Towards a European-wide harmonised transport-specific LCA Approach

TranSensus LCA

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EXECUTIVE SUMMARY
see below

Extended Executive Summary

The TranSensus LCA project (funded by the EU's Horizon Europe programme) aims to develop a baseline for a European-wide **harmonised**, **robust**, **transparent**, **commonly accepted** and applied **single life cycle assessment approach** for **zero emission road** vehicles, including **environmental** and **social** aspects.

This report is the first deliverable from Work Package (WP) 3 and compiles the documentation that was shared with the advisory boards to support their voting on the Life Cycle Assessment methodology being developed under WP2.

Three voting rounds have been organised to date to gather feedback from the advisory boards:

- First voting round from 14/12/2023 to 14/01/2024
- Second voting round from 28/03/2024 to 26/04/2024
- Third voting round from 10/09/2024 to 04/10/2024

The **first voting round** focused ONLY on (S)-LCA of existing products, also called retrospective product-scale LCA. It included the TranSensus LCA consortium's proposals and rationale on the following topics:

- **Ontology and database management:** including proposals on how and to what extent should S-LCA be integrated in TranSensus LCA ontology, the recommended approach for the baseline TranSensus LCA ontology, and the recommended approach for a vehicle and battery decomposition tree.
- **Goal & Scope:** including proposals on the LCA typology, technology coverage, system boundary, functional unit and the goal & scope for S-LCA.
- **Inventory:** including proposals on data collection (primary/secondary data choices, how data should be collected, and how to evaluate its quality), recommendations on multifunctionality of systems (e.g., allocation rules) and choices related to electric energy modelling. Specific proposals are also made for Social LCI.
- **Impact Assessment:** including proposals on the impact categories and life cycle impact assessment (LCIA) methods as well as normalisation and weighting. For S-LCA, recommendations on impacts sub-categories and stakeholder categories are also included.
- **Interpretation, decision making and frontloading concept:** including recommendations for conducting sensitivity analysis, scenario analysis and uncertainty analysis.

A slide pack containing the executive summary of these methodology options is provided in a separate file to this report.

The **second voting round** included refined or additional proposals for the TranSensus LCA methodology, based on the continuation of the WP2 work validated in 1st voting session, such as:

- **Goal & Scope:** including refined proposals on technology coverage, system boundary and functional unit.
- **Inventory:** including proposals on electricity modelling (production phase, use phase, End of Life phase, on-site electricity production, market-based electricity modelling), multifunctionality and data requirements.
- **Impact assessment:** including proposals on normalisation, prospective and fleet-level LCIA, use of LCA software, and the mandatory set of LCA impact categories.
- **Interpretation, Decision making and frontloading concept:** including proposals on the mandatory vs recommended vs optional analysis of parameters.

A slide pack containing a summary of these methodology options is provided in a separate file to this report (this is the same slide deck as provided to the beneficiaries and associated partners).

The **third voting round** built on the outcomes for the second voting and the continuation of the work under WP2. It included the TranSensus LCA consortium's proposals on the following topics:

- **Goal & Scope:** including refined proposals on the functional unit (segments and the default values for lifetime distance driven in km for two-wheelers, default values for lifetime distance driven in km for heavy-duty vehicles, default values for lifetime in years), the OEM fleet LCA approaches, the prospective LCA approach, and the macro fleet LCA approach.
- **Inventory:** including refined proposals on electricity modelling, multifunctionality and data collection on specific aspects (energy consumption, non-exhaust emissions, hydrogen supply mix, maintenance, wear and consumables)
- **Impact assessment:** including refined proposals on the mandatory set of LCA impact categories and methods and the recommended social impact indicators.
- **Interpretation, Decision making and frontloading concept:** including refined proposals on the mandatory vs recommended analysis of parameters, the recommended S-LCA interpretation parameters, the integration in product development process and the reporting.

A slide pack containing a summary of these methodology options is provided in a separate file to this report (this is the same slide deck as provided to the beneficiaries and associated partners).

Table of Contents

1. Introduction

The TranSensus LCA project (funded by the EU's Horizon Europe programme) aims to develop a baseline for a European-wide **harmonised**, **robust**, **transparent**, **commonly accepted** and applied **single life cycle assessment approach** for **zero emission road** vehicles, including **environmental** and **social** aspects.

This method should allow real-data-based LCA, be adaptative (depending on the goal, the practitioner and the level of knowledge), be comprehensive including all life cycle stages and relevant impact categories (not focusing only on GWP), cover a wide range of Zero Emission technologies, allow confidentiality, be standardized, differentiating, auditable (TranSensus LCA D1.2, 2023)

Structured in 6 work packages (WP), the first WP1 of TranSensus LCA aims to review existing standards and guidelines, OEM reports and literature, addressing LCA and S-LCA for vehicles and batteries. Based on this review, surveys and internal expertise, gaps and needs have been identified. Based on the WP1 findings and recommendations, WP2 aims to conceptualize a common Life Cycle Assessment methodology. In parallel, WP3 aims to facilitate the review-feedback process between the Advisory Boards and WP2. This involves the compilation of documentation from WP2 into a presentable format for review, the creation of questionnaires to collect feedback, the delivery of workshops to enable effective communication between the advisory boards, and the evaluation, clustering and prioritisation of the feedback from the advisory boards.

Three voting rounds have been organised to date to gather feedback from the advisory boards:

- First voting round from 14/12/2023 to 14/01/2024
- Second voting round from 28/03/2024 to 26/04/2024
- Third voting round from 10/09/2024 to 04/10/2024

The survey questionnaires are provided in a separate file to this report.

This report compiles the documentation that was shared with the advisory boards to support their voting. This included the following documents which are included in this deliverable:

- **WP3 Feedback Session n°1 Preparation Document - Consultation with the advisory boards based on WP2 results:** focused ONLY on (S)-LCA of existing product, also called as retrospective product-scale LCA to support the first survey planned with the TranSensus LCA industry and scientific advisory boards.
  - In addition, a **slide pack containing the executive summary of methodology options** included in the above document was also shared with the advisory boards and is provided in a separate file to this report

- **WP2 Voting Session n°2 Preparation Document - Building blocks of TranSensus LCA methodology:** given that the voting for both **beneficiaries and involved associated partners as well as the advisory boards** was conducted in parallel, the same documentation was used. It includes the continuation of preliminary work performed in 2023 and validated in 1st voting session (October 2023).
    - In addition, a **slide pack containing a summary of methodology options** included in the above document was also shared with the advisory boards and is provided in a separate file to this report (this is the same slide deck as provided to the beneficiaries and associated partners).
- **WP2 Voting Session n°3 Preparation Document - Building blocks of TranSensus LCA methodology:** as in the previous voting round, the third voting round was conducted in parallel for both **beneficiaries and involved associated partners as well as the advisory boards**. This documentation reflects the continuation of preliminary work performed since the start of the project in January 2023 and validated in two voting sessions (October 2023 and March 2024).
    - In addition, a **slide pack containing a summary of methodology options** included in the above document was also shared with the advisory boards and is provided in a separate file to this report (this is the same slide deck as provided to the beneficiaries and associated partners)

2. Documentation to support first round of voting

2.1 Ontology and database management (Task 2.1)

This task covers the creation of a common ontology for an LCI database for the road transport sector and battery value chain. The ontology creation will be tackled using the FAIR principles: promoting data indexation and metadata (to ensure **F**indability; handling IP protection and access to the LCI database (for **A**ccessibility); promoting data exchange to ensure **I**nteroperability; and documenting data quality and data requirements (for **R**eusability). It will describe how "social" and "economic" aspects must adhere to the ontology, to be able to be considered in an LCA perspective consistently. Intervals of maintenance (in terms of evolving standards and method) and updates (in terms of evolving technology) of the database will be proposed time-wise and process-wise.

Figure 2-1: Summary of recommendation & voting options

2.1.1 S-LCA & economic factors

The goal of this subtask is to decide how and to what extent should S-LCA be integrated in TranSensus LCA ontology.

S-LCA STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

Description & Analysis

In the Social Life Cycle Assessment context, ontology refers to a structured knowledge representation that defines and categorizes the various elements, relationships and concepts within the domain of social impacts of products and services. It provides a framework for systematically understanding, assessing and communicating the social implications throughout the life cycle of a product, from raw material extraction to disposal.

The ontology proposed in the TranSensus LCA project for the S-LCA domain is primarily based on the UNEP Guidelines. **This core structure serves as the foundational blueprint. However, to ensure a comprehensive and holistic approach,** the ontology also integrates elements from other prominent ontologies, namely those presented by ILCD, BONSAI and the ORIENTING (ORIONT) project. **A significant feature of this ontology is** the adoption of the Reference Scale approach**, which provides a comprehensive method for assessing and comparing social impacts.**

Product Social Impact Assessment (PSIA) Framework is another guideline for social life cycle assessments. It was created based on UNEP guideline 2013. The UNEP Guideline, however, is more thorough and incorporates PSIA into the reference scale approach. We won't be consistent with ISO 14040 and ISO 14075 if we solely use PSIA, and we won't be considering anything quantitative either. Additionally, the UNEP Guidelines have attained a greater level of consensus that involves more organisations and businesses (see the nine pilots, which also include one developed by the Roundtable), rather than just a small number of companies (as it is for the PSIA).

The reference scale approach is in common use rather than the impact pathway approach in social life cycle assessment (S-LCA) because it is more advanced. The reference scale approach uses performance reference points (PRPs) which are defined as thresholds or targets that set different levels of performance. In contrast, the impact pathway approach assesses the consequences resulting from the product system through one or multiple characterization models that employ cause-effect relationships for evaluating impact categories that are comparable to environmental life cycle assessment (E-LCA). The reference scale approach is more advanced because it focuses on the past or current social performance or social risks related to the behaviour of the organizations involved in the product system along its life cycle stages. Additionally, the current development of characterization models within the impact pathway S-LCIA is limited to potential social and socio-economic impacts, and for a very restricted number of impact subcategories.

S-LCA STEP 2: Recommended approach and options for voting from WP2 – T2.1 Ontology - S-LCA and economic factors

The consortium recommends basing the S-LCA ontology on the UNEP guidelines and to adopt the Reference Scale approach.

This approach is more thorough than other alternatives and incorporates PSIA into the reference scale approach, being consistent with ISO 14040 and ISO 14075. Additionally, the UNEP guidelines have attained a great level of consensus. On the other hand, the Reference Scale approach is more advanced than other alternatives.

2.1.2 Baseline for TranSensus LCA Ontology

Ontology STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

What is an ontology?

Definition of ontology

In the context of environmental life cycle assessment (LCA) for zero-emission road transport, an ontology can be defined as a structured and formal representation of knowledge that encompasses the environmental aspects, variables, and relationships specific to the life cycle of zero-emission vehicles and associated infrastructure. It provides a standardized framework for organizing, categorizing, and interconnecting information related to LCA in the context of zero-emission road transport, including resource consumption, emissions, waste generation, energy use, and other environmental impacts.

Properties or attributes are assigned to each class to describe their characteristics, values, and relationships with other classes. These properties can include quantitative parameters such as energy consumption, emissions, resource use, as well as qualitative attributes like technology type, vehicle specifications, and operational conditions.

The ontology is developed with consideration for existing standards and guidelines specific to zero-emission road transport and LCA methodologies. It undergoes iterative refinement and validation through expert feedback and stakeholder engagement to ensure accuracy, consistency, and applicability.

By providing a standardized and structured representation of knowledge, an ontology facilitates data integration, interoperability, and consistency in environmental life cycle assessments for zero-emission road transport. It supports decision-making processes, enables comparison of different vehicles and technologies, identifies areas for improvement, and promotes sustainable practices in the development and deployment of zero-emission vehicles and associated infrastructure.

Description of ontology

In the context of environmental life cycle assessment (LCA), an ontology refers to a structured and formal representation of knowledge about the environmental aspects of products, processes, and systems. It provides a standardized and systematic framework for organizing and categorizing information related to LCA.

