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**Economic Commission for Europe**

Inland Transport Committee

**World Forum for Harmonization of Vehicle Regulations**

[Mutual] Resolution No. [8 (R.E.8)] concerning Automotive Life Cycle Assessment (A-LCA)

The text reproduced below was prepared by the Informal Working Group on Automotive - Life Cycle Assessment (A-LCA) and was adopted on XX XXXX 202X by the World Forum for Harmonization of Vehicle Regulations (WP.29). It is based on document ECE/TRANS/WP.29/202X/XXX

**[Mutual] Resolution No. [8 (R.E.8)] concerning Automotive Life Cycle Assessment (A-LCA)**

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1. Preamble

1. The Administrative Committee of the 1958 Agreement (AC.1) and the Executive Committee of the 1998 Agreement (AC.3),

2. DESIRING to harmonise technical requirements while ensuring high levels of safety, environmental protection, energy efficiency and anti-theft performance of wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles,

3. BEARING IN MIND that the 1958 Agreement established on 20 March 1958 provides for the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition by Contracting Parties of approvals granted on the basis of these prescriptions,

4. BEARING IN MIND that the 1998 Agreement provides for the establishment of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles was opened for signature in Geneva on 25 June 1998,

5. BEARING IN MIND that both Agreements facilitate the trade of wheeled vehicles, equipment and parts with harmonized performance requirements among the respective Contracting Parties,

6. BEARING IN MIND that this Resolution does not hold regulatory status within Contracting Parties and does not constitute a global technical regulation.

7. RECOMMENDS that Contracting Parties and manufacturers refer to this [Mutual] Resolution when establishing studies used for the assessment of life cycle CO2 equivalent emissions in the framework of the 1958 or 1998 Agreements respectively.

1. Statement of technical rationale and justification
   1. Introduction [SG1]

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all developed and developing countries in a global partnership.

UN SDG 12 on "responsible consumption and production" and 13 on "climate action" encourage efficient use of natural resources and to limit climate warming through long term societal goals. Sound and reasoned resource use and climate change mitigation are key preoccupation of citizens, corporations, investors, legislator and society as a whole.

The Paris Agreement has set ambitious targets to limit global warming to well below 2 degrees, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve this long-term temperature goal, stakeholders aim to reach a global peak of GHG emissions as soon as possible and transition towards achieving a climate neutral world by mid-century.

In 2010, the transport sector wass a major contributor to global greenhouse gas (GHG) emissions (23% of global GHG emissions[[1]](#footnote-2)) and road transport had the majority of the overall transport sector emissions (72.06%1).

In the event that a contracting party seeks to have comprehensive, comparable and consistent values for the carbon footprint over the whole life of new automotive products across the globe, from material extraction and processing, to manufacturing, use and dismantling / recycling at the end of life, it is desirable to define and develop an internationally unified guidelines for GHG Life Cycle Assessment (LCA).

The ISO 14040 series has been in effect since 2006 as an international standard on LCA for environmental management, and automotive manufacturers have been publishing results of LCA in accordance with these ISO standards for several types of vehicles.

However, the ISO standards state that the scope of the investigation and the preconditions for conducting LCAs should be determined by the investigator, such as the automotive manufacturer, and since each investigator conducts LCAs according to their own method, an internationally harmonized LCA methodology designed for the automotive industry with global business activity is needed. While LCA is intended to be a multi-impact tool accounting for impact trade-offs, the ISO standards allow for single-impact assessments provided such a choice is acknowledged at the outset and the resulting limitations are noted. This LCA effort focuses entirely on GHG emissions and makes no claims regarding other potential impacts that may arise throughout the life cycles of the assessed technologies. ~~<Alternative>For the time being this resolution deals with GWP only and thus does not cover the diversity of impact categories of a complete LCA, but the described method is supposed to be fit for extention to other impact categories.~~

* 1. Methodology background [SG1]

During the 85th GRPE session in January 2022, Japan and Korea proposed to work on clarifying methodologies for assessing life cycle GHG emissions of automotive products in the context of GRPE (GRPE-85-29r1e). GRPE agreed to organise a dedicated workshop during the 86th GRPE session in June 2022. Following the successful workshop, GRPE agreed to put the automotive LCA (A-LCA) methodology on its priority list and agreed to create a new Informal Working Group (IWG) on A-LCA under GRPE (ECE/TRANS/WP.29/GRPE/86/Rev.1). Accordingly, the first session of the IWG on A-LCA was held in October 2022 in Okinawa, Japan.

The IWG on A-LCA is an open structure that will enable the exchange of information and experiences on relevant regulations, policy measures, and standardization efforts. It is intended that the discussions will encompass all types of road automotive products with different technologies for energy pathways.

The 1958 Agreement and the 1998 Agreement do not define methods of measuring GHG emissions from automotive life cycles. The objective of the IWG on A-LCA is to develop an internationally harmonized procedure[methodology] to determine the carbon footprint (CFP) for all stages of the life-cycle of a passenger car, also considering energy use for energy pathways and automotive types from production to use and disposal as a resolution under the framework of WP.29. The ISO 140xxx series of LCA standards and definitions serves as the foundation of the A-LCA methodology. The definition of CFP used within this methodology is based upon the 100-year global warming potentials (GWP100) – as defined by the United Nations Intergovernmental Panel on Climate Change (IPCC).

This [mutual] resolution can inform policy and can help encourage automotive industries to reduce CFP via improved efficiencies at all stages of the life-cycle. The methodology shall be[was] developed respecting the principles of transparency and consistency. It shall also strike[also strikes] a balance between accuracy and workload, considering the automotive industry's complex supply chain.

* 1. Existing regulations and standards [SG7/SG1]

Several countries and organisations throughout the world have already introduced guidelines and standards related to the Life Cycle Assessment of vehicles. However, these guidelines and standards differ in terms of methodology, scope of application, objectives and targeted audiences.

Examples of existing standards:

⦁ ISO 14040 & 14044 &: describing the principles and framework for general LCA.

⦁ ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification.

⦁

Examples of existing guidelines from the automotive industry:

⦁ EPD PCR passenger cars2: providing rules for the assessment of the environmental performance of passenger’s cars including internal combustion engine vehicles ICEVs, battery electric vehicles BEVs, fuel cell electric vehicles FCHVs, hybrid electric vehicles HEVs …

⦁ PFA LCA guidelines[[2]](#footnote-3): where the French automotive platform provided methodological guidelines on vehicle and component LCA for 7 environmental indicators.

⦁ VDA LCA guidelines[[3]](#footnote-4): where the German Association of the Automotive Industry provided methodological guideline on vehicle and component LCA for 5 environmental indicators.

⦁ JAMA LCA guidelines[[4]](#footnote-5): the Japanese Automobile Manufacturers Association provided a certified methodology for passenger car, truck, bus and motorcycle, focusing on GHG emissions only.

Example of regulations:

⦁ TBD

* 1. Technical rationale and justification [SG1]

The purpose of this Resolution is to support the global automotive sector's efforts to reduce GHG emissions throughout the supply chain. In other words, it is intended to provide a process[methodology] for automotive manufacturers, component suppliers and government authorities to assess carbon footprints (CFP).

1. Text of the [Mutual] Resolution
   1. Introduction [SG1]
      1. Purpose and principles [SG1]

This [Mutual] Resolution provides an internationally harmonised methodology to determine the CFP for passenger cars, also considering energy use for energy pathways and automotive types from production to use and disposal, as a [mutual] resolution under the framework of WP.29. Note that the methodology is specifically limited in scope to passenger cars.

This [mutual] resolution inform policy and can help encourage automotive industries to reduce CFP via improved efficiencies at all stages of the life-cycle. The methodology shall be developed respecting the principles of transparency and consistency and shall be consistent with the ISO 140xxx series of LCA international standards. It shall also strike a balance between the accuracy and the workload considering the complex supply chain of the automotive industry.

To produce reliable, reproducible, verifiable and ~~across companies~~ comparable A-LCA studies, a core suite of analytical principles shall be adhered to. They shall be considered with respect to each phase, from defining the goal and the scope, through data collection, impact assessment, reporting [and verification] of study outcomes.

~~Considering that in the near future, most emissions will come from for the supply chain and the common goal of reducing GHG emissions from vehicles, as this rule will provide clarity on carbon accounting for the automotive sector, it also needs to ensure consistency of rules at product/material level.~~

Users of this methodology shall observe the following principles in conducting a CFP study:

(1) Relevance

The selection of data and methods shall be appropriate to the assessment of the GHG emissions and removals arising from the system under study.

(2) Completeness

Quantification of the CFP shall include all GHG emissions and removals that provide a significant contribution to the CFP of the product system under study. The level of significance is determined by the cut-off criteria.

(3) Consistency

Assumptions, methods and data shall be applied in the same way throughout the A-LCA study to arrive at conclusions in accordance with the goal and scope definition.

(4) Accuracy

Quantification of the CFP shall be accurate, verifiable, relevant and not misleading, and bias and uncertainties shall be reduced as far as is practical.

(5) Transparency

All relevant issues shall be addressed and documented in an open, comprehensive and understandable presentation of information. Any relevant assumptions shall be disclosed, and methodologies and data sources used shall be appropriately referenced. Any estimates shall be clearly explained, and bias shall be avoided so that the A-LCA study report represents what it purports to represent.

* + 1. Scope and application

This [Mutual] Resolution applies to passenger cars[[5]](#footnote-6).

* + 1. Definitions

| Term | Definitions proposed | Reference if any |
| --- | --- | --- |
| Allocation | Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems | ISO 14040, Feb. 2021 |
| Attributable process | Those processes that consist of all service, material and energy flows that become, make and carry a product throughout its life cycle. | WBCSD Pathfinder |
| Attributional | Process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects. | PEF guidelines (EC-JRC, 2021) |
| Background System | In contrast (to the foreground system) … processes that are operated as part of the system but are **not** under direct control or decisive influence of the producer of the good (or operator of the service, or user of the good). | ILCD Handbook  - General guide on LCA |
| Bill of Materials | A bill of materials or product structure (sometimes bill of material, BoM or associated list) is a list of raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture the product in the scope. In some sectors it is equivalent to the bill of components. | Adapted from PEF guidelines (EC-JRC, 2021) |
| Biogenic carbon | Carbon derived from biomass | ISO 14067, Feb. 2019 |
| Biomass | Material of biological origin, excluding material embedded in geological formations and material transformed to fossilized material. Biomass includes organic material (both living and dead), e.g. trees, crops, grasses, tree litter, algae, animals, manure and waste of biological origin. Biomass excludes peat. | ISO 14 067 / ISO 14021 |
| Carbon Footprint of a Product or Product Carbon Footprint (PCF) | Sum of GHG emissions and GHG removals in a product system, expressed as CO2 equivalents and based on a life cycle assessment using the single impact category of climate change | DIN EN ISO 14067, Feb. 2019 |
| Carbon offsetting | Mechanism for compensating for a full PCF or a partial PCF through the prevention of the release of, reduc­tion in, or removal of an amount of GHG emissions in a process outside the product system under study | DIN EN ISO 14067, Feb. 2019 |
| Characterization factor | Factor derived from a characterisation model, which is applied to convert an assigned life cycle inventory analysis (3.4.26) result to the common unit of the category indicator (3.10.8) | ISO 14050:2020, 3.6.23 |
| Circular Footprint Formula | The Circular Footprint Formula (CFF) is a framework for evaluating the environmental impacts of a product throughout its entire life cycle, particularly based on the principles of a circular economy. This method calculates the environmental benefits obtained from recycling a product and aims to improve resource use efficiency. | European Commission (2020). "Circular Footprint Formula: A methodology for calculating the environmental footprint of products." European Commission Report. |
| Climate Change | Environmental Footprint impact category considering all inputs and outputs that result in greenhouse gas (GHG) emissions. The consequences include increased average global temperatures and sudden regional climatic changes. | PEF guidelines (EC-JRC, 2021) |
| Closed-loop recycling | In a closed loop, the secondary material from one product system is either reused in the same product system (real closed-loop) or used in another product system without changing the inherent technical properties of the material (quasi closed-loop). | ISO 5157:2023(en), 3.2.6.6 |
| CO2eq (carbon dioxide equivalent) | Unit for comparing the radiative forcing of a greenhouse gas to that of carbon dioxide | ISO 14050:2020(en) Environmental management — Vocabulary, 3.9.3. |
| Co-product | Any of two or more products coming from the same unit process or product system | DIN EN ISO 14067, Feb. 2019, p. 22 |
| Cradle to grave | A product’s life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle. | PEF guidelines (EC-JRC, 2021) |
| Cradle-to-gate | System boundary that is applied for a partial PCF assessment that includes a part of the product’s life cycle. Cradle-to-gate represents the GHG emissions and removals arising from all life cycle stages, up to the point where the product leaves the production site (the ”gate”). This explicitly excludes the life cycle stages use and end-of-life. | adapted from TFS PCF Guideline and in reference to ISO 14067 6.3.4.2 System boundary options |
| Cut-off criteria | Specification of the amount of material or energy flow or the level of significance of GHG emissions associated with unit process or the product system, to be excluded from a PCF study | DIN EN ISO 14067, Feb. 2019 |
| Declared unit | Quantity of a product for use as a reference unit in the quantification of a partial PCF | DIN EN ISO 14067, Feb. 2019 |
| Direct emissions | GHG emissions from the processes that are owned or controlled by the reporting company | WBCSD Pathfinder |
| Downstream emissions | Indirect GHG emissions that occur in the value chain following the processes owned or controlled by the reporting company | WBCSD Pathfinder |
| Elementary flow | Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation | DIN EN ISO 14067, Feb. 2019 |
| End of Life allocation | Rules that define how to allocate environmental credits and/or burdens derived from reuse, recycling or recovery of materials and products after the vehicles’ first life cycle (after End of Life vehicle disposal) | Adapted from DIN EN ISO 14040/44 and ILCD handbook |
| End-of-life | Point in time during the life cycle at which a product or resource is taken out of use and is disposed. | ISO/DIN 59004 |
| End-of-waste | The end-of-waste state for waste in Europe is reached when the material is no longer considered waste under the national implementation of the Waste Framework Directive. | EN 15804 |
| Energy Modular Burdens and Benefits method | In case of CFF application on incineration with energy recovery, it is calculated with thermal energy deduction and electric energy deduction in expanded system boundary with CFF. |  |
| Foreground system | Processes of the system that are regarding their selection or mode of operation directly affected by the decisions analysed in the study. The foreground processes are hence those that are under direct control of the producer of the good or operator of the service or user of the good or where they have decisive influence. | ILCD Handbook  - General guide on LCA |
| Functional unit | Quantified performance of a product system for use as a reference unit | DIN EN ISO 14067 / ISO 14040 : 2006 |
| GLEC framework | Global Logistics Emissions Council framework, to harmonise the calculation and reporting of logistics GHG emissions across multi-modal supply chains. | Smart Freight Centre GLEC |
| 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 (CO2) | DIN EN ISO 14067, Feb. 2019 |
| Greenhouse gases (GHGs) | 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 | DIN EN ISO 14067, Feb. 2019 |
| ILCD Format | International Life Cycle Data Format |  |
| Indirect emissions scope 2 | GHG emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company | adapted from GHG Protocol |
| Indirect emissions scope 3 | All indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions | GHG Protocol |
| Infrastructure emission | Embodied emissions that arise due to the production or dismantling of infrastructure. Note 1: infrastructure refers to any capital goods e.g. production facilities, energy provision (powerplants, transmission lines) or transport services (roads, railways, vehicles). Note 2: emissions arising from the operation of infrastructure (operation of a power plant) is not understood as infrastructure emissions. |  |
| Input | Product, material, or energy flow that enters a unit process | DIN EN ISO 14040, Feb. 2021 |
| Land use | Human use or management of land within the relevant boundary | DIN EN ISO 14067, Feb. 2019 |
| Life cycle | Consecutive and interlinked stages related to a product, from raw material acquisition or generation from natural resources to end-of-life treatment | DIN EN ISO 14040 or 4,, Feb. 2019 |
| Life cycle assessment (LCA) | Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle | ISO 140, Feb. 2019 |
| Life cycle emissions | The sum of GHG emissions resulting from all stages of the life cycle of a product and within the specified boundaries of the product | WBCSD Pathfinder |
| Life Cycle impact Assessment (LCIA) | The phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product | DIN EN ISO 14040, Feb. 2021 |
| Life cycle inventory (LCI) | The phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle (such as a product’s GHG emissions and sources) | DIN EN ISO 14067, |
| Life cycle inventory results | GHG impact of the studied product per unit of analysis | GHG Protocol |
| Marked-mediated effects | "Marked-mediated effects" refer to the indirect impacts that arise from the market dynamics associated with a product or service throughout its life cycle. These effects can occur due to changes in supply and demand, price fluctuations, and shifts in consumer behaviour that are influenced by the introduction or modification of a product. |  |
| Material | Physical goods that are further processed (and not consumed) in manufacturing processes. | adapted from WBCSD Pathfinder |
| Material Modular Burdens and Benefits method | In case of CFF application on material recycling, it is calculated with burdens and benefits related to secondary materials input and output in expanded system boundary with CFF. |  |
| Multi-input-output unit process | Operation or process with multiple inputs, such as materials and energy, and multiple outputs, such as co-products and waste | WBCSD Pathfinder |
| Negative emissions | Removal of greenhouse gases (GHGs) from the atmosphere by deliberate human activities, i.e., in addition to the removal that would occur via natural carbon cycle processes | IPCC glossary |
| Net negative emissions | A situation of net negative emissions is achieved when, as the result of human activities, more green­house gases are removed from the atmosphere than are emitted into it. Where multiple greenhouse gases are involved, the quantification of negative emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon). | IPCC glossary |
| Open-loop recycling | In open-loop recycling, the material is reused in other product systems and its inherent properties are changed (e.g., recycled material may have a different chemical composition, a different structure or a higher concen­tration of dissolved impurities compared to primary material). | Catena-X PCF Rulebook V2 |
| Output | Product, material, or energy that leaves a unit process | DIN EN ISO 14040, Feb. 2021 |
| Packaging | Any product to be used for the containment, protection, handling, delivery, storage, transport and presentation of goods, from raw materials to processed goods, from the producer to the user or consumer, including processor, assembler or other intermediary. | ISO 21067:2007(en)] |
| Partial PCF | Sum of GHG emissions and GHG removals of one or more selected process(es) in a product system, expressed as carbon dioxide equivalents and based on the selected stages or processes within the life cycle. | DIN EN ISO 14067, Feb. 2019 |
| Primary data | Primary data is a quantified value of a process, or an activity obtained from a direct measurement or a calculation based on direct measurements. Primary data can include greenhouse gas emission factors and/or greenhouse gas activity data. Average data from industry associations or global averages do not qualify as primary data. | DIN EN ISO 14067, Feb. 2019 |
| Primary material | Material extracted from nature also referred to as virgin material |  |
| Process | Set of interrelated or interacting activities that transforms inputs into outputs. | DIN EN ISO 14067, |
| Product | any good or service  Note 1: The product can be categorized as follows: ⎯ services (e.g. transport); ⎯ software (e.g. computer program, dictionary); ⎯ hardware (e.g. engine mechanical part); ⎯ processed materials (e.g. lubricant). Note 2: Services have tangible and intangible elements. Provision of a service can involve, for example, the following: ⎯ an activity performed on a customer-supplied tangible product (e.g. automobile to be repaired); ⎯ an activity performed on a customer-supplied intangible product (e.g. the income statement needed to prepare a tax return); ⎯ the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission); ⎯ the creation of ambience for the customer (e.g. in hotels and restaurants). Software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures. Hardware is generally tangible and its amount is a countable characteristic. Processed materials are generally tangible and their amount is a continuous characteristic. | DIN EN ISO 14040, Feb. 2021 |
| Product category | Group of products that can fulfil equivalent functions. | DIN EN ISO 14067, Feb. 2019 |
| Product category rules (PCR) | Set of specific rules, requirements and guidelines for developing Type III environmental declarations | DIN EN ISO 14040, Feb. 2021 |
| Product system | Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product | Adapted from ISO 14067: 2019 |
| Raw material | Primary or secondary material that is used to produce a semi-finished good, product or service. | Adapted ISO 14040/44 |
| Recycled Content Method | The Recycling Credit Method (RCM) is a technique used to assess the contribution of recycled materials to new products. This method quantifies the extent to which the use of recycled materials reduces the environmental impact of new products. Specifically, it considers the environmental benefits gained by substituting recycled materials for newly extracted raw materials. | Weidema, B. P., et al. (2008). "Overview of the Recycling Credit Method." International Journal of Life Cycle Assessment. |
| Reference flow | Measure of the inputs to or outputs from processes in a given product system required to fulfil the function expressed by the functional unit. | DIN EN ISO 14067, Feb. 2019 |
| Reference vehicle | "Reference vehicle" means [in the context of UN Regulation 133] the version within a type of vehicle, which is identified by the Type Approval Authority, in consultation with the manufacturer and in accordance with the criteria laid down in Annex 1, paragraph 4. to this Regulation, as being the most problematic in terms of reusability, recyclability and recoverability; | UN-R133 |
| Renewable Energy | Energy from renewable sources’ or ‘renewable energy’ means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovo­ltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas. | Renewable Energy Directive (2018/2001) |
| Representative product | The representative product can be a real or an aver­aged (non-existing) product. The averaged product should be calculated based on sales-weighted characteris­tics of all technologies/materials used in the compa­ny’s production system. | Catena-X PCF Rulebook V3 |
| Repurposing Modular Burdens and Benefits method | In case of CFF application on drive battery repurposing, it is calculated with burdens and benefits related to secondary battery input and output in expanded system boundary with CFF. |  |
| Risk management | Plans, actions, strategies, or policies to reduce the likelihood and/or consequences of risks or to respond to consequences. | IPCC Glossary |
| Secondary data | Data which do not fulfil the requirements for primary data. Note 1: Secondary data can include data from databases and published literature, default emission factors from national inventories, calculated data, estimates or other representative data, validated by competent authorities. Note 2: Secondary data can include data obtained from proxy processes or estimates. | DIN EN ISO 14067, Feb. 2019 |
| Secondary material | Material taken from a recycling flow |  |
| Sectoral guideline | PCF reporting rules issued by industry associations or initiatives as guidance for their members, | Catena-X PCF Rulebook V3 |
| Sensitivity analysis | Systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a CFP study | DIN EN ISO 14067, Feb. 2019 |
| Supplier gate | The supplier's factory (out-bound) gate, through which the product leaves the production site and is ready for shipment to the customer. | Catena-X PCF Rulebook V3 |
| Supply chain | Those involved, through upstream and downstream linkages, in process and activities relating to the provision of products to the user. | DIN EN ISO 14067, Feb 2019 |
| Sustainability | A dynamic process that guarantees the persistence of natural and human systems in an equitable manner. | IPCC Glossary, p. 49 |
| System boundary | Boundary based on a set of criteria representing which unit processes are a part of the system under study. | DIN EN ISO 14040, Feb. 2021 |
| Transport / distribution packaging | Packaging designed to contain one or more articles or packages, or bulk material, for the purposes of transport, handling and/or distribution. | ISO 21067: 2007(en) |
| Type III environmental declarations | Type III environmental declarations present quantified environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function. Such declarations ⎯ are provided by one or more organizations, ⎯ are based on independently verified life cycle assessment (LCA) data, life cycle inventory analysis (LCI) data or information modules in accordance with the ISO 14040 series of standards and, where relevant, additional environmental information, ⎯ are developed using predetermined parameters, and ⎯ are subject to the administration of a programme operator, such as a company or a group of companies, industrial sector or trade association, public authorities or agencies, or an independent scientific body or other organization. | DIN EN ISO 14025, Oct. 2011 |
| Unit process | Smallest element considered in the life cycle inventory analysis for which input, and output data are quantified. | DIN EN ISO 14067, Feb 2019 |
| Upstream emissions | Indirect GHG emissions that occur in the value chain prior to the processes owned or controlled by the reporting company. All upstream transportation emissions are also included as part of upstream emissions. | WBCSD Pathfinder |
| Use stage | That part of the life cycle of a product that occurs between the transfer of the product to the consumer and the end-of-life of the product. | Adapted from WBCSD Pathfinder |
| Value chain | All upstream and downstream activities associated with the product system. |  |
| Waste | Materials, co-products, products, or emissions that the holder intends or is required to dispose of. | DIN EN ISO 14067, Feb. 2019; WBCSD Pathfinder |

* + 1. Abbreviations

AAAAA - American Association Against Abbreviation Abuse 😉

[BEV/PEV

BoM

CE

CFF

CFP

CO2/CO2e/CO2eq

EF

EoL

FCHV

GHG

GWP

ICE

IPCC

IP family

IWG

A-LCA

LCI

(I)MDS

NOVC-HEV

OEM

OVC-HEV

R&D

RV

SUV

UNECE

WtW

To be added]

* + 1. Future review [SG1]

The methodology under this [mutual] Resolution is a first for WP.29. We have organised as much as possible under the current circumstances while understanding the issues that need to be considered. We anticipate that there will be matters that need to be more appropriately considered, new market demands, and challenges that may arise in situations where this methodology will be utilised. In light of such circumstances, revising the methodology as necessary will be desirable.

