissions using recognized tank-to-wheel and well-to-tank emission factors.

Note: Potential sources for applicable emission factors (Environmental Protection Agency, 2022) (UK Department for Business, Energy & Industrial Strategy, 2022)

Careful consideration is needed to apply appropriate scopes, boundaries and functional units for the output analysis to drive consistency and allow for relevant comparisons.

If the improvements of the fuel economy savings outweigh the difference in CFPs then there is an emission avoidance overall. As these two pairs of figures are derived on quite different basis (sum of absolute life cycle emissions contributions, vs. avoided emissions from unburned fuel), these pair of figures should be shown side by side, rather than directly subtracted from each other. In this particular case, the study in fact touches on a different product life-cycle – (extended boundary output) the one of the fuel that is not combusted due to the fuel economy benefit.

This type of avoided emission study is strongly dependent on the robustness of the underlying fuel economy data. Therefore, industry recognized fuel economy test methods should be used for quantification, where available. The test method utilized should be clearly documented.

Furthermore, credibility of such a study to determine avoided emissions, is dependent on the realism of the point of comparison and therefore the reference/baseline[8] selected. Guidance on how to define a suitable "reference" or "functionally equivalent baseline" can be found in section 3.2 of a study by ICCA (International Council of Chemical Associations) and the WBCSD (World Business Council for Sustainable Development). (ICCA and WBCSD, 2017) Some of the contained guidance has been quoted below for reference:

> *The solution to compare to shall meet a number of criteria to ensure a credible avoided emissions claim:*
>
> - *Ideally one wants to compare the studied solution to what the studied solution really replaces.*
> - *The solution being replaced could be the market average, an average of several solutions of the market, a very specific solution, the dominant solution, or a marginal solution […]*

As part of the associated documentation, it has to be stated transparently, which reference/baseline was chosen and how the comparison was performed.

Note: A recent study by Ricardo, which was commissioned by ATIEL (Technical Association of the European Lubricants Industry), highlights the overall avoided emissions enabled through lubricants for the EU vehicle fleet as the market transitions to lower viscosity lubricants. (Ricardo, 2019) The magnitude of the avoided emission quantified both backward looking to 2005 and forward looking to 2030, highlights the significant contribution of lubricants to the decarbonization of the road transport sector.

6.2. Avoided Emissions from Extended Oil Drain Interval

Another source of avoided emission applicable to lubricants is emissions avoided through extension of the oil drain interval (ODI).

For this type of avoided emissions estimation, at a high level, the following steps and data will be needed to draw a comparison:

- The CFPs for the lubricant[9] under investigation and for the lubricant being used as the functionally relevant baseline need to be determined (converted via respective densities to kg CO_2e/Liter; both CFPs should be determined in line with this TR).
- Required lubricant volume based on sump size (any top up volume used should be included), normalized to the extended ODI should be determined (e.g. if the lubricant under investigation doubles the ODI while providing the equivalent performance (e.g. fuel economy), twice the volume of the baseline lubricant is needed to cover the same ODI in the same application – with a 5 L sump size and no top-ups required this means 5 L of the lubricant under investigation vs. 10 L of baseline lubricant).
- Multiplication of the CFPs with their respective required volume determines the associated GHG emissions over a given ODI interval for both lubricants.
- The delta of these GHG emission figures for the two lubricants being compared yields the associated avoided emissions from the ODI extension.

Overall, this equates to a change of the functional unit from the functional unit described in section 4.2 – emissions are no longer provided relative to the lubricant mass or volume but relative to the new extended ODI interval (e.g. emissions in kg CO_2e associated with lubricant life cycle required to enable vehicle Z to travel 10,000 miles – therefore: kg CO_2e/10,000 miles in vehicle Z). Both lubricants would be compared

[8] In certain engine tests, performance is measured against a "reference lubricant", which are often of higher viscosity grades (e.g. 15W-40) than viscosity grades generally found in the market place today, and hence would not be a suitable reference/baseline to determine avoided emissions.

[9] With a use profile differentiated by lower oil volume over a functional unit equal to the lubricant used for comparison.

using this revised functional unit.

This type of estimation is very dependent on the robustness of the data quantifying the extension of the ODI duration. The test method utilized should be clearly documented.