An ontology in LCA defines a set of concepts, relationships, and properties that enable the representation and modeling of various environmental factors and their interconnections. These factors can include resource consumption, emissions, waste generation, energy use, and other impacts associated with the life cycle of a product or service.

The ontology typically consists of a hierarchy of classes, where each class represents a specific environmental aspect or variable. For example, classes could include "raw material extraction," "manufacturing process," "transportation," "energy consumption," "emissions to air," "water consumption," and so on. These classes are interconnected through relationships that capture the dependencies and associations between different aspects of the life cycle.

Properties or attributes are used to describe the characteristics and values associated with each class. For instance, properties can include parameters such as mass, volume, energy intensity, emission factors, and environmental impact indicators.

By utilizing ontology in LCA, researchers, practitioners, and decision-makers can achieve several benefits. It facilitates data integration and interoperability by providing a common language and structure for organizing and sharing LCA data. It also enables the development of consistent and standardized LCA methodologies and tools. Furthermore, an ontology allows for the identification of data gaps and uncertainties, supports sensitivity analysis, and enhances the overall understanding of the environmental implications of different life cycle stages and activities.

Overall, an ontology in the context of environmental life cycle assessment serves as a valuable knowledge representation framework that aids in structuring and analyzing complex environmental information, promoting better decision-making towards sustainable development and resource management.

What are OEMs practices on data collection?

Statements and sample data sheets from the OEMs were compared to find similarities or differences in their approach. The information provided was the basis to develop a questionnaire on what information would be required for the development of the ontology, with following questions:

1. How is the BOM (list of parts) obtained?
2. To how many datasets are the IMDS materials matched?
3. Are there plans already on how to implement possible future GWP results shared via IMDS? If yes, how?
4. What are the logistic distance assumptions?
5. Is maintenance included in the use-phase and based on which assumptions/maintenance cycles?

6. Which emissions are asked for at plant level/production phase and for the use phase? Which of these data is actually reported and then used for LCA?
7. Which production processes (suppliers and inhouse) are included in the LCA?
8. What type of fuel/energy is considered for the different drive types (ICE, HEV, PHEV, BEV)?
9. Is the same driving cycle (e.g. WLTP) used for all drive types?
10. How long is the product cycle (when are LCAs updated and to what extent)?
11. How did the assumptions for mileage/durability/lifetime evolve? Do these change for different vehicles types or regions?
12. When doing an LCA update, is the BOM/primary or background data/the LCA model updated?
13. How many LCAs were done already and how many were about ZEV?

Considering S-LCA:

14. Which organizations participate in the various stages of the product system (Considering the entire life cycle of the product)?
15. What are the stakeholder groups (e.g. Workers; Local Community; Value Chain Actors; Consumer; Society; Children) that could be impacted by the product system?
16. What are the significant social topics* that are material/relevant throughout the product system?

Note: Not all OEMs received all these questions, as some of them might have been sufficiently answered during the respective interview.

The answers from the different OEMs have been analyzed for each question/topic. It has been stated whether there is consensus on their approach or where there are differences. This is lined out in the table below.

Table 2-1: Synthesis of OEM interviews and the respective questionnaire

Topic/Question	Synthesis of the answers
What is the granularity of the materials?	- Mostly based on IMDS and a company specific mapping list.
Which background data sources are used?	- LCA FE/MLC (former GaBi SW/databases) - Supplier data rarely used today, but desired in the future.
How is the Bill of Materials (BOM) obtained?	- Different approaches exist on how to receive data from several internal areas.
How are delivered parts considered?	- Mostly based on IMDS

	- Most of the time 100 % of the BOM is mapped - Not every single material can be mapped precisely, due to unclear naming in IMDS or a missing match in databases
Is IMDS used?	- This is an integral part for most OEMs. - Vehicles are mapped to a few hundred datasets.
Is there a standardized approach on how to conduct an LCA?	- Internal workflows are more or less standardized (but differ between the companies). - For vehicle LCA no published standard is in use for all aspects of a certain LCA.
How is the inhouse production considered?	- Companies use different approaches regarding multi-output allocation, included emissions or use of aggregated secondary data/own modelling.
Which production processes (suppliers and inhouse) are included in the LCA?	- All relevant inhouse processes are included. - Often no specific information is available from the suppliers.
Which emissions are asked for at plant level/production and for the use phase? Which of these data is actually reported and then used for LCA?	- Different approach on how and which emissions are reported and how these are grouped to workshops/production plants.
What are the assumptions for the different life cycle steps (production, use, end-of-life)?	- Different assumptions regarding mileage and maintenance. - At end-of-life mostly Cut-Off is used.
What are the logistic distance assumptions?	- Different assumptions for the distance value and differs in split between inbound and outbound transport.
What type of fuel/energy is considered for the different drive types?	- Mostly EU-mixes used. - Sometimes country specific or future mixes for scenario analysis.
What is the update cycle?	- Most LCAs are done before or at start of production (SOP). - Some companies rarely do updates, some when major changes occur, some on a yearly basis.
How many LCAs were done already?	- The experience, especially regarding BEVs highly differs between the companies.

Revision of existing ontologies that are similar to the scope of TranSensus LCA and OEMs data collection practices

Literature review

A detailed literature review on ontology was conducted, relevant findings were collected in a shared Word-file.

Several guidelines, standards, ontologies or other documents have been checked for relevant information relating to this subtask. As the concept of ontology has almost not been used in the context of LCA, this was a major challenge. Which elements exactly the ontology should contain could not be determined easily and from the start. The research thus was done in an iterative manner, to expand the knowledge about ontologies and at the same time cross-checking different documents of interest.

While the concept of ontology can be used in many different areas, **only a few ontologies in the context of life cycle assessment or the vehicle/battery value chain could be found.** These ontologies however had a different scope than what is needed for TranSensus LCA. Thus, these could only be used to understand the concept of ontology itself, but not many useful elements could be extracted to be directly used in our case. This changed however, as soon as we were given access to the **ORIENTING deliverable**. Here, they created an ontology for LCSA. From this point on, this file could be used as a starting point to understand the use of ontology in our use case.

Table 2-2: List of analysed guidelines, standards, ontologies and other documents

Publisher / Author	Document / Hyperlink
Ghose et al., 2021	A core ontology for modeling life cycle sustainability assessment on the Semantic Web https://doi.org/10.1111/jiec.13220
Chungoora, 2019	A formal ontology describing LCA methodology https://tishchungoora.medium.com/a-formal-ontology-describing-lca-methodology-97a2da2250bc
OICA	Application of LCA in the automotive industry https://unece.org/sites/default/files/2022-05/13_OICA_20220531_OICA%20presentation_UNECE%20GRPE%20LCA_v4.pdf
Stier & Gold, 2023	Battery Value Chain Ontology (BVCO) https://doi.org/10.5281/zenodo.8114726

China Automotive Carbon Digital Technology Center	Carbon footprint of road vehicle products - Product category rule - Passenger car http://en.cpp.auto-cices.com/Download/Index
ORIENTING EU Project	Data ontologies: Documentation of the ORIENTING LCSA ontology (ORI-ONT) https://orienting.eu/publications/
EPD International	Draft PCR Passenger Cars https://www.environdec.com/product-category-rules-pcr/get-involved-in-pcr-development#pcrsinopenconsultation
European Committee for Standardization	EN 15804:2012+A2:2019
Green NCAP	Estimated Greenhouse Gas Emissions and Primary Energy Demand of Passenger Vehicles: Life cycle assessment methodology and data https://www.greenncap.com/wp-content/uploads/Green-NCAP-Life-Cycle-Assessment-Methodology-and-Data_2nd-edition.pdf
Bitencourt de Oliveira et al., 2022	Exploring automotive supplier data in life cycle assessment – Precision versus workload https://doi.org/10.1016/j.trd.2022.103247
Global Battery Alliance	Greenhouse Gas Rulebook: Generic Rules - Version 1.5 https://www.globalbattery.org/media/publications/gba-rulebook-v1.5.pdf
eLCAr	Guidelines for the LCA of electric vehicles http://dx.doi.org/10.13140/RG.2.1.2782.8244
Fraunhofer ISC	KIproBatt_v1 https://kiprobatt.de/wiki/Fraunhofer_ISC/Processes/KIproBatt_v1
RISE Viktoria	LCA guidelines for electric vehicles https://www.ri.se/sites/default/files/2019-06/Bilaga%202%2C%20LCA%20Guidelines%20for%20electric%20vehicles.pdf
RISE Viktoria	LCA guidelines for electric vehicles – Literature review https://www.ri.se/sites/default/files/2019-06/Bilaga%203%2C%20LCA%20guidelines%20for%20electric%20vehicles_Literature%20Review.pdf
China Automotive Technology and Research Center	LCA Research Progress of CATARC

	https://wiki.unece.org/download/attachments/172852238/LCA-01-07r1_China_CATARC%20presentation%20LCA%20Research%20Progress%20of%20CATARC%2020221027%20update.pdf?api=v2
PFA	LIFE CYCLE ASSESSMENT APPLIED TO A VEHICLE OR A VEHICLE EQUIPMENT - METHODOLOGICAL RECOMMENDATIONS https://pfa-auto.fr/wp-content/uploads/2023/04/DT_Me%cc%81thodologie_2023_V15_ENGLISH.pdf
EPD International	PCR Public and Private Buses and Coaches https://api.environdec.com/api/v1/EPDLibrary/Files/fd9df997-77fe-41af-ea11-08db041ce1b6/Data
Recharge	PEFCR for High Specific Energy Rechargeable Batteries for Mobile Applications https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_Batteries.pdf
JRC	Rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries (CFB-EV) https://eplca.jrc.ec.europa.eu/permalink/battery/GRB-CBF_CarbonFootprintRules-EV_June_2023.pdf
CAESAR Systems	S-TEN http://www.caesarsystems.co.uk/
CATENA-X	SUS - 004 Product Carbon Footprint Rulebook https://catena-x.net/fileadmin/user_upload/Standard-Bibliothek/Archiv/1_UC_Sustainability_v2.1/SUS_-_004_PCF_Rulebook_v2.1.pdf
Wilkinson et al., 2016	The FAIR Guiding Principles for scientific data management and stewardship https://doi.org/10.1038/sdata.2016.18
Verband der Automobilindustrie e. V. (VDA)	VDA 231-106: Material classification in motor vehicle construction: Structure and nomenclature (Version 10/2021) https://webshop.vda.de/VDA/de/vda-231-106-102021
Verband der Automobilindustrie e. V. (VDA)	VDA 900-100: Guidance for conducting life cycle assessment studies of passenger cars (Version 08/2022) https://webshop.vda.de/VDA/de/vda-900-100-082022
TranSensus LCA	WP1 Survey Results

No existing ontology covers directly the TranSensus scope / use case. The existing knowledge on ontologies is limited: The concept of ontologies itself is very abstract, complex and can be hard to understand in the beginning. Some existing ontologies cover LCA in some way or another, but as mentioned above with no direct concordance to TranSensus.

Some relevant existing ontologies

Following ontologies were found, that roughly cover LCA or the vehicle/battery value chain or production processes. These ontologies will be explained in the following sections.

Examined ontologies

- KiproBatt_v1
- LCA methodology ontology
- Battery Value Chain ontology (BVCO)
- Catena-X Ontology
- BONSAI ontology (BONT)
- ORIENTING ontology (ORIONT)

KIproBatt_v1

Describes the process of manufacturing battery cells (Fraunhofer ISC, 2022). While this is too specific for the overall scope of this deliverable, this ontology could potentially be implemented in the future.

LCA methodology ontology

This ontology is too broad and high-level for the scope of this report. Elements that are additionally covered in this ontology are e.g., Organization & Assignment, Decision Making or Process Design. (Chungoora, 2019) In case the TranSensus ontology should cover these elements as well, the LCA methodology ontology can be used as a foundation.