* + 1. Language [SG7]

English is the original language of this document. Only translations in French and Russian have legal character.

* 1. General methodology
     1. Level Concept [SG1]

The Level Concept was developed in UNECE IWG A-LCA to reflect the different motivations and goals to address the determination of CFP for passenger cars and indicates four classes of intended use cases of an LCA. The importance of LCA has grown considerably in recent years and the number and type of use cases for LCA expanded as a result. The Level Concept also takes into account the increasing demand for LCA results based on primary data used. By transparently addressing these new forms of vehicle LCAs and their input data variation, the Level Concept helps to ensure a consistent application of the vehicle LCA method and the appropriate selection of a product system model for an intended application and scope.

Figure 1 : Life cycle assessment framework according to ISO 14040

Interpretation

Life cycle assessment framework

Impact assessment

Inventory analysis

Goal and scope definition

Direct applications:

* Product development and improvement
* Strategic planning
* Informing public policy
* Marketing
* Other

Based on the ISO 14040 standard, a life cycle assessment (LCA) consists of four steps (Figure 1). Goal and scope definition is the first step of these four. In this step the study is defined in detail and central choices are made regarding its conduct.

“The goal definition shall firstly state the intended application(s) of the LCA results in a precise and unambiguous way. The decision-context is one key criterion for determining the most appropriate methods for the LCI model.”[[6]](#footnote-7)

For the practitioner it is crucial to define appropriate requirements for modelling the product system according to the intended purpose and application of an LCA.

At the same time, vehicle LCAs are used by a growing number of stakeholders for an increasing range of different purposes and applications. Traditionally, vehicle LCAs were mainly used in R&D for technology comparisons and support of strategic decision making (e.g. which powertrain / material / production technology / … is environmentally superior?) or by OEM’s (Original Equipment Manufacturer) to show that their successor models were more environmentally friendly than the previous ones (continuous improvement). This is also reflected in the list of direct applications in ISO 14040 (compare Figure 1, box on the right). Currently, an extension of applications towards implementation and reporting of reduction measures – especially in the context of GHG reduction and circular economy (CE) – can be observed by various stakeholders with different expectations from automotive LCAs.

Potential stakeholders are listed below :

⦁ Society/ Policy makers

⦁ Green finance & ESG rating

⦁ Customer

⦁ OEM

⦁ Suppliers

Potential motivations are listed below:

⦁ Decision support of policy making

⦁ Comparison / rating

⦁ Communication /marketing

⦁ Fair competition

⦁ Incentivisation

⦁ Internal steering of decarbonisation

⦁ Proof of decarbonisation

⦁ Identification of reduction potentials

As a consequence, this [Mutual] Resolution on A-LCA addresses different types of use cases and highlights where these require different scope definitions and requirements concerning methodology and data granularity.

* + 1. Use cases and application of Level Concept

The Level Concept distinguishes four different levels based on the underlying questions of the assessment. This could range from “what is the right mobility concept for a city?” to “what is the carbon footprint of a certain vehicle model?”. This leads to different requirements for the product system model especially with regard to the upstream life cycle phases in the foreground system (supply chain and vehicle production).

In general, every LCA practitioner who has the necessary data (granularity) available for the respective level, may conduct an LCA study for this level. However, in practice mainly OEMs have access to the bills of material (BoM) which are required as basis of the vehicle models for Levels 2 to 4. Following the product development stages, the determination of the concept can be divided into four levels as follows (see Figure 2).

Figure 2 : General product development stages and level allocation

Stage 2 of Product

Development

Stage 3 of Product

Production

Stage 4 of Product

Assessment in a Market

Stage 1 of Product

Design/Planning

Level 1

Level 2

Level 3, 4

Level 3, 4

Level 1 for example, assumes that the OEM is in the process of planning a new vehicle, which is often determined as the LCA on a hypothetically defined vehicle.

Level 2 for example, assumes determinations at the stage of product development by OEMs, whereas for specific parts, determinations using primary data are possible. Therefore, it is assumed to be used to check the effects of introducing specific components.

Level 3 for example, assumes a situation where primary data exists for parts, etc. of the vehicle in question, where the determination is made at the manufacturing stage by the OEM. I

Level 4 for example, assumes a situation where primary data exists for the whole supply chains and manufacturing of the vehicle in question. Therefore, the main difference between Levels 3 and 4 is laid on the modelling of the supply chain.

Although the selection of the level is aligned with the product development stages, it doesn’t exclude general use cases other than vehicle OEM’s own. For example, Level 1 can be used by government officials for public policy making or by researchers for general research purpose, since it doesn’t require proprietary information by OEM, such as BoM. The following provides intended use cases and general approaches for each level. The practitioner can refer to Chapter 4 for the application of the level concept to different life cycle stages.

* + - 1. Description of Level 1

⦁ Intended use case:

 General uses, including research and public policy making based on generic data sources

 Industry strategic planning: future projection, fleet modelling, etc.

⦁ Approach:

 Flexible in applying “mix&match” of methodologies from different life cycle stages in this resolution, depending on the purpose of the study, availability of data, etc.

 For comparability and transparency, practitioners should specify and maintain the discrete combination of methodologies (“mix&match”) used for their applications

* + - 1. Description of Level 2

⦁ Intended use case:

 Research and public policy development based on specific data sources relevant to the use case (e.g. bill of material, material information system)

 OEM’s internal assessment and strategic planning

 Product development and improvement

 Marketing, e.g. of technology choices

⦁ Approach:

 Flexible in applying “mix&match” of methodologies from different life cycle stages in this resolution, other than vehicle modelling, depending on the purpose of the assessment

 For comparability and transparency, practitioners should specify and maintain the discrete combination of methodologies (“mix&match”) used for their applications

* + - 1. Description of Level 3

⦁ Intended use case:

 OEM’s and supplier’s official reporting for public information, marketing, etc.

 OEM’s reporting for government programs

⦁ Approach:

 Each lifecycle stage provides one fixed methodology for one harmonised A-LCA approach.

* + - 1. Description of Level 4

⦁ Intended use case:

 OEM’s and supplier’s official reporting for public information, marketing, etc.

 OEM’s and supplier’s official reporting for government programs

⦁ Approach:

 Each lifecycle stage provides one fixed methodology for one harmonised A-LCA approach.

According to questions of the assessment granularity, product specificity and the scope of the foreground and background is chosen. To put it the other way round: whereas Level 1 study is representative of a broad range of products, e.g. all vehicles, Level 4 is more focused on the fine variations of individual vehicle models and the supply chain of their specific components (parts).

The choice of representativity and specificity also concerns downstream life cycle stages (Well To Wheel (WtW) / use stage, End of Life (EoL)) or background system processes (e.g. energy production). Also, for the use stage or EoL the data for a specific vehicle could be used. This implies however that the LCA is done retrospectively. For many use cases the analysis (declaration) point in time is the moment the product is put on the market. Consequently, the following life cycle stages can only be analysed prospectively. For predictive data, average data (e.g. for lifetime milage) should be used. For predictive data there is no way to provide primary data, as you cannot measure something that happens in the future.

Table 1: General structure of the level concept

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Purpose** | **Industry involvement** | **Degree of freedom** | **vehicle model** | **Supply chain model** | **Possible audiences** |
| Level 1 | Strategy | No | Multiple approaches possible | generic | generic | policy makers, researchers |
| Level 2 | Strategy | Yes, through OEM’s documentation | Multiple approaches possible | BoM1 & MDS2 | generic | company strategy/product developers, customers |
| Level 3 | Reporting | OEM’s reporting, including hotspot suppliers’ reporting | single fixed approach | BoM1 & MDS2 | partly specific | government programs, customers |
| Level 4 | Reporting | OEM’s and extensive suppliers’ reporting | single fixed approach | BoM1 & MDS2 | mainly specific | government programs, customers |

It is crucial to understand that the magnitude of emissions is only comparable between studies on the same level. Vehicle LCAs with different level choices may not be compared on a quantitative basis. The approach for modelling, including primary/secondary data share of the different lifecycle phases, might differ between levels due to the scope change.

<Alternative> It is crucial to understand that emission magnitudes are only comparable between studies that use the same combination of levels applied to each life phase. Vehicle LCAs that differ in their combination of levels should not be compared on a quantitative basis. The methodology for modelling, including primary/secondary data share, of the different lifecycle phases stages might differ between levels due to the scope change.

This does not imply any rating on the quality of studies. Level 1 LCA is not necessarily of lower quality than Level 4 study. Both serve different purposes / use cases (strategy focused or reporting focused) and therefore have different underlying “models of reality”.

* + 1. Product Category

This [Mutual] Resolution applies to passenger cars.

[Should we give more specification on the type of powertrain?]

* + 1. Functional Unit and reference flow [SG4]

The primary function of a passenger car is to transport people from one location to another. Therefore, the functional unit (FU) for a passenger car is defined as the distance travelled per passenger over vehicle lifetime.

As the real-life occupancy of passenger cars (number of passengers per vehicle) is difficult to estimate, a more conservative approach should be considered and single passenger per vehicle should be assumed, with the presumption that vehicle technologies and energy sources will not change passenger car occupancy rate. This will also ensure comparability between different vehicles.

Considering the above assumption, the functional unit (FU) for a passenger car is defined as the transportation of 1 passenger over the vehicle’s service life (i.e. the distance travelled over in km over the vehicle lifetime [as the transportation per km of distance travelled over the vehicle lifetime]).

The reference flow for a vehicle, such as a passenger car, is defined as the measurable quantity of inputs and outputs necessary to meet the defined *functional unit* of the product over its lifecycle. The reference flow in automotive LCAs translates this functional unit into specific, quantifiable measures of resources consumed and emissions produced, covering aspects such as:

⦁ Vehicle components and materials (e.g., steel, aluminium, plastics required to manufacture the car),

⦁ Fuel and/or energy consumption over the vehicle’s lifetime,

⦁ Maintenance and replacement parts (such as tyres, fluids, batteries, etc.),

⦁ End-of-life treatment for disposal or recycling.

The standardised reference flow enables consistent and comparable assessments across different automotive products, focusing on the impacts associated with achieving the defined service.

* + 1. System boundaries [SG1]
       1. Life cycle stages

The following life cycle stages are covered (Figure 3):

⦁ Material production stage

⦁ Parts production and vehicle assembly stage

⦁ Use stage

⦁ End-of-life stage

All life-cycle stages include fuel and energy cycle

More details regarding system boundaries per life cycle stages are given in dedicated life cycle stage chapters.

<Alternative> Figure 3

ダイアグラム

AI によって生成されたコンテンツは間違っている可能性があります。

Figure 3 : Life cycle stages covered by this Resolution

Key:

Process to be calculated

Material production

Material

Material transport

Waste

Maintenance parts

Disposal/

Recycle

Material parts transport

Fuel production/ energy generation

Fuel/ electricity

Driving

Fluorocarbons

Fluorocarbon emissions

Material parts production

Waste transport

ELV

ELV transport

Dismantling

Dismantled ELV

Recovered parts transport

Shredding

Recovered parts

Inputs, outputs etc.

ASR landfill

Disposal/ recycle

Dismantled ELV transport

ASR

ASR recycle

Residue

Residue transport

Landfill

ASR transport

Material for recycling

Recycling

Material

Waste transport

Parts production

Waste

Disposal/ recycle

Material transport

Parts

Vehicle assembly

Parts transport

Waste transport

Material production

Waste

Disposal/ recycle

Finished vehicle

Finished vehicle transport

**(1) Material (2) Parts production and (3) Use stage (4) End of life stage**

**Production Vehicle assembly stage**

**stage**

* + 1. Infrastructure and capital goods [SG6/SG1]

This section provides rules for infrastructure and capital goods, such as the building in which the product or upstream materials or components are produced, machinery used in the manufacturing of the product or its materials or components, vehicles used for transportation in the product system, the equipment used in the production and supply of energy (e.g. electricity generation equipment), the construction and maintenance of roads and production of charging infrastructure (list without claiming completeness). The applicable infrastructure and capital goods are limited to those that are not consumed and retain their function for a certain period.

In general, the production and end-of-life processes of infrastructure and capital goods used in the product system shall be excluded from the system boundaries. The exception are those infrastructure and capital goods for the production of fuels and for generation of electricity, which should be included by default within the system boundary for the vehicle use stage (as is also the best practice adopted by UNECE publications on LCA of electricity generation , the GREET model , and other models and publications available in different global regions). The general cut-“”off criteria apply.

Deviations from the above requirements may be possible in the following case:

Infrastructure/capital goods (i.e. also others in addition to those for/resulting from production of fuels and generation of electricity) may be included for any lifecycle phase if a dataset used for A-LCA already includes infrastructure/capital goods, and it is not possible, within reasonable effort, to subtract the data on infrastructure/capital goods from this dataset.

* + 1. Land Use Change

[TBD under SG6]

* + 1. Representative vehicle

Accurately estimating the carbon footprint (CF) of vehicles is essential for understanding their environmental impact and guiding efforts to reduce emissions, ultimately contributing to the decarbonization of the automotive industry.

Vehicles are highly complex products composed of numerous parts manufactured through complex supply chains. Each vehicle’s unique configuration and customizable options make providing and managing life cycle assessments (LCAs) for individual vehicles administratively burdensome for OEMs and but also for authorities. To address this, the methodology introduces the concept of a representative vehicle.

In order to ensure comparability of different vehicles /technologies / materials in Automotive industry the compared vehicles ideally should:

* be calculated with the same functional unit,
* be of the same vehicle category,
* have the same body structure characteristics, comparable dimensions (length, width, height, wheelbase) and number of seats in order to ensure a comparable purpose and usability,
* have comparable drive system type and the same range (if possible)
* have the same or comparable equipment & configuration considered for the calculation of the ‘test mass’ under the WLTP (e.g. tires dimension, ADAS level, trim level)

Accordingly, comparability is a central challenge. For Level 1 and Level 2 LCA studies, different options (vehicles, technologies, powertrains, materials) are compared within one LCA study. In contrast, for Level 3 and Level 4 it is the aim to allow comparability between the individual LCA studies from different practitioners / OEMs. This comparability requires to define a representative vehicle.

Level 1 and Level 2 LCAs are mainly conducted to support strategic decisions. It is recommended to model a vehicle which is representative of the considered entity of vehicles / vehicle fleet. Regarding all parameters relevant for the intended research question, it should have generic & average value depending on the availability of the data (e.g. public studies or literature data). For comparison of vehicle LCAs this requires special attention. See the list above.

For level 3 & level 4, the objective is to rationalize the high administrative burden of LCA reporting, while the representative vehicle ensures that the selected vehicle accurately reflects the characteristics and impacts of the entire group of vehicles, which is clearly defined. This group of vehicles can be defined based on specific parameters that influence their lifecycle emissions in the upstream, downstream and end-of-life stages. By doing so, different types of emissions are considered throughout the entire life cycle.

A ‘Representative Vehicle’ is a benchmark vehicle that reflects the typical characteristics of a defined group of vehicles, allowing for consistent and meaningful environmental impact evaluations. The benchmark vehicle shall be selected in a way that remains representative of the group of vehicles it represents across their lifecycle, promotes the reduction of emissions and energy consumption, and incentivizes the use of actual data when possible.

This is in line with the terms of representative outlined by UNECE IWG A-LCA, Article 2.3, “The methodology shall be developed respecting the transparency and consistency. It also shall have balance between the accuracy and the workload considering the complex supply chain of automotive industry”.

This section 3.2.5 provides a detailed definition of the representative vehicle, which serves as a solid foundation for the calculation of carbon footprint by considering the entire lifecycle of vehicles.

The representative vehicle is applicable at Levels 3 and 4 (as described in paragraph ‘3.2.1 Level concept) for reporting purposes (where comparability of results is crucial).

* + - 1. Representative Vehicle: Modular Approach

Given the complexity of vehicle production and use, a ‘modular approach’ is adopted for carbon footprint calculation. This involves separately calculating each phase of the vehicle lifecycle, according to the methodology described in chapter 4, and then combining the results for the given vehicle.

⦁ Upstream Emissions: These emissions are associated with production, raw material acquisition, and manufacturing, they depend on the production region..

⦁ Downstream Emissions: These emissions, which occur during the use phase, are well-documented in certified fuel and energy efficiency data. They vary based on the vehicle’s sales region. Consumables and parts used for the scheduled maintenance, according to the manufacturer specifications, are considered.

⦁ End-of-Life (EoL) Emissions: These emissions, which occur during the recycling processes, depend on region of sell/use or -recycling

* + - 1. Representative Vehicle Selection

The representative vehicle is selected based on the highest actual, expected or known (from predecessor) sales numbers (model with most relevant options and equipment) within a group of vehicles (“best-selling vehicle”). This group of vehicles is defined based on specific parameters in section 3.2.5.3.1 called LCA group.

To obtain the representative vehicle for a LCA group based on the highest expected or known sales figures within the LCA group, the selection shall be done consistently and be fixed for the time (representative period) when the LCA in the LCA group is performed. Hence, the best-selling vehicle is determined once for a LCA group and remains the representative vehicle thereafter. If a new LCA group is formed, the first vehicle to go into production, if available, is the representative vehicle of the newly formed LCA group.

To achieve consistency, actual or estimated sales data shall be chosen based on the following principles.

For an LCA group of vehicles already in serial production, actual sales figures for the respective reporting year shall be used to identify the ‘representative vehicle’.

For a newly formed LCA group of multiple vehicles before Start of Production (SOP), planned or estimated production/sales volumes shall be used, depending on the internal reporting structure (e.g. production planning, financial controlling, business planning). Proof/documentation for the choice of the representative vehicle shall be provided during the third-party certification (see verification section xx).

The emissions factors within an LCA group strongly correlate to the mass of the vehicle for a given LCA group, due to similar production characteristics. This selection further decreases deviations when applying to the Emissions Factor (EF). Additionally, using the highest sales numbers in an LCA group increases representativeness of the performed LCA in absolute terms, as typically vehicles with the highest mass consist of custom-made options and additional equipment, as well are not produced in high volumes compared to the best-selling vehicles.

Comparability of LCA classes between different OEMs can be achieved by checking EFs of comparable LCA groups against each other.

Important Considerations:

1) If the LCA group includes vehicles with a traction battery, the battery shall be excluded from the calculation of the emissions factor (EF) and the carbon upstream & EoL emission of the individual vehicle (CFP). This is due to the fact that the capacity of a traction battery and its weight do not have a proportional relationship, which would distort the correlation via vehicle mass.

2) The carbon footprint of the traction battery must be calculated separately. For the calculation of the total vehicle carbon emissions, the carbon footprint of the traction battery shall be subsequently added to the carbon upstream & EoL emission of the vehicle (CFP).

Once the representative vehicle is selected, its carbon footprint is calculated using the harmonized UNECE methodology (refer to chapters xxx), considering upstream, downstream and ‘end of life’ emissions, in case of powertrain using traction battery the carbon footprint of the traction battery shall be calculated separately.

* + - 1. Upstream Emission

Carbon emissions related to upstream emissions should be calculated according to the method described in section (refer to SG3 draft )

To determine the upstream emission for representative vehicle and upstream emission factor, we need to group vehicles into a ‘upstream emission group’ (3.2.5.3.1) and then choose a representative vehicle according to 3.2.5.2.

* + - * 1. Definition of Upstream LCA Group

The main factors that greatly impact the upstream carbon footprint of a vehicle are the body structure, powertrain, energy storage system (only in case this is present in the drivetrain system), [refer to Ricardo[[7]](#footnote-8) & CATARC[[8]](#footnote-9) study] and production region.

Based on these factors, vehicles can be grouped into clusters (Upstream LCA group):

1. Vehicle Structure Family: Means a cluster of vehicles of an automobile manufacturer’s vehicle fleet in which the vehicle has a degree of commonality in technological development level and body construction characteristics, such as in body or chassis design (if applicable), including external dimension span and floor clearance span. Characteristics like vehicle type, model name, brand, marketing division, or roof line, number of doors, seats, windows or level of decor are not relevant for a classification as vehicle structure family.
2. Powertrain (drive System) type: to reflect the impact of the energy storage system/traction system e.g. ICE, OVC-HEV, NOVC-HEV, PEV and FCEV.

c) Region of production: further expansion of the definition to the region of production place is possible

(d) Additional parameters will be declared by the OEMs (with justifications) if required to specify the definition of the LCA group.

If there are shared upstream grouping criteria, a single Life Cycle Assessment (LCA) group can include multiple downstream groups, such as drive system type families.

* + - * 1. Determination of Upstream Emission factor

In case that CFP values for the vehicles other than the representative vehicle need to be declared, the following subchapter will introduce the methodology to estimate the CFP for these vehicles.

The upstream emission factor, UEF, shall be calculated as follows:

Equation 1

Where,

is the upstream emission factor, kg CO2 eq./kg

is the upstream carbon emission of the representative vehicle, kg CO2 eq.;

is the actual mass of the representative vehicle (vehicle curb weight with the accessories & options best-selling vehicle), kg;

In case of powertrain using traction battery the emission factor shall be calculated as follows:

Equation 2

Where,

is the upstream carbon emission of the representative vehicle, kg CO2 eq.;

is the upstream carbon emission of the traction battery of the representative vehicle, kg CO2 eq.;

is the actual mass of the representative vehicle (vehicle curb weight with the accessories & options), kg;

is the weight of the traction battery of the representative vehicle, kg;

Both and shall be measured on the same representative vehicle.

The UEF shall be included in all relevant test reports.

The UEF shall be rounded to 2 points of decimal, the unit of UEF is kg CO2 eq/kg.

* + - 1. Downstream Emission: In-use

Carbon emissions related to use phase emissions should be calculated according to the method described in section (refer to SG4 draft). These emissions are typically derived from certified fuel consumption and energy consumption data, which are included in official homologation documents and regulatory certifications.

* + - 1. Powertrain group

As each region or country have their own definition of the powertrain group (e.g. interpolation family approach in EU) it is recommended to use the same powertrain family criteria defined in the ‘fuel and energy consumption regulation’ (refer to section of SG4). In case of WLTP it is defined in GTR 15.xx.

* + - * 1. Representative vehicle: Use phase

Each individual vehicle has an ‘energy consumption’ value provided in official documentation (e.g., Certificate of Conformity). Two common approaches to determine downstream emissions are:

* Interpolation
* Inertia Class

For representative mass, inertia class defined in the regional fuel consumption regulation must be considered.

|  |  |
| --- | --- |
| **Interpolation** | **Inertia class** |
| Cycle Energy Demand  CO2 | Mass  CO2 |

Figure 4: explanation of interpolation and inertia approach.

The carbon footprint of a particular type of powertrain and vehicle configuration (mass, aerodynamic, tire etc.) should be reflected in the selected representative or declared vehicle:

* In case of ‘interpolation approach’: Individual vehicle configuration of the ‘interpolation family’ should be used as described in the Certificate Of Conformity document.
* In case of ‘inertia class approach’: Individual inertia class configuration of the ‘powertrain family’ should be used as described in the Certificate Of Conformity document.
  + - * 1. Representative vehicle: maintenance and leakage

The carbon footprint during the maintenance and leakage does not vary in each powertrain family and hence it is recommended to determine this value for the highest selling vehicle of the powertrain family.

* + - 1. End of Life Emission

End of life emissions encompass carbon emissions generated throughout vehicle collection at the end of life and recycling. Carbon emissions related to end of life emissions should be calculated according to the method described in section (refer to SG5 draft )

* + - * 1. Definition of End of Life (EoL) LCA group

The main factors that greatly impact the end-of-life carbon footprint of a vehicle is same as that of the upstream phase except the region of recycling. Based on these factors, vehicles can be grouped into clusters (EoL LCA group) according to their common traits such as:

1. All criteria defined for upstream emission except the region of production (3.2.5.2.1)
2. Expected region of vehicle end-of-life: further expansion of the definition to the region of recycling place is possible

If the vehicle is produced in the same region as that of expected region of end of life, then both LCA groups Upstream and EoL are the same.

* + - * 1. Determination of End of Life (EoL) Emission factor

The EoL emission factor, EEF, shall be calculated as follows:

Equation 3

Where,

is the EoL emission factor, kg CO2 eq./kg

is the EoL carbon emission of the representative vehicle, kg CO2 eq.;

is the actual mass of the representative vehicle(vehicle curb weight with the accessories & options best-selling vehicle), kg;

In case of powertrain using traction battery the emission factor shall be calculated as follows:

Equation 4

Where,

is the EoL carbon emission of the representative vehicle, kg CO2 eq.;

is the EoL carbon emission of the traction battery of the RV, kg CO2 eq.;

is the actual mass of the representative vehicle (vehicle curb weight with the accessories & options), kg;

is the weight of the traction battery of the RV, kg;

Both and shall be measured on the same representative vehicle.