The guidance regarding the selection of a realistic reference/functionally relevant baseline, as outlined in section 6.1 above, remains applicable for this section.

> Note: As practitioners perform estimations for avoided emissions, there are many different factors to consider such as, oil consumptions, weather/environment/changes in the fluid that impact fuel economy and associated emissions. These factors need to be considered on a case by case basis to provide the realistic benefit estimation for a given application/end user.

6.3. Supporting “Carbon Neutral” Claims on Products

ISO14021 defines “carbon neutral” in section 7.17.3.2 and for a product provides the following definition:

> *[…] “carbon neutral” requires that all the GHG […] emissions from all stages of the product life cycle, and within the specified product system, have been reduced, removed or accounted for through a system of offsets or credits, or by other means.* (International Organization for Standardization, 2016)

ISO14021 furthermore references ISO14067 for guidance on determination of a carbon footprint of product (CFP), which is one of the normative references provided in section 2 of this TR. Based on this definition a CFP which is derived on cradle-to-grave basis, in line with the applicable selected standard (e.g., ISO14067) and aligned with the guidance of this TR, would need to be determined as an important step towards a “carbon neutral” claim. All associated life cycle emissions determined in this fashion would then need to be shown to be avoided/reduced or offset to reach “carbon neutrality”.

The British Standards Institution released PAS2060 in 2014, which gives more detailed guidance on the demonstration of carbon neutrality. This includes guidance on permissible declarations, ongoing documentation in form of a carbon footprint management plan and actions to be taken to maintain carbon neutrality on an annual basis. Annex C of PAS2060 also provides a list of standards and codes that that could be used for the quantification of a carbon footprint of a product or service. These include PAS2050, the precursor for ISO14067[10] and the GHG protocol “Product life cycle accounting and reporting standard” all of which are listed as normative references in section 2 of this TR.

It should be noted that the standards around “carbon neutrality” are still evolving. The International Organization for Standardization is currently preparing ISO14068, which similar to PAS2060 will provide additional guidance and requirements in this space, which is set for release in 2023 (International Organization for Standardization, n.d.). While further requirements around “carbon neutrality” are being defined, reliable and robust quantification of the CFP will remain as a key step.

[10] It should be noted that PAS2060 was released in 2014 and pre-dates the release of ISO14067 in 2016.

Annex A
(informative)

List of Publicly Available Data Sources

Source	LCA Stage	Description	Link
API	End-of-Life	Life Cycle Assessment of Used Oil (2017)	https://www.api.org/~/media/Files/Certification/Engine-Oil-Diesel/Publications/LCA-of-Used-Oil-Mgmt-ERM-10012017.pdf
ATIEL	Avoided Emissions	Lubricants' contribution to fuel economy; aka Ricardo Study	https://atiel.eu/wp-content/uploads/2021/04/DOC-20.pdf
CalRecycle	Loss in Use	California Used Oil LCA; Losses during use phase by lubricant type; Kline & Company	https://www2.calrecycle.ca.gov/Publications/Details/1512
CIMAC	General resource	Internal Council on Combustion Engines	https://www.cimac.com/publications/guidelines/index.html
DEFRA (frmly)- United Kingdom	Loss in Use/End-of-Life	Emission factor for combustion, 2021	https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021
DOE	End-of-Life	Waste fate material flows – US market Used Oil Management and Beneficial Reuse Options to Address Section 1: Energy Savings from Lubricating Oil	https://www.energy.gov/sites/prod/files/2020/12/f81/Used%20Oil%20Management%20and%20Beneficial%20Reuse%20Options%20to%20Address%20Section%201.%20E....pdf
Ecoinvent	Packaging	Emission factors for raw materials (e.g. plastics, metal)	https://ecoinvent.org/
Ecoinvent, general	End-of-Life	General Introduction Waste Material Compositions Municipal Waste Collection	https://www.doka.ch/13_I_WasteTreatmentGeneral.pdf