Battery Value Chain Ontology

The Battery Value Chain Ontology (BVCO) is a cross-project development coordinated by Fraunhofer ISC (both EU and national research projects). The purpose of this ontology is to describe processes within the value chain of batteries. A process is a holistic perspective element that transforms inputs and outputs (matter, energy, information) into outputs and products through the application of tools (devices, algorithms). They may be decomposed into sub-processes and have predecessor and successor processes may exist. The ontology is based on the General Process Ontology (GPO) and the Elementary Multiperspective Material Ontology (EMMO). In comparison to BattINFO, BVCO manages the higher-level process chains for material processing and manufacturing, while BattINFO focuses on the internal components and chemical processes. The two ontologies are therefore complementary. (Stier & Gold, 2023)

BVCO is focused on the production processes of a battery and does not specifically include the aspects of Life Cycle Assessment. The ontology only covers lithium-ion batteries and no further technologies. It is therefore out of scope for this project.

Catena-X ontology

The Catena-X ontology aims to be an integrative framework, focusing on automotive manufacturing. Building a federated virtual knowledge graph enabling data access across companies in the automotive industry. (Catena-X, 2023)

The Catena-X approach on ontologies and taxonomy is complex and rather hard to understand in full without deeper knowledge about ontologies, IT and an ontology applications like Protégé. As they are not specifically modelled to represent Life Cycle Assessment (LCA), they don't fit the scope of this project.

The BONSAI ontology

The BONSAI ontology unites previous sustainability assessment ontologies (General data model by Pauliuk et al., 2019; LCA ontology by Kuczenski et al., 2016; LCA ontology by Janowicz et al., 2015), with two main applications: Firstly, integration of relevant data from the publicly available databases, such as the EXIOBASE and the Yale Stock and Flow Database, and secondly querying the resulting integrated database. (Ghose, Lissandrini, Hansen, & Weidema, 2021) Descriptions and examples of the different BONSAI elements are given in Table 2-3, Figure 2-1 and Figure 2-2.

Table 2-3: Description and examples from the BONSAI ontology (Ghose, Lissandrini, Hansen, & Weidema, 2021) & (ORIENTING, 2022)

Description	Example
Activity	
Making or doing something within a spatial and temporal delimitation.	"Cultivation of wheat" in Germany in the year 2020 or "Aluminium production" in China in the year 2020.
Activity Type	
This class includes the labels of activities.	"Cultivation of wheat" or "Aluminium production".
Agent	
An entity (person or thing) that performs an activity. An agent may have a location that may be different from the location of an Activity performed by it.	Within an activity, agents can perform different roles, for example, laborer, owner, purchaser, consumer.
Flow	
An input or output of an entity to or from an instance of an Activity or a directional exchange of an entity between two instances of Activity. A flow can be unidirectional, that is, a flow can be defined as an input or output of an activity without defining its origin or destination. The determining flow is a	Input of 2393 tonnes of "Aluminium and aluminium products" (FlowObject) to "Manufacture of motor vehicles" (ActivityType) in Germany in the year 2011.

specific flow of an activity for which a change in demand or supply will affect the activity level.	
Flow Object	
This class includes the labels of entities that are produced or consumed by an activity or added to or removed from a stock accumulation.	"Wheat" or "Aluminium and aluminium products".
Balanceable Properties	
Properties of Flows.	Dry mass, wet mass, energy, elemental mass, monetary value (when measured in the same valuation) (non-balanceable properties: volume, number of units, Becquerel (unit to measure radioactivity).
Balanceable Property Type	
The property/"quantity" that is quantified.	Mass
Reference Unit	
A measure to which the numeric value representing the measure of a flow is expressed in proportion to, e.g. CO2-emissions per kg-km transport covered. "Functional Units" are reference units, but not all reference units are "Functional Units."	Amount of CO2 emitted from a transport activity may be expressed in proportion to the quantity of another flow of this activity (e.g., 1 km of distance covered) or to a time period (e.g., CO2 emissions per year from transport).
Numerical Value	
	1
Unit	
	kg
Quantity	
	Mass

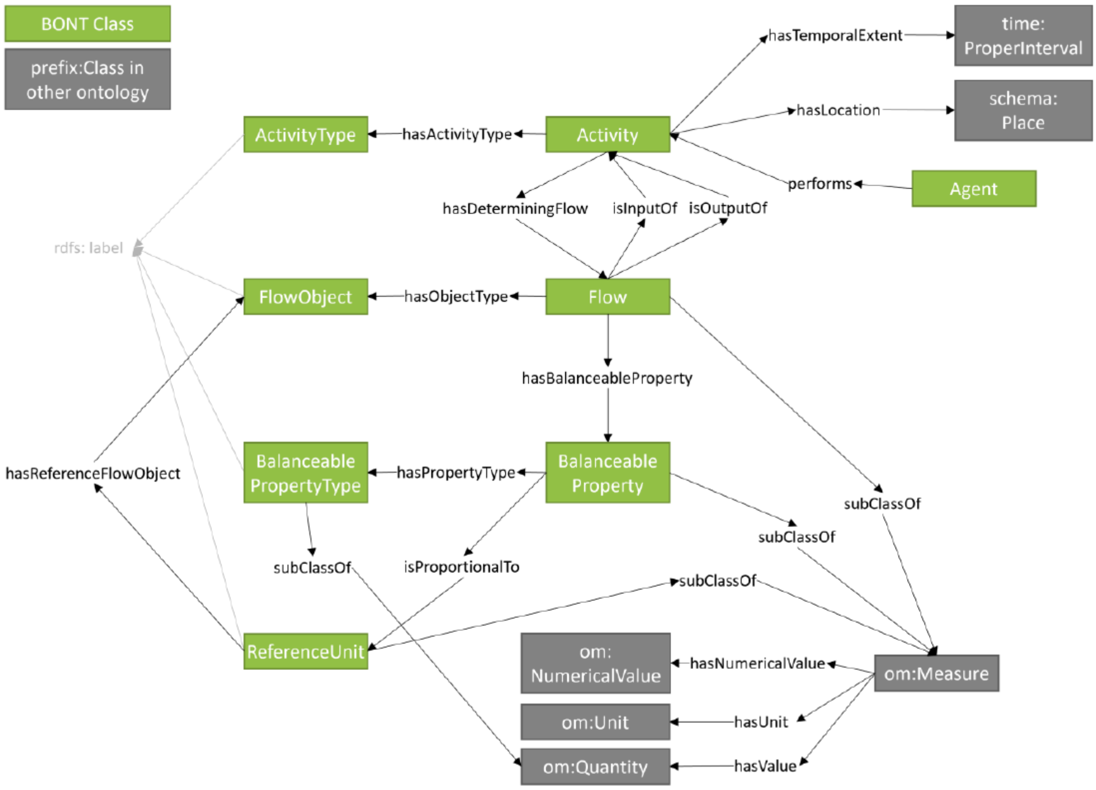


Figure 2-2: The BONSAI ontology (Ghose, Lissandrini, Hansen, & Weidema, 2021) rdfs: Resource Description Framework Schema; om: Ontology of units of Measure

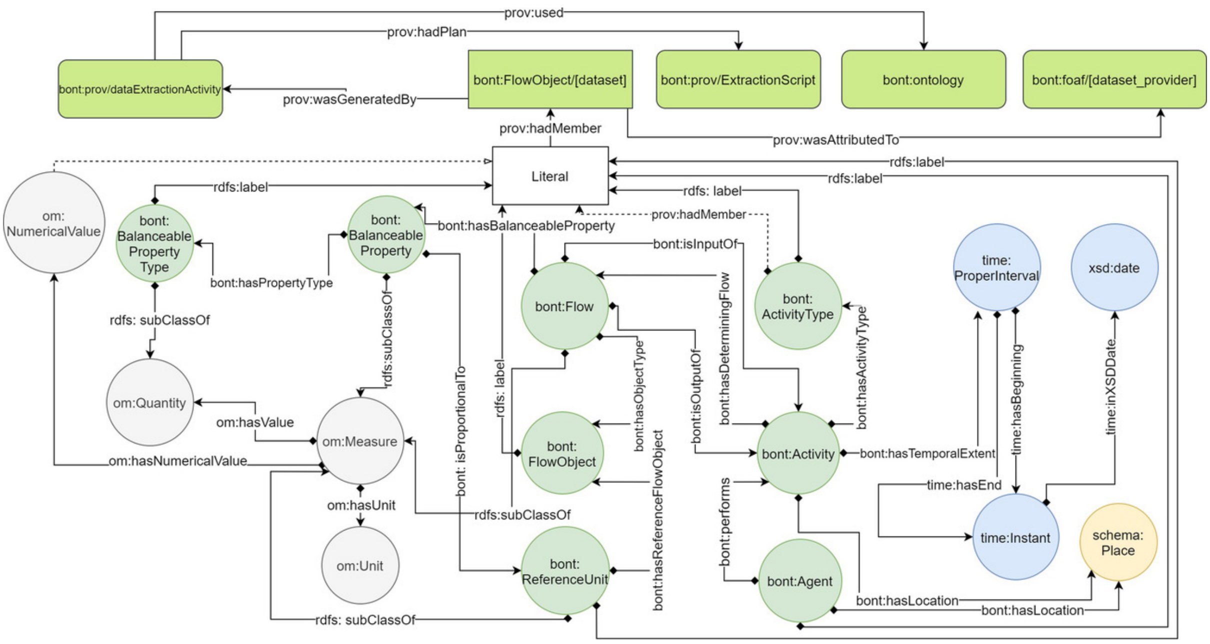


Figure 2-3: Visualization of BONT (Ghose, Lissandrini, Hansen, & Weidema, 2021)

The ORIENTING Ontology

The ORIENTING research project aims to develop an operational methodology for product Life Cycle Sustainability Assessment (LCSA). This should include environmental, social, and economic aspects. For structuring the most important methodological and data elements and their relationships, the ORIENTING LCSA ontology (ORIONT) was created. The BONSAI ontology (BONT) forms the basis for ORIONT. (ORIENTING, 2021)

Product system and BONT classes

As BONT is rather generic/macro-level, it was deemed necessary to adapt it with the aim to be more specific and to cover all sustainability topics" (ORIENTING, 2022). To reach this, several additional elements were added, which are based on the extended International Life Cycle Data format (eILCD). The central aspects for this report are the product system and the BONT classes, which can be seen in Figure 2-3.

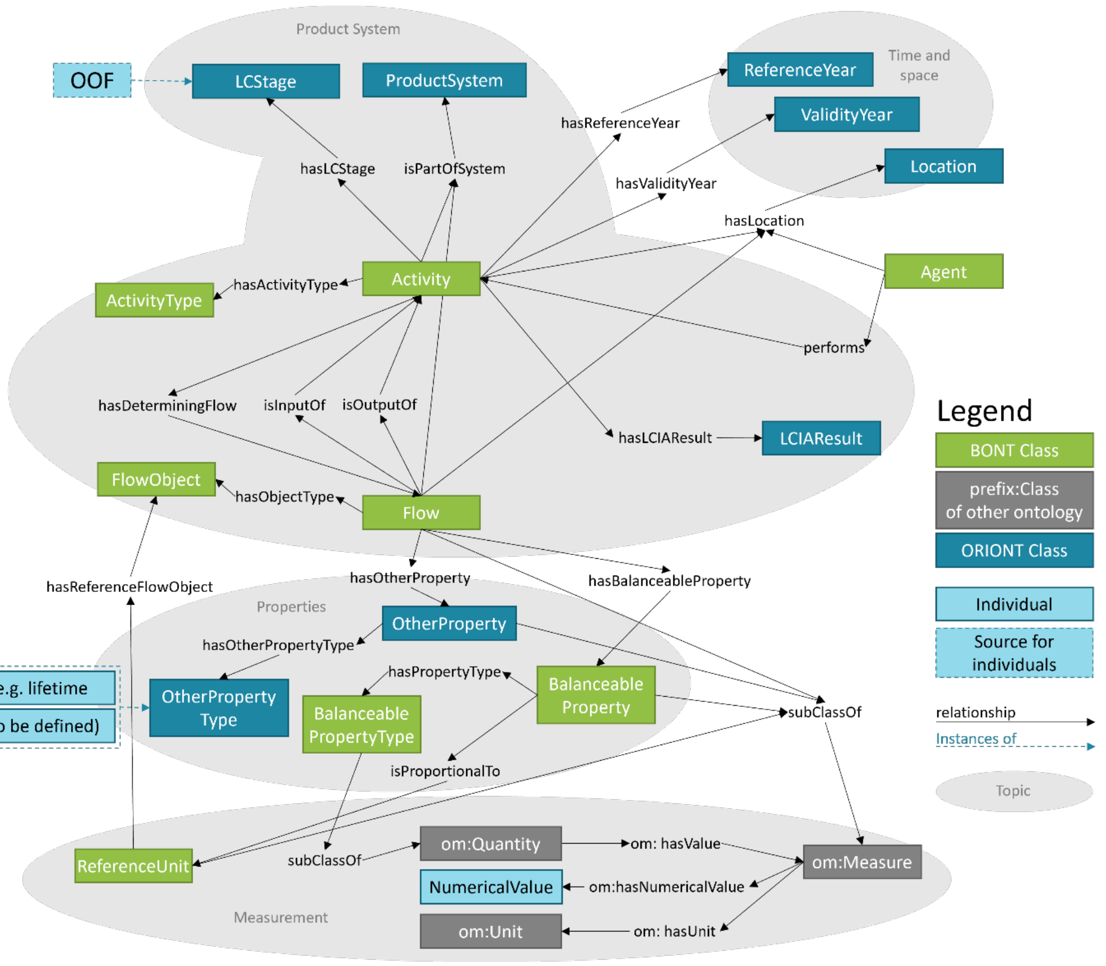


Figure 2-4: Selection of the main topics from ORIONT (ORIENTING, 2022)