The EEF shall be included in all relevant test reports.

The EEF shall be rounded to 2 points of decimal, the unit of EEF is kg CO2 eq/kg.

* + - 1. Total carbon footprint

The total carbon footprint of a vehicle is the sum of:

* Upstream Emissions (3.2.5.3)
* Upstream Emissions: Traction Battery Emissions (if applicable)
* Downstream Emissions: use phase energy consumption and maintenance (3.2.5.4)
* End-of-Life Emissions (3.2.5.5)
* End-of-Life Emissions: Traction Battery Emissions (if applicable)
  + - 1. Carbon footprint value for ‘Declared vehicle ‘

The selected representative vehicle (section 3.2.5.2) should serve as the baseline for estimating the carbon footprint for the values of the other vehicles, if a declaration is required. These vehicles and the representative vehicle shall be members of the same emission group.

The Emission Factors [UEF & EEF] (i.e. carbon emission per kilogram of vehicle weight) is calculated by the ratio between the carbon emissions (upstream & EoL) of the representative vehicle and its weight (excluding the weight of the traction battery).

Figure 5: explanation of baseline approach

Vehicle weight [kg]

Carbon Emissions [kg CO2eq.]

Representative

Vehicle

**EF**

declared

Vehicle Y

declared

Vehicle X



Carbon emissions (upstream & EoL)

UEF & EEF are describing the correlation between vehicle mass and the CFP value of the representative vehicle, as illustrated in Figure 4.

The correlation of CFP value according to the ‘representative vehicles’, should be allowed both below and beyond the mass of the representative vehicle,

The carbon emission of the declared vehicles, which belong to the same emission group, can be estimated using the EF & the weight of the evaluated vehicle.

The definition of the Representative Vehicle & the Declared Vehicle is considered as follow:

* the “representative vehicle” is the one for which to perform the precise and detailed carbon footprint calculation to determine the emission factors for the upstream- & EoL emission;
* the “declared vehicle” is the vehicle for which to calculate the carbon footprint based on the emission factor of its emission groups (according to section 3.2.5.7.1).
  + - * 1. Estimated value for the declared vehicles

The upstream emission for the declared vehicles within the same LCA group is estimated using the following formula:

Equation 5

Where,

is the upstream carbon emission of the declared vehicle, kg CO2 eq.;

is the emission factor, kg CO2 eq./kg;

is the actual mass of the declared vehicle (vehicle curb weight with the accessories & options).

For vehicles with traction batteries:

Equation 6

Where,

is the carbon emission of the traction battery, kg CO2 eq.;

is the weight of the traction battery, kg;

The downstream emission for the declared vehicles (compare section 3.2.5.4.2)

The EoL emission for the declared vehicles within the same LCA group is estimated using the following formula:

Equation 7

Where,

is the EoL carbon emission of the declared vehicle, kg CO2 eq.;

is the EoL emission factor, kg CO2 eq./kg;

is the actual mass of the declared vehicle (vehicle curb weight with the accessories & options).

For vehicles with traction batteries:

Equation 8

Where,

is the EoL carbon emission of the traction battery, CO2 eq. kg;

is the weight of the traction battery, kg;

* + - * 1. Steps to determine carbon footprint value of the ‘declared vehicle’

Step 1: Is the initial step to define & calculate the carbon footprint of the representative vehicle

* Step 1.1: Define the ‘upstream LCA Group’ (3.2.5.3.1)
* Step 1.2: Define a representative vehicle out of the defined ‘upstream LCA group’ (3.2.5.2)
* Step 1.3: Calculate the upstream carbon footprint of the representative vehicle (excl. traction battery)
* Step 1.4: Calculate the Emission Factor (EF) of the ‘upstream LCA group’ (3.2.5.3.2)
* Step 1.5: Add upstream carbon emission of traction battery if available
* Optional – Step 1.6: Calculate the upstream carbon footprint of declared vehicle (3.2.6.2)

Step 2: Downstream carbon footprint (depend on cycle energy demand in WLTP and mass for inertia approach)

* Step 2.1: Check which interpolation family or inertia class the 'defined vehicle' belongs to.
* Step 2.2: calculate downstream emission (considering service life, deterioration factor etc.) (3.2.5.4.2)
* Step 2.3: calculate the carbon emission related to leakage & maintenance (3.2.5.4.3)

 Step 3: End of Life carbon footprint (depend on mass)

* Step 3.1: Define the ‘end of life LCA group’ (3.2.5.5.1)
* Step 3.2: Calculate the EoL carbon footprint of the representative vehicle (excl. traction battery)
* Step 3.3: Calculate the Emission Factor (EF) of the ‘EoL LCA group’ (3.2.5.3.2)
* Step 3.4: Add EoL carbon emission of traction battery if available
* Optional – Step 3.5: Calculate the EoL carbon footprint of declared vehicle (3.2.5.5.2)

Step 4: Total carbon footprint

* Total carbon footprint = Upstream carbon footprint + Downstream carbon footprint + EoL carbon footprint
  + - * 1. Environmental impact category and indicator [SG1]

The calculation of the CFP shall include [non-CO2 GHGs].

The GHGs to be included shall be considered with reference to the latest IPCC Assessment Report. The potential climate change impact of each GHG emitted and removed by the product system shall be calculated by multiplying the mass of GHG released or removed by the 100-year GWP given by the IPCC in units of kg CO2e per kg emission.

Where GWP values are amended by the IPCC, the latest values shall be used in the calculations. For example, once IPCC releases Assessment Report 7 (AR7), the GWP100 values for AR7 shall supersede those of Assessment Report 6 (AR6). In any case, there should be a clear statement by the LCA practitioner regarding which AR is used. All life-cycle stages include fuel and energy cycle. The AR6 characterisation factors for the substances that are not listed in case of AR6 in Table 7.15 of the IPCC AR6 shall be extracted from Table 7 SM6 in Section 7 Supplementary Materials of the AR6 Climate Change 2021 .

* + - * 1. Inclusion of biogenic CO2

Biogenic GHG emissions and removals shall be calculated in an A-LCA study and should each be expressed separately.

All relevant unit processes of the life cycle of biomass-derived products shall be included in the system under study, including, but not limited to, cultivation, production and harvesting of biomass.

A product’s biogenic carbon content shall be calculated and documented separately in the CFP study report. Separated emission values shall be reported as follows:

1. Net fossil GHG emissions and removals

2. Net biogenic GHG emissions and removals other than biogenic CO2 (if applicable)

3. Net biogenic GHG emissions and removals including biogenic CO2 (if applicable)

4. GHG emissions resulting from aircraft transportation (if applicable)

If separate emission values do not occur, these emission values may be reported as zero.

Removals in the PCF shall not include any measures not related to the product system, usually referred to as carbon offsets.

In addition, the biogenic carbon content and total carbon content of products shall be reported separately. If mass-balanced materials are used in the supply, the attributed biogenic carbon content shall additionally be reported to accurately account for emissions from combustion of these materials.

* + 1. Data collection requirements and data types [SG1/SG3]

Primary data is a quantified value of a process, or an activity obtained from a direct measurement, or a calculation based on direct measurements. Primary data can include greenhouse gas emission factors and/or greenhouse gas activity data. Average data from industry associations or global averages do not qualify as primary data., however, data available from national or regional governmental authorities based upon regulatory and/or legislated requirements for company data reporting shall be considered as primary data.

Secondary data do not fulfil the requirements for primary data. Secondary data can include data from databases and published literature, prospective emission factors from national inventories, calculated data, estimates or other representative data, validated by competent authorities. Secondary data can include data obtained from proxy processes or estimates.

Primary data shall include primary activity data, i.e., a technical flow, and primary GHG emission factor, i.e., the carbon footprint of the corresponding activity expressed in kgCO2eq per unit (Table 2). Consequently, the combination of a measured materials consumptions and a secondary GHG emission factor is not considered as primary data. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material or product balances, stoichiometry or other methods for obtaining data from specific processes in the supply chain of the company. A single calculation might include both primary, secondary data and a mix of both expressed by the primary data share. For example, calculating emissions from the consumption of electricity could involve primary activity data, such as data on consumption in kWh, multiplied by a secondary emission factor representing GHG emission intensity (CO₂eq per kWh) provided by relevant national or regional governmental authorities. Note also that activity data and secondary data for electricity GHG emissions factors would need to be temporally and spatially aligned at each relevant stage of the analysis.

Table 2 : Variance of Primary and secondary data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Approach | Direct emission measurement | | | |
| Primary data | Source of emission is within company boundaries and is measured | | | |
| Approach | Activity data source | | Emission factor source | |
| Energy | Material | Energy | Material |
| Primary data | Consumption measured (primary) | | On-site energy production emission factor  Or energy supplier-specific emission factor | Measured and reported as a share by supplier  Or certified value |
| Secondary data | Consumption/ production measured (primary) | | Secondary databases, data proxy | |

Requirements regarding data collection and data types (primary or secondary) are given for each of the life cycle stages in dedicated sections (Chapter 4).

* + - 1. Primary data quality [SG1]

Primary data should follow the following criteria [(US suggestion) Primary data should follow data quality considerations outlined in ISO 14044 sec. 4.2.3.6, including:]:

1. Time representativeness: the data should be collected within the previous year. Or it shall be within a scope that is reasonably equivalent to the period.

<Alternative> Emissions shall by default be reported averaged over the period of one year (reporting or calendar year) to avoid seasonal fluctuations and reflect typical production conditions. Shorter periods may be considered if data on a full year are not yet available. Longer averaging periods may be considered but shall not exceed three years. Any averaging period deviating from the default shall be flagged and justified.

(b) Geographical representativeness: Regional differences shall be considered, and appropriate calculations shall be done based on data from each region. However, if regional differences are very small or non-existent, then they do not need to be considered.

<Alternative> Emissions shall by default be reported on the plant level. Averaging over a region or country may be considered but shall be flagged as such.

If the scope of primary data collection includes multiple sites, then primary data shall be collected using methods with low bias from sites which cumulatively comprise 50% or more of the production volume or acquisition volume of all sites. Or it shall be within a scope that is reasonably equivalent.

(c) Technological representativeness: It shall be the production technology of the applicable product.

(d) Completeness: 100% of flow that is measured or estimated;

(f) Consistency: qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis.

(g) Reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study.

(h) Sources of the data; the source of the data should be communicated and transparent.

(i) Uncertainty of the information (e.g. data, models and assumptions).

Measurements are prioritised in the collection of input/output flow data for each process, if no primary data is available, it is also acceptable to use designed values and planned values from product proposals, specification sheets, standard formula sheets, etc., and estimated values from processes of similar products. These data are the considered as secondary data.

* + - 1. Primary data share [Korea/France/SG3]

To create visibility on the share of primary data in PCF calculations for vehicle product, the primary data share (PDS) indicator in each data set shall be determined and shared (under the following conditions). The Primary Data Share (PDS) is defined as the proportion (percentage) of a PCF that is derived from primary data. Reporting of a PDS is only relevant in case of detailed supply chain and vehicle modelling. Therefore the PDS shall only be determined and communicated for Level 4 LCA and based only on the GHG emissions from material production stage (4.1), and parts production and vehicle assembly stage (4.2) (excluding the use and end of life phases). Thus PDS is reported for the total PCF (PCFtotal) of the vehicle production only.

To ensure that a consistent PDS can be reported no matter if reporting is done stepwise or collectively for multiple steps, the percentage of the primary data shall relate to the absolute sum of all positive or negative PCF contributions (PCFas). The positive or negative PCF contributions (PCFi) are to be understood as intermediate summands to the total PCF, which might reflect the total PCF contributions from suppliers or contributions from individual process steps under the control of the reporting company. Figure 3.2.6 1 illustrates the definition of PCFas.

Equation 9

Figure 6: Definition of PCFas

e

c

d

b

a

PCFas

PCFtotal

Sum

PCF

|  |  |  |  |
| --- | --- | --- | --- |
| Contribution | PCFi | PCFtotal,i | PCFas,i |
| a | 1.00 | 1.00 | 1.00 |
| b | 1.50 | 1.50 | 1.50 |
| c | 2.00 | 2.00 | 2.00 |
| d | -1.00 | -1.00 | -1.00 |
| e | -0.75 | -0.75 | -0.75 |
| Results |  | 2.75 | 6.25 |

In case there are no negative PCF contributions PCFtotal is equal PCFas.

In case PCFas is not yet reported PCFtotal shall be used instead.

Having introduced PCFas the primary data share can now be defined:

Equation 10

The aggregated primary data share for multiple PCF contributions reported with individual PDS (PDSi)

Equation 11

As an example, three suppliers, Company A, Company B and Company C, provide parts to Company D. Each part has a different primary data share and contribution to the absolute value total PCF of the part of Company D (cf. Figure 13). According to formula above, the primary data share of Company D’s part is calculated from the primary data share and contributions to the absolute value total PCF (see Figure 7).

Figure 7: PCF cascade of primary data for an exemplary supply chain

PDSA  
= 75%

Primary Data Share (PDS)

10 kg CO2 eq.

Company A

Contribution to PCF

PDS  
= 54%

PDSB  
= 25%

100 kg CO2 eq.

15 kg CO2 eq.

25 kg CO2 eq.

Company E

Company B

Company D

PDSC  
= 50%

PDSD  
= 100%

50 kg CO2 eq.

Company C

Table 3: Primary data share of the example as in Figure 7

|  |  |  |  |
| --- | --- | --- | --- |
|  | PDSi | PCF*total,i* | PDS *Aggregation* |
| CompanyA | 75% | 10 | 75% \* 10 = 7.5 |
| Company B | 25% | 25 | 25% \* 25 = 6.3 |
| Company C | 50% | 50 | 50% \* 50 = 25 |
| Company D | 100% | 15 | 100% \* 15 = 15 |
| Total |  | 100 | ≈ 54 , (7.5 + 6.3 + 25 + 15) ≈ 54% PDStotal |

When calculating the primary data share, a contribution to the primary data share shall only be attributed, if both the activity data (e.g., amount in kWh) and the GHG emission factor (expressed in kgCO2eq per unit) information is derived from primary data. Supplier data shall only be considered as primary data if declared as such in percentage of primary data share.

Only product or company-specific data may contribute to the primary data share.

When a product with a high PDS is decarbonized through carbon reduction measures, the PDS may decrease as a result of the lower PCF. However, the PDS is not the focus. The goal should be to measure PCF, as the main objective is to reduce the carbon footprint, not the primary data share.

* + - 1. Secondary data quality

Secondary data should follow the following criteria [(US suggestion) Secondary data should data quality considerations outlined in ISO 14044 sec. 4.2.3.6, including:]:Commented

1. Time representativity: If practitioners collect data independently, then the data shall be from any one year within the previous five years. Or it shall be within a period that is reasonably equivalent.

<Alternative> The reference year for the secondary data shall correspond to the assessment period of the activity data. The reference period should not be more than five years ago.

1. Geographical representativity: the data should correspond to the geographical area from which data for unit processes should be collected to satisfy the goal of the study. However, if it is not possible (e.g. missing data, uncomplete databases …), the choice of the data and corresponding geographic area should be justified and reported.

<Alternative> The geography of the data shall correspond to the activity data most geographically relevant to the process.

1. Technological representativity: It shall be very similar to the production technology used for the product. Or it shall be the production technology used for the product.

<Alternative> The secondary data source shall correspond to the activity data that is technologically representative of the process.

(d) Sources of the data; Sources of data shall be published. Publishing refers to publication in books or journals, members-only publication, publication in software, etc.

* + 1. Cut-off rule

In general, all processes and flows that are attributable to the analysed system shall be included. The analysed system can be the complete product to which the functional unit is associated, (e.g. a passenger car,) but also a subsystem (component, part) to the product or an individual life cycle stage that contributes additive to the life cycle GHG emissions of the final product. For practical reasons (see ISO 14067, PEF method), process modules, inputs and outputs may only be excluded if their sum represents less than [3]% of the GHG emissions of the analysed system. It is not permitted to cut-off an entire life cycle stage, even if that falls below the threshold value. GHG emission reported from upstream entities shall be regarded as correct and complete and may not be subject to any further cut-off. A documentation shall be provided to give evidence that the cut-off criterion is met, and which cut-offs were applied. The documentation can be given in the form of a screening analysis.

Compliance with the cut-off threshold value can be proven on a product category or sectoral level and does not have to be executed on a product level. Product category rules or sectoral guidance can specify simplified rules to be applied.

* + 1. Screening Analysis [SG3]

A screening analysis ensures that cut-offs in total do not exceed a threshold value of the GWP impact.

The screening shall allow further refinement of the LCI and the associated emission factors of the system in scope in an iterative manner. Within screening, no exemption of flows is allowed, and readily available primary or secondary data may be used. If data, such as emission factors, activity data, or measurements are unavailable or challenging to identify, it is essential to find the most appropriate data or proxy emission factors, in case of doubt a conservative choice shall be taken. Emission factors or activity data received from upstream reporting entities shall be regarded as correct and complete. The scope of the final screening iteration shall be documented to inform on the cut-offs and prove compliance with the cut-off threshold value.

* + 1. Energy modelling [SG6]

**(a) Fuel modelling**

The definiton of fuels’ emission factors follows the methodology outlined in the Renewable Energy Directive 2018/2001 and shall include:

⦁ Upstream processes referring to the extraction or cultivation of raw materials.

⦁ Processes related to the fuel’s processing.

⦁ Transport and distribution processes at each life cycle stage.

⦁ Emissions from the fuel in use.

Additionally, concerning fuels originated from bio-materials, the following conditions shall be considered;

⦁ Additional emissions related to changes from soil carbon stock caused by land-use change.(e.g. wetlands conversion, some specific forest areas, etc.).

⦁ Emission savings from soil carbon accumulation via improved agricultural management (e.g. shifting to reduced or zero-tillage, using cover crops, etc.), CO2 capture and geological sequestration, and CO2 capture and replacement.

In the case of one or more other products (co-products, e.g. sugar beet pulps, Distillers Dried Grains with Solubles), allocation shall be determined in proportion to the energy content of the products, determined by lower heating value in the case of co-products other than electricity and heat.

**(b) Electricity modelling**

Two main approaches exist for modelling electricity consumption by a product system: the location-based approach and the market-based approach.

a. The location-based approach is a method of allocating electricity impacts among end-users based on geographical representativeness (economic area, country, bidding zone , etc.); this approach is currently the most commonly used by LCA practitioners, with main LCA databases offering detailed models at a relatively fine geographic scale. The same average profile per kWh is applied to all electricity consumers within a single grid. The GHG Protocol defines it as follows: “A location-based method reflects the average emissions intensity of grids on which energy consumption occurs (using mostly grid-average emission factor data).”

b. The market-based approach allocates electricity impacts among end-users based on a principle of individual contractual instruments, which can be claimed by different consumers. This approach seeks a more precise accounting of the environmental impacts of energy choices made by companies and consumers. The GHG Protocol defines it as follows: “A market-based method reflects emissions from electricity that companies have purposefully chosen (or their lack of choice). It derives emission factors from contractual instruments, which include any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims.”

Development of electricity emission factors shall be based on ISO 14067:2018 and shall include:

⦁ Upstream processes and production of electricity generation infrastructure for the electricity supply system (e.g. mining of fuels, transport of fuels to power plants, growing and processing of biomass fuel feedstock, and production of equipment generating renewable energy, such as photovoltaic installations) .

[The inclusion of such upstream elements should be prioritized for those components that have been shown to contribute significantly to the emissions of the specific technology (e.g., it is established that the embodied emissions of photovoltaic solar panels may significantly contribute to the g CO2e/kWh of that pathway’s electricity). ]

Details about infrastructure/capital goods for production of fuel or electricity, must be referred to 3.2.4.

⦁ Processes related to electricity generation, including losses during transmission and distribution

⦁ Downstream emissions (e.g. treatment of waste arising from the operation of nuclear electricity generators or treatment of ashes from coal -fired electricity plants)

Where possible, the generator specific emission factor for the consumed energy shall be applied. Otherwise, if information on supplier-specific electricity is not available, GHG emissions associated with the respective electricity grid by which the electricity is provided shall be used. The respective grid shall reflect the electricity consumption of the related region, ,

In addition to data based on the average electricity mix of a country or region, specific electricity generation mix data can be used if all of the conditions are met for any of the following sections. .

**(b-1) Electricity from the grid via a contractual instrument**

Electricity data from electricity certificates for a specific generator site or supplier documented by energy certificates may be used in the calculation of emission factors for electricity supplied from the grid if it can be ensured that all the following conditions are met.

⦁ Information on the unit of electricity is provided, together with the characteristics of the electricity generator.

⦁ It is guaranteed to be a unique claim.

⦁ Tracking, redemption, depreciation, cancellation, etc., of the certificate is carried out by the reporting company, For the same year that electricity was produced whitin the country, or within the market boundaries where consumption occurs and to which the grid is interconnected

In ISO 14067:2018, there are examples of certificates that can be used by contractual instruments, such as European Guarantee of Origin (GOs) and US Renewable Energy Certificates (RECs) which meet the above conditions. Electricity certificates that do not guarantee compliance with the above conditions shall not be used. Contractual instruments may include utility tariffs, power purchase agreements (PPAs) or energy attribute certificates (EACs) themselves.

Notes on handling power certificates

In order to use electricity certificates in this guideline, their reliability and traceability must be ensured, and it must also be guaranteed that double counting does not occur in LCA calculations. Therefore, in addition to ensuring that electricity certificates meet the above requirements, the following must be ensured in LCA calculations that use electricity certificates

• The environmental value of electricity certificates must not be biased.

• There is no double counting with grid electricity (the LCI data for grid electricity uses the residual mix, excluding the value of the electricity certificate. If no residual mix is available, the fossil generation mix for the respective grid shall be used).

• Mixing location-based and market-based modelling shall be avoided within one life cycle stage of an LCA.

• Information about the electricity certificate is clearly stated in the LCAreport.

The electricity certificate should be accompanied by the following information:

Name and location of the generating facility

Method of generation

Amount of electricity generated and amount of electricity certificates issued

If available, tracking number assigned by the electricity certificate system

When a practitioner choose Market based approach with any kinds of Certifications of electricity, the condition in below should be met…

**Conditions for Market-based approaches**

The market-based approach for electricity may be used only when the supplier is able to guarantee through a contractual arrangement that the electricity product:

— conveys the information associated with the unit of electricity delivered;

— is assured with a unique claim, to avoid double-counting of GHG emissions and GHG removals within the boundary of the subject;

— is tracked and redeemed, retired or cancelled by, or on behalf of, the reporting entity;

— is produced as close as possible to the period to which the contractual instrument is applied and

comprises a corresponding timespan;

— is produced within the country, or within the market boundaries where consumption occurs if the grid is interconnected.

If processes within the subject are located in Small Island Developing States (SIDS)3), the carbon footprint may additionally be quantified using contractual instruments for such processes, irrespective of grid interconnectivity.

The entity shall document in the carbon neutrality management plan its plans to improve the efficiency of electricity use of the subject and report actions that have been taken to implement such activities.

The entity should consistently apply the selected approach in subsequent carbon neutrality reports. If the entity changes its selected approach in subsequent reporting periods, it shall reflect this change in the carbon neutrality management plan, including a recalculation of the baseline, and make it transparent in the carbon neutrality report.

To promote the development of additional renewable energy capacity, entities should apply the following sourcing hierarchy:

a) self-generation or physical power purchase agreements with direct line connections;

b) financial power purchase agreements from renewable sources;

c) contractual instruments from a generation facility no older than 15 years.

NOTE 1 Contractual instruments are any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims. This can include energy attribute certificates (EACs), renewable energy certificates (RECs), guarantees of origin (GOs), power purchase agreements (PPAs), green energy certificates or supplier specific emission rates.

NOTE 2 The market-based approach is a method to quantify the indirect emissions from energy of a reporting organization based on GHG emissions emitted by the generators from which the reporting organization contractually purchases electricity bundled with contractual instruments, or contractual instruments on their own.

NOTE 3 The location-based approach is a method to quantify indirect emissions from energy based on physical delivery of energy, using average energy generation emission factors for defined geographic locations at a national or sub-national level.

NOTE 4 Using biofuels or other bio-based materials based on contractual instruments can result in GHG emissions reductions. These market-based approaches involve a separate certification process, which includes use of contractual arrangements that:

— convey the information associated with the unit of fuel or materials delivered;

— are assured with a unique claim, to avoid double-counting of GHG emissions and GHG removals within the boundary of the subject;

— are tracked and redeemed, retired or cancelled by, or on behalf of, the reporting entity.

Detailed conditions shall be based on ISO14068 -1:2023.

**(b-2) Electricity from a directly connected supplier**

Site-specific electricity data may be used in the calculation of emission factors for electricity supplied directly from electricity generators via dedicated transmission lines to facilities manufacturing the respective products and consumed in the manufacture of such products, if no contractual instruments have been sold to a third party.

**(b-3) On-site generated electricity**

Site-specific electricity data may be used in the calculation of emissions factors for on-site electricity generated and consumed on the premises where the respective product is produced, if no contractual instruments have been sold to a third party.