Source	LCA Stage	Description	Link
EPA	End-of-Life	EPA has emission factors for 'used oil' on their Climate Leadership site.	https://www.epa.gov/climateleadership/ghg-emission-factors-hub
EPA, AP-42	General resource	Fuel Oil Combustion	https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s03.pdf
EPA, eGFRID2014	General resource	Grid factors	https://www.epa.gov/sites/default/files/2015-10/documents/egrid2012_summarytables_0.pdf
EPA, Facts and Figs Guide	End-of-Life	Looks at generation, recycling, composting, combustion with energy recovery, landfilling for a variety of materials and products and other pathways for food.	https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/guide-facts-and-figures-report-about#Materials_and_Products
EPA, GHG Equivalence Calculator	Conversion Reference	This calculator may be useful in communicating your greenhouse gas reduction strategy, reduction targets, or other initiatives aimed at reducing greenhouse gas emissions	https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Source	LCA Stage	Description	Link
EPA, NEPIS	General resource	Life Cycle Inventory (LCI) Data Treatment Chemicals, Construction Materials, Transportation, On-site Equipment, and Other Processes for Use in Spreadsheets for Environmental Footprint Analysis (SEFA)	https://nepis.epa.gov/Exe/ZyNET.exe/P100SNDQ.txt?ZyActionD=ZyDocument&Client=EPA&Index=2016%20Thru%202020&Docs=&Query=%28Incineration%29%20OR%20FNAME%3D%22P100SNDQ.txt%22%20AND%20FNAME%3D%22P100SNDQ.txt%22&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C16THRU20%5CTXT%5C00000000%5CP100SNDQ.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=4
EPA, Scope 3	General resource	Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly impacts in its value chain.	https://www.epa.gov/climateleadership/scope-3-inventory-guidance
EPA, Vermont Used Oil Study	End-of-Life	Vermont Used Oil Analysis and Waste Oil Furnace Emissions Study	https://www3.epa.gov/ttn/catc/dir1/w_oilacr.pdf
ERASM	General resource	Environment and Health - Risk Assessment & Management	https://www.erasm.org/
Eurostat	End-of-Life	Waste fate material flows – European Union EuroStat Data browser; waste category: used oil; data can be split by waste management operation	https://ec.europa.eu/eurostat/databrowser/view/ENV_WASTRT__custom_429516/default/table?lang=en

Source	LCA Stage	Description	Link
GaBi	General	Databases, cross-sector calculation tool	https://ghgprotocol.org/gabi-databases
GHGprotocol - CHP	Allocation	Allocation of combined heat and power (CHP) plants	https://ghgprotocol.org/sites/default/files/CHP_guidance_v1.0.pdf
GLEC	Logistics	Emission factors by transport type.	https://www.smartfreightcentre.org/en/downloads/
GREET	General resource	Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model; Argonne National Laboratory	https://greet.es.anl.gov/
PEF	General resource	Multi-criteria measure of the environmental performance of a good or service throughout its life cycle.	https://ec.europa.eu/environment/eussd/pdf/footprint/PEF%20methodology%20final%20draft.pdf
Springer Link	General resource	LCA of petroleum-based lubricants: state of art and inclusion of additives	https://link.springer.com/article/10.1007/s11367-012-0437-4?utm_medium=affiliate&utm_source=commission_junction&CJEVENT=b60feaf25d0a11ec802bdf3f0a82b838&utm_campaign=3_nsn6445_brand_PID100357191&utm_content=de_textlink&?utm_medium=affiliate&utm_term=PID100357191
Springer Link	Uncertainty	How to treat uncertainties in life cycle assessment studies?	https://link.springer.com/article/10.1007/s11367-018-1477-1?utm_medium=affiliate&utm_source=commission_junction&CJEVENT=ce8c683f5d0b11ec83ec781d0a82b839&utm_campaign=3_nsn6445_brand_PID100357191&utm_content=de_textlink&?utm_medium=affiliate&utm_term=PID100357191
Wiley.com	Bio-lubricant	Sustainability Assessment of Biolubricant	https://onlinelibrary.wiley.com/doi/pdfdirect/10.1162/108819803323059460

Annex B
(informative)

Applications of “In Use” and “End-of-Life” Formula

In alignment with Figure 3, to determine the contribution to the CFP from the “in use” (section 5.5) and “End-of-Life” stage (section 5.6.1), an overall formula for the release of embedded carbon in the lubricant could look as follows.