Activities can be grouped in life cycle stages (LCStages) in eILCD, to enable having Life Cycle Impact Assessment (LCIA) results per life cycle stage. Different life cycle stages implemented in ORIONT are given in the ORIENTING Output Format (OOF). (ORIENTING, 2022)

It should be highlighted, that **while temporal and spatial information can also be given in BONT, ORIONT uses the implementation according to eILCD.** Additionally, they added the possibility to assign a location to a flow, which was not possible in BONT. While in most cases, the flow should have the same location as the respective activity, in special cases they must differ (European activity, with the flow having a specific country linked). An especially useful addition in ORIONT are two classes (conform to the eILCD format) for the reference year and the validity year. (ORIENTING, 2022)

Classification of Flows

Another relevant aspect is the classification of flows, as seen in Figure 2-4. This is based on eILCD as well.

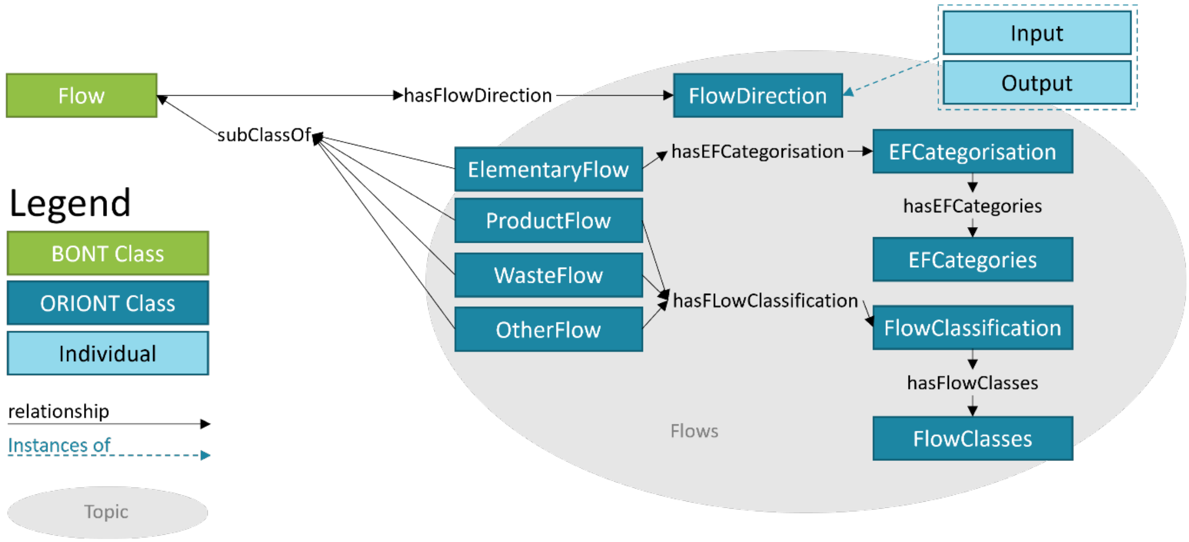


Figure 2-5: Classification of Flows (ORIENTING, 2022)

LCIA Part of ORIONT

The third big part of ORIONT deals with LCIA, as seen Figure 2-5. In the report detailed information is given on specific elements within this part. The basic building block is the class "Method". This class is linked to the class "Characterization Model," which can be used to quantify impacts indicators. "Method" is also a part of a certain methodology, being a set of different methods to assess different impact categories. (ORIENTING, 2022)

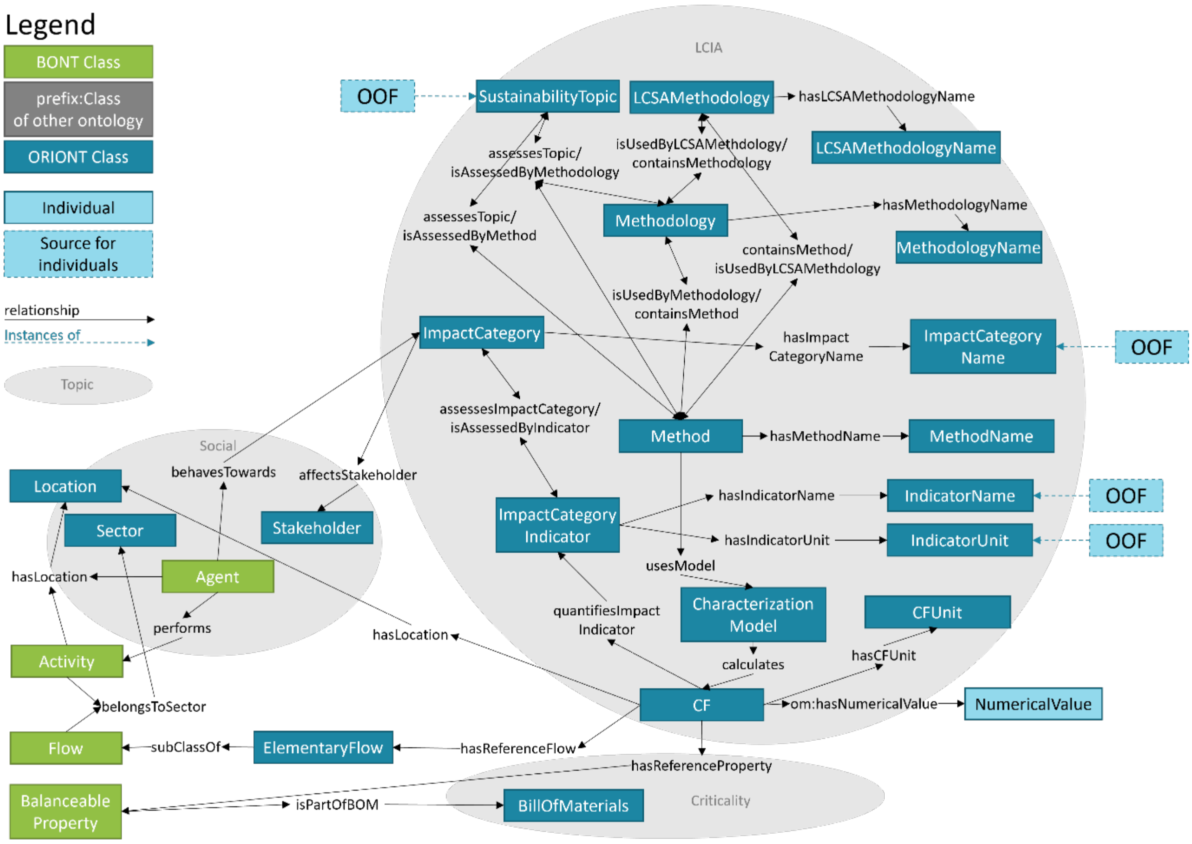


Figure 2-6: LCIA part of ORIONT (ORIENTING, 2022)

The closest match was found with the ontology from ORIENTING, which can be used as a baseline for our new TranSensus ontology (TLCAO). As the scope and technical implementation of ORIONT is more generic than the scope of TranSensus LCA, we create a specific use case of ORIONT by adding several elements and therefore being more detailed. This is especially done for covering S-LCA and by integrating a decomposition tree.

There are a few benefits from using this approach:

1) It is a common method to build up on existing ontologies,

2) the workload is drastically reduced,

3) we create a linkage to another EU project,

4) the main author of ORIONT is part of TranSensus and of big help in creation of TLCAO, and

5) improved consistency in the field of ontologies for LCA in a broader context.

The drawbacks are that ORIONT has not yet been officially published yet, and it would have to be checked, if possible future changes in ORIONT would have to be implemented in TLCAO.

Ontology STEP 2: Recommended approach and options for voting from WP2

The consortium recommends using the ORIENTING ontology (ORIONT) as a baseline for our new TranSensus ontology (TLCAO)

2.1.3 Material Tree

Material Tree STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

To better understand the system studied and facilitate the implementation of a methodology a decomposition tree is sometimes used in LCA guidelines. However, this tree is rarely part of an ontology and rather a support for a specific methodological aspect. In the scope of the TranSensus LCA project, it was decided that **a decomposition tree of a Zero Emission Vehicle, which would be drafted in task 2.1, could be useful in several tasks and work packages.**

The following decomposition trees were found and analyzed:

- GREET
- IMDS - VDA
- CATARC
- GBA
- GRB-CBF

The above listed trees cover the vehicle and/or the battery.

The closest match was found with the GREET for the vehicle and the GRB-CBF for the traction battery, which were used as a basis. These decomposition trees will be adapted to fit the scope of TranSensus LCA, in close collaboration with several OEMS.

Compared to using an existing decomposition tree or creating something from scratch, this approach has a few benefits:

1) the workload decreases,

2) the proposal will be generic enough for every OEM and LCA practitioners to find themselves in this decomposition and therefore to reach a consensus,

3) while it will be specific enough to reflect the products studied under TranSensus LCA, and

4) we create a link with another project (already approved).

The balance between generality and specificity is very important to find, that way we make sure that the tree can be useful in the project/methodology and can be adopted by everyone.

A drawback is, that this will need to be adapted if technological breakthroughs occur, but most probably this would also be the case for other approaches to build a decomposition tree. Depending on how this progresses further in other tasks, it might still not reflect all OEM value chains.