**(b-4) Grid Mix and On-Site Electricity Production:**

On-site electricity production can only be accounted for under the following conditions:

1. The production asset is owned by the same entity as the factory, or the asset has a direct connection to the factory and is not connected to the grid.

2. Only the fraction of electricity that is used on-site and not sourced from the grid shall be accounted for.

3. No credits can be claimed for electricity produced in excess and sent to the grid.

Any deviation, along with detailed explanations of the calculation methods or models used to revise emission factors, must be reported in the LCA report

(c) Future Changes in Energy Mix

Practitioners shall also account for any potential changes in the fuel or electricity production pathways during the lifetime of the vehicle. (Detailed methodology is provided in section 4.3.5.)

For any prospective LCA, secondary data will be needed. Secondary LCI data should be sourced from data sets provided directly by government authorities. If such data is not available, region-specific secondary data from IEA should be used.

⦁ Including LCI from regulatory authorities will thus include relevant statutes and regulations under implementation that impact the sector within a specific country or region and within a specified timeframe.

⦁ When using IEA data, specific sensitivities from the IEA should also be used

The scenario shall also be explained in the final report. Details must be referred to in the “Reporting” section.

* + 1. Allocations [SG3]

In case a process has more than one output, the question how to allocate the CO2e-burden to the outputs arises. Outputs of a process can be viewed as products, co-products or waste. Products or co-products share the CO2e-burden of the production/generation process, whereas waste eventually increases the CO2e-burden for the product. In a first step the question: ‘Is this a waste or a product?’ must be answered (see Figure 8).

Figure 8: Product, Co-Product or Waste

Multiple Process Outputs:

Waste or Co-Product?

Waste

Co-Product

Apply multi-functionality allocation hierarchy

Apply recycling accounting

Apply waste treatment rules

Waste Criteria: No

Waste Criteria: Yes

Recycle

Discard

* + - 1. Waste vs Co-product

Waste is any material or process output which is not deliberately produced as an integral part of a multi-output production process. No further use of the material or process output is certain. Additionally, the holder discards or intends to discard or is legally required to discard the residue based on national waste legislation.

Waste materials with certain further use but requiring further treatment other than normal industrial practice before use (i.e., waste recovered by recycling) shall follow the requirements on material recycling.

“Normal industrial practice” can include all steps which a producer would take for a product, such as the material being filtered, washed, or dried; or adding materials necessary for further use; or carrying out quality control. However, treatments usually considered as a recovery operation cannot, in principle, be considered as normal industrial practice in this sense. Some of such processing tasks considered as normal industrial practice can be carried out on the production site of the manufacturer, some on the site of the next user, and some by intermediaries, as long as they also meet the criterion of being ‘produced as an integral part of a production process’ (adopted from the EU’s Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste).

A co-product in contrast is produced as an integral part of a multi-output process where its further use is certain. Typically, co-products directly replace a raw material or fuel without requiring further processing other than normal industry practice. For co-product allocation, multi-output allocation applies (please refer to section Allocation Rules).

The following hierarchy shall be applied (please refer to Annex A1 for definitions of the respective criteria):

Figure 9: Waste vs. co-product classification hierarchy based on EU Waste Framework Directive

Product

1. Is the material/component deliberately produced?

2. Is the further use of the material/component certain?

3. Can the material/component be used directly without any further processing other than normal industrial practice?

4. Is the material/component produced as an integral part of the production process?

5. Is the further use lawful under regional waste legislation?

Co-Product

Waste

Waste

Waste

Waste

Yes

Yes

Yes

Yes

Yes

Yes

No

No

No

No

Waste

No

Residues classified as waste following the hierarchy can also be transformed into recycled feedstock. However, this transformation would require further processing other than normal industry practice (see point 3 in Figure 9), such that the residue would be classified as waste in the first instance.

Pre-consumer scrap that is not reintroduced into the same process (i.e., all scrap except run-around scrap) shall be defined as waste unless legal evidence (following legislation of the region where scrap is generated, e.g., legal judgement or legal report from regional waste legislation) exists that classifies the pre-consumer scrap material as co-product.

* + - 1. Multi-output allocation

Allocation shall be avoided whenever possible. If allocation cannot be avoided, follow the approach in Figure 10.

Figure 10: Multi-output allocation decision procedure

Allocation shall be avoided wherever possible!

➀ Is subdivision of the process possible?

➁ Is there a dominant, identifiable substitute product\*?

➂ Is the ratio of economic value\*\* for product and co-product > 5?

➃ Is there a physical relationship, e.g. mass, energy …

⑤Use economic allocation\*

①

②

③

④

⑤

Yes

Yes

Yes

Yes

Unavoidable

No

No

No

No

Apply physical allocation!

Apply economic allocation

Apply system expansion via substitution

Apply process subdivision

\* Single output product  
\*\* Market price averaged over 3 years

Yes

1- If allocation cannot be avoided and subdivision is possible, subdivision shall be applied. Subdivision refers to disaggregation of multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output.

2 - If subdivision cannot be applied, but a dominant substitute product can be identified, expanding the product system to include the additional functions related to the co-products shall be applied. System expansion via substitution shall only be used if no new multi output allocation is introduced.

System expansion via substitution should only be used if there is a dominant, identifiable displaced product and production path for the displaced product based on sector consensus. Dominant means that the production process is the main process on the market. If available, positive lists of co-products and displaced products based on sector consensus shall be used to model the system expansion and the respective substitution credits. For the emissions data, primary data shall be used, and secondary data may only be used if primary data is not available. In case of secondary data, the requirements in section 3.2.7 shall apply to guarantee that the dataset and source for calculating system expansion credits are compliant. If no sector consensus exists, the following requirements shall always be fulfilled:

⦁ The production of the co-product is an integral part of the production process.

⦁ A dedicated, single-output process to produce the co-product exists.

⦁ The alternative dataset must be representative of the dominant production route.

⦁ A clear description of the process for selecting the alternative product substituted by the co-product shall be documented.

Double counting shall be avoided. No market-mediated effects shall be applied, as the attributional LCA approach shall be used.

3 - When allocation cannot be avoided, no subdivision is possible and no dominant substitute product can be identified, LCA-practitioners shall calculate the ratio of the economic value of the reference product to each co-product per declared unit. This ratio is employed in the next step of the decision tree to determine the most suitable allocation approach. For the use of economic values, sales prices shall be averaged over the last 3-5 years to smooth out fluctuations. If sales prices are not available or not applicable, other economic factors can be applied (e.g., cost).

4 - If the calculated economic value ratio is equal or lower than five, companies shall apply allocation using a physical relationship to partition inputs and outputs between the studied co-product(s). The physical relationships to choose from are:

⦁ produced masses

⦁ produced pieces

⦁ contained exergy

⦁ contained energy

5 - If the calculated ratio is higher than five, companies shall apply an economic allocation using economic value as criterion to partition inputs and outputs between the studied co-product(s).

For the determination and use of economic allocation factors, the following hierarchy shall be applied. Only one type of economic allocation factor shall be chosen consistently in the order of priority of the hierarchy. Only if the respective prioritised factor is not available, the next factor in the hierarchy may be chosen. The chosen factor shall always be averaged over the last multiple years to smooth out fluctuations. A period of 3-5 years is recommended, and a systematic approach should be internally documented for materials with high fluctuations of the selected factor of price/ cost.

⦁ Global market price (global market prices are usually only available for commodities)

⦁ Regional market price

⦁ Other economic allocation factors (i.e., production costs or sales price)

* + 1. Chain of custody [SG3]

The LCA methodology guidelines for automobiles assume that the inputs (input resources), outputs (products), and processes are not each a single system, but a complex system with multiple inputs and outputs. In a complex system, it is necessary to introduce the concept of Chain of Custody to increase the transparency and reliability of allocation of product characteristics.

Chain of Custody models are classified into the following five categories according to the definitions of ISO 22095.

Table 4: Chain of Custody Models

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Input/Output Relation | Identity preserved | Segregated | Controlled blending | Mass balance | Book and claim |
| All input characteristics translate unchanged to output characteristics | ✓ | ー | ー | ー | ー |
| Mixing of inputs from different sources | ー | ✓ | ✓ | ✓ | (✓) |
| Output characteristics reflect the average of input flow characteristics | ✓ | ー | ✓ | ー | ー |
| Physical connection | ✓ | ✓ | ✓ | ✓ | ー |

Figure 11 : Overview of chain of custody models

Une image contenant capture d’écran, diagramme, conception

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In Process Out

In Process Out

In Process Out

In Process Out

In Process Out

**Identity Preservation**

**Segregation**

**Book & Claim**

**Mass Balancing**

**Controlled Blending**

**Segregation**

From the five Chain of Custody models, two shall meet specific requirements when applied in LCAs for automobiles: “Mass balance” and “Book and Claim”. Although Book and claim is generally used mainly for electricity, it shall be allowed to be used for purposes other than electricity as well, if minimum requirements are met (Table 5).

Table 5: Requirements for the use of Mass balance and Book and claim

|  |  |  |
| --- | --- | --- |
| Requirement | Mass balance | Book and claim |
| Physical connection between input and output | ✓ | ー |
| Separation of flow and  flow characteristic | ー | ✓ |
| Boundary for accounting: Same product system | ✓ | ✓ |
| Defined accounting period | ✓ | ✓ |
| Traceability (Physical or certificates) | ✓ | ✓ |
| Certification scope within company operations | ✓ | ー |
| Certification scope beyond company operations (tracking and cancellation of certificate) | ー | ✓ |

In implementing chain-of-custody methods, including mass balancing/book and claim, the following set of guiding principles shall be fulfilled:

1. The use of chain-of-custody approaches shall achieve significant changes and an effective transition towards a more circular, more bio-based and lower GHG emissions production in complex value chains.
2. The choice and implementation of chain-of-custody approaches and models shall be transparent, clear, and credible – abiding by relevant standards such as ISO.   
   Note: Certification schemes are not yet available in all sectors.
3. Labels and claims referring to chain-of-custody controlled specified characteristics and used on products shall fulfil the following requirements:
   1. description of the chain-of-custody approaches and models
   2. accurate and appropriate implementation of the chain-of-custody model
   3. compliant with existing standards and regulations
   4. non-misleading

If the “specified characteristic” content in products cannot be measured and verified, labels and claims shall mention this. For example, this often applies to mass balancing (e.g., chemically recycled content in plastics).

1. No double counting: A reliable accounting system shall be installed at each operating site to ensure that the claimed volume on the output side exactly matches the actual volume on the input side within the declared time and regional scope.

Additional requirements for a mass balance/book and claim chain of custody approach:

1. The operating sites in the spatial boundaries for mass balancing　are under the operational control of the same company/corporate group/joint venture.
2. It shall be technically possible according to standard industry practice to produce a mass-balanced product from an alternative feedstock. Share of mass-balanced material can be technically lower than the attributed share.
3. Applied emissions factors for the mass-balance system boundaries shall be product and process specific
   * 1. Waste treatment, disposal and recycling modelling [SG5]

Any GHG emissions arising from the treatment of production waste shall be included in the total CFP. Waste can be generated during different stages of a product’s life cycle (cradle-to-grave), including:

□ Resource extraction, raw material sourcing

□ Production of materials, semi-finished products

□ Production of vehicle parts and components

□ Logistics to supplier, OEM, customer and recycler (including internal logistics)

□ End of Life of the vehicle

All inputs and outputs shall be fully considered in the calculation of the product carbon footprint. Cut-off rules as described in 3.2.8 shall be applied.

The party generating waste is responsible for treatment until final disposal (for example, incineration or landfill). This is also referred to as the “polluter pays principle”. If there I no final disposal, then the further processes are attributed to the company using the recycled or reused material flow as a secondary material (see 3.2.11.1).

The impact of preparatory steps and supporting activities such as collection, transportation, sorting, dismantling, or shredding shall be added to the inventory results of the product system generating the waste.

The impact of the process treating waste with energy recovery (e.g., incineration) shall be added to the inventory results of the product system that generated the waste treated in the process. Burdens and benefits coming from energy recovery are calculated based on section 3.2.13.2.

Production processes may also generate material scrap that is recycled. In this case, please see 3.2.11.

GHG emissions shall be calculated using primary data regarding the type of waste, its composition and type of waste treatment activity. Depending on the type of waste treatment (for example landfill or incineration), companies may use waste treatment emission factors based on internal primary data. If no primary emission factors are available, emission factors derived from accepted secondary databases can be employed.

If no primary data for waste treatment are available, waste treatment emissions should be estimated based on primary data on the waste type and composition and specific emission factors according to the quantity and type of waste treatment and final disposal (landfill, incineration).

* + - 1. Material recycling modelling [SG5]

The Circular Footprint Formula (CFF) or Recycled Content Method (RCM) shall be applied to the evaluation of material recycling for all levels, based on regulation or market observation. The selected method shall be clearly indicated in the vehicle CFP declaration.

In the present guidelines, the material part of the CFF, as originally introduced in the EC recommendation 2021/2279 Annex III, has been rearranged as sum of the three components, having, overall, the same mathematical results of the original CFF introduced in the EC 2021/2279 Annex I.

The rearranged CFF presented in this document is indicated hereafter as “UNECE A-LCA CFF concept”, and it is composed by the three following elements:

1) Production burdens (this term constitutes the RCM method)

2) Burdens and benefits related to secondary materials input

3) Burdens and benefits related to secondary materials output

Circular Footprint Formula (CFF) as per EC recommendation 2021/2279.

Equation 12

as Recycled Content Method (RCM)

asModular Burdens and Benefits method (MBBM) which is the sum of 2) and 3)

1) Production burdens

2) Burdens and benefits related to   
secondary materials input   
3) Burdens and benefits related to secondary materials output

Rearranged structure of the CFF, as introduced in this recommendation.

When applying the material part of the CFF, in the production stage for materials, the RCM term (corresponding to CFF part 1) shall be evaluated. For the complete vehicle CFP in addition to CFF part 1, the emission shares from recycling (corresponding to CFF parts 2 and 3) shall be evaluated with the Modular Burden and Benefits Method (MBBM) term in the EoL stage.

Overall, the terms of the UNECE A-LCA CFF concept for material recycling have been defined as following:

Equation 13

Where;

means the specific GHG emissions of a material in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

means the specific GHG emissions of a material calculated with the CFF in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

means the specific GHG emissions of a material calculated with the RCM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

means the specific GHG emissions of a material calculated with the MBBM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

The and emission contributions are defined as follows:

Equation 14

; CFF part 1

Equation 15

; CFF part 2 and 3

In the case of CFF application, shall be reported as the part of the total vehicle CFP In addition, ,and shall be reported separately. The materials to which the CFF is applied shall be reported.

In the case of [just only?] RCM application, only shall be evaluated in the material production stage and reported in the total vehicle CFP.

The meaning and definition of the parameters of the CFF are the same of the ones reported in the EC recommendation 2021/2279 Annex I Chapter 4.4.8.1.

- ; Allocation factor of burdens and credits between supplier and user of recycled materials.

-; Quality of the ingoing secondary material or parts, i.e. the quality of the recycled material at the point of substitution.

-; Quality of the outgoing secondary material or parts, i.e. the quality of the recyclablematerial at the point of substitution.

-; Quality of the primary material or parts, i.e. quality of the virgin material.

-; Proportion of material input to the product that has been recycled from a previous system. [%]

-; Proportion of the material in the product that will be recycled (or reused) in a subsequent system. [%]

-; Specific emissions and resources consumed (per unit of analysis) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process. [kgCO2e/kg]

-; Specific emissions and resources consumed (per unit of

analysis) arising from the recycling process at EoL, including collection, sorting and transportation process. [kgCO2e/kg]

-; Specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material [kgCO2e/kg]

-; Specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials. [kgCO2e/kg]

Data set () to be used in CFF and CFF parameters () may be referred to the secondary data set and reference documents in 4.4 EoL stage.

Parts recycling modelling is specified in the EoL stage (4.4).

* + - 1. Incineration with energy recovery

The incineration with energy recovery shall be evaluated by following the energy formula in the Circular Footprint Formula (CFF).

Equation 16

= =

*Where;*

means the specific GHG emissions of a material arising from incineration with energy recovery in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

means the specific GHG emissions related to the credit obtainable by an energy recovery process calculated per MBBM for energy in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

means the allocation factor of energy recovery processes.

means the proportion of the material in the product that is used for energy recovery at EoL.

means the specific emissions and resources consumed (per unit of analysis) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, …). [kgCO2e/kg]

means the specific emissions and resources consumed (per unit of analysis) that would have arisen from the specific substituted energy source (heat). [kgCO2e/MJ]

means the specific emissions and resources consumed (per unit of analysis) that would have arisen from the specific substituted energy source (electricity). [kgCO2e/MJ]

means the efficiency of the energy recovery process for heat.

means the efficiency of the energy recovery process for electricity.

- means the Lower Heating Value of the material in the product that is used for energy recovery. [MJ/kg]

Thermal energy deduction and electric energy　deduction () shall be evaluated and merged as Modular Burdens and Benefits method for Energy. Modular Burdens and Benefits method for Energy shall be merged to other Modular Burdens and Benefits method e.g. Material recycling. Modular Burdens and Benefits method separately reported and included into total vehicle CFP. shall be reported separately the same as in Material recycling modeling.

The meaning and definition of the parameters of the CFF are the same of the ones reported in the EC recommendation 2021/2279 Annex III Chapter 4.4.8.1.

Data set (,) to be used in CFF and CFF parameter (,) may be referred to the secondary data set and reference documents in 4.4 EoL stage.

* + - 1. Disposal [SG5]

The disposal shall include all of waste treatment except for the material recycling and the incineration with energy recovery, e.g. landfill. The disposal shall be evaluated by following disposal formula in Circular Footprint Formula (CFF)

Equation 17

*Where;*

means the specific GHG emissions of a material arising from the disposal in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

means the proportion of the material in the product that will be recycled (or reused) in a subsequent system. [%]

means the proportion of the material in the product that is used for energy recovery at EoL.

: means the specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery. [kgCO2e/kg]

The meaning and definition of the parameters of the CFF are the same of the ones reported in the EC recommendation 2021/2279 Annex III Chapter 4.4.8.1.

Dataset (ED) to be used in CFF and CFF parameter (R2, R3) may be referred to the secondary data set and reference documents in Section (4.4).

* + 1. Logistics

In addition to emissions from production, manufacturing, use stage and end of life, there are also emissions from the transportation and logistics of vehicles, products, or materials.

Emissions from transportation shall cover emissions from well-to-wheel, i.e., the system boundaries span from energy provision, production and distribution ending at the transportation operation itself, and should be compliant with Section 3.2.4.

Figure 12 :System boundaries for transportation.

Une image contenant capture d’écran, Rectangle, fenêtre

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Energy provision, production & distribution

Well-to-Tank (WTT)

Well-to-Wheel (WTW)

Tank-to-Wheel (WTW)

Transport Operation

Energy Consumption

Energy Distribution

Refineries/  
Power Plants

Extraction/  
Generation

Energy related to construction

Infrastructure

Vehicles

Not considered

In case of transport chains (transport of a product by more than one transport mode) the chain links shall be individually quantified and subsequently summed up.

The ultimate approach of quantifying transportation emissions shall be based on measuring the fuel and energy consumption of a trip and multiplying it by the emission factor of the fuel/energy that covers all upstream emissions of the fuel/energy. Only transport emissions quantified on the basis of measured fuel/energy consumption shall be considered as primary data. In case of collective transport, the primary data-based transport emissions require allocation to the individual product. Such allocations do not change the classification of emission data as being primary data.

Direct measurement of fuel/energy consumption of a transport operation may however not always be possible and modelling transport emissions is required. Calculation of transport emissions shall follow the recommendation set out in the GLEC Framework V3.1 or latest, except for the mandate to include emissions from the construction and dismantling of energy infrastructure. The GLEC framework allows for three approaches to establish transport distances: Shortest feasible distance (SFD), great circle distance (GCD) and actual distance. These approaches shall be used according to the following hierarchy:

⦁ Actual distance

⦁ SFD

⦁ GCD

Emissions reduction from the use of low-carbon fuels may only be claimed if a statement of sustainability (origin and emissions reduction) for the fuel is provided as issued by a bonded warehouse.”

1. Methodology per life cycle stages
   1. Material production stage [SG2]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Level | Activity Data | | | Intensity Data |
|  | Vehicle Weight [kg] | Material Distribution [%] | Scrap Rate of Material [%] | Carbon Intensity of Material Acquisition  [kg-CO2e/kg] |
| Amount of Material Use at the Vehicle [kg] | |
| Level 1 | Primary data | All Secondary data | All Secondary data | All Secondary data |
| Level 2 | All Primary data | | All Secondary data | All Secondary data |
| Level 3 | All Primary data | | Partially Primary data | Partially Primary data |
| Level 4 | All Primary data | | All Primary data | All Primary data |

At the material production stage, the development of the assessment method will be focused only on Level 3, and for other levels, only the concept and overview will be described.

To calculate the CFP of the vehicle’s base materials (CMP in kgCO2eq.) 4 parameters are defined:

⦁ the total amount of material used in the vehicle TA,

⦁ the material distribution MD (%): mass composition of each material inside the vehicle

⦁ the scrap rate of material SR: corresponding to the XXX

⦁ the carbon intensity of the material acquisition CEF MA in kgCO2eq. / kg of material

Equation 18

Depending on the level, these 4 parameters can either be primary or secondary data (

Table 6).

In Level 1, the material distribution of the vehicle, the scrap rate and the carbon intensity of each material (in kgCO2eq. / kg) are secondary data.

In Level 2, the weight of the vehicle but also its materials distribution are primary data. The scrap rate and carbon intensity of each material acquisition are secondary data.

Details of Level 3 will be described in a later chapter, but the assessment of the produced vehicle is set as the purpose of use, and the weight of the material used, its yield, and material carbon intensity are collected as much as possible as primary data, and the environmental impact is assessed according to the actual situation.

Finally, Level 4 is an ideal LCA, with the goal of compiling the basic carbon intensity of all materials as primary data. However, it is challenging to collect data on approximately 100,000 items per vehicle, and this is assumed to be an ideal state.

Table 6: Level concept of material production stage

* + 1. Declared unit

The product carbon footprint shall be assessed for a declared unit. A functional equivalent is established by the data recipient and is defined from a material production perspective.

For a material production stage, the declared unit shall be 1 kg of material products, regardless of its state, as its specific density is considered.

* + 1. Automotive material classification

Material classification is described in level 3. It is basically extracted by investigating composed materials species in typical automotive vehicle models, i.e., ICE, HEV, FCV and EV. As material information, BOM (Bill of Materials) and IMDS (International Material Data Sheet) are commonly referenced in worldwide automotive industry.

Then material classification shall be set from its PCF impact viewpoint and be derived in accordance with other stages as Parts production and vehicle assembly, Use, and End of Life.

From a viewpoint of high PCF impact in automotive materials, system boundaries of these dominant materials (steel, aluminium, copper, and plastic) are defined in Figure 14, Figure 15, Figure 16, and Figure 17 referring to the documents from international institutions e.g., worldsteel, IAI, EA, ICA, and TfS. Regarding other materials used in a vehicle, the list is shown in Table 7.

Although it depends on a target vehicle specification, prodedures to select material classification should be explained.

The cut-off criteria, should be in line with Section 3.2.8.

Table 7: Automotive material list

|  |  |
| --- | --- |
| Material group | Material classification |
| Steel | Cast iron, Cast steel, Hot-rolled steel sheet, Cold-rolled steel sheet, Electromagnetic steel sheet, Hot-rolled hot-dip galvanized steel sheet, Hot-rolled electrogalvanized steel sheet, Cold-rolled hot-dip galvanized steel sheet, Cold-rolled electro galvanized steel sheet, Carbon steel bar/wire rod, Special steel bars, Special steel wire rod/spring steel, Stainless steel sheet/bar, Sintered steel |
| Aluminium | Cast aluminium, Die cast aluminium, Wrought aluminium(sheet), Wrought aluminium(extruded) |
| Copper | Tough pitch bare/coated copper wire, Oxgen free bare/coated copper wire, Tough pitch copper strip/bar, Oxgen free copper strip/bar |
| Plastic | PP(Polypropylene), PE(Polyethylene), PVC(Polyvinyl Chloride), ABS (Acrylonitrile Butadiene Styrene), PA (Nylon), PC (Polycarbonate), PET (Polyethylene Terephthalate), PBT (Polybutylene Terephthalate), PUR (Polyurethane), POM (Polyacetal), ASA (Acrylonitrile Styrene Acrylate), PMMA (Acrylic resin), EP(Epoxy resin), PPS (Polyphenylene Sulfide), TPO (Thermoplastic Olefin), TPV (Thermoplastic Vulcanizate) |
| Non-ferrous metals | Magnesium alloy, Zinc alloy, Platinum/Rhodium, Lead, Other metals |
| Other organic materials | SBR (Styrene-Butadiene Rubber), EPDM (Ethylene Propylene Diene Monomer), Other thermoplastic resins, Other thermosetting resins, Natural rubber, Synthetic rubber, Anti-rust oil, Leather, Adhesives |
| Other materials | Laminated Glass, Paints, Electrodeposition Coating, Electronic Components (Silicon), Engine oil, Brake fluid, Coolant, Refrigerant, Other inorganic materials, Tyres, Battery materials (Lead-Acid battery, Ni-MH battery, LiB: Lithium-Ion Battery) |

* + 1. System boundaries

Figure 13 shows a system boundary of the material production stage.