Contribution to CFP for both “In Use” and “End-of-Life” stages =

MF_{use} x EF_{CC} +

MF_{EoL} x $F_{informal}$ x EF_{CC} +

MF_{EoL} x F_{formal} x ($F_{recycle}$ x $EF_{recycle}$ + F_{CHR} x EF_{CHR} + F_{CD} x EF_{CD} + $F_{landfill}$ x $EF_{landfill}$)

Where $MF_{use} + MF_{EoL} = 1$ (Total embedded carbon in the product is accounted for)

and $F_{informal} + F_{formal} = 1$ (MF_{EoL} is subdivided into informal and formal channels)

and $F_{recycle} + F_{CHR} + F_{CD} + F_{landfill} = 1$ (applies to lubricant waste undergoing formal waste treatment)

Terms definition:

A “mass fraction” (e.g., MF_{use}) is defined as a ratio of mass over total lubricant mass and is unitless.

MF_{use}: Mass fraction of lubricant lost in use based on “use profile data”

MF_{EoL}: Mass fraction of lubricant entering the End-of-Life stage.

A “fraction” (e.g., $F_{informal}$) is the ratio of mass entering a treatment channel over the combined mass that remains to be accounted for (e.g., total mass entering EoL stage). A fraction is unitless.

$F_{informal}$: Fraction of used oil entering informal treatment channels.

F_{formal}: Fraction of used oil entering formal treatment channels.

$F_{recycle}$: Formal fate – fraction of used oil undergoing recycling.

F_{CHR}: Formal fate – fraction of used oil undergoing combustion with heat recovery (CHR).

F_{CD}: Formal fate – fraction of used oil undergoing combustion for disposal (CD).

$F_{landfill}$: Formal fate – fraction of used oil being disposed in a landfill.

Emission factors will carry the unit of kg CO_2/kg.

EF_{CC}: Complete combustion emission factor (all embedded carbon released as CO_2).

$EF_{recycle}$: Emission factor for recycling of used oil.

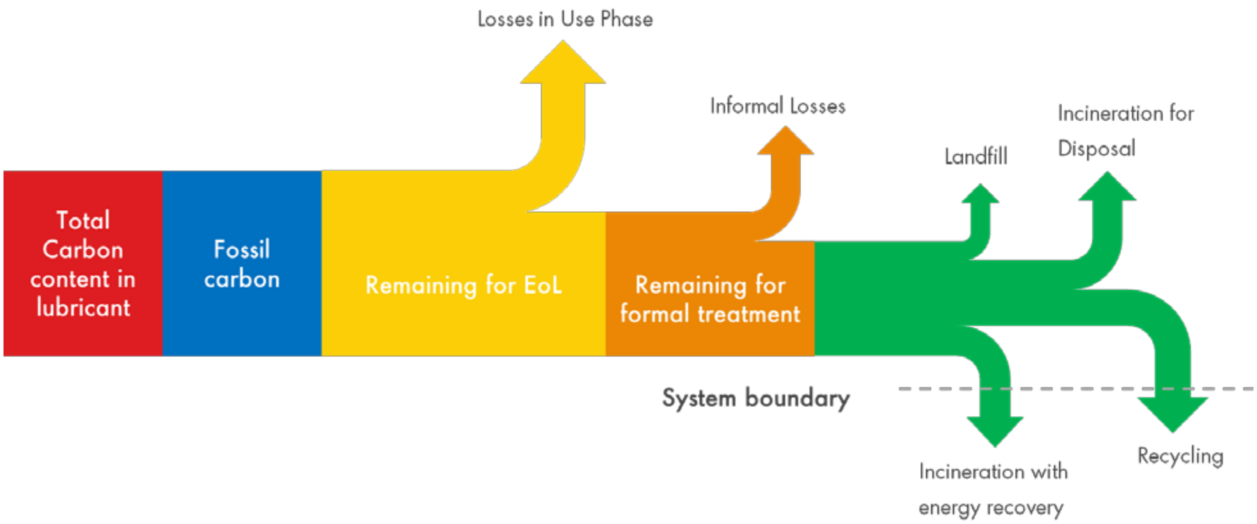
EF_{CHR}: Emission factor for combustion of used oil with heat recovery.

EF_{CD}: Emission factor for combustion of used oil for disposal.

$EF_{landfill}$: Emission factor for disposal of used oil in landfill.

Shown below are possible application scenarios of the generic formula provided above.