System	ICEV	HEV	PHEV	EV	FCV
Body system	✓	✓	✓	✓	✓
Powertrain system	✓	✓	✓	✓	✓
Transmission system	✓	✓	✓	✓	✓
Chassis system	✓	✓	✓	✓	✓
Traction motor		✓	✓	✓	✓
Generator		✓	✓		
Electronic controller		✓	✓	✓	✓
Fuel cell auxiliary system					✓
Batteries	✓	✓	✓	✓	✓
Fluids (excluding fuel)	✓	✓	✓	✓	✓

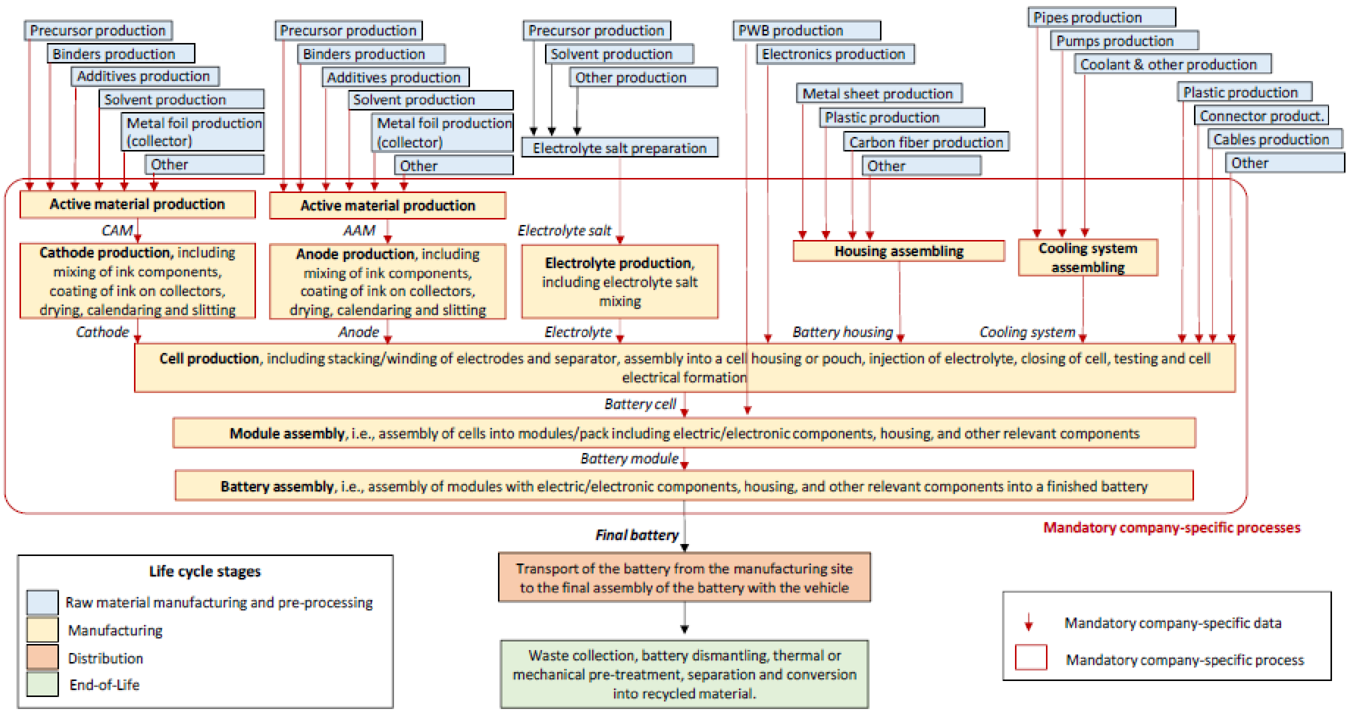
Figure 2-7: Vehicle systems included in GREET

Table 2-4: Material composition for vehicle components from GREET (U.S. Department of Energy, 2022)

Body	Powertrain System (including BOP)	Transmission System/Gearbox
Steel	Steel	Steel
Wrought Aluminum	Stainless Steel	Copper
Cast Aluminum	Cast iron	Cast Iron
Copper/Brass	Wrought Aluminum	Magnesium
Zinc	Cast Aluminum	Wrought Aluminum
Magnesium	Copper/Brass	Cast Aluminum
Glass Fiber-Reinforced Plastic	Magnesium	Carbon Fiber-Reinforced Plastic
Glass	Glass Fiber-Reinforced Plastic	Average Plastic
Carbon Fiber-Reinforced Plastic	Average Plastic	Rubber

Average Plastic	Rubber	Others
Rubber	Carbon Fiber-Reinforced Plastic	**Chassis (w/o battery)**
Others	PFSA	Steel
Traction Motor	Carbon Paper	Cast Iron
Steel	PTFE	Wrought Aluminum
Stainless Steel	Carbon & PFSA Suspension	Cast Aluminum
Cast Aluminum	Platinum	Copper/Brass
Copper/Brass	Carbon	Zinc
Nd(Dy)FeB magnet	Nickel	Magnesium
Phenolic resin	Silicon	Glass Fiber-Reinforced Plastic
Enamel	Others	Average Plastic
Nickel	**Electric Controller**	Rubber
PET	Steel	Others
PBT	Cast Aluminum	**Fuel Cell Onboard Storage**
Mica	Copper/Brass	Steel
Fiberglass	Rubber	Stainless Steel
Silicone	Average Plastic	Carbon Fiber-Reinforced Plastic
Epoxy resin	Alumina	Glass Fiber-Reinforced Plastic
Nylon	Epoxy resin	Wrought Aluminum
Methacrylate ester resin	Fiberglass	Copper
Paint/Varnish	Gold	Average Plastics
Zinc	Nickel	Rubber
Others	Nylon	Nickel
Generator	PET	Silicon
Steel	Polypropylene (PP)	Others
Cast Aluminum	Polyurethane	
Copper/Brass	Zinc	
Others	Zinc oxide	
	Others	

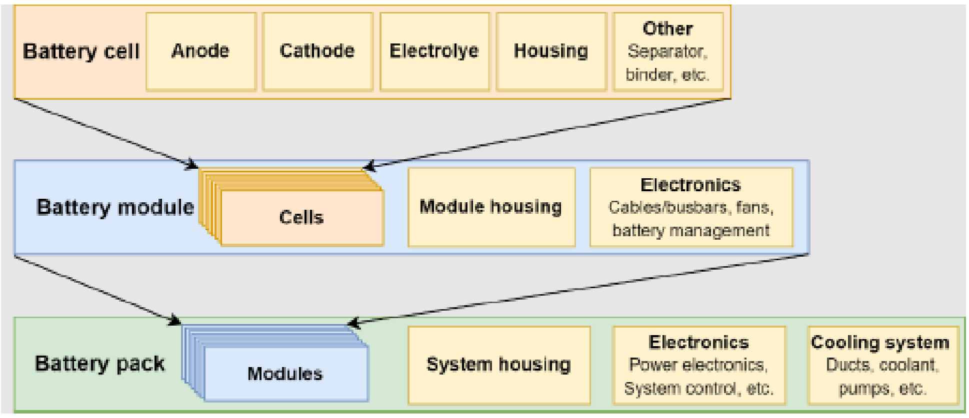
Figure 1. System boundaries of the carbon footprint of a generic EV battery. Other types of batteries (e.g., anode-free batteries, cell-to-pack design) may have a different visualization of their system boundaries. Each square represents a process, while each arrow represents an activity data (e.g., kg of solvent, kg of additive). The different colours (blue, yellow, orange, and green) indicates in which life-cycle stage each process belongs, while red arrows and red borders indicates if a process/activity data shall be company-specific (section 6.1). PWB: Printed Wiring Board. CAM: cathode active material, AAM: anode active material.



Source: JRC

Figure 2-8: Battery decomposition according to GRB-CBF

Figure 2. System components. The inner boxes depict the individual components of each product e.g., the battery cell comprises the components 'anode', 'cathode', 'electrolyte', 'housing' and 'other', while the components of the battery module are 'cells', 'housing' and 'electronics'.



Source: JRC

Figure 2-9: System components according to (Andreasi Bassi, et al., 2023)

Material Tree STEP 2: Recommended approach and options for voting from WP2

The consortium recommends using an adaptation of GREET for the vehicle decomposition tree, and an adaptation of GRB-CBF for the traction battery decomposition tree, including explanations of elements that need further improvement or that are worked on in 2024.

2.2 Goal & Scope (Task 2.2)

Task 2.2 elaborates a common Goal and Scope definition by integrating environmental and social aspects for the transport sector, in particular for electromobility, from best available techniques and informed by the needs and gaps identified in WP1.

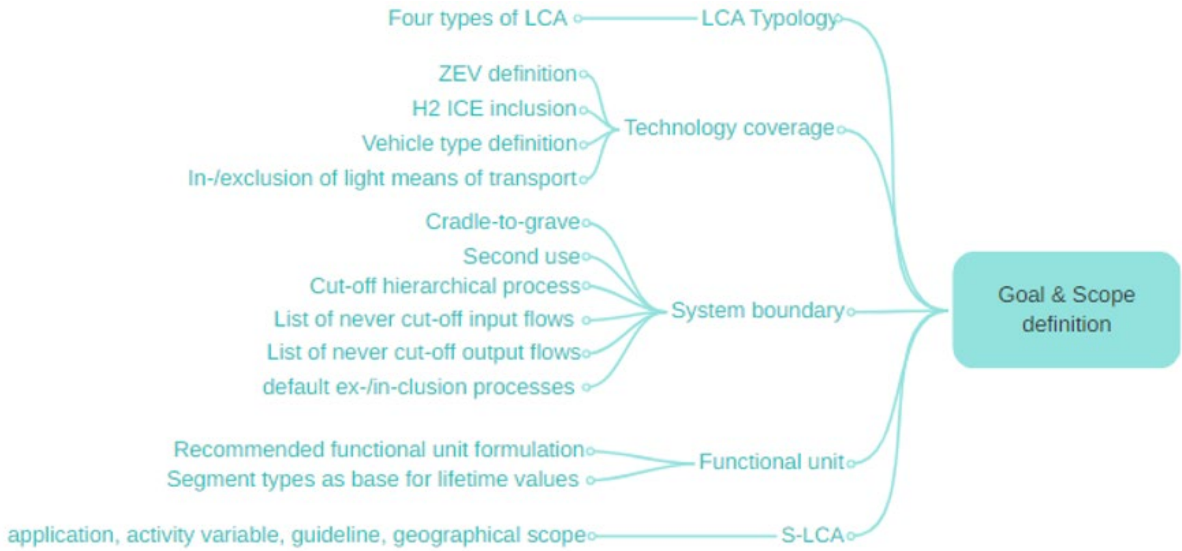


Figure 2-10: Summary of recommendation & voting options

2.2.1 Subtask 1: Goal definitions

In the goal definition we cover several aspects: we define the LCA types and the reasons for carrying out the LCA as well as who is the user and who is the target audience.

Goal & Scope STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

Three main types of LCA were identified in the WP1 TranSensus LCA deliverables:

- **Retrospective LCA:** The retrospective LCA is on the product level and is conducted for already existing products.
- **Prospective LCA:** The prospective LCA is also on the product level but it is performed for future products. This can be emerging technologies or products or also products that are still in development.
- **Fleet level LCA:** The fleet-level LCA is on a higher system-level and can be performed in the present or in the future.

Based on this, initial definitions from the ILCD decision context were analysed (see Table 2-5) in WP 2.2. Inputs from partners were collected. The definition for retrospective vehicle LCA and the prospective vehicle LCA were well aligned with the understanding in the consortium. However, different understanding for the fleet level existed – one seeing the fleet level as the ILCD on the macro economy level and one seeing the fleet level on the manufacturer level. Therefore, the fleet LCA was divided into two different levels (see Table 2-6). To provide more details, we decided to add the user of the LCA type to our definition.

Table 2-5 : Definition of LCA types with decision context and audience and reason from ILCD

LCA type and ILCD decision context	Definition	Audience and reason
Product LCA Decision context C1 ("accounting with interactions") Decision context C2 ("accounting without interactions")	A Product LCA aims to evaluate environmental impacts after the product is developed. It can thereby be defined as an accounting type of assessment. The main applications of the result are for monitoring and reporting purposes	• Compliance & reporting (article 7a CO2 emission perf. standards; article 7 Battery Directive) • Product declarations (e.g. ecolabels) • Consumer info
Prospective LCA Decision context A ("Micro-level decision support")	A Prospective LCA aims to identify environmental hotspots before or during the developing phase of a product. Decisions drawn from the LCA primarily influence the foreground system and not the background system, thus, no structural changes occur.	• Eco-Design • Comparisons/Benchmarking • Development of PCR • Development of Ecolabel criteria • Development of product specific indicators such as "Carbon Footprint"
Fleet Level LCA Decision context B ("Meso-/Macro-level decision support")	A Fleet Level LCA (context: mobility sector) aims to evaluate the environmental impacts related to the transition of one technology to another. In contrast to Product/Prospective LCA, it is (typically) dynamic and has a time-scope of many years. Fleet Level LCA uses scenario analysis. Decisions drawn from the LCA have large-scale, structural effects on the background system due to market mechanisms.	• Policy development ("backcasting analysis", "what-if analysis") • Policy information (groups of products) • Strategy analysis

Goal & Scope STEP 2: Recommended approach and options for voting from WP2

The Consortium recommends categorizing LCAs into 4 types (see decision tree and definitions underneath).