Figure 13: A system boundary of materials production stage

Virgin

raw material

Recycled raw material

Fuel and Electricity

Upstream

Material production

Transportation

Disposal

[A-1] Upstream process

Intermediate material

[A-2] Downstream process

Parts production

and

vehicle assembly stage

Recycled

raw material

Fuel and Electricity

Transportation

Disposal

Downstream

Material production

Material product

Transportation

[A1] Processes related to material mining, refining, and impurity removal (defined as upstream process)

[A2] Processes related to material production (defined as downstream process)

In the material production stage, an actual production flow for each automotive part shall be reflected.

These materials production stages are mainly divided into two processes.

The first is ‘upstream process’ which has mining, refining, and impurity removal with relatively high CO2 impact.

Then, ‘downstream process’ which has from the intermediate material stage (e.g. crude steel, aluminium ingot) to the material product stage (e.g. steel sheet, aluminium extruded bars).

After that, it is transferred to the Parts production and vehicle assembly stage.

System boundaries of the main dominant materials (steel, aluminium, copper, plastic, Lithium-Ion Battery) in automotive are shown in Figure 14, Figure 15, Figure 16, Figure 17 and

Figure 18.

Figure 14: A system boundary of steel material production stage

Iron ore

Coke

Lime

stone

Blast furnace

Scrap

Crude steel

Direct reduction furnace

Direct reduction furnace

Iron ore

Natural gas

Iron ore

Hydrogen

[A-1] Upstream process

Atomization

Sintered steel

Pig iron

NG-DRI

H-

DRI

Converter furnace

Electric furnace

Special steel wire rod/ spring steel

Cast Iron

part

Cast Steel

part

Electromagnetic steel sheet

Cold-rolled steel sheet

Cold-rolled hot-dip galvanized steel sheet

Hot-rolled hot-dip galvanized steel sheet

Hot-rolled electro galvanized steel sheet

Cold-rolled electro galvanized steel sheet

[A-2] Downstream process

Melting

Continuous

casting

Heat treatment

Cold rolling

Annealing

Hot dip galvanizing

Electro galvanizing

Heating

Hot rolling

Hot-rolled steel sheet

Carbon steel bar/wire rod

Special steel bar

Stainless steel sheet/bar

Basic Oxygen Furnace process

Electric Arc Furnace process

Natural gas-based DRI

Hydrogen gas-based DRI

Figure 15: A system boundary of aluminium material production stage

Bauxite

Calcined lime

Electricity

NaOH

Cathode carbon

Aluminium fluoride

Scrap

Alumina

Ingot casting

Petrol coke

Pitch

Anode

Electrolysis

Aluminium ingot

Ingot casting

Additive alloys

Melting

Aluminium slabs

Rolling

Extrusion

Die cast

aluminium

part

Cast aluminium

part

Heat treatment

Melting

Liquid aluminium

Aluminium billet

[A-1] Upstream process

[A-2] Downstream process

Wrought aluminium

(Sheet)

Wrought aluminium

(Extruded)

Primary aluminium ingot production process

Secondary aluminium ingot production process

Figure 16: A system boundary of copper material production stage

Silica

Lime

stone

Leaching

Scrap

Copper ore

Electricity

Pyrometallurgy process

Hydrometallurgy process

OFC

wire rod

Oxygen free

Casting

OFC

coated wire

TPC

bare wire

OFC

bare wire

TPC strip/

bar

OFC strip/

bar

Scrap

Copper ore

Flash furnace smelting

Electrolytic copper

Crude copper

Anode copper

Fire refining

Casting

Rolling

TPC

wire rod

Drawing

Annealing

TPC

coated wire

Covering

Baking

Melting

[A-1] Upstream process

[A-2] Downstream process

Electro

winning

Electrolytic refining

Figure 17: A system boundary of plastic material production stage

Crude oil

Distillation

Coal

Natural gas

Recycled oil

Bio-based oil

Naphtha

cracking

Monomer

Polymerization

Polymer

Polyol

Polyisocyanate

Thermosetting reaction

Naphtha

Thermo

setting resin

part

Pelletization

Thermo

plastic resin

pellet

[A-1] Upstream process

[A-2] Downstream process

Figure 18: A system boundary of Lithium-Ion Battery material production stage

Lithium sulphate

Mixing

Nickel sulphate

Manganese sulphate

Cobalt sulphate

Drying

Cell

Active material

(Cathode)

Cell Production

[Material acquisition and pre-processing phase]　　　　[Production phase]

Lithium Sulphate

Graphite

Mixing

Active material

(Anode)

Additives

Alluminium foil

Solvent

Additives

Copper foil

Solvent

Lithium sulphate

Solvent

Housing

Pressing

Drying

Pressing

Cathode

Anode

Electrolyte

Mixing

Separator

Steel

Sheet

Other

Housing production

Especially, globally regional dependency of electricity and fuel in the material production process, and usage ratio of recycled and bio-derived material greatly affect on PCF.

Burdens related to recycled material to raw material shall be evaluated using the RCM methodology described in Section 3.2.13.

Equation 19

Where;

means the specific GHG emissions of a material calculated with the RCM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

means the proportion of material input to the product that has been recycled from a previous system. [%]

means the specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material [kgCO2e/kg]

means the specific emissions and resources consumed (per unit of analysis) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process. [kgCO2e/kg]

* + 1. Data collection and data type

Material data is known as follows; material name, material classification (VDA, ISO code, and other standards), the number of materials, material weight, chemical substance composition, recycled material ratio, biomass blended ratio, yield rate, electricity, and fuel consumption, etc.

**Primary data collection**

In level 3, the weight of the material used, its yield, and material carbon intensity are collected as much as possible as primary data, and the environmental impact is assessed according to the actual situation.

In case it is not practically possible, secondary data should be collected. When collecting primary data from suppliers, the prerequisites should be reported. When collecting secondary data from available databases, data quality should be explained.

⦁ PCF dominant impact factor of material production process along system boundary should be considered.

⦁ Unit process data of material production process should be considered

⦁ country or region where material production was conducted

⦁ amount of electricity and fuel used, rate of renewable energy used

⦁ usage rate of recycled material and bio-derived material to total material weight

**Secondary data collection**

When collecting secondary data from available databases, data quality shall be explained as follows.

⦁ PCF dominant impact factor of material production process along system boundary should be considered.

⦁ Unit process data in material production process should be considered as well as primary data as described above.

⦁ It should be utilized as not a consequential data but an attributional data to avoid an assumption for material production process.

⦁ PCF reduction using an allocation between some life cycle generations should not be utilized to assure data transparency.

* + 1. Energy Modelling [SG6]

General rules must be referred to Section 3.2.10.

**Energy Mix:**

Practitioners should account for the fuel or electricity production pathways associated with the production locations of each material. (detailed methodology shall be considered)

The energy mix shall be based on the latest dataset associated with the location or region of production in question.

The methods described in Section 3.2.8 shall guide the modelling of fuel and electricity for these regions.

* 1. Parts production and vehicle assembly Use [SG3]
     1. Levels in parts production and vehicle assembly

The analysis of global warming potential can also be carried out for parts production and vehicle assembly in different levels of detail. In case the goal of the analysis is e.g. concerned with mobility concepts rather than individual vehicles or the specific details of the vehicle production are not the main interest, an archetypal vehicle production is included in the analysis. The cradle to gate carbon footprint of parts production or vehicle manufacturing can thus reflect:

⦁ an average for a vehicle fleet (various segments, models on global or national level) –> Level 1

⦁ an average for vehicles of a specific segment (various models on global or national level) or a vehicle chosen as representative for a specific segment both based on BoM-Data –> Level 2

⦁ an average for specific vehicle models (with different equipment variants on global, national or local production site level) –> Level 3

⦁ a specific vehicle model. –> Level 4

In the ideal case, the average values are calculated as weighted averages of a population of individual vehicles. If the analysis of the individual vehicle were based on real emission data (primary data), even the averages would reflect the correct averages of real emissions. As there is no abundance of analysis data on individual vehicles very often the average vehicle is defined by assumptions and modelling and secondary data is used to quantify the environmental impact.

Within this resolution four levels detail are differentiated.

* + - 1. Level 1

As described in 3.2.1 there are multiple approaches possible for Level 1, the following section minimum standard for calculation. GHG-emissions due to the production of vehicle parts and vehicle assembly are quantified with a (lump) carbon emission factor which is a function of net vehicle weight. All specific emission effects due to different materials, gross material input, different production processes or transport of parts or vehicles is included in the carbon emission factor. The calculation of vehicle carbon footprint from production is simply given by:

Equation 20

Wherein:

CVP Carbon emissions due to material production, component and vehicle manufacturing in kilogram of carbon dioxide equivalent (kgCO2e)

CMP Carbon emissions due to material production in kilogram of carbon dioxide equivalent (kgCO2e)

CEFMP Carbon emission factor of material production in kilogram of carbon dioxide equivalent per vehicle net mass (kgCO2e/kgNM)

MNM Net mass of the vehicle in kilogram (kg), i.e. mass of the vehicle in running order minus the mass of the driver (75kg) minus the mass of any fuels.

SCV Surcharge factor for carbon emissions from parts/component and vehicle manufacturing on top of carbon emissions due to material production.

CTP Carbon emissions due to transport of the fully assembled vehicle to customer in kilogram of carbon dioxide equivalent (kgCO2e)

The SCV may be determined from literature or OEM publications. The factor may reflect geographical differences, if there is evidence that parts/component and vehicle production is more CO2e-intense in some parts of the world than in others. For transparency all the factors used in calculation shall be reported.

* + - 1. Level 2

GHG-emissions due to the production of vehicle parts and vehicle manufacturing are quantified by breaking down the vehicle as delivered to the customer by mass of materials. Breaking down by material is common in automotive industry because material and mass declaration systems are mandatory for decades. The calculation of the cradle to gate vehicle carbon footprint is given by:

Equation 21

Wherein:

CVP Carbon emissions due to material production, component and vehicle manufacturing in kilogram of carbon dioxide equivalent (kgCO2e)

COP Carbon emissions due to manufacturing processes at the OEM in kilogram of carbon dioxide equivalent (kgCO2e)

CMP,i Carbon emissions due to production of material i in kilogram of carbon dioxide equivalent (kgCO2e)

SC,i Surcharge factor for carbon emissions from parts/component and vehicle manufacturing on top of carbon emissions due to production of material i.

CTP Carbon emissions due to transport of the fully assembled vehicle to customer in kilogram of carbon dioxide equivalent (kgCO2e)

Again, all specific emission effects due to different production processes, production rejects or transport of parts or vehicles is included in the surcharge factor. COP may be determined from literature or OEM publications. For transparency all the factors used in calculation shall be reported.

* + - 1. Level 3

The contribution of different subsystems of a vehicle to the GHG-emissions of vehicle production is by far not evenly distributed. Accounting these most relevant subsystems in terms of GHG-emissions from vehicle production (so called ‘hotspots’) in a more detailed manner differentiates Level 3 from Level 2 in the calculation of the cradle to gate vehicle carbon footprint.

[For a hotspot, company specific (OEM / supplier specific) data shall be used for at least one material or component of choice.

This means, for the selected component / material:

* for at least one process at OEMs’ and/or preceding suppliers’ production sites   
  (depending on availability and vertical integration)
* it is required to collect primary information on either activity data[[9]](#footnote-10) or material carbon footprint[[10]](#footnote-11)
* which is then utilised for the calculation of the cradle-to-gate carbon footprint.

The selected component as well as the chosen process or material or supplier component shall be named including type of primary information collected.

As a recommendation, the following should be taken into account:

⦁ steel, aluminium,

⦁ body-in-white, battery, wheel rims, tires.]

For hotspot primary data-based reporting is the preferred approach and the use of available site-specific primary data is mandated. In case primary data cannot be obtained, secondary data shall be used. Secondary data shall be traceable and based on field survey data and released by government authorities.

The calculation of vehicle carbon footprint from production is given by:

Equation 22

Where:

CVP means thecarbon emissions due to material production, component and vehicle manufacturing in kilogram of carbon dioxide equivalent (kgCO2e)

CHS means the carbon emissions due to manufacturing of hotspot subsystems (including material production processes and component production) and their assembly to the vehicle in kilogram of carbon dioxide equivalent (kgCO2e)

CBV means the carbon emissions due to material production, component and vehicle manufacturing with the exception of hotspot subsystems in kilogram of carbon dioxide equivalent (kgCO2e)

CTP means thecarbon emissions due to transport of the fully assembled vehicle to customer in kilogram of carbon dioxide equivalent (kgCO2e)

CHS is calculated according to Level 4 definitions. CBV for the remaining vehicle materials, parts and production processes excluding hotspots follow the calculation defined for Level 2. Intermediate transport operations are covered by CHS and CBV.

* + - 1. Level 4

GHG-emissions due to the production of vehicle parts and vehicle assembly are quantified by a stepwise attributional reporting of real emissions (site specific, primary data) for the material and components along the supply chain until the final assembly in the vehicle. For each Tier level this requires to add the GHG-emissions for the manufacturing of a product in its own operations to the sum of GHG-emissions of the purchased parts or materials for that product. Transport within the supply chain is accounted according to the definitions in Section 3.2.14 and 4.2.6.

The calculation of vehicle carbon footprint from production is given by:

Equation 23

Equation 24

Where:

CVP means thecarbon emissions due to component and vehicle manufacturing in kilogram of carbon dioxide equivalent (kgCO2e)

Cop means thecarbon emissions due to manufacturing processes at the OEM in kilogram of carbon dioxide equivalent (kgCO2e)

CTP1 means thecarbon emissions due to transport from Tier 1 supplier to the OEM in kilogram of carbon dioxide equivalent (kgCO2e) per part

CT1 means thecarbon emissions reported from the Tier 1 supplier for supplied parts in kilogram of carbon dioxide equivalent (kgCO2e) per part

CTP means thecarbon emissions due to transport of the fully assembled vehicle to customer in kilogram of carbon dioxide equivalent (kgCO2e)

CTi means thecarbon emissions reported from the Tier j supplier for the component production of supplied parts in kilogram of carbon dioxide equivalent (kgCO2e)

CTPj means thecarbon emissions due to transport of parts from Tier j-1 supplier to Tier j in kilogram of carbon dioxide equivalent (kgCO2e) per part

Cop,j means thecarbon emissions due to manufacturing processes at the Tier j in kilogram of carbon dioxide equivalent (kgCO2e) per part

In case primary data cannot be obtained, secondary data shall be used. Secondary data shall be traceable and based on field survey data and released by government authorities.

Any product during parts and vehicle production generating material/parts for recycling, re-use or re-manufacturing follows a cut-off approach in a cradle-to-gate scope, i.e. only the RCM methodology is applied. Preparatory steps for recycling shall generally be allocated to the waste receiving system (i.e., the product system using the (to be) recycled material/parts). This deviation from the polluter pays principle is a pragmatic exemption as following the polluter pays principle in this context would require defining material- and component-specific system boundaries. Other than the emissions from the respective preparatory steps and the recycling, re-used or re-manufactured treatment emissions, to be recycled, to be re-used, or to be re-manufactured materials/parts enter the product system using recycled material/parts burden-free.

For pre-consumer scrap, preparatory steps shall be accounted for by the producer of the waste (they might be insignificant; cut-off rules apply).

* + - 1. Level overview

The following Table 8 gives an overview how relevant aspects in vehicle and parts production should/shall be handled in the different levels.

Table 8 : Level overview for parts production and vehicle assembly stage

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Level1 | Level 2 | Level 3 | Level 4 |
| Waste | Included in SCV | Included in SC,i | Hotspot:  Considered explicitly.  Rest of vehicle:  Included in SC,i | Considered explicitly |
| Gross vs. net material input (Scrap) | Included in SCV | Included in SC,i | Hotspot:  Considered explicitly.  Rest of vehicle:  Included in SC,i | Considered explicitly |
| Transport | Included in CTP & SCV | Included in CTP & SC,i | Transport from OEM gate to customer  reported explicitly.  Hotspot:  Considered explicitly.  Rest of vehicle:  Included in SC,i | Considered explicitly |
| Primary/secondary material use | Included in CEFMP | Included in CMP,i | Hotspot:  Considered explicitly.  Rest of vehicle:  Included in CMP,i | Considered explicitly |
| Temporal validity | Most recent data | Most recent data | Hotspot:  Annual update  Rest of vehicle:  Most recent data | Annual updates |
| Geographical Representativeness | As specific as possible for research question | As specific as possible for research question | Hotspot:  Plant level  Rest of vehicle:  As specific as possible | Plant level |

* + 1. Declared unit

The product carbon footprint shall be assessed for a declared unit. A functional equivalent is established by the data recipient and is defined from a product use perspective (see 3.2.3).

For countable products, i.e., a component or part, the declared unit shall be 1 piece as described in the part description including a defined weight and a unique identifier (part number).

For materials, i.e., mass products or commodities, the declared unit shall be 1 kg of products, regardless of its state (solid, liquid, gas), as its specific density is considered.

If packaging is included, the declared unit is 1 kg or 1 piece of unpackaged product at the factory gate. The PCF however includes the PCF contribution of packaging.

For the vehicle manufacturer the declared unit it the fully assembled vehicle delivered to customer at show room.

* + 1. System boundaries

The system boundary of the parts and vehicles production stage is outlined in Figure 19.

Figure 19: System boundaries in production.

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Gate-to-Gate System Boundary in Production

Transport to Dealer

Vehicle

Disposal

Waste

Vehicle  
Manufacturing

Parts  
Transport

Parts

Waste

Disposal

Recycling

Parts  
Manufacturing

Material  
Transport

System Boundary of Parts and Vehicle Production

Cradle-to-Gate System Boundary in Production

System Boundary of Material Production

Materials

The transport of the final assembled vehicle to the end customer is also included in the parts and vehicle production and therefor to be included in the CFP of the vehicle in production.

The cradle-to gate CFP includes all attributable upstream and direct emissions of producing a product, including all upstream transportation activities.

When accounting for emissions all attributable processes shall be listed to clearly define the cradle-to-gate boundary of their studied product.

The system boundaries for parts/components and vehicle production are therefore including:

⦁ Production of materials from virgin or recycled materials, semi-finished products

⦁ Production of vehicle parts and components

⦁ Auxiliary production processes (e.g., lighting, air conditioning, storage facilities)

⦁ Disposal of production waste

⦁ Packaging of vehicle parts and components, including all operations required for performing packaging

⦁ Disposal of production waste (incl. packaging waste, see 3.2.13)

⦁ Logistics (including internal logistics and transport packaging, see 3.2.14 and 4.2.6)

⦁ Quality control in production

⦁ Energy consumption of IT for process and manufacturing control

Despite of being included in the system boundaries in principle, insignificant processes may be excluded based on the cut-off rules (see 3.2.8).

In general, GHG emissions not connected directly to the production system relevant for the product shall be excluded from the system boundaries. These are amongst others:

⦁ Employee commuting and work travel

⦁ Research and development, administration, or sales processes

⦁ Auxiliary inputs not directly related to the production process (such as heating and lighting of associated office rooms, secondary services like maintenance, sanitary facilities, canteen services, facility management e.g., plant security and fire safety and general IT)

⦁ Auxiliary inputs to maintain the manufacturing equipment

⦁ Emissions from construction or dismantling of capital good (such as buildings, manufacturing equipment or any other infrastructure for transport, media or energy distribution and energy generation, within or outside the control of the reporting company)

* + 1. Data collection and data types

The following table describes the type of data that should be used for each level.

Table 9 : XX

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Level |  | Activity Data | | | Intensity Data |
|  |  |  |  |
| Level 1 | Material production |  |  |  |  |
| Component |  |  |  |  |
| Assembly |  |  |  |  |
| Manufacturer’s own operations |  |  |  |  |
| Logistic |  |  |  |  |
| Level 2 |  |  | |  |  |
| Level 3 |  |  | |  |  |
| Level 4 |  |  | |  |  |

Emissions shall by default be reported averaged over the period of one year (reporting or calendar year) to avoid seasonal fluctuations and reflect typical production conditions.

Shorter periods may be considered if data on a full year are not yet available. Longer averaging periods may be considered but shall not exceed five years. Any averaging period deviating from the default shall be flagged and justified.

Emissions shall by default be reported for the most recent year (reporting or calendar year). An annual check is recommended to ensure data actuality. To perform the annual check, the initial screening analysis should be updated based on data for the most recent year. An update of data is recommended if the reported emission increases by 10% or more based on the screening analysis compared to the previous reporting period. Additionally, an update of data is mandatory in the following situations (adapted from GHG protocol):

⦁ Structural changes in operation to the product system under study, including significant process change in operation, change in production technologies or technology advancement, raw material or energy changes.

⦁ Changes in calculation methodology or improvements in the accuracy of emission factors or activity data or inclusion of new types of sources that result in a significant impact on the emissions data.

⦁ Discovery of significant errors, or a number of cumulative errors that are collectively significant.

Emissions shall by default be reported on the plant level. Averaging globally or over a region, country, continent may be considered but shall be flagged as such. Reasoning shall be provided if continental or global average values are used in cases where the use of primary data is recommended.

* + 1. Energy modelling

General rules must be referred to Section 3.2.10.

**Energy Mix:**

Practitioners should account for the fuel or electricity production pathways associated with the production locations of each material. (detailed methodology shall be considered)

The energy mix shall be based on the latest dataset associated with the location or region of production in question.

The methods described in Section 3.2.8 shall guide the modelling of fuel and electricity for these regions.

* + 1. Logistics

This section deals with transportation from a supplier to its customer. The general rules for logistics apply (see Section 3.2.14)

Figure 20: Definition of scopes

Production

Une image contenant capture d’écran, texte, conception

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Components

Modules

Vehicle

Raw Materials

OEM

Cradle-to-Gate Tier n

Cradle-to-Gate Tier 1

Mine-to-Gate

Gate-to-Gate

Transport

As for the product carbon footprint, the cradle-to-gate boundaries end at the suppliers' outbound gates (cf. Section 3.2.4 System Boundaries). This boundary applies independently from the responsibilities in economic or operative terms for transportation processes.

Nonetheless, if a supplier is responsible in economic or operative terms for the outbound logistics (i.e., transportation from the supplier to its customer), the supplier shall report the product carbon footprint from this transportation in addition to and separately from the product carbon footprint (Table 10). Otherwise, the customer shall account for transportation between the supplier’s and its own shipping site (factory gate or distribution centre, see Figure 21 and Figure 22).

The table below describes different cases of responsibility and accountability for transportation from supplier to customer:

Table 10: Transportation between supplier and customer.

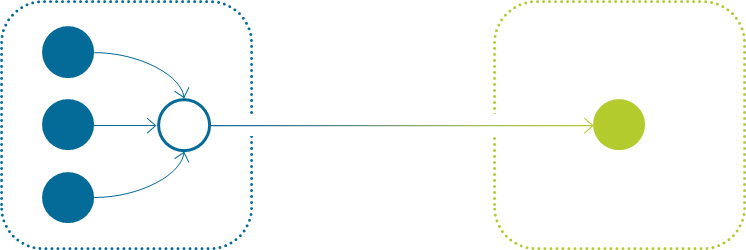
| **Case** | **Description** | **Economic/operative responsibility for transportation from supplier to customer** | **Accounting for transportation emissions** |
| --- | --- | --- | --- |
| **1** | Multiple shipping sites, and/or multiple unloading sites  Une image contenant capture d’écran, cercle, diagramme, Caractère coloré  Le contenu généré par l’IA peut être incorrect.  Customer  Supplier | Inbound transportation contracted or operated by customer | Customer respon­sible for quantifica­tion of transporta­tion emissions.  As for multiple transportation relations, emissions shall be attributed by mass between the respective products |
| **2** | Multiple shipping sites, and/or multiple unloading sites  Une image contenant capture d’écran, cercle, diagramme, Caractère coloré  Le contenu généré par l’IA peut être incorrect.  Customer  Supplier | Outbound transportation contracted or operated by supplier | Transportation emissions to be reported separately by supplier to the customer (additionally to supplier's PCF).  As for multiple transportation relations, emissions shall be attributed by mass between the respective product |

Transports from production sites to suppliers' distribution centres are deemed as suppliers' in-house logistics, i.e., the distribution centre is regarded as the shipping point (Figure 21).

Figure 21: Distribution centre on supplier side.