The illustration below shows the visual representation of the formula shown above, in the scenario where the lubricant is completely based on fossil carbon. This is drawn as a Sankey diagram, analogous to Figure 3.



B.1 Example of a 2-Cycle Oil

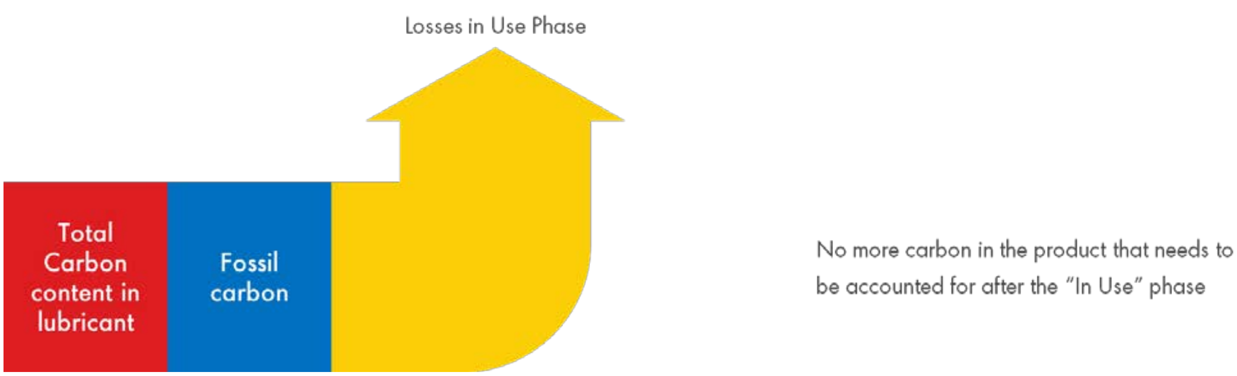
All lubricant is combusted as part of the intended application in the “in use” stage of the life cycle.

The formula simplifies as follows:

$$\text{Contribution to CFP} = EF_{CC}$$

This is as MF_{use} =1, so all material has been accounted for – meaning MF_{EoL} = 0 and associated terms disappear from the formula.

The Sankey diagram, for this scenario is shown below.



B.2 Example of Lubricant with 100% of Lubricant Collected for Recycling

The formula simplifies as follows:

$$\text{Contribution to CFP} = MF_{use} \times EF_{CC} +$$
$$MF_{EoL} \times F_{informal} \times EF_{CC} +$$
$$MF_{EoL} \times F_{formal} \times (EF_{recycle})$$

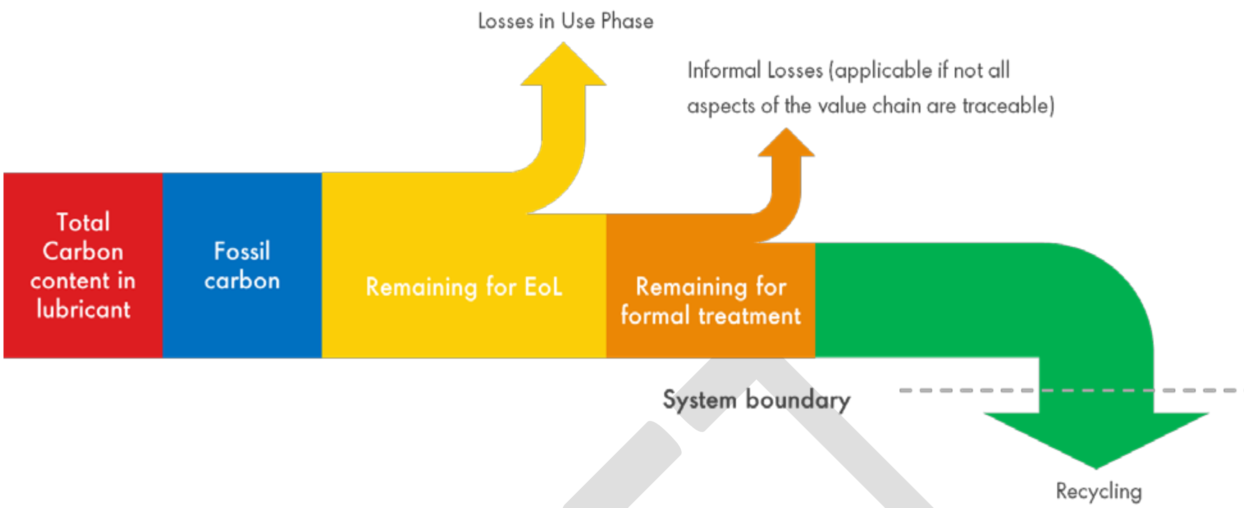
If $F_{recycle}$ =1 this means F_{CHR}, F_{CD}, $F_{landfill}$ = 0 and associated terms disappear.