The following definitions (see Table 2-6) are proposed:

Table 2-6 : Definitions proposed in TranSensus LCA

LCA type	Definition	Reason	User of the LCA	Target audience
Retrospective vehicle LCA	A Product LCA aims to evaluate environmental impacts slightly before or after the start of production. A nearly finalised bill of materials of all parts is available to the OEM.	• Reporting + compliance • Calculation base for sustainability report • Identification of hot-spots • Target setting • Comparison between vehicles	• LCA experts within the R&D department / product department • External consulting firms	• Customers • Internal stakeholders (decision makers, product developers) • Auditors
Prospective vehicle LCA	A prospective LCA is conducted in the development stage and aims to estimate environmental impacts before the start of production (several years). The TRL is low (TRL<6) and the BOM is not completely defined.	• Research and development (eco-design) • Target setting • Identification of levers to reach targets • Comparison between vehicles	• R&D department • Purchase department (targeting supply chain) • External consulting firms • Researchers (universities and RTOs)	• Internal stakeholders (decision makers, strategy developers) • Policy makers (informative) • Scientific community
Manufacturer fleet LCA	A manufacturer fleet LCA aims to evaluate the weighted environmental impact of a series of different products introduced by a single manufacturer. Typically it is based on an extrapolation of vehicle LCAs.	• Corporate reporting of fleet emissions • Inform future decarbonisation strategy • Fleet portfolio optimisation	Same as retrospective/prospective vehicle LCA	Managers for target tracking + general public (infos in Annual and Sustainability report), CDP, sustainability ratings, financial ratings

Macro level fleet LCA	Macro level fleet LCA is conducted at the sub, national or international level to support economy-scale strategies. Fleet is typically generic, i.e. representative of a variety of manufacturers	• Inform policy decision making • Strategic & sustainability planning • Evaluation of consequences of large scale decisions	• Research institutes • Consultancies • Governmental agencies	• Policy makers • Scientific community • General public

And a decision tree that shows when to apply which LCA type was developed:

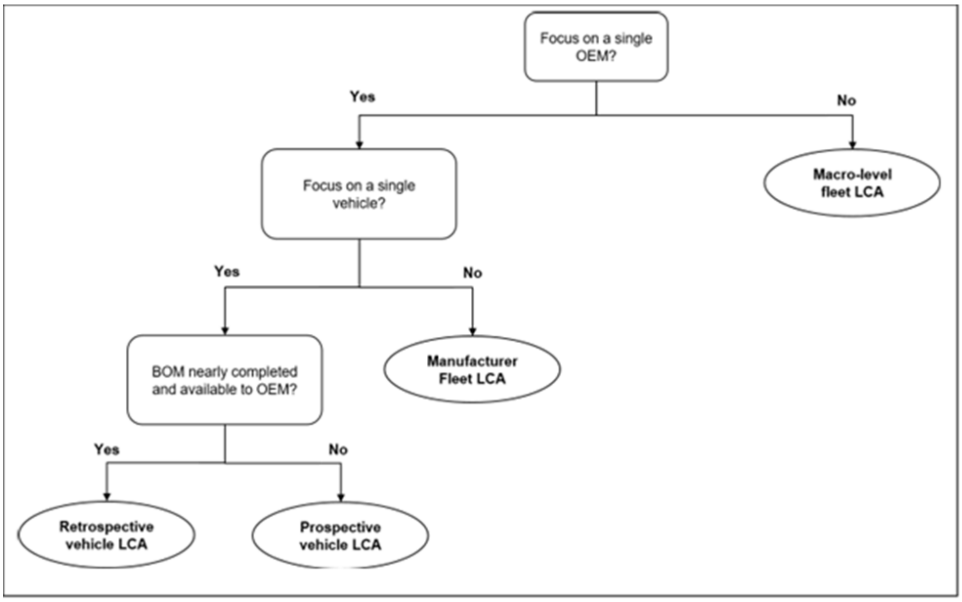


Figure 2-11: Decision tree showing the differentiation between the LCA types

2.2.2 Subtask 2: Technology coverage

This subtask has several goals including the definition of a zero-emission vehicle, which vehicle types, which powertrains and components to include in the LCA.

Technology coverage STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

To define the zero emission vehicle (ZEV) in TranSensus, available definitions from literature were collected (Table 2-7). In available literature ZEVs are defined as vehicles that operate without any tailpipe emissions. In all sources, this includes different power trains:

- BEV – Battery electric vehicles

- FCEV – Fuel cell electric vehicles
- FC-REEV – Fuel cell range extended electric vehicles
- BEV-ERS – Battery Electric Vehicles with dynamic charging operation on Electric Road Systems (e.g. includes BCEV = battery catenary electric vehicles, as well as vehicles operating on dynamic wireless/inductive charging, or rail conductive charging)

Some sources include plug-in hybrid electric vehicles (PHEVs). This is not aligned with the understand of ZEVs in TranSensus because over their full life cycle they do emit tail pipe emissions since they cannot operate fully electrically 100% of the time. Sometimes hydrogen fuelled ICEs (H_2 ICE) are included in ZEVs as well. While they do not emit CO_2 during the use, they do emit some other tail pipe emissions.

Table 2-7 : Definitions on ZEVs in different sources of literature

Year	Author	Title	DOI / Weblink	Definition
2022	Axsen et al.	What Do We Know about Zero-Emission Vehicle Mandates?	10.1021/acs.est.1c08581	The definition of ZEV commonly includes any vehicle that can operate fully or partially with zero tailpipe emissions, namely battery electric (BEVs), plug-in hybrid electric (PHEVs), and hydrogen fuel cell vehicles (HFCVs).
2022	Rosales-Tristancho et al.	Analysis of the barriers to the adoption of zero-emission vehicles in Spain	10.1016/j.tra.2022.01.016	Zero-emission vehicles (ZEVs) are motor vehicles that do not produce direct tailpipe emissions. These vehicles can be divided into two groups: electric vehicles that store energy in a battery (Battery Electric Vehicles or BEVs), and electric vehicles in which energy is stored in the form of hydrogen (Fuel Cell Electric Vehicles or FCEVs).
2020	Miele et al.	The role of charging and refuelling infrastructure in supporting zero-emission vehicle sales	10.1016/j.trd.2020.102275	Following the governments of California, Canada and others, we use the term ZEV in reference to vehicles that can operate without emitting any tailpipe GHGs. This definition includes battery electric vehicles (BEVs) which are powered solely by electric batteries charged from the grid, **plug-in hybrid electric vehicles (PHEVs)** which can be powered interchangeably between electricity and gasoline (or both together), and hydrogen fuel cell vehicles (HFCVs) which are powered by hydrogen gas.
2002	Dixon et al. (RAND)	Driving Emission to Zero: Are the Benefits of Califonia's Zero Emission Vehicle Program Worth the Costs	_	ZEVs were defined as vehicles that produce zero exhaust emissions **under all operating conditions**. Battery-powered electric vehicles (BPEVs) and direct hydrogen fuel-cell vehicles (DHFCVs, which are fueled with hydrogen gas) are the only ZEVs considered to be technically feasible for commercial production.

1995	Woods	Zero-emission vehicle technology assessment. Final report		The definition of ZEV used is based on Title 13, California Code of Regulations, Part 1900, as modified by the California Air Resources Board (CARB), and was approved by NYSERDA for this study: "A Zero Emission Vehicle (ZEV) is a vehicle that produces zero emissions of all criteria pollutants (carbon monoxide, oxides of nitrogen, non-methane hydrocarbons, and particulate matter [PM-10]) **under all possible operating modes and conditions**, with the exception of emissions from fuel-fired heaters. Fuel-fired heaters are permitted in ZEVs provided that the fuel system is completely sealed and leak-free and that the heater cannot operate when the ambient temperature exceeds 40°F."
2023	EU	EU CO2 regulations for cars and vans	Publications Office (europa.eu)	"... **Zero-emission vehicles currently include battery electric vehicles, fuel-cell and other hydrogen powered vehicles**, and technological innovations are continuing. Zero- and **low-emission vehicles, which also include well performing plug-in hybrid electric vehicles**,…"
2023	EC	Proposed CO2 regulations for HDVs	EUR-Lex - 52023PC0088 - EN - EUR-Lex (europa.eu)	'zero-emission vehicle' means the following vehicles: (a) a heavy-duty motor vehicle with not more than 5 g/(t·km) or 5 g/(p·km) of CO2 emissions as determined in accordance with Article 9 of Regulation (EU) 2017/2400; (b) a heavy-duty motor vehicle fulfilling the conditions of point 1.1.4 of Annex I to this Regulation if no CO2 emissions have been determined according to Regulation (EU) 2017/2400; (c) a trailer equipped with a device that actively supports its propulsion and has no internal combustion engine or has an internal combustion engine emitting less than 5 g CO2/kWh as determined in accordance with Regulation (EC) No 595/2009 of the European Parliament and of the Council and its implementing measures or UNECE Regulation (EC) No 49.

Furthermore, vehicle types to include were collected based on typical means of road transport:

- Passenger car
- Light commercial vehicle/ van
- Lorry/ truck
- Urban bus
- Coach
- Motorcycles/ Mopeds etc.
- Light Means of Transport (e-bikes, e-scooters..)

Technology coverage STEP 2: Recommended approach and options for voting from WP2

The consortium recommends defining a zero-emission vehicle as 'a vehicle without any tail pipe emissions'.

The consortium recommends considering the following powertrains in the Transensus LCA methodology:

- BEV - Battery Electric Vehicles
- FCEV - Fuel cell electric vehicles
- FC-REEV – Fuel Cell Range Extended Electric Vehicles
- BEV-ERS – Battery Electric Vehicles with dynamic charging operation on Electric Road Systems (e.g. includes BCEV = battery catenary electric vehicles, as well as vehicles operating on dynamic wireless/inductive charging, or rail conductive charging)
- H2 ICE – H2 internal combustion engine.

The TranSensus LCA consortium recommends including the following vehicle types:

- Passenger car
- Light commercial vehicle/ van
- Lorry/ truck
- Urban bus
- Coach
- Motorcycles/ Mopeds etc.

Regarding the inclusion or not of light means of transports such as e-bikes and e-scooters, the consortium proposes two voting options:

Table 2-8 : Voting options on light means of transport

	Option 1	Option 2
Descrip-tion	Include light means of transport such as e-bikes and e-scooters in the vehicle types additional to the types mentioned above	Not Include light means of transport such as e-bikes and e-scooters
Pros	• Probably fairly easy to model since it is a simple product • Relevant in some regulations coming into place	• Probably not directly in the scope of the ZEV guidelines • Quite different purpose and there-fore challenging to capture it in the same system boundary and func-tional unit as the other vehicles

		• Quite different supply chain compared to vehicles – additional effort in including it in the guidelines
Cons	• Probably not directly in the scope of the ZEV guidelines • Quite different purpose and therefore challenging to capture it in the same system boundary and functional unit as the other vehicles • Quite different supply chain compared to vehicles – additional effort in including it in the guidelines	• Probably fairly easy to model since it is a simple product • Relevant in some regulations coming into place

2.2.3 Subtask 3: System boundary for retrospective vehicle LCA

In this subtask, the system boundary for the retrospective vehicle LCA is defined, including the life cycle stages. Cut-off rules for flows and Inclusion/ Exclusion for processes are also defined.

System Boundaries STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

An overview of the input from guidelines and the survey on the life cycle stages to include and cut-off rules for processes was compiled. Inputs from all WP2 partners on their system boundaries and cut-off rules were collected.