Customer

Supplier

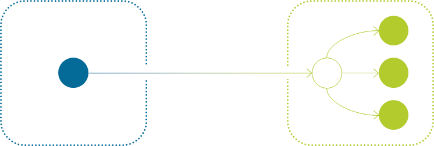


Transports from customers' distribution centres to production sites are deemed as customers' in-house logistics, i.e., the distribution centre is regarded as the unloading point (see Figure 22).

Figure 22 : Distribution center on customer side.

Customer

Supplier



Regardless of whether transportation emissions are quantified by a supplier or a customer, they shall be consolidated within the customers' PCFs.

* 1. Use Stage [SG4]
     1. Service life and functional unit

The vehicle lifetime (or service life) is defined as the full period of time during which a vehicle is operated and thereby contributes to GHG emissions. This lifetime is expressed in terms of kilometres (km) driven and is chosen to represent typical usage patterns. Alongside the distance travelled, the years of operation for a vehicle is defined as the assumed total number of years a vehicle remains in active use. Both are relevant for the purpose of the methodology.

Vehicle lifetime mileage is required to translate vehicle production emissions (in tonnes of CO2e) into the functional unit (gCO2e per km driven over the lifetime). Vehicle lifetime in years is needed to calculate the lifetime mileage, but also to determine the period of time over which the changes in the emission intensity of the fuel and electricity will be accounted for. Lifetime duration is also needed to calculate the number of replacements/refills for certain maintenance and consumable items.

* + - 1. Service life: methodology and guideline

The service life is the phase between point of sale and point of recycling. Precisely assessing these values for each region may present further challenges, underscoring the need for flexibility and regional adaptation in their definition and application.

The actual service life and lifetime distance reference flow of a vehicle can vary significantly depending on the region and its specific applications. This variability makes it challenging to accurately estimate these values universally. Therefore, this guideline proposes to define service life for each region or country of usage.

De-registration in a country (i.e., as indicated by “survival curves”) can be significantly earlier than reaching end of life. In some countries, a significant share of vehicles is exported before reaching the end of service life. Here, the average age when being de-registered (e.g., 13 years in Germany) is lower than the average age when being recycled (e.g., 19 years in Germany). In general, this document recommends to consider statistical evidence on the average vehicle age at the point of recycling. For the reasons discussed below, statistics on the average age at the point of de-registration in a country is not recommended, as these values exclude the potential export and continued operation of a proportion of the vehicle in other countries. Therefore, for all vehicles, the lifetime used to calculate life cycle emissions should align with the average age of vehicles at the time of recycling, considering only those registered and recycled within the same country.

There are both advantages and disadvantages to offering differentiation by segments. (1) Differentiation offers a more accurate representation of the typical usage expected, which also partly highlights the greater potential utility that larger vehicles can provide. (2) However, near the boundaries between segments, it may unintentionally influence consumer decisions (for instance, a specific user is unlikely to choose a vehicle solely because it belongs to a different segment – it's typically bought for a particular use). Until further in-depth analysis is conducted, this guideline does not recommend differentiating service life by segment.

Although statistics indicate that service life varies considerably between powertrains, this may be influenced by user behaviour. Since one of the main objectives of LCA is to compare different powertrains, based on the same functionality, i.e., the same use case, this guideline does not recommend assigning different service lives to different powertrains.

Some vehicles, such as special purpose or sports vehicles, have very low usage, leading to a significantly reduced service life. The guidelines suggest that the OEM can indicate a shorter service life supported by primary data, which will lead to a more stringent functional unit. However, the guidelines currently do not advise declaring a longer service life than the regional default value, as this could result in a more favourable functional unit.

[ To be completed with an example to illustrate usage of the methodology => TBC ]

* + - 1. Service life values

Service life will be defined by each contracting parties according to official available data on vehicle service life until point of recycling.

In the absence of the above values, the following values as defined in some peer-reviewed reports or methodology can be used as fall-back option.

Table 11 : TITLE

|  |  |  |  |
| --- | --- | --- | --- |
| Region / Country | Year | Duration  (Years) | Source |
| Belgium | 2022 | 18.5 | [**Febelauto** (2023), rapport annuel 2023 *(Febelauto is the extended producer responsibility organization for vehicles in Belgium)*](https://urldefense.com/v3/__https:/www.febelauto.be/rapportannuel2023/chiffres-cles-vehicules-hors-d-usage.html__;!!DOxrgLBm!EZu9Z_zxq39CVwSFNGRMbY8VBNolYXfI0SxW1f7WFWWbg4-vGSaHVd5r4xGdtvjmUVI74M_rSymdgt4BCWJjGQGkLY8LEJE$) |
| Finland | 2024 | 22.8 | [**Finnish Information Centre of Automobile Sector** (2025), based on Statistics Finland](https://urldefense.com/v3/__https:/www.aut.fi/en/statistics/statistics_of_scrapped_vehicles/average_scrapping_age_of_passenger_cars__;!!DOxrgLBm!EZu9Z_zxq39CVwSFNGRMbY8VBNolYXfI0SxW1f7WFWWbg4-vGSaHVd5r4xGdtvjmUVI74M_rSymdgt4BCWJjGQGkDg4zfHk$) |
| France | 2022 | 19.8 | [**Agence de l'environnement et de la maîtrise de l'énergie**(2024), Véhicules : données 2022](https://urldefense.com/v3/__https:/librairie.ademe.fr/economie-circulaire-et-dechets/7602-vehicules-donnees-2022.html__;!!DOxrgLBm!EZu9Z_zxq39CVwSFNGRMbY8VBNolYXfI0SxW1f7WFWWbg4-vGSaHVd5r4xGdtvjmUVI74M_rSymdgt4BCWJjGQGkDgBXkpA$) |
| Germany | 2022 | 18.6 | [**Federal Ministry for the Environment and Umweltbundesamt**(2024), Jahresbericht über die Altfahrzeug-Verwertungsquoten in Deutschland im Jahr 2022](https://urldefense.com/v3/__https:/www.bmuv.de/download/jahresberichte-ueber-die-altfahrzeug-verwertungsquoten-in-deutschland__;!!DOxrgLBm!EZu9Z_zxq39CVwSFNGRMbY8VBNolYXfI0SxW1f7WFWWbg4-vGSaHVd5r4xGdtvjmUVI74M_rSymdgt4BCWJjGQGk4RxaejI$) |
| Netherlands | 2023 | 19.6 | [**Auto Recycling Nederland**(2024), Highlights of the Sustainability Report 2023 *(ARN covers 84% of vehicles recycled in the Netherlands)*](https://urldefense.com/v3/__https:/duurzaamheidsverslag2023.arn.nl/en/__;!!DOxrgLBm!EZu9Z_zxq39CVwSFNGRMbY8VBNolYXfI0SxW1f7WFWWbg4-vGSaHVd5r4xGdtvjmUVI74M_rSymdgt4BCWJjGQGkikdnc9w$) |
| Portugal | 2022 | 23.8 | [**Portuguese Environment Agency** (2024), Reporte de Qualidade VFV 2022](https://urldefense.com/v3/__https:/apambiente.pt/residuos/reporte-comunitario__;!!DOxrgLBm!EZu9Z_zxq39CVwSFNGRMbY8VBNolYXfI0SxW1f7WFWWbg4-vGSaHVd5r4xGdtvjmUVI74M_rSymdgt4BCWJjGQGkJc_MoDY$) |
| Spain | 2023 | 21.1 | [**SIGRAUTO***(Spanish Association for the Environmental Treatment of End-of-Life Vehicles)*](https://urldefense.com/v3/__https:/www.sigrauto.com/cuantos-vehiculos-fuera-de-uso-se-tratan-al-ano/antiguedad-vehiculos__;!!DOxrgLBm!EZu9Z_zxq39CVwSFNGRMbY8VBNolYXfI0SxW1f7WFWWbg4-vGSaHVd5r4xGdtvjmUVI74M_rSymdgt4BCWJjGQGkEKqbvX0$) |
| United Kingdom | 2022 | 18 | [LSE, 2024 - Estimating the longevity of electric vehicles: What do 300 million MOT test results tell us?] TBC |
| Japan | 2022 | 16.5 | [**Ministry of Economy, Trade and Industry**, 2023 - Status of the Enforcement of the Automobile Recycling Law](https://www.meti.go.jp/shingikai/sankoshin/sangyo_gijutsu/resource_circulation/jidosha_wg/pdf/058_03_00.pdf#page=4) |
| USA | 2003 | 18 | US DoT |
| Brazil | 2020 | 22 | Ministry of Science, Technology and Innovations of Brazil, 2020 |

* + 1. System boundaries

When defining the system boundaries, it is pivotal to highlight that the scope is to provide a comprehensive methodology for calculating realistic GHG emissions and energy consumption over vehicle use stage at various levels of detail and considering the availability of different information and datasets. Therefore, in an intermediate step this requires the calculation of energy consumption as activity data for electrified vehicles such as HEV, PHEV, FCHV and PEV. As outlined in the figure below, the use stage encompasses the operation of the vehicle itself and direct impacts from this, as well as impacts from the production and distribution of fuel/electricity, and for impacts relating to vehicle maintenance and replacement parts.

Impacts directly from the energy used in operation of the vehicle include in the CO2 equivalent calculation the tank-to-wheel (TTW) contribution are hereby addressed, hence:

⦁ Electric energy: from vehicle charging port to the wheels , if already included in the certification protocol;

⦁ Fuel: from tank to wheel

Conversely, impacts resulting from the production and distribution of fuel and electricity for the operation of the vehicle, i.e. well-to-tank (WTT), shall follow the methodology outlined in Section 3.2.4 and Section 3.2.10.

These latter WTT GHG emissions shall be covered in the conversion factor of each energy type according to 3.2.10.

Use stage boundaries are depicted in the figure below:

Figure 23 : Use stage Life-cycle flow schematic

Material production

Material

Material transport

Maintenance parts

Disposal/

Recycle

Maintenance parts & Consumables transport

Fuel production/ energy generation

Fuel/ electricity

Driving

AC Refrigerant

Fluorocarbon emissions

Material parts production

Waste transport

ELV

Maintenance parts & Consumables

Finished vehicle transport

Leakages

Leakages emissions

Unburnt GHG Species

Unburnt GHG emissions

Processes

Input/Output

Fuel Combustion

Combustion CO2 emissions

Combustion non-CO2 emissions

As a matter of fact, the use stage covers mainly two aspects of the whole life cycle, such as the “In-use energy consumption and GHG emissions” (covering WTT and TTW impacts), and the “Maintenance and consumables” impacts. It is relevant to address also leakages such as emissions of methane and other hydrocarbons, together with emissions of climate active species from the vehicles (e.g. methane leakage from CNG cars) and the formation of non-CO2 GHG gasses (e.g. N2O) during the fuel combustion. More in detail, the figure below shows the system boundaries related to vehicle operation.

Figure 24 : Vehicle operation system boundaries

Driving Fuel and Energy Consumption

Finished vehicle transport

EoL vehicle transport

Maintenance & Regular Consumables

Leakages and Fluorocarbons

The hand over point with “Parts production and vehicle assembly” stage is set at the “showroom level, when the vehicle is passed on from the OEM to the final customer”. On the disposal and recycling side, GHG emissions after the vehicle service lifetime fall within the EoL (End-of-Life) domain. Therefore, it is acknowledged that the transportation of the vehicle to EoL treatment facilities is included within the EoL domain.

Considering the proposed system boundaries, the CO2 equivalent emissions for the use stage comprise emissions from in-use consumption, emissions due to maintenance parts and consumables, and the contribution of leakages and fluorocarbon emissions. The following equation highlights these components:

Equation 25

Where,

means thecarbon emissions for the whole use stage (kgCO2e);

means the carbon emissions due to the in-use vehicle operation, including emissions from fuel combustion and unburnt GHG species (kgCO2e);

means thecarbon emissions due to maintenance and consumables (kgCO2e);

means thecarbon emissions due to leakages (kgCO2e);

means thecarbon emissions due to fluorocarbons emissions (kgCO2e);

means thecarbon emissions due to unburnt GHG species emissions (kgCO2e);

In the following paragraphs, the methodology for assessing each term of the equation is detailed.

* + 1. Use phase consumption

Contrary to upstream activities where carbon footprint is unique for a vehicle, downstream activities are different for different regions for the same vehicle. The LCA vehicle's GHG emissions are declared at the point of sale, but it is difficult to measure energy consumption after sale. Instead, for Level 1 and Level 2 analysis, [projections or estimations can be made based on available information such as certification values. These should be considered as minimum requirements and do not prevent the use of more realistic or detailed data to better characterise vehicle behaviour, where such data is available.]

Usage of passenger cars depends on regional customer behaviour. To provide a standard approach that ensures repeatability, comparability and verifiability by authorities, each region has defined homologation driving cycles and test conditions to be followed. In some regions, these certification values are repeatedly found to underestimate the average fuel consumption in real-life operation. In this regard, Table 13 provides an overview of the primary certification protocols used globally. This table serves as an illustrative example of the methodologies employed in key regions to determine fuel and energy consumption for passenger cars, depending on the powertrain type. The selection and verification of the appropriate homologation procedure remain the responsibility of each contracting party, to be determined on a case-by-case basis. As a result, using regional certification values is considered to be a good starting point to later reach an accurate representation of in-use energy consumption, compared to using globally standardised values.

The scientific community widely acknowledges that there remains a substantial disparity between certification values and actual energy or fuel consumption in real-world conditions across all types of powertrains in some regions. This gap is particularly pronounced for plug-in hybrid electric vehicles, as evidenced by numerous scientific studies. The gap may vary per powertrain, region, driving behaviour and other variables that have to be taken into account. However, in some regions such as Europe and Japan, real-world fuel consumption can be monitored through on-board systems. This data is compiled annually and shows the gap between certified values and actual usage for each powertrain. To address this, the guidelines propose using a "discrepancy factor" if data are available for the region in question. If the factor is not available for a specific region, then the factor should be calculated based on best available data and expert qualified assumptions with a minimum value of ‘1’. For vehicles that have more than one mode of operation (e.g. PHEVs working in Charge Depleting and Sustaining mode), distinct discrepancy factors should be applied to accurately characterise each operational mode.

For example, considering a ‘Level 4’ calculation (see 3.2.1**.**), it would also be permissible to use OEM-specific average data to determine the “discrepancy factor” based on analysis of data from their vehicles operating in the real-world for similar powertrains (e.g. for ICEVs, or ZEV/electric powertrains = BEVs, FCHVs, etc.), matched to the defined region of operation (i.e. sale). However, OEM-specific average data cannot substitute publicly available official data, such as EU OBFCM data. Practitioners must disclose details about the fleet sample used to derive the data, including, for example, the sample size and period of collection “Discrepancy factor” can only be quantified at the first time of vehicle registration (0 km). these factors should be defined and updated on a regular basis by the authorities.

The performance of certain powertrains, such as fuel cell and plug-in hybrids, may deteriorate over time because of fuel cell and battery degradation. If "deterioration factors" for the specific modules are available for a particular region, they should be used to account for this issue. If the factor is not available for a region, then the factor should be calculated based on best available data and expert qualified assumptions with a minimum value of ‘1’. Since the deterioration effect covers vehicle aging, it is important to note that this factor may also be reflected in on-board fuel consumption monitoring data used to quantify the “Discrepancy factor”, and hence double counting shall be avoided.

As far as the mere Fuel and/or Energy consumption is considered, the in-use consumption, ECin-use shall be calculated as follows for vehicles with powertrains with only one mode of operation:

Equation 26

Where,

means theenergy consumption or fuel consumption (MJ/km or Wh/km);

means thediscrepancy factor   
(if not available for a region, then 1 should be used)

means thedeterioration factor   
(if not available for a region, then 1 should be used)

For vehicles with powertrains with two modes of operation (for example plug-in hybrid vehicles – PHEVs, or range-extended electric vehicles – REEVs), the in-use energy consumption shall be defined separately for each mode of operation, so that overall in-use energy consumption may be defined. An additional formula shall be used to account also for changes to the share of operation (i.e. in fuel mode 1 – e.g. charge depleting electric, or fuel mode 2 – liquid or gaseous fuel/charge sustaining) that may result from accounting for the discrepancy and deterioration factors for each fuel mode:

Where,

is the in-use Utility Factor (= share of operation) in fuel mode 1 (= electric charge depleting for PHEVs and REEVs), calculated according to the regional vehicle certification procedures. For example, under European WLTP this is defined by the electric range in charge depleting mode.

For regions where the Utility Factor (or equivalent) is defined according to the range operating in Mode 1 / electric charge depleting, the in-use electric range is needed, which shall be calculated according to the following equation:

Where,

is the certified electric range (i.e. in charge depleting mode of operation) in km or miles.

is the in-use electric range (i.e. in charge depleting mode of operation) in km or miles, i.e. including accounting for the discrepancy and deterioration factors.

is the certified electric energy consumption (in MJ/km or Wh/km) in 100% charge depleting mode (i.e. draining the on-board battery).

is the in-use electric energy consumption (in MJ/km or Wh/km) in 100% charge depleting mode.

*Note*: in defining regional discrepancy and deterioration factors for different modes of operation based on real-world energy consumption monitoring, care should be taken to avoid double-counting of the effects of the Utility Factor.

Table 13: Energy consumption certification protocols for main regions

|  |  |  |
| --- | --- | --- |
| Region | Powertrain | Protocol |
| Europe | ICE, HEV, PHEV, FCHV, PEV | WLTP (WLTC 4 phases) |
| Japan | ICE, HEV, PHEV, FCHV, PEV | WLTP (WLTC 3 phases) |
| China | ICE, HEV, PHEV | WLTP (WLTC 4 phases) |
|  | FCHV, PEV (PassCar) | CLTC-P |
|  | FCHV, PEV (Vans/LCV) | CLTC-C |
| Korea | ICE, HEV, PHEV, FCHV, PEV | Combined (FTP75+HWFET) |
| US | ICE, HEV, PHEV, PEV, FCHV | Combined (FTP-75+HWFET) |
| Canada | ICE, HEV, PHEV, PEV, FCHV | Combined (FTP-75+HWFET) |

* + - 1. Calculation of ‘Discrepancy Factor’

A significant gap remains between certification values and real-world energy or fuel consumption across all powertrains. To address this, guidelines suggest applying a "discrepancy factor" where regional data exists. If unavailable, the factor should be estimated using the best available data and expert assumptions, with a minimum value of 1. For vehicles with multiple modes, such as PHEVs, discrepancy factors should reflect each mode of operation separately, as outlined in the previous section.

Table 14: Prioritisation for discrepancy factor calculation

| Proposed prioritisation in order of accuracy and specificity (highest to lowest) | UNECE Level |
| --- | --- |
| OEM-specific average data based on analysis of data from their vehicles operating in the real-world for similar powertrains (i.e. for ZEV/electric powertrains = BEVs, FCHVs, etc.), matched to the region of operation. | Level 4  (Optional, depending on availability) |
| Default values provided by CPs based on methodology development/impact assessment/internal studies on RW gap (OBFCM or equivalent standardised) | Level 3 |
| If OEM/ CPs / supplier-specific data is not available, assume Official monitoring info, inventories like EMEP/EEA Guidebook, COPERT, MOVES, APEI, etc… | Level 2 and below. |

* + - 1. Calculation of ‘Deterioration Factor’

**Fuel Cell Electric Vehicles**

Given the loss in (charge/discharge) efficiency of batteries over the lifetime of the vehicle is reportedly relatively low, and no approaches have been identified to quantify this objectively, it is not proposed to include this aspect for BEVs. However, the situation for fuel cells is different, where efficiency degradation is expected to be significant, particularly for HDVs. Therefore, the following overall methodological approach is proposed for determining fuel cell efficiency degradation over lifetime of the vehicle.

For fuel cells, efficiency losses occur over the operational life of the vehicle. It is proposed to calculate the average loss of efficiency (used to calculate an amended lifetime average energy consumption in MJ/km) based on the fuel cell durability assumptions and operational lifetime km, as outlined below. Fuel cell durability is defined as the number operational hours to reach 10% degradation of the original fuel cell rated power (in kW). The following general methodological approach is therefore proposed to determine the average loss in efficiency over the service lifetime of a vehicle using fuel cell based powertrain (i.e. an FCHV or FC-REEV powertrain).

Potential for further development of knowledge in this area is expected. To adjust to this perspective, TSLCA allows OEM or suppliers to propose an alternative owned methodology to define operational fuel cell efficiency loss, as long as it is validated by an independent third party expert on fuel cells.

For operation on hydrogen for FCHV – amended to account for fuel cell degradation, the maximum efficiency loss should be to a maximum of 5% degradation over the life of the vehicle, i.e. in the case where FC [lifetime energy] >FC [max energy], where a fuel cell replacement will be required in any case:

Where:

EnCon [AvLife] means the average input hydrogen energy consumption in MJ/km over the entire lifetime of the vehicle.

EnCon [Start] means the input hydrogen energy consumption in MJ/km at the start of the vehicle life (i.e. before any FC degradation), as defined in vehicle certification (i.e. before any real-world adjustments being applied).

FCHV [lifetime energy] means the lifetime vehicle operational electrical energy requirement (i.e. fuel cell output, kWh) based on the input hydrogen energy consumption (in kWh/km), the lifetime activity (in km) and the average fuel cell efficiency (%).

FC [max energy] means the maximum energy delivered by the fuel cell (in kWh) over the defined service life (in hours) at the average fuel cell running power (in kW).

NB: Fuel cell durability/service life is defined as based on the number of operational hours to 90% of original peak power rating, hence an efficiency loss of 10% over the life of the fuel cell = an average reduction in overall efficiency of 10%/2.

The (i) maximum lifetime energy that can be delivered by the fuel cell before reaching 10% degradation (FC [max energy]), and (ii) fuel cell electric vehicle lifetime energy requirements (FCHV [lifetime energy]) are calculated as follows:

(i) Fuel cell lifetime maximum electrical energy output (= FC [max energy]):

Where:

Fuel cell average running power (kW) means the maximum rated fuel cell power (kW) \* average operation % of rated fuel cell power.

(ii) Fuel cell electric vehicle lifetime electrical energy requirement (i.e. energy output from fuel cell)

(= FCHV [lifetime energy]):

Where:

EnCon [Start] means the input hydrogen energy consumption in MJ/km at the start of the vehicle life (i.e. before any FC degradation), as defined in vehicle certification (i.e. before any real-world adjustments being applied).

EnConConversion means the conversion factor for converting MJ to kWh = 3,6 MJ/kWh

*Prioritisation for fuel cell durability assumptions:*

The following recommended prioritisation is proposed for the underlying assumptions of fuel cell life and average operational efficiency, with the choice of which option is most appropriate or feasible left to the practitioner (i.e. depending on the availability of data and objective of the study).

The different options are listed in order of accuracy and preference. The third option is proposed as a mandatory minimum default approach, where sufficient information is not available for the other options.

Table 15 : Prioritisation for fuel cell durability assumptions

| Proposed prioritisation in order of accuracy and specificity (highest to lowest) | UNECE Level |
| --- | --- |
| OEM / supplier specific methodological approach to define operational fuel cell efficiency loss, if validated by an independent third-party expert on fuel cells. | Level 4  (Optional, depending on availability) |
| OEM / supplier specific data on fuel cell life (to 10% loss in power) and average operational power level (as % of the peak power of the fuel cell, according to regulatory testing cycles) | Level 4  (Optional, depending on availability) |
| If OEM/ supplier-specific data is not available, assume an operational life of 6000/24000 hours (for LDVs/HDVs)(a), an efficiency of 55%/52% (at the start of the fuel cell life for LDVs/HDVs)(b), with efficiency loss of 10% over the life of the fuel cell, and running at an average of 25%(c)/25%(d) (for LDVs/HDVs) of the peak power rating. | Level 3 and below. |

*Notes: (a) based on 2025 targets from FCH2JU KPIs FCH 2 JU - MAWP Key Performance Indicators (KPIs) - European Commission (europa.eu); (b) based on Ricardo review of typical fuel cell efficiency for LDV and HDV applications; (c) based on Fuel Cell Electric Vehicle Durability and Fuel Cell Performance (nrel.gov), (d) average approximation based on Ricardo analysis of VECTO simulation results for different HDVs and cycles.]*

**Plug-in Hybrid Electric Vehicles**

The proposed methodology should account for the effect of the change in the battery capacity (i.e. State of Health) over the lifetime of the vehicle and its impact on electric range and via the Utility Factor UF on the share of operation in charge sustaining and charge depleting modes, which ultimately affects the combined fuel consumption and CO2 emissions

The average lifetime in-use electric range for vehicles operating in dual-mode shall be calculated according to the following formula, accounting for the average loss in capacity (i.e. as defined by the battery SOH – state-of-health):

Equation 27

Where,

is the certified electric range (i.e. in charge depleting mode of operation) in km or miles.

is the in-use electric range (i.e. in charge depleting mode of operation) in km or miles, i.e. including accounting for the discrepancy and deterioration factors.

is the net usable battery capacity (in kWh) available at the start of the vehicle lifetime.

is the average net usable battery capacity (in kWh) available over the lifetime of the vehicle, which may be defined as the average of the capacity available at the start of the vehicle lifetime, and the capacity left at the end-of-life of the vehicle (i.e. according to the state-of-health – SOH), i.e. according to the following equation:

Equation 27

=

And where,

is the average net usable battery capacity (in kWh) available at the end of the vehicle lifetime.

is the average battery state-of-health (SOH) in % of the original capacity at the end-of-life of the vehicle (or battery, whichever comes first).