If also all informal disposals are ruled out and all waste materials available after the “in use” stage are reaching the formal channel of recycling, the formula simplifies further to:

$$\text{Contribution to CFP} = MF_{use} \times EF_{CC} +$$

MF_{EoL} x $EF_{recycle}$

The Sankey diagram, for this scenario is shown below.



B.3 Example of Lubricant with 50% of Biogenic Carbon Content

As defined in section 5.5, the complete combustion factor (EF_{CC}) for a product based on both biogenic and fossil carbon is defined as follows:

EF_{CC}: kg CO_2 /kg product = (%total carbon x (1-%biogenic carbon)) x (mw $_{CO2}$/mw $_{C}$)

If the product consists of 50% biogenic carbon this formula simplifies to:

EF_{CC}: kg CO_2 /kg product = (%total carbon x 0.5) x (mw $_{CO2}$/mw $_{C}$)

Therefore, half of the total carbon content, that is not covered by a biogenic credit, still needs to have the contribution to the CFP during the “use” and “End-of-Life” stages determined.

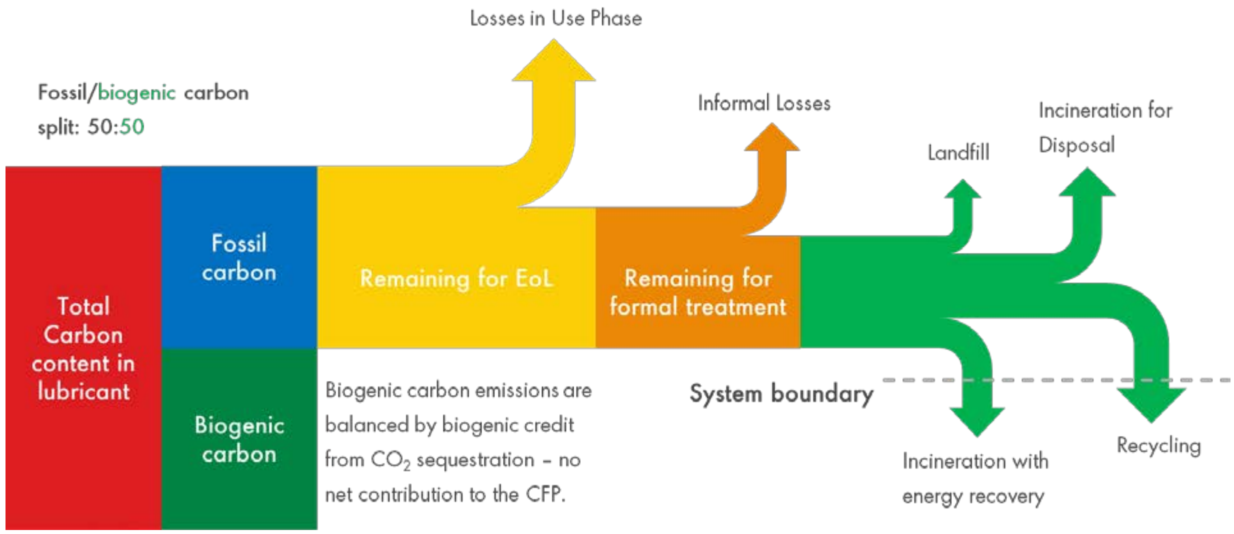
Applying the assumptions from section 5.6.1 and the definition of EF_{CC} above to the formula, the resulting formula for the contribution to the CFP is as follows:

Contribution to CFP = MF_{use} x (%total carbon x 0.5) x (mw $_{CO2}$/mw $_{C}$) +

MF_{EoL} x $F_{informal}$ x (%total carbon x 0.5) x (mw $_{CO2}$/mw $_{C}$) +

MF_{EoL} x F_{formal} x (F_{CD} x (%total carbon x 0.5) x (mw $_{CO2}$/mw $_{C}$) + $F_{landfill}$ x (%total carbon x 0.5) x (mw $_{CO2}$/mw $_{C}$))

The Sankey diagram, for this scenario is shown below.