System boundary

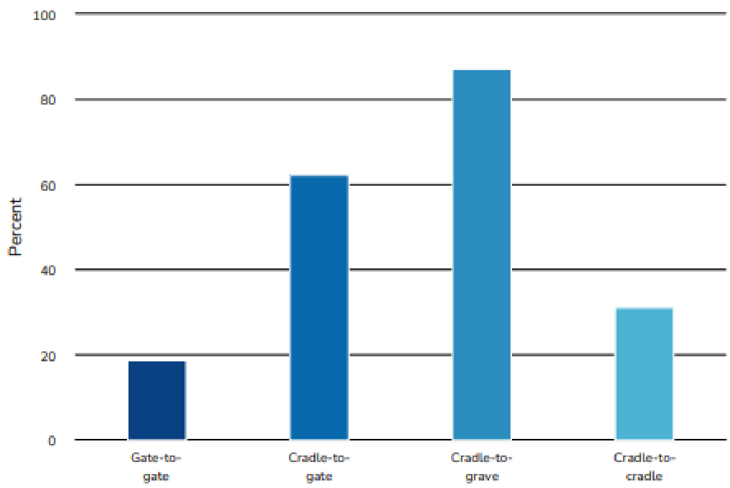
Several key findings were highlighted in the WP1 TranSensus deliverables and surveys, regarding system boundaries:

- 1: guidelines & standards: As Table 2-9 shows the guidelines either apply cradle-to-gate (potentially + use-phase) or cradle-to-grave. None of the mentions second life in their system boundary.
- 2: Survey: Figure 2-11 shows that industry is also mainly applying cradle-to-gate and cradle-to-grave as their system boundary.
- 3: WP2 partners: Inputs were collected from WP2 partners regarding their practice for system boundaries. The answers are well aligned with the analysis of guidelines and standards and the survey by mostly using either cradle-to-gate or cradle-to-grave. Second life is typically not considered.

Based on the proposal and the goal in TranSensus, the system boundary should be cradle-to-grave to capture the full life cycle for ZEVs. Since the use phase is included, the energy in the use phase should be modelled well-to-wheel. A question that still needs to be addressed is whether or not to include second life.

Table 2-9 : Overview on system boundaries from WP1

Guidelines and standards report	System boundary
CATARC	Cradle-to-gate + use
GBA-rulebook	Cradle-to-gate (+ recycling in new version v1.5)
GRB-CBF_Carbon FootprintRules-EV	Cradle-to-grave: Raw material acquisition, manufacturing of the battery system, distribution, EoL
PEFCR Batteries	Cradle-to-grave
Catena-X Product Carbon Footprint Rule-book	Cradle-to-gate
eLCAr	Cradle-to-grave
PCR Buses and coaches v.2 EDP Int	Cradle-to-grave
RISE - LCA Guidelines for electric vehicles	Cradle-to-grave
VDA - VDA - Guidance for Conducting Life Cycle Assessment Studies of Passenger Cars	Cradle-to-grave
PFA technical guidance	Cradle-to-grave



Value	Percent	Responses
Gate-to-gate	18.8%	3
Cradle-to-gate	62.5%	10
Cradle-to-grave	87.5%	14
Cradle-to-cradle	31.3%	5

Figure 2-12: Survey results on system boundaries modelled

Cut off rules for flows and exclusion of processes

The ISO 14044 gives the following guidance on cut-off:

The cut-off criteria are defined as a *"Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study"*.

The cut-off criteria for initial inclusion of inputs and outputs and the assumptions on which the cut-off criteria are established shall be clearly described. The effect on the outcome of the study of the cut-off criteria selected shall also be assessed and described in the final report.

Several cut-off criteria are used in LCA practice to decide which inputs are to be included in the assessment, such as mass, energy and environmental significance. Making the initial identification of inputs based on mass contribution alone may result in important inputs being omitted from the study.

Accordingly, energy and environmental significance should also be used as cut-off criteria in this process.

a) Mass: an appropriate decision, when using mass as a criterion, would require the inclusion in the study of all inputs that cumulatively contribute more than a defined percentage to the mass input of the product system being modelled.

b) Energy: similarly, an appropriate decision, when using energy as a criterion, would require the inclusion in the study of those inputs that cumulatively contribute more than a defined percentage of the product system's energy inputs.

c) Environmental significance: decisions on cut-off criteria should be made to include inputs that contribute more than an additional defined amount of the estimated quantity of individual data of the product system that are specially selected because of environmental relevance.

Similar cut-off criteria may also be used to identify which outputs should be traced to the environment, e.g. by including final waste treatment processes. Where the study is intended to be used in comparative assertions intended to be disclosed to the public, the final sensitivity analysis of the inputs and outputs data shall include the mass, energy and environmental significance criteria so that all inputs that cumulatively contribute more than a defined amount (e.g. percentage) to the total are included in the study.

When looking at the standards and guidelines (Table 2-10), there is no real differentiation between the cut-off of flows and the exclusion of processes. Cut off rules as defined in the existing guidelines deviate often from what the standard ISO 14044 proposes or focus on cut-off of processes instead of flows. OEMs seems to apply no cut-off of flows at all. There is no real consensus between the existing guidelines, and none is giving full guidance on cut-off of flows and exclusion of system boundaries. The analysed OEM reports in WP1 were mostly in line with the ISO 14044.

Table 2-10 : Overview of cut-off rules from WP1

Guidelines and standards report	Cut off rules
CATARC	Infrastructure and equipment excluded
GBA-rulebook	Cut off rule from the Commission Recommendation on the use of the Environmental Footprint has been adopted
GRB-CBF_Carbon FootprintRules-EV	Manufacturing of capital goods for battery production, Battery use-stage, battery assembly with the OEM system components, auxiliary inputs not related to battery production to be excluded
PEFCR Batteries	Processes and elementary flows up to 3.0% (cumulatively) based on material and energy flows and the level of environmental significance (single overall score)
Catena-X Product Carbon Footprint Rulebook	Development/administration expenses and emissions from employee commuting are excluded. If based on the results of a screening study, individual material or energy flows are found to be insignificant for the carbon footprint, these may be excluded for practical reasons

eLCAr	Not specified
PCR Buses and coaches v.2 EDP Int	Upstream: exclusion of materials, energy and manufacturing facilities, transportation of raw materials, packaging Core: production equipment and building, travels. Downstream: waste treatment facilities, road infrastructure and services facilities, cleaning agents
RISE - LCA Guidelines for electric vehicles	Not specified
VDA - VDA - Guidance for Conducting Life Cycle Assessment Studies of Passenger Cars	components, processes or emissions can be excluded if the effort required for including them seems unjustified (e.g. short distance forklift transport of components within the production site). No intentional cut-off should be applied for the parts lists and bill of materials. The modelled weight of cars shall range within 3% of the certification weight. No cut-off criteria for manufacturing processes and emissions are defined. Capital goods shall not be included in the foreground system. Inbound logistic (delivery from suppliers) should be included if considered relevant. The replacement of wear parts and warranty parts, after sales services, and washing of cars do not have to be included (strongly user dependent). Recycling processes or environmental benefits resulting from the provision of secondary material shall be considered.
PFA technical guidance	The document recommend excluding: 1) Infrastructure of administration/marketing) 2) commuting and travel business for employees 3) manufacturing of supplier infrastructure and tools (optional to exclude or include) 4) manufacture of packaging for the logistics of parts returning to the plant (recommendation to take lost packaging into account) 5) manufacture of auxiliary materials for manufacturing (cutting oils, gloves, etc) : optional to include however they are usually integrated in used datasets 6) manufacture of terminal plant infrastructure and tools or equipment manufacturing plant 7) operation of the aftersales network and distribution of parts and accessories 8) particulate emissions from tyre wear and brake pads (optional)

Inputs from partners practices were collected. Either no intentional cut-off is applied, or the specific cut-off rules are based on the project. A process on how to deal with cut-off of flows when it cannot be avoided is developed. Process stages/elements that are frequently discussed whether to include them or not in the system boundary are analysed in WP2 to give recommendations for TranSensus LCA.

System Boundaries STEP 2: Recommended approach and options for voting from WP2

The consortium recommends that the system boundary model should be cradle-to-grave.

This is also in line with most existing guidelines and standards as well as upcoming regulations. Including the use phase and recycling comes with modelling challenges that will be addressed in the functional unit (use phase) and the allocation (recycling).

Table 2-11 : Voting options on the second use

Regarding the second use, the consortium proposes two options for voting:		
	Option 1	**Option 2**
Description	**Cradle-to-grave system boundary for ZEV without second use**	**Cradle-to-grave system boundary for ZEV with second use**
Pros	• In line with current regulations, modelling of second use very case dependent, no commonly applied methodology	• More complete system boundary, second use might become a relevant application
Cons	/	• Difficult to foresee second use and its relevance at the moment, modelling is very case dependent, no commonly applied methodology
Possible consequences	Rejection of methodology by key stakeholders (particularly the EC) as not compliant with legislative requirements for batteries.	-
Recommendation of subtask	none	

For the cut-off of flows, the consortium recommends following a hierarchical process:

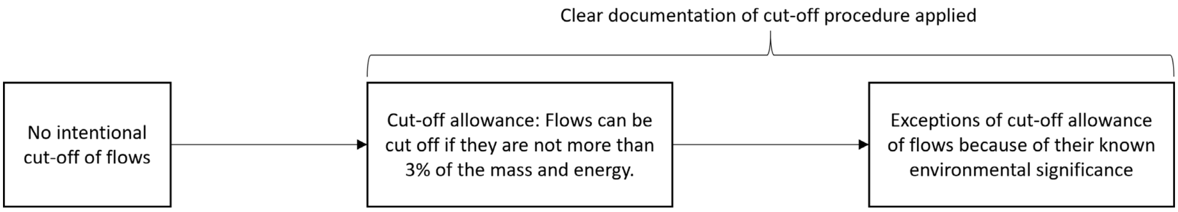


Figure 2-13: Hierarchy on how to deal with cut-off of flows

No intentional cut-off of flows should be made. In case, cut-off is needed, we suggest thresholds based on 3% of mass and energy of the flows. 3% are common thresholds in existing guidelines such as PEFCR batteries and the GBA rulebook. We don't recommend cut-off based on environmental significance because it is hard to estimate and highly depends on the impact category considered. Combined with the allowance thresholds, we provide a list of inputs and outputs that are known to be relevant from an environmental perspective, even if they have rather small shares of mass or energy and are therefore mandatory to include. When a cut-off is applied, transparent documentation of the approach is of high importance – why was something cut off and how.

From the best of knowledge and experience of the WP2 TranSensus LCA, the following list of input and output flows are highly relevant from an environmental perspective and should never be cut-off. This list might experience changes in the future with new technologies.

The consortium recommends to include and never cut-off all cited input and output flows in the following table:

Table 2-12: Overview of flows that are not allowed to be cut-off based on the knowledge of WP2

Inputs	**Outputs**
Flow	**Flow**
Platinum Group Metals (PGM) - e.g. used in catalysts	All fluorinated gases (incl. CFCs, HCFCs, HFCs, HFEs, Halons, SF6, NF3, etc.)
Gold (Au) and Silver (Ag) - e.g. used in electronics	Arsenic (As), Lead (Pb), Mercury (Hg), Chromium (Cr), Cadmium (Cd) and their salts
Rare Earth Elements (REEs) and their salts - e.g. used in electric motors	NMP (n-methyl pyrrolidone)
Cobalt (Co), Lithium (Li), Nickel (Ni) and their salts – e.g. used in LIBs	methane (CH4)
Carbon fibers, VGCF, carbon nanotubes	Heavy metals in general (nickel, copper, organic chemicals, lead, thallium etc),

For including/excluding processes from the system boundary, the consortium recommends the following for frequently raised discussion points in LCAs.