The average available battery capacity at end-of-life of the vehicle (or ) may be defined according to alternative methodologies, as outlined in [Table xxxxx] below. Where OEM / supplier specific calculated value for end-of-life available battery capacity or is not available, the following formula shall be used to estimate the , which assumes as an approximation a linear relationship for battery degradation based on the number of full charge/discharge cycles:

Equation 27

)

Where,

is the operational cycle lifetime (i.e. number of full charge/discharge cycles) of the battery to reach 80% SOH.

is the average number of full battery charge/discharge cycles over the use-stage vehicle lifetime, which may be estimated according to the following formula:

Equation 27

Where,

Service Life = number of km driven over the use stage lifetime.

Charging Losses = charging losses included within the certified or in-use vehicle electricity consumption in charge-depleting mode of operation.

Other parameters are defined as earlier.

Table 16: Prioritisation for average battery SOH reduction assumptions

| Proposed prioritisation in order of accuracy and specificity (highest to lowest) | UNECE Level |
| --- | --- |
| OEM / supplier specific methodological approach to define operational battery SOH loss, if validated by an independent third party expert on batteries. | Level 4  (Optional, depending on availability) |
| OEM / supplier specific data on battery cycle life (to 80% loss in capacity), according to regulatory durability testing requirements. | Level 4  (Optional, depending on availability) |
| If OEM / supplier-specific data is not available, assume an operational cycle life of 2000/3000 charge/discharge cycles hours (for LDVs/HDVs) to calculated the average SOH according to the defined formula. | Level 3 and below. |

*Notes: xxxx*

* + - 1. Quantification of Leakages

**Methodology for EVAP, Hydrogen, LNG/CNG emissions.**

*Evaporative emissions*

Evaporative emissions occur in vehicles due to the nature of the fuel system and the volatility of gasoline. As part of the homologation process, vehicles are subjected to emissions testing to ensure compliance with regulations, including limits on evaporative emissions.

Limits of evaporative emission (2g to 0.5g of HC) and duration of measurement (24h to 48h) varies between different regions of the world (worst case limit will be 2g / 24h)

A rough estimation of evaporative emission can be done by taking into account the evaporative emission by assuming this as a worst-case situation.

Example:

Vehicle lifetime: 10 years

Lifetime millage = 200 000 km

Maximum permitted evaporative emission = 2 g/2days

Lifetime evaporation: 4.9 litters

Fuel consumption: 5 litter / 100 km

Lifetime fuel consumption: 10 000 litters

Proportion of use phase: 0.05%

Two possible options:

⦁ Option 1 (OICA proposal): exclude from calculation. Justification: due to its nonsignificant impact

⦁ Option 2: calculate taking into account the evaporative emission limit of the region

*Hydrogen leakage*

Hydrogen emissions are not commonly included in life cycle inventory (LCI) datasets, highlighting the need for a standardized approach to estimate hydrogen leakage rates for consistency in modelling.

Hydrogen emissions primarily occur during production and distribution, mainly due to fugitive leakage. To a lesser extent, emissions can also arise directly from hydrogen-fuelled vehicles, although standardized test methods to quantify these emissions are currently lacking. Hydrogen can also escape from combustion engines and storage systems, particularly in the case of liquefied hydrogen.

Recent research suggests that hydrogen leakage rates across the supply chain may be comparable to methane losses in the natural gas supply chain. Estimates indicate that green hydrogen supply chains could experience net leakage rates between 2.6% and 6.9% (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022).

* + - 1. Quantification of fluorocarbons emissions

**[List HFCs and address impact]**

Refrigerant leakage has a direct environmental impact, primarily due to the use of hydrofluorocarbons (HFCs), a class of synthetic gases that replaced hydrochlorofluorocarbons (HCFCs). HCFCs were phased out due to their destructive effects on the ozone layer, attributed to their chlorine content. While HFCs do not pose a significant threat to the ozone layer, they are potent greenhouse gases with high global warming potential (GWP).

Although HFCs are considered short-lived climate pollutants with an atmospheric lifespan of approximately 15 years, many exhibit strong global warming effects. One of the most widely used and concerning refrigerants, HFC-134a, has a GWP100 of 1,300, making it a significant contributor to climate change.

In automotive applications, HFC leakage is nearly unavoidable, leading to continuous emissions throughout a vehicle's lifespan.

Processes concerning AC (Air Conditioning) use:

⦁ Air conditioning refrigerant leakage volume [kg/year]

⦁ Fluorocarbon GWP100

⦁ Fluorocarbon production intensity [kg-CO2e/kg-fluorocarbon]

⦁ Years of use [years]

The refrigerants leakage shall be calculated as follows:

Equation 27

* + - 1. Quantification of vehicle emissions exported out of region of sales

Ideally, the GHG emissions related to operation of vehicles exported from the country where they are sold/used shall be evaluated by using energy consumption performance (and fuel mix) and vehicle lifetime (and km activity) of the country where they are exported, used and eventually disposed/recycled. However, to avoid unnecessary complexity, if data in the country to which they are exported cannot be tracked down or it is difficult to grasp the needed values of the country where they are exported, used and eventually disposed/recycled, a simplified approach can be adopted. Hence, the full lifetime period (and km activity) shall be considered but the energy consumption performance (and fuel mix) and vehicle life (activity) of the primary region of sale/use are adopted for the calculations. For those countries and regions that export used vehicles, the actual average vehicle lifetime is higher than the average period during which the vehicles are used domestically.

Therefore, for all vehicles, the lifetime used to calculate life cycle emissions shall align with the average age of vehicles at the time of recycling, considering only those registered and recycled within the same country. Studies considering split use among different regions/countries in a more detailed way could be performed for scenario analysis.

* + 1. Data Collection and data type

Data shall be collected for the item outlined below. Activity data shall be collected as primary data. In case of the difficulty, secondary data may be applied to activity data. GHG emission intensity data shall be collected as secondary data. Secondary data source shall be reported. The following data shall be collected:

Process of driving

⦁ Certified fuel or electricity consumption

⦁ Discrepancy factor

⦁ Degradation factor

⦁ Utility Factor/share of modes of operation for dual-fuel/operation vehicles (e.g. PHEVs, REEVs, etc.)

⦁ GHG emission factor for fuel and energy [SG6]

⦁ Electric charging efficiency if not included in the certification values [SG6]

⦁ Vehicle service life (in years)

⦁ Vehicle lifetime activity (in km)

⦁ Leakages (evaporative emissions, hydrogen, LPG/CNG, etc…)

⦁ Boundary conditions:

⦁ average ambient temperature

⦁ vehicle occupancy rates for potential scenario analysis

Process of emitting fluorocarbons

⦁ Fluorocarbon emissions

⦁ GHG emission factor for emitting fluorocarbons

Process of producing maintenance parts and consumables

⦁ List of maintenance parts and consumables

⦁ Frequency for the maintenance parts

⦁ Frequency for consumables

⦁ GHG emission factor for producing maintenance parts and consumables

Process of transporting maintenance parts and consumables

⦁ List of maintenance parts and consumables

⦁ Frequency for the maintenance parts

⦁ Frequency for consumables

⦁ Distance

⦁ GHG emission factor for transporting maintenance parts and consumable

Vehicle activity out of region of sales

⦁ Service life should be based upon the average lifetime up to the point of scrappage for a country/region, i.e. excluding de-registrations for exports for further use in other regions.

* + - 1. Primary data collection items

The following data shall be collected as primary data:

* + - * 1. Process of driving

⦁ Certified fuel or electricity consumption

⦁ Discrepancy factor

⦁ Degradation factor

⦁ Utility Factor/share of modes of operation for dual-fuel/operation vehicles (e.g. PHEVs, REEVs, etc.)

⦁ Electric charging if not included in the certification values [SG6]

⦁ Leakages (evaporative emissions, hydrogen, LPG/CNG, etc…)

⦁ Vehicle service life (in years)

⦁ Vehicle lifetime activity (in km)

* + - * 1. Fluorocarbons emissions

⦁ List of main Fluorocarbons to be included

* + - * 1. Process of producing maintenance parts

⦁ List of maintenance parts and consumables

⦁ Maintenance frequency of the maintenance parts and consumables

Process of transporting maintenance parts

⦁ List of maintenance parts and consumables

⦁ Maintenance frequency of the maintenance parts and consumables

* + - * 1. Vehicle activity out of region of sales

Out of scope – all vehicles will be characterized with data from region of sales up to the point of scrappage.

* + - 1. Secondary data collection items

The following data shall be collected as secondary data, provided and regularly updated by the authorities and contracting parties. The default values in Appendix Figure X may be adopted, or data collected independently by the party performing the calculation may be used. In this case, the validity of their own data is subject to verification.

Process of driving

⦁ GHG emission factor for burning fuel

⦁ Leakages

⦁ boundary conditions:

⦁ average ambient temperature

⦁ vehicle occupancy rates for potential scenario analysis

Fluorocarbons emissions

⦁ GHG emission factor for emitting fluorocarbons

Process of producing maintenance parts

⦁ GHG emission factor for producing maintenance parts

Process of transporting maintenance parts

⦁ GHG emission factor for transporting maintenance parts

**Vehicle activity out of region of sales**

Out of scope – all vehicles will be characterized with data from region of sales up to the point of scrappage

Table 17: Processes and Data to be included in Use stage

| Processes | Activity data | GHG emissions Intensity Data |
| --- | --- | --- |
|  |  |
| Driving | Certified Fuel consumption [l/100km] and/or electricity consumption [kWh/100km] |  |
|  | Discrepancy factor RW data |
|  | Degradation factor |
| xEV charging efficiency if not embedded in Certification values | Average xEV charging efficiency if not included in TA value |
| Vehicle lifetime (years), and reference flow (km) | Vehicle recycling statistics/ Nationally authorized statistics/OEM's average vehicle life |
|  | GHG emission factor for burning fuel |
| Emitting Fluorocarbons | Fluorocarbon emissions | GHG emission factor for emitting fluorocarbons |
| Maintenance and Consumables Production | List of maintenance parts and consumables | Fixed percentage of upstream emission attributed to maintenance processes depending upon powertrain, service life, vehicle segment and region of use. |
| Frequency of replacement |  |
|  | GHG emission factor for producing maintenance parts |
| Maintenance and Consumables Transportation | List of maintenance parts and consumables |  |
| Frequency of replacement |  |
| Transport Weight [kg] Transport Distance [km] | GHG emission factor for transporting maintenance parts |
| Maintenance and Consumables End of Life | To be evaluated in line with **Erreur ! Source du renvoi introuvable.** | To be evaluated in line with **Erreur ! Source du renvoi introuvable.** |
| Driving in secondary countries | Out of scope | Out of scope |
| Second life of components | Out of scope | Out of scope |

* + 1. Application of the energy modelling schemes [SG6]

General rules must be referred to the section 3.2.10.

**Future Changes in Energy Mix:**

Practitioners shall also account for any expected changes in the fuel or electricity production pathways during the lifetime of the vehicle. (detailed methodology shall be considered)

The energy mix for the use stage shall be based on the latest available dynamic scenario following the defined hierachy for prioritising this outlined below; a static scenario may be used only where a dynamic scenario is not available for the geographical region of interest, or to meet specific corporate GHG emission reporting requirements (if relevant).

For renewable fuels, future scenario issued or recognized by an official source or by a regional association can be considered, specifying the future evolution of the share of renewable fuel versus fossil fuel in a specific geographical region or country of interest.

Specifically, the following recommendations are made on how to model electricity inputs to the use phase:

**Use phase electricity:**

1. A scenario for the expected future evolution of the electricity grid mix in the geographical region of interest shall be selected, according to the following order of preference:

The official published scenario specifically for electricity supply mix for the country or geographical region of interest.

⦁ The official general scenario based on currently implemented policy for the country or geographical region of interest (providing this has been updated within < 3 years).

⦁ Stated Policies Scenario (STEPS) from the most recent International Energy Agency’s World Energy Outlook (IEA WEO) report, for the geographical region of interest.

⦁ (reinstate) If none of the previous options above are available for the geographical region of interest, dispatch modelling may be used within the reference year.

2. The grid mix composition for each year of vehicle operation shall be estimated (i.e., the shares Si,n of electricity supplied by each technology i in the year n), by applying linear interpolation between the respective electricity supply shares reported for the nearest pre-defined time horizons in the scenario selected at point 1 above.

3. The average representative grid mix composition over the full service life of the vehicle shall be calculated as follows:

⦁ By default, as the arithmetic average of the individual electricity supply shares at point 2 above. Doing so entails the implicit simplifying assumption that the vehicle’s use is distributed homogenously over its full service life (i.e., L/N km are driven each of the N years of operation, where L = total lifetime activity).

⦁ Alternatively, if there is reason to expect that the vehicle’s use intensity will change over time, and if year-specific activities may be estimated with sufficient confidence, then a more refined (and accurate) modelling approach may be adopted, employing a weighted average (as opposed to a simple arithmetic average) of the individual shares ***Si,n*** of electricity supplied by each technology ***i*** in the year ***n***, i.e.: , where ***Wn = An/L*** (***An*** = vehicle activity in year ***n***, ***L*** = total lifetime activity).

4. A bespoke grid mix model shall finally be built using the grid mix composition calculated at point 3 above and leveraging the most up-to-date database processes available for the individual electricity generation technologies. The resulting grid mix thus modelled shall be used to estimate the Emission Factor of the electricity input to the use phase of the vehicle.

* + 1. Maintenance

Vehicle maintenance refers to the recommended regular inspection defined by the vehicle manufacturer in order to ensure its optimal performance, longevity, and safety by preventing issues from arising and preserving its overall condition. Maintenance in the use stage of a vehicle's life cycle can have a none-negligible impact on its carbon footprint. Recent life cycle assessment studies estimate that the greenhouse gas emissions produced by vehicle maintenance during the use stage can range from 2%- 5% of total vehicle carbon footprint, depending on the powertrain type and vehicle segment.

* + - 1. Maintenance scope

Two types of maintenance are included in this methodology:

⦁ *Consumables:* These are materials, fluids, and components that are regularly used, replaced, or replenished during the operation and maintenance of a vehicle. These items typically have a limited lifespan and require periodic replacement to ensure the vehicle's proper functioning, safety, and performance. This includes items such as engine oil, transmission fluid, brake fluid, windshield washer fluid, filter, brake pads and discs, etc… For these items recycling is not required, and hence only carbon footprint related to material and production shall be considered.

⦁ *Maintenance parts:* This refers to the replacement of parts due to normal wear and tear, including components that are not designed to last the entire lifespan of a vehicle, such as the brakes, clutch, tyres, starter battery etc... The range of parts that need to be replaced during maintenance varies between different cars, depending on factors such as the driver's behaviour, road conditions and other variables (weather etc.). Hence, it is difficult for OEMs to recommend a frequency of exchange of these parts to the customer. The frequency of maintenance of such parts can only be estimated with acceptable probability through statistical analysis and a generic frequency of these parts shall be used for the purpose of carbon footprint estimation. For these parts recycling aspects must be considered and are same as that of original production parts.

Other repair or maintenance activities not included in the methodology are:

⦁ *Unexpected repairs (i.e., accident):* Looking at the challenge of estimating the consequences of road accidents and premature fails (for components expected to last for service life), the guideline does not address such cases. Furthermore, impact of such cases is not very significant compared to overall carbon footprint of a car.

⦁ *Cleaning operations:* Effect of car wash may not be a significant factor in the calculation as it is a very small fraction of the overall carbon footprint of a car. Hence, the guideline does not address cleaning operations.

* + - 1. Maintenance carbon emission estimation

Since the carbon footprint related to maintenance occurs after the vehicle is placed on the market, it can only be calculated based on the known frequency specified by the vehicle manufacturer.

For level3 and level 4, there are two possibilities (considered in a hierarchical order):

⦁ a) List of maintenance parts/consumable and associated frequency provided by the manufacturer.

⦁ b) List of maintenance parts/consumable not available

**Maintenance Data Availability**

If list of maintenance parts/consumable and associated frequency is provided by the OEM then the following estimation shall be used.

As this will reflect the effort from the OEM to reduce carbon footprint of maintenance, OEM should provide all the assumptions (list, frequency, carbon emission) used for carbon footprint estimation.

Equation 27

Where,

i Consumable/ maintenance parts

Maintenance frequency of the consumable/maintenance parts defined

Carbon emission factor of the consumable/maintenance parts as used for calculation of upstream emissions

**Determination of list of consumables and parts**

The following table provides a list of consumables and parts for guidance and should not be considered as exhaustive. The manufacturer should provide the list adapted to the powertrain and vehicle segment for which the carbon footprint is calculated.

Table 18: List of consumables and maintenance parts

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Petrol | Diesel | CNG | NOVC-HEV | OVC-HEV | Pure EV | FCHV | OVC-FCHV | H2-ICE | . . . |
| Consumables | Engine coolant | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | ✓ |  |
| Engine lubricant | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | ✓ |  |
| Screen wash | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Brake fluids | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Electric drive unit fluids | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | - |  |
| Transmission fluid | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| AC Refrigerant | ✓ | ✓ | ✓ | ✓  Under discussion | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| AdBlue/Urea/Reagent | - | ✓ | - | - | - | - | - | - | - |  |
| Maintenance parts | Passenger air filter | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Engine air/oilfilter | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | ✓ |  |
| Spark plug | ✓ | - | ✓ | ✓ | ✓ | - | - | - | - |  |
| Windshield wiper blades | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Tyres | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Brake linings | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Brake discs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| SLI battery (12V) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
| Aftertreatment | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | ✓ |  |
| Traction battery | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | - |  |
| Fuel cell | - | - | - | - | - | - | ✓ | ✓ | - |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

The impacts resulting from different maintenance items can vary greatly, with some items being less significant and others usually accounting for a significant proportion of overall impacts. It is therefore proposed that the following items should be mandatorily included (where relevant for a given vehicle powertrain type):

⦁ Consumables: AdBlue/Urea, Refrigerants for HVAC (heating, ventilation and air conditioning) systems

⦁ Maintenance and wear parts: Tyres, starter battery (i.e. 12V), brake pads, brake discs, traction/storage battery (i.e. for electric powertrain vehicles), [fuel cell stack (for fuel cell electric vehicles)], additional auxiliary batteries (if relevant for commercial vehicles – e.g. for temperature controlled payload areas).

For certain items, including mandatory items, replacements might not be needed in the vehicle’s typical operational lifetime based on an OEM’s assessment. In these cases, exclusions made on this basis should be justified.

**Determination of Frequency**

For most maintenance items frequency can be simply calculated by the following two approach:

Frequency by distance

Equation 27

Frequency by duration

Equation 27

In case OEM recommends frequency by both distance and duration, both calculations should be performed, and most conservative frequency should be considered for the carbon footprint estimation.

In case traction batteries and fuel cells systems are designed in the way that no replacement is needed during the vehicle lifetime, they shall not be included in the life cycle analysis. This is generally the case of passenger cars, however, due to the major impact of battery and fuel cell on the vehicle lifecycle analysis, the exclusion of these systems from the study shall be checked and justified.

The following approaches are adopted to provide a structured hierarchy for determining the need for replacements of traction batteries and fuel cells, which could be applied across all types of LCA study (i.e. for general analyses and scientific studies, as well as product LCA or prospective LCA).

***Methodology for calculating the need for traction battery replacement(s)***

The following recommended prioritization is proposed for the underlying assumptions of traction battery replacement, with the choice of which option is most appropriate or feasible left to the practitioner (i.e. depending on the availability of data and objective of the study). The different options are listed in order of accuracy and preference. It is recognized that OEMs and battery suppliers will likely have more sophisticated battery performance modelling supporting their product development and specification. The most important point is that in all cases the study should clearly indicate whether a battery replacement is included or not, and the basis/explanation for this assumption.

Table 19 : Prioritisation for traction battery replacement

| Proposed prioritization in order of accuracy and specificity (highest to lowest) | UNECE Level |
| --- | --- |
| OEM / supplier specific methodological/modelling approach to define the need for a battery replacement (or not) over the operational life of the vehicle. An explanation/justification for the result should be provided. | Level 3/4  (Optional, depending on availability) |
| Standardized methodology based on battery cycle life and lifetime operational activity (below). An explanation/justification for the result should be provided. | Level 3/4 or below |
| Simple assumption on whether battery replacement is needed or not, including explanation for this. | Level 2 and below. |

For vehicle traction batteries, the following approach for accounting for the frequency of energy storage replacement for Option 2, which is based on a combination of parameters including the anticipated battery cycle life (i.e. number full charge/discharge cycles)[[11]](#footnote-12). This methodology also provides a dynamic link to the vehicle battery capacity and the lifetime activity/service life (as defined in the study Goal & Scope), which can be used in product LCA, prospective LCA or other more generic studies.

The methodology for determining the number of traction battery replacements is as follows (i.e. where a value of N > 1 means at least one replacement is likely to be needed):

Equation 27

Where:

**N** = Total number of traction batteries needed over the vehicle lifetime

**C** [Battery usable] = usable (i.e. ‘net’) traction battery capacity in kWh

**CL** [Battery] = average battery cycle life – number of full charge/discharge cycles (within the usable capacity)

**A** [Lifetime] = vehicle lifetime activity (in km) \*

**E** [Average] = vehicle average electrical energy consumption, in kWh per km

*\*As a sensitivity it is recommended to also explore the potential number of replacements needed based on the warrantied number of km for the battery (where this is present).*

In the absence of manufacturer-specific data on the battery cycle life (parameter ‘CL’ above), then it is proposed to use a value of 2000 charge/discharge cycles, which is representative of a typical value for current technology. Should the battery come with an expected calendar lifetime lower than the defined vehicle lifetime in the Goal & Scope of the LCA study, then a replacement will also be required.

***Methodology for calculating the need for fuel cell system replacement(s)***

Fuel cell durability(/life) is defined as the number operational hours to reach 10% degradation of the original fuel cell rated power (in kW)[[12]](#footnote-13). The following general methodological approach is therefore proposed to determine the need for one or more fuel cell replacements over the service lifetime of a vehicle using fuel cell based powertrain (i.e. an FCHV or FC-REEV powertrain), consistent with the similar methodology proposed for fuel cell efficiency degradation (see earlier Section 4.3.3.2).

(Recognising the potential for further development of knowledge in this area, it is also proposed to that should an OEM / supplier specific methodological approach be subsequently developed to define operational fuel cell efficiency loss and/or replacements, this would also be acceptable, if validated by an independent third party expert on fuel cells.)

***Fuel cell lifetime max energy output (= FC [max energy]):***

Equation 27

Where:

Fuel cell average running power (kW) = maximum rated fuel cell power (kW) \* average operation % of rated fuel cell power

*Fuel cell vehicle lifetime energy requirement (energy output from fuel cell) (= FC [lifetime energy]):*

Equation 28

Where:

MJ/km = hydrogen energy input to the vehicle, i.e. hydrogen energy consumption.

The number of fuel cells needed (and therefore the number replacements) is defined by the ratio of the vehicle’s lifetime energy requirements and the maximum fuel cell lifetime energy delivered:

Equation 29

**Maintenance Data not available**

The maintenance parts/consumable are already included in the upstream emission as they are part of the vehicle before placing the vehicle on the market. Hence, if list of maintenance parts/consumables is not available then a fixed percentage of upstream emissions can be attributed to maintenance depending upon powertrain, service life, vehicle segment and region of use.

These factors can be defined by each region through statistical analysis. For all passenger cars it can be assumed that there is no variation within segments.

Equation 30

Where,

: means themaintenance frequency as defined in table 2.2

: means thecarbon footprint of material acquisition stage,

means thecarbon footprint of production stage

: means thecarbon footprint of recycling stage for maintenance parts, to be evaluated in line with Section 3.2.13.

Table 20: Default maintenance frequency as a function of powertrain

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Powertrain | Petrol | Diesel | CNG | NOVC-HEV | OVC-HEV | Pure EV | FCHV | OVC-FCHV | H2-ICE | . . . |
| fmaintenance | YY % | ZZ % |  |  | Under discussion |  |  |  |  |  |

* 1. End of life
     1. Levels in disposal and recycling stage

As introduced in paragraph 3.2.1., the analysis of global warming potential can also be carried out for Disposal and recycling stage in different levels of detail according to the chart below.