B.4 Numerical Example for Calculation with Formula

The assumption are as follows:

- 10% of lubricant is lost to combustion in the “in use” stage
- EF_{CC} is 2.93 kg CO_2/kg lubricant based on a carbon content of 80% in the lubricant.
- Informal losses are assumed at 25%
- Half the material is recycled, and half is combusted for purpose of disposal.
- Cut-off approach is applied.

Contribution to CFP = 0.1 x 2.93 kg CO_2/kg lubricant +

0.9 x 0.25 x 2.93 kg CO_2/kg lubricant +

0.9 x 0.75 x (0.5 x 0 kg CO_2/kg lubricant + 0.5 x 2.93 kg CO_2/kg lubricant) =

1.94 kg CO_2/kg lubricant

Annex C
(informative)

Alternative Treatment Approaches of "Combustion of used oil with heat recovery"

According to this TR a cut off approach for the used oil fate of "Combustion of used oil with heat recovery" shall be used. Other treatment approaches that might be encountered are shown below but are not recommended by this TR.

An alternative approach could be, if alignment with proposed approaches in Europe is desired, to share the associated emissions burden between the life cycle assessment for the lubricant product and the downstream beneficiary of the energy use. As per the above, if transport emissions associated with the pick-up fall to the downstream beneficiary the associated emission factor would become $EF_{CHR} = ½ \times EF_{CC}$. Using this approach, downstream communication would be necessary, that only half of the combustion emission need to be accounted for to avoid double counting of the emission associated with the embedded carbon in the product.

Another approach that could be applicable to this used lubricants fate is to fully account for the associated combustion emissions (so application of EF_{CC}) as part of the life cycle assessment, but to balance these emissions with an emissions credit for the energy sources that are displaced. For this approach it should be considered that from a practical perspective it can be challenging to identify what the fuel mix is that has been displaced in various applications by the used oil combustion. But for limited applications of the methodology, where such data is available, this approach could be considered. The applicable emission factor would become $EF_{CHR} = EF_{CC} – EF_{credit}$, where EF_{credit} is the sum of emissions that are associated with the displaced fuel mix.

Annex D

(informative)

Considerations on the "Production (Section 5.2) Stage"

Section 5.2 specifies that data that needs to be collected from a Lubricant Blending Plant (LBP), to assess the contribution to the CFP.

Additional details are provided in the following points, that can contribute to consumption of energy and therefore production of emissions at the asset:

Blend components

Lubricant blending plants operate in such a way as to assemble raw materials into sellable products. The three broad classes of components most likely to be encountered in such operations are:

- Base oil(s) and/or base stocks.
- Additives
- Packaging materials

Base oils and base stocks

Moreover, these products are largely consumed due to their inherent viscosity. On arriving at the blend plant, especially in bulk, that inherent viscosity may preclude easy dispensing from the inbound vehicle to on-site storage. A frequent means of minimizing this hindrance is to apply heat to the container. For example, many bulk delivery truck wagons (and railcars) are designed with an outer jacket. The space between the outer jacket and the inner tank is lined with coils. Since many industrial plants generate and/or have access to high-pressure steam, a steam line is frequently connected to the inbound truck's coils to heat the inbound base oil (or base stock). On heating, viscosity generally decreases, and so pumpability is enhanced. The means by which the steam (or other form of heat) is generated and applied in the base oil offloading process should be assessed regarding GHG emissions.

Additionally, once offloaded (commonly into a tank), bulk base oil will tend to return to ambient temperature. As with delivery vehicles, base oil storage tanks are frequently designed with steam coils to either constantly or intermittently apply heat to the tank's contents, thus making pumping operations easier. Again, the means and energy intensity of steam generation applied in such storage and pumping modes must be evaluated. If means other than steam are employed to warm a storage tank's contents, their energy intensity must also be evaluated. These considerations are especially significant in Nordic climates.