Table 21 : Level concept of disposal and recycling stages

|  |  |  |  |
| --- | --- | --- | --- |
|  | Level Concept of Disposal and Recycling stage | | |
|  | 1. Activity data of each EoL processes | 2. Intensity data of each EoL processes | 3. Recovered parts disposal and recycling process |
| e.g. Weight of vehicle, parts, material etc | e.g. Dismantling and shredding/sorting, ASR thermal recovery, Materials. recycle etc | e.g. Tyre, Lead battery, Driving battery, etc |
| Level 1 | Global or Generic secondary data | Global or Region or Country primary data or secondary data can be chosen, depend on the study | Global or Region or Country process can be chosen, depend on the study |
| Level 2 | Primary data (BoM&MDS) |
| Level 3 | Global or Region or Country primary data or secondary data shall be specified by LCA owner (e.g. CPs) | Global or Region or Country process shall be specified by LCA owner (e.g. CPs) |
| Level 4 |

* + 1. System boundaries

The system boundary of the disposal and recycling stage as well as its calculation method are outlined below.

Figure 26: System boundaries of Disposal and Recycling stages

E2 b-1

E2 c)

E2 e)

Disposal

Recycle

Incineration

E2 a-2

E2 b-2

E2 d)

E2 f-1)

E2 q-1)

E2 f-2)

E2 q-2)

Disposal

Disposal

Incineration

E5

E2 a-1

transport

transport

transport

Disposal

Disposal

Disposal

Incineration

Incineration

Recycle

E2 f-3)

Recycle

Recycle

Repurposing

Schredding / Sorting

E3

E5

E5

Scrap

ASR

ASR transport

ASR recycling

Residue

Residue transport

Landfill

Example \* 1

e) waste oil

g) catalytic

converter

transport

transport

Process to be calculated

Process to be calculated as Modular Burdens and Benefits method

Inputs, Outputs

Recovered parts

a) tyre

b) lead battery

c) Airbag

d) AC refrigerant

f)Drive battery

h)

transport

E5

**ELV**

ELV transport

Dismantl-ing

Dismantled ELV transport

E1

**ASR**

Dismantled ELV

System boundary of Disposal and Recycling stage

Disposal and Recycling stage

GHG emissions=Σ(

GHG emissions= Activity data × Intensity data

E1

E5

**E2 b-1)**

**E2 c)**

Whole Dismantled Vehicles Recycling

E4

Materials Recycle

ELV

**E2 f-1)**

Process to be calculated as Modular Burdens and Benefits method

Process to be calculated as Modular Burdens and Benefits method

Process to be calculated

**E5**

\*1 The recovered parts type with disposal/recycling process shall be specified and evaluated based on the regulation or market observation in each country

**E2 g-1)**

Recycle Content Method basis

Modular Burdens

and Benefits method

GHG emissions) and Σ( GHG emissions)\*2

\*2To be reported separately

Scrap

Data collection applies to the processes outlined below.

E1; End-of-life vehicle (ELV) dismantling and shredding/sorting process

E2; Recovered parts disposal and recycling process

E3; Automobile shredder residue (ASR) disposal and recycling process

E4; Materials recycling processes

E5; Transport processes

* + 1. Data collection and data types

Data shall be collected for the item outlined below. Activity data shall be collected as primary data in level 2 or 3 or 4. The secondary data may be applied to activity data in level 1. GHG emission intensity data shall be collected as primary or secondary data in all levels. Scenarios for secondary data and secondary data source shall be reported. Secondary data may be referred, among others, to the following data set.

□ Environmental Footprint (EF) compliant data sets

□ IDEA

□ JAMA CFP guideline

Table 22: Data types for disposal and recycling stages

| Processes | | | Activity data | GHG emissions intensity data |
| --- | --- | --- | --- | --- |
| (Primary data basis) | (Secondary data basis) |
| E1; End-of-life vehicle (ELV) dismantling and shredding/sorting process | | | ･ELV Weight [kg] | ･ELV dismantling and shredding/sorting [kgCO2e/kg] |
| E2; Recovered parts disposal and recycling process -Example-  Remarks)  The recovered parts type with disposal and recycling process shall be specified and evaluated based on the regulation or market observation in each country | a) Tyre | a-1) Disposal, Incineration | ･Tyre weight [kg] ･Wearing ratio [%] | ･Tyre incineration with thermal and electricity recovery [kgCO2e/kg] and Disposal [kgCO2e/kg] which may include residue landfill and transport. |
| a-2) Recycle | ･Material weight to which CFF is applied | ･Modular Burdens and Benefits method of each material [kgCO2e/kg] |
| b) Lead battery | b-1) Disposal, Incineration | ･Lead battery weight [kg] | ･Plastic parts incineration with thermal and electricity recovery [kgCO2e/kg] and Disposal [kgCO2e/kg] which may include lead scrap treatment and electrolyte neutralization treatment and transport. |
| b-2) Recycle | ･Material weight to which CFF is applied | ･Modular Burdens and Benefits method of each material [kgCO2e/kg] |
| c) Airbag | | ･Air bag weight [kg] | ･Airbag proper disposal [kgCO2e/kg] |
| d) Air conditioner (AC) refrigerant | | ・AC refrigerant weight [kg], filled in air conditioner at vehicle production. | ･AC refrigerant (fluorocarbons) disposal [kgCO2e/kg], which may include fluorocarbons destruction, CO2 from destruction and transport |
| e) Waste oil | | ･Waste oil weight [kg] | ･Waste oil incineration with thermal and electricity recovery [kgCO2e/kg] |
| f) Drive battery | f-1) Disposal, Incineration | ･Used battery pack weight[kg] ･Combustibles material weight in used battery packs [kg] | ･Used battery pack proper treatment [kgCO2e/kg] which includes battery pack incineration (where allowable) with thermal and electricity recovery and Disposal which may include residue landfill and transport. |
| f-2) Secondary use (Repurposing) | ･Number of Driving battery pack | ･Modular Burdens and Benefits method for the battery repurposing[kgCO2e/pack] |
| f-3) Material recycle | ･Material weight to which CFF is applied and battery cell weight to which CFF is applied | ･Modular Burdens and Benefits method of each single material [kgCO2e/kg Material] recovered from the battery disassembly process, and Modular Burdens and Benefits method of battery cells specific recycling process [kgCO2eq/kg battery cells], if applicable according to regional regulations |
| g) Catalytic converters | | ･Catalytic converters weight [kg] | ･Catalytic converters disposal [kgCO2e/kg], which may include residue landfill after recycling process |
| ･Material weight to which CFF is applied | ･Modular Burdens and Benefits method of each material [kgCO2e/kg] |
| E3; Automobile shredder residue (ASR) disposal and recycling process | ASR | | ･ASR thermal recovery material weight [kg] | ･ASR disposal [kgCO2e/kg] which include ASR incineration with thermal and electricity recovery and residue landfill |
| Wood (mainly for truck/bus use) | | ･Wood material weight [kg] | ･Wood disposal [kgCO2e/kg], which may include the incineration with thermal and electricity recovery , not including CO2 absorption effect |
| E4; Materials recycling processes | | | ･Material weight to which CFF is applied | ･Modular Burdens and Benefits method of each material [kgCO2e/kg] |
| E5; Transport processes | | | ･Transport weight [t]  ･Transport distance [km] | ･Transport ton-km GHG intensity [kgCO2e/t/km] |

* + 1. Scenario
       1. Recycling modelling for second life parts

The second life parts for Remanufacturing, Reuse or Repurposing shall be evaluated based on regulation or market observation, data availability for parameters and verification criteria. In any case the second life parts traceability shall be confirmed with following recommendation of recycling modelling.

Table 23: recycling modelling recommendations for second life

|  |  |  |
| --- | --- | --- |
| Second life application | Definition | Recycling modelling Recommendation |
| 1. Remanufacturing | ELV parts recycling  to new vehicle parts | RCM |
| 2. Reuse | ELV parts recycling  to repair vehicle | RCM |
| 3. Repurposing | ELV parts recycling  to another function in other industries  e.g. Drive battery in EoL EV to the stationary battery in a building | CFF |

RCM formula for Remanufacturing or Reuse shall be referred to C\_(M,RCM) formula in 3.2.13.2 Material recycling modelling. CFF formula for Repurposing shall be referred to C\_(M,MBBM) formula in 3.2.13.2 Material recycling modelling and (f-2) Secondary use (Repurposing) of E2; (f) Drive battery in 4.4.8 GHG calculation for each process. The type of date for RCM or CFF parameter shall be confirmed according to the regulation or market observation.

* + 1. EoL emissions treatment of ELV exported out of region of sales

Ideally, the EoL GHG emissions of vehicles exported from the country where they were originally sold and used shall be evaluated based on the EoL processes of the country where they are eventually used and disposed/recycled. However, to avoid unnecessary complexity, if the country to which the vehicle is exported cannot be tracked or the EoL process of the country where they were exported, used and disposed/recycled cannot be determined, a simplified approach can be adopted. In such cases, the EoL emissions may be evaluated using the process of the country where the vehicle was first registered and primarily used.

* + 1. Future recycling process and technology modelling

GHG emissions intensity for each disposal and recycling process and CFF parameters shall be set in view of the process and recycling technology about 13-17 years later in the future. For recycling, process data should be those available at the point of declaration of the vehicle (First time vehicle registration).When a specific recycling process does not yet exist, and assumptions on such a future process cannot be appropriately justified, a scenario based on the current process and recycling technology may be applied.

* + 1. Energy modelling [SG6]

General rules must be referred to the Section 3.2.10.

**Future Changes in Energy Mix:**

Practitioners shall also account for any expected changes in the fuel or electricity production pathways during the lifetime of the vehicle. (detailed methodology shall be considered)

Specifically, the following recommendations are made on how to model electricity inputs to the EoL phase:

**EoL phase electricity:**

1. The same scenario for the expected future evolution of the electricity grid mix in the geographical region of interest shall be adopted, as previously selected for the dynamic modelling of the use phase electricity input in section 4.3.5.

2. The grid mix composition for the specific year of vehicle decommissioning (i.e., year of vehicle registration + expected lifetime) shall be estimated (i.e., the shares Si,N of electricity supplied by each technology i in the year N), by applying linear interpolation between the respective electricity supply shares reported for the two nearest pre-defined time horizons in the scenario selected at point 1 above

3. A bespoke grid mix model shall be built using the grid mix composition calculated at point 2 above and leveraging the most up-to-date database processes available for the individual electricity generation technologies. The resulting grid mix thus modelled shall be used to estimate the Emission Factor of the electricity input to the EoL phase of the vehicle.

For dynamically evolving fuel mixes (e.g., “green”/”grey” hydrogen; bio/fossil diesel blends; etc.), a similar approach to the one described above for electricity should be employed, whereby the respective fuel mix models for the use phase and EoL phase are arrived at by considering the existing future scenarios. "

[When a specific recycling process does not yet exist, and assumptions on such a future process cannot be appropriately justified, the static electricity and fuel modelling may be applied in line with Section 3.2.13.] Request to SG6

* + 1. GHG calculation for each process

E1; End-of-life vehicle (ELV) dismantling and shredding/sorting process

Equation 40

CE1 = WE1 × CD,E1

-CE1 ; GHG emissions in ELV dismantling and shredding/sorting process [kgCO2e]

-WE1 ; ELV weight [kg]

-CD,E1 ; specific GHG emissions intensity for ELV arising from dismantling and shredding/sorting in kilogram of carbon dioxide equivalent per kilogram of ELV[kgCO2e/kg]

E2; Recovered parts disposal and recycling process

The recovered parts type with disposal and recycling process shall be specified and evaluated based on the regulation or market observation in each country following GHG caluculation example for each processes.

(a) Tyre

(a-1) Disposal, Incineration

Equation 41

CE2a-1 = WE2a × (1- RE2a) × (CI, E2a + CD,E2a)

- CE2a-1 ; GHG emissions in tyre incineration with thermal and electricity recovery (CI, E2a) and disposal (CD, E2a), which may include residue landfill and transport [kgCO2e]

- WE2a ; Tyre weight [kg]

- RE2a ; Percentage of weight loss during total tire wear based on calculations of tire specifications [%].

- CI, E2a ; specific GHG emissions of tyre arising from incineration with energy recovery in kilogram of carbon dioxide equivalent per kilogram of tyre. [kgCO2e/kg]

- CD,E2a ; specific GHG emissions of tyre arising from the disposal in kilogram of carbon dioxide equivalent per kilogram of tyre. [kgCO2e/kg]

CI,E2a and CD,E2a shall be evaluated following Section 3.2.13.2 and 3.2.13.3 .

(a-2) Recycle

Equation 42

CM,MBBM,E2a = (1- RE2a) × Σi (WMi,E2a × CMi,MBBM)

-CM,MBBM,E2a ; specific GHG emissions in tyre materials recycling [kgCO2e]

- WMi,E2a ; each tyre material weight to which CFF is applied[kg]

- CMi,MBBM ; specific GHG emissions of a tyre material calculated with the MBBM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

CMi,MBBMshall be evaluated following Section 3.2.13.1.

b) Lead battery

(b-1) Disposal, Incineration

Equation 43

CE2b-1 = WE2b × ( CI, E2b + CD,E2b )

- CE2b-1 ; GHG emissions in lead battery incineration with thermal and electricity recovery (CI, E2b) and disposal (CD, E2b), which may include lead scrap treatment, electrolyte neutralization treatment and transport [kgCO2e]

- WE2b ; lead battery weight [kg]

- CI, E2b ; specific GHG emissions of lead battery plastic parts arising from incineration with energy recovery in kilogram of carbon dioxide equivalent per kilogram of lead battery. [kgCO2e/kg]

- CD,E2b specific GHG emissions of a lead battery material arising from the disposal in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

CI, E2b and CD,E2b shall be evaluated following Section 3.2.13.2 and 3.2.13.3.

(b-2) Recycle

Equation 44

CM,MBBM,E2b = Σi (WMi,E2b × CMi,MBBM)

- CM,MBBM,E2b ; specific GHG emissions in lead battery materials recycling [kgCO2e]

- WMi,E2b ; each lead battery material weight to which CFF is applied[kg]

- CMi,MBBM ; specific GHG emissions of a lead battery material calculated with the MBBM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

CMi,MBBMshall be evaluated following Section 3.2.13.1.

(c) Airbag

Equation 45

CE2c = WE2c × CD,E2c

- CE2c ; GHG emissions in Airbag disposal [kgCO2e]

- WE2c ; Airbag weight [kg]

- CD,E2d specific GHG emissions of airbag arising from the proper disposal in kilogram of carbon dioxide equivalent per kilogram of airbag. [kgCO2e/kg]

CD,E2c shall be evaluated following Section 3.2.13.3.

(d) Air conditioner (AC) refrigerant

Equation 46

CE2d = WE2d × CD,E2d

- CE2d ; GHG emissions in AC refrigerant disposal [kgCO2e]

- WE2d ; AC refrigerant weight [kg], filled in air conditioner at vehicle production.

- CD,E2d specific GHG emissions of AC refrigerant arising from the disposal in kilogram of carbon dioxide equivalent per kilogram of AC refrigerant . [kgCO2e/kg], which may include fluorocarbons destruction, CO2 from destruction and transport.

CD,E2d shall be evaluated following Section 3.2.13.3.

(e) Waste Oil

Equation 47

CE2e = WE2e × CI, E2e

- CE2e ; GHG emissions in waste oil incineration with thermal and electricity recovery [kgCO2e]

- WE2e ; Waste oil weight [kg]

- CI, E2e ; specific GHG emissions of a lead waste oil arising from incineration with energy recovery in kilogram of carbon dioxide equivalent per kilogram of waste oil. [kgCO2e/kg]

CI, E2e shall be evaluated following Section 3.2.13.2

(f) Drive battery

(f-1) Disposal, Incineration

Equation 48

CE2f-1 = (1- RE2f-2 - RE2f-3) × (WE2f × ((CI, E2f + CD,E2f )+ Σi (CRi × 44/12 × WMi,E2f )))

- CE2f-1 ; GHG emissions in used battery pack proper treatment which includes battery pack incineration (where allowable) with thermal and electricity recovery (CI, E2f) and disposal (CD, E2f) which may include residue landfill and transport [kgCO2e]

- RE2f2 ;  (F-2) battery repurposing ratio [%]

- RE2f3 ;  (F-3) battery material recycling ratio [%]

- WE2f1 ; used battery pack weight [kg]

- CI, E2f ; specific GHG emissions of a used battery pack from incineration with energy recovery in kilogram of carbon dioxide equivalent per kilogram of battery pack. [kgCO2e/kg]

- CD,E2f; specific GHG emissions of a used battery pack arising from the disposal in kilogram of carbon dioxide equivalent per kilogram of battery pack. [kgCO2e/kg]

- CRi ; Carbon ratio of each combustible material [%]

- WMi,E2f; Each combustible material weight in used battery pack [kg]

CI, E2f and CD,E2f shall be evaluated following Section 3.2.13.2 and 3.2.13.4.

(f-2) Secondary use (Repurposing)

The repurposing of the drive battery shall be specified and evaluated based on the regulation or market observation, data availability for parameters and verification criteria.

Battery repurposing Environmental Footprint (EF) compliant studies shall follow EF recommendations and regional regulations. Battery repurposing for other studies/other regions can follow other recommendations (e.g., the JAMA CFP guidelines)

Strong evidence shall be provided by the industry and the practitioner about the definition of the parameters, the definition of the new product substituted by the repurposed one, and the source of data to be used for modelling

In the case of applying the UNECE A-LCA CFF concept to the repurposing of the drive battery from the vehicle substituting a virgin battery into a different application, the evaluation will be based on the regulation or market observation, and the availability of data for parameters and verification criteria.

The evaluation will consist of two parts, each corresponding to the CFF components outlined in the CFF equation in Section 3.2.13.1.

The production burden for the drive battery, which corresponds to CFF part 1, will be evaluated in the production stage of the drive battery. The burdens and benefits related to the output of secondary batteries, corresponding to CFF part 3, will be evaluated in the disposal and recycling stage as the Modular Burdens and Benefits method for drive battery repurposing. The value derived from the Modular Burdens and Benefits method for drive battery repurposing will be integrated with the values from other Modular Burdens and Benefits methods. The total value of the Modular Burdens and Benefits method shall be reported and included in the total vehicle CFP.

Modular Burdens and Benefits Method formula for drive battery repurposing

Equation 40

*-* ; specific GHG emissions of drive battery repurposing in kilogram of carbon dioxide equivalent per kilogram of battery pack. [kgCO2e/battery pack]

-*DBR*; Allocation factor of burdens and credits between supplier and user of repurposed battery.

-; Proportion of the battery that will be reused in a subsequent system. [%]

- ; Quality of outgoing secondary drive battery / quality of virgin battery substituted by the repurposed battery

-; Specific GHG emissions (per unit of analysis) arising from the production of virgin battery that is going to be substituted by the repurposed battery. [kgCO2e/battery pack]

-; Specific GHG emissions (per unit of analysis) arising from the recycling process at EoL, including collection, sorting and transportation process. [kgCO2e/battery pack]

Datasets () to be used in the Modular Burdens and Benefits method for the drive battery repurposing may be collected as primary data. Parameters in the Modular Burdens and Benefits Method for drive battery repurposing (*D****BR***) may be defined as default values in reference documents.

f-3) Material recycle

Equation 50

CM,MBBM,E2f = Σi (WMi,E2b,Material × CMi,MBBM,Material) + Σi (WMi,E2b,cells × CMi,MBBM,Cells)

- CM,MBBM,E2f ; specific GHG emissions in drive battery materials recycling [kgCO2e/kg]

- WMi,E2b,Material ; each drive battery material weight except for in cells to which CFF is applied[kg]

- WMi,E2b,cells ; each drive battery material weight in cells to which CFF is applied[kg]

- CMi,MBBM,Material ; specific GHG emissions of a drive battery material except for in cells calculated with the MBBM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

- CMi,MBBM,Cells ; specific GHG emissions of a drive battery material in cells calculated with the MBBM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

CMi,MBBM,Material or Cells shall be evaluated following Section 3.2.13.1.

In case that the used battery is repurposed, the recycle of the material which is used in the repurposed drive battery shall not be evaluated.

g) Catalytic converters

g-1) Disposal

Equation 51

CE2g-1 = WE2g × CD,E2g

- CE2g-1 ; GHG emissions in catalytic converters disposal [kgCO2e] , which may include residue landfill after recycling process. [kgCO2e]

- WE2g ; Catalytic converters weight [kg]

- CD,E2g specific GHG emissions of catalytic converters arising from the disposal in kilogram of carbon dioxide equivalent per kilogram of catalytic converters. [kgCO2e/kg]

CD,E2g shall be evaluated following Section 3.2.13.3.

g-2) Recycle

Equation 52

CM,MBBM,E2g = Σi (WMi,E2g × CMi,MBBM)

- CM,MBBM,E2g ; specific GHG emissions in catalytic converters materials recycling [kgCO2e]

- WMi,E2g ; each catalytic converters material weight to which CFF is applied[kg]

- CMi,MBBM ; specific GHG emissions of a catalytic converters material calculated with the MBBM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

CMi,MBBMshall be evaluated following Section 3.2.13.1

E3; Automobile shredder residue (ASR) disposal and recycling process

Equation 53

CE3 = WE3,ASR × ( CI, E3,ASR + CD,E3,ASR ) + WE3,Wood × CI, E3,Wood

- CE3 ; GHG emissions in ASR incineration with thermal and electricity recovery (CI, ASR) and disposal (CD, ASR), which may include the residue landfill and the transport [kgCO2e]

- WE3, ASR ; ASR thermal recovery material weight [kg]

- WE3, Wood ; wood material weight [kg]

- CI, E3, ASR ; specific GHG emissions of ASR arising from incineration with energy recovery in kilogram of carbon dioxide equivalent per kilogram of ASR. [kgCO2e/kg]

- CI, E3, Wood ; specific GHG emissions of a wood material arising from incineration with energy recovery in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

- CD,E3 ; specific GHG emissions of ASR arising from the disposal in kilogram of carbon dioxide equivalent per kilogram of ASR. [kgCO2e/kg]

CI,E3,ASR or Wood, and CD,ASR shall be evaluated following Section 3.2.13.2 and 3.2.13.3.

E4; Materials recycling processes

Equation 54

CM,MBBM,E4 = Σi ( WMi,E4 × CMi,MBBM )

-CM,MBBM,E4 ; specific GHG emissions in materials recycling [kgCO2e]

- WMi,E4 ; each material weight to which CFF is applied[kg]

- CMi,MBBM ; specific GHG emissions of a material calculated with the MBBM in kilogram of carbon dioxide equivalent per kilogram of material. [kgCO2e/kg]

CMi,MBBMshall be evaluated following Section 3.2.13.1.

E5; Transport processes (transfer to SG1; t,b,c )

Equation 55

CE5 = Σi ( WE5i × DE5i, × CTi)

- CE4 ; specific GHG emissions in transport processes [kgCO2e]

- WE5i ; each transported goods weigh [t]

- DE5i, ; each transport distance [km]

- CTi ; specific GHG emissions arising from a transport in kilogram of carbon dioxide equivalent per kilogram of transport goods and per transport distance. [kgCO2e/t-km]

Transport processes in disposal and recycling stage may cover following transport processes.

- Dealer → Dismantler

- Dismantler → Shredder

- Shredder → ASR recycler

- ASR recycler → Landfill

DE5i, and DTi shall be evaluated according to paragraph 3.2.14.

* 1. Reporting [SG1]

[TBD]

* 1. Verification process [SG1]

[TBD]

1. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc\_wg3\_ar5\_chapter8.pdf [↑](#footnote-ref-2)
2. https://pfa-auto.fr/wp-content/uploads/2023/04/DT\_Me%CC%81thodologie\_2023\_V15\_ENGLISH.pdf [↑](#footnote-ref-3)
3. https://webshop.vda.de/VDA/en/vda-900-100-082022 [↑](#footnote-ref-4)
4. https://www.jama.or.jp/operation/ecology/LCA/pdf/JAMA\_guidelines\_CFP\_2024\_en.pdf [↑](#footnote-ref-5)
5. As defined in paragraph 2.1. of Consolidated Resolution on the Construction of Vehicles (R.E.3) [↑](#footnote-ref-6)
6. ILCD handbook [↑](#footnote-ref-7)
7. Ricardo study: Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA, Section A1.1.2.1 Figure A13 [↑](#footnote-ref-8)
8. CATARC study: Exemplary research cases of the different levels and Hotspot analysis, LCA-SG3-04-03 [↑](#footnote-ref-9)
9. activity data: e.g. energy consumption, material weights, production scraps [↑](#footnote-ref-10)
10. material carbon footprint certified values are considered as primary information as long as they are compliant with *A-LCA guideline‘s most important principles (*Allocation hierarchy, Electricity modelling, End-Of-Life allocation (RCM value)*)* [↑](#footnote-ref-11)
11. As also previously implemented in (Ricardo et al., 2020) based on consultation with stakeholders. [↑](#footnote-ref-12)
12. [FCH 2 JU - MAWP Key Performance Indicators (KPIs) - European Commission (europa.eu)](https://www.clean-hydrogen.europa.eu/knowledge-management/strategy-map-and-key-performance-indicators/fch-2-ju-mawp-key-performance-indicators-kpis_en) [↑](#footnote-ref-13)