If received in drums or IBCs, base oils are likely to be moved to storage using mechanical devices such as cranes or forklifts. Many forklifts are powered by Compressed Natural Gas, though in some locations the forklifts are battery-operated. The energy consumption of the equipment should be reviewed and evaluated, and the means of disposal of drums and/or IBCs after use must be evaluated.

Additives

As with base oils, the means and distance of transport, offloading and disposal of waste packaging should also be assessed for energy intensity and emissions.

Packaging Materials

Most packaging materials are palletized for transport, so the distance traveled as well as forklift and/or crane operations must be assessed at time of receipt. Additionally, most palletized packaging features secondary packaging, commonly involving polymeric film wrap and/or securing the packaging with straps (metallic or polymeric). The nature and fate of this secondary packaging should be investigated.

Labels

When performed offsite, production of labels (including environmental impact of subcomponents like ink/pigments, as well as energy requirements of production) followed by transport to the packaging site should be accounted for. In parallel, onsite spray-on application of labels should be assessed for emissions and energy intensity. The environmental impact of labels (e.g., hindrance on recycling) should be considered, whether the labels are sprayed or glued. Section 5.1.3 details considerations on packaging – as a special case if production of labels is on site, the associated contribution should be included in the “production” section of the life cycle.

Blending

For liquid lubricants, the two key processes are generally invoked are “batch” and “inline”.

Batch processing generally involves combining formulation ingredients into a fixed receptacle, mixing the contents mechanically or using blown air, and transferring the ensuing mixture to storage (or directly to packaging operations). In some formulations, pre-treatment of additives is required, e.g., a drum of additive may be set in a heating cabinet overnight to allow its contents to become fluid enough for easy transfer into the mixing receptacle. The energy requirements of all these operations should be assessed. As one example, if a tank of bulk material has to be pre-heated just prior to mixing, the energy requirements of this operation should be accounted.

Inline blending simultaneously injects the required liquid (or pre-dissolved) components into a mixing chamber, with only a brief residence time before transport to storage, packaging, or bulk loading. In this case, the components will frequently be constantly maintained at an elevated temperature in their respective storage tanks to ensure ready fluidity at time of mixing. The energy required for this constant heating of stored raw materials should be accounted.

The manufacture of solid and semi-solid lubricants, such as greases, is often complex and process details are usually considered proprietary. However, since high-temperature kettles are frequently required to produce a grease, the energy requirements of these processes can be significant. For some publicly available insights please see presentation by Dodos et al. (Dodos, Dodos, Kay, & Fathi-Najafi, 2019)

Line flushing operations

Most blending plants have segments of pipe travelled by two or more products. To minimize contamination between products traveling through these segments, two key strategies exist.

Flushing is an approach whereby the volume of product trapped in the line at a given moment is displaced by injecting a suitable quantity of the next product to be sent through the line. This injected quantity (and the residual amount of first product) is usually treated as a waste stream. Common names for this waste stream include “flushings” and “line wash”. The fate of these volumes of fluid should be assessed.

Additionally, it is frequently necessary to use flushing operations on packaging lines that package multiple product families.

The other strategy, commonly referred to as "pigging", involves mechanical displacement of the residual product in the line. The action is similar to that operating in a syringe: the pipe acts as the syringe's barrel, and a mechanically propelled oblong object (whose shape is somewhat reminiscent of a "pig") operates as the plunger. While this process generates less waste fluid than flushing, implementing it requires capital expenditure, especially if it is adopted after the system is commissioned.

Storage

Bulk product

After blending, bulk product may be stored with or without temperature control. If heating is constantly applied to maintain fluidity at all times, the energy requirements should be assessed. If heating is only intermittently applied, the power consumption should also be assessed since "spikes" and "troughs" in consumption may have different implications.

In parallel, some bulk storage tanks have internal mixers, to ensure homogeneity over time. Whether mixing is effected by a mechanical device or blown air, and applied constantly or intermittently, will affect energy consumption.

Packaged product

The extent to which product must be discarded due to storage past its shelf life, the means of disposal (including disposal of packaging), and the use of any moving equipment (e.g. forklifts) should be part of the assessment.

Recovered product

If a blending plant also operates a used-oil collection system, the energy/emissions details must be analysed.

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