Table 2-13: Recommendations on inclusion and exclusion from system boundary in TranSensus LCA

Element	**Definition**	**Consensus in WP2**	**Note**
Development, administration, marketing expenses	Refers to inputs to the manufacturing plant that are not directly related to the production process (e.g. heating and lighting of associated office rooms, secondary services, sales processes, administrative and research departments, etc.) (JRC-CBF)	Exclude	
Employee commuting	Transport of employees to and from works	Exclude	
Capital goods - infrastructure and equipment	Refers to capital goods (e.g., machinery, trucks, infrastructure) with a lifetime longer than one year. The lifetime is the period between the time of production and the time of initiating waste treatment of the product (ecoinvent, see Weidema et al., 2013)	Exclude	Excluding capital goods in line with PEF.
Charging station		Exclude	

Infrastructure for electricity and hydrogen generation	This includes: power plant, transmission (+ losses), transformers	Include	
Auxiliary materials for production	Refers to materials needed for production that do not end up in the product (e.g. solvents, cleaning materials). This also includes capital goods with a lifetime shorter than 1 year.	Include	
Maintenance: consumables	Consumable during the use phase of the vehicle. The minimum items to consider are: engine oil, oil filters, 12V battery, engine coolant and traction battery, air conditioning gas (PFA)	Include	
Maintenance: wear parts	Replacement of **wear parts** (such as tyres or brake linings), whose renewal depends heavily on the driver's driving mode. Reference should be made to the theoretical change frequencies specified in the maintenance book where they exist. The minimum elements to take into account are: tyres, brake linings and windscreen wipers (PFA)	Include	
Non-exhaust emissions from tyres and brakes	Emissions of particulate matter due to road vehicle tyre and break wear (NFR code 1.A.3.b.vi). 1.A.3.b.vi-vii Road tyre and brake wear 2019 — European Environment Agency (europa.eu)	Include	Currently no mature methodology or database. Needs to be aligned with the data collection (WP2.3)
Charging cable		Include	

2.2.4 Subtask 4: Functional Unit for retrospective vehicle LCA

In this subtask, the functional units for ZEVs for the retrospective vehicle LCA are defined.

Functional Unit STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

Several key findings were highlighted in the WP1 TranSensus deliverables regarding functional units:

- The most common FUs for product-level vehicle LCAs (across all reviewed guidelines and standards, and scientific studies) were "passenger*km" (for passenger vehicle), "tonne*km" (for freight vehicles). and "vehicle*km".

- Almost all reviewed OEM reports adopted “transport of passengers or goods over the *vehicle service lifetime* (km)” as FU. Exceptions where the use of Passenger*kilometer for buses and Tonne*kilometer for some of the truck LCAs.
- All these FUs are acceptable, but it is worth pointing out that strictly speaking, the former two (i.e., “passenger*km” and “tonne*km”) would be preferable, since they more directly relate to the intended “function” of the vehicles in question, i.e., respectively “transporting passengers” and “transporting goods”, and they implicitly include considerations of capacity, which may lead to more meaningful comparisons across different vehicle types.

The definition of the functional unit is based on the lifetime of the vehicle. Therefore, the lifetime considered is a key topic. The survey in WP1 shows that industry mostly assumed lifetimes of their vehicles between 150 000 and 200 000 km. Only some differentiate based on the vehicle type. Occupancy rates are typically not included in the functional unit.

The inputs from the partners on functional unit and lifetimes were collected. The functional units are well aligned with the findings from the review by using the vehicle lifetime. How the lifetime is defined deviates. Some partners use the same life time for all vehicles, others differentiate per vehicle segment. CEA suggests a new approach by developing mission profiles for vehicles and using them as the base for the functional unit and the assumed life time. Mission profiles describe the typical use of a vehicle over the year and therefore the kilometre driven in total.

Furthermore, literature inputs on lifetime and durability were collected (see Table 2-14). It has to be noted that all the collected sources use assumptions and are based on well-known ICE vehicles. They do not consider degradation data from EVs.

Table 2-14: Literature inputs on lifetime and durability

Papers reviewed	Link	Authors	Year of analysis	Lifetime miles assumed	Location and comments
A Range-Based Vehicle Life Cycle Assessment Incorporating Variability in the Environmental Assessment of Different Vehicle Technologies and Fuels	https://www.mdpi.com/1996-1073/7/3/1467	Messagie et al	2014	230,000 km (13.7 years)	Belgium
Sensitivity Analysis in the Life-Cycle Assessment of Electric vs. Combustion Engine Cars under Approximate Real-World Conditions	https://www.mdpi.com/2071-1050/12/3/1241	Helmers et al	2020	200,000 km (-)	Germany Today, batteries can offer > 90% of the original capacity even at 200,000 km [40,41]. Use phase mileages between 150,000 and 200,000 km were most often applied in scientific reports [26,42]
Trends in life cycle greenhouse gas emissions of future light duty electric vehicles	https://www.sciencedirect.com/science/article/pii/S1361920919310466	Ambrose et al	2020	250,000 km (-)	US
The role of pickup truck electrification in the decarbonization of light-duty vehicles	https://iopscience.iop.org/article/10.1088/1748-9326/ac5142	Woody et al	2022	330,000 km (18 years)	US projected technological developments
Statistical analysis of empirical lifetime mileage data for automotive LCA	https://link.springer.com/article/10.1007/s11367-015-1020-6	Weymar and Finkbeiner	2016	230,000 km (-)	US

Comparison of advanced fuels—Which technology can win from the life cycle perspective?	https://www.sciencedirect.com/science/article/pii/S0959652619327490?via%3Dihub	Rosenfeld et al	2019	200,000 km (-)	Austria
Comparative analysis of the life-cycle emissions of carbon dioxide emitted by battery electric vehicles using various energy mixes and vehicles with ICE	http://www.combustion-engines.eu/Comparative-analysis-of-the-life-cycle-emissions-of-carbon-dioxide-emitted-by-battery,147159,0,2.html	Borkowski and Zawaslak	2022	300,000km (20 years)	Europe and US
Vehicle's lightweight design vs. electrification from life cycle assessment perspective	https://www.sciencedirect.com/science/article/pii/S0959652617318711	Mayyas et al	2017	200,000km	US
16 - Life cycle assessment of hybrid passenger electric vehicle	https://www.sciencedirect.com/science/article/pii/B9780128237939000176	Candelaresi, D et al,	2022	200,000-300,0300+00 km	Europe
Life Cycle Assessment of Traditional and Electric Vehicles	https://link.springer.com/chapter/10.1007/978-981-15-9529-5_16	Ruben Boros, R et all	2020	300,000km	Europe

All sources are well aligned regarding using one vehicle as the functional unit and estimating its lifetime based on kilometres. Three main options regarding the functional unit exist:

- Vehicle*km for all vehicles
- Passenger*km (passenger vehicle) and tonne*km (freight vehicles)
- Vehicle*km (passenger vehicle) and tonne*km (freight vehicles)

For the lifetime assumptions, three main options could be identified:

- One lifetime regardless the vehicle, differentiate between passenger and freight vehicles
- Lifetime assumptions more differentiated by vehicle type
- Mission profiles

STEP 2: Recommended approach and options for voting from WP2

For the functional unit of vehicles for retrospective vehicle LCA, the consortium recommends to use:

- **ton*km** for **freight** vehicles,
- **passenger*km** for **busses**
- and **passenger*km** for passenger cars with the default assumption of one passenger which then **equals to vehicle*km** for **passenger cars**.

Occupancy rates are to be addressed as part of a **sensitivity analysis**.

We choose this approach for occupancy rates since passenger*km is the more accurate functional unit as it is more reflective of the actual function. However, estimating occupancy rates adds a layer of complexity and therefore uncertainty to the functional unit and hinders international comparisons.

Table 2-15: Voting options on lifetime assumptions

For the life time assumptions, the consortium recommends default values for segment types (very small car, small car…) and mission profiles in the sensitivity analysis.

In the mission profiles, different default values are developed for example for Uber, couples, family using the same car, etc. The default values will be developed in the next weeks.

Justification:

- More details about car segments as compared to car types (passenger, freight, bus)
- Relatively easy to estimate
- Also allows comparison worldwide

2.2.5 Subtask 5: Goal and Scope for S-LCA

To establish consistency between LCA and S-LCA, the definition of goal, technology, system boundary, and functional for S-LCA will be defined similarly to LCA. In the Goal and scope phase, S-LCA's application, Activity Variable, Regulations, Standards and guidelines followed, and Geographical Coverage are all independently decided. The S-LCI and S-LCIA phases will address other aspects of the purpose and scope, such as data collecting sources, data quality evaluation, impact assessment methodology, stakeholder category, and impact category selection.

S-LCA STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

The main application of S-LCA studies identified from the WP1 TranSensus LCA deliverables (see IV.2.1 Goal definition D1.1) is to compare different scenarios, create evaluation tools and provide indicators for social risk assessments. In-sight from the studies can be used to inform decision-makers as well as trigger actions and collaborations among stakeholders to mitigate negative impacts and reduce social risks throughout the life of a product or service.

The main Activity Variable of S-LCA studies identified in the WP1 TranSensus LCA deliverables are: The concept "activity variable" is also an additional feature in S-LCA. According to the Guideline, "The activity variable is a measure of process activity which can be related to process output." "The activity variable may be used to represent the impact share of a process compared to that of the product system (e.g., working injuries can be partitioned among processes based on worker hour(s) per process". However, it is not compulsory to use activity variables, so it is not used in all studies. In SHDB and PSILCA databases the activity variable is worker hours, therefore the reviewed studies that used SHDB or PSILCA (for example Shi et al., (2023 and Thies et al., (2019) used worker hours as the activity variable) (for information on databases, please refer to section 4.3.1 in D1.1). The chosen variables will determine the importance of different activities in the product system. Worker-hours are the most used activity variable. Another activity variable used is added value. It considers the amount of added value created in each process.

The main Regulations, standards and guidelines of S-LCA studies were identified in the WP1 TranSensus LCA deliverables are Guidelines for SOCIAL LIFE CYCLE ASSESSMENT OF PRODUCTS AND ORGANIZATIONS 2020 and Product Social Impact Assessment (PSIA) Framework.

The geographical scope of study for Social Life Cycle Assessment (S-LCA) of Battery Electric Vehicles (BEVs) varies depending on the study. Some studies have a global scope, while others focus on specific countries or regions. For example, one study evaluated the environmental life cycle assessment of BEVs from the current and future energy mix perspective in the top 10 countries for BEV sales, including China, USA, Germany, South Korea, France, Sweden, Norway, the Netherlands, Canada, and the UK. Another study reviewed the life cycle assessment studies of electric vehicles with a focus on resource use globally. A third study conducted a social life cycle assessment, focusing on the case of LiFePO4 globally. Therefore, the geographical scope of study for S-LCA of BEVs depends on the research question and objectives of the study.

STEP 2: Recommended approach and options for voting from WP2

Table 2-16: Recommended approach on S-LCA

S-LCA Questions	Application of S-LCA	Activity Variable	Standard/Guideline	Geographical Scope
Consortium recommendation	**- Assessing Social Performance or Social Risk - Decision making - Identification of social hotspots -Enhancing sustainability reporting -Comparing alternatives -Supply chain management -Policy development and regulations**	**Worker Hours**	**UNEP 2020 guideline**	**Global**
Explanation	**Assessing Social Performance or Social Risk:** S-LCA can be used to assess the social performance or social risk of a product system. This can help identify areas where social performance can be improved, and social risks can be mitigated. **Decision making:** S-LCA can be used as a tool for decision making based on sustainability criteria. By using S-LCA, decision makers can evaluate the social impacts of different alternatives and choose the most socially sustainable option.	S-LCA practitioners use the activity variable for social performance or social risk assessment because it provides quantitative data that can be used to evaluate the social impacts of a product system. The activity variable refers to the activities that are involved in the life cycle of a product system, such as production, transportation, use, and disposal. By using the activity variable, S-LCA practitioners can identify the social impacts associated with each activity and evaluate the overall social performance or social risk of the product system.	Guidelines for SOCIAL LIFE CYCLE ASSESSMENT OF PRODUCTS AND ORGANIZATIONS 2020 and Product Social Impact Assessment (PSIA) Framework are the two major guidelines that are commonly used for S-LCA. Product Social Impact Assessment (PSIA) Framework is created based on UNEP guideline 2013. The UNEP Guideline 2020, however, is more thorough and incorporates PSIA into the reference scale approach. We won't be consistent with ISO 14040 and ISO	To carry out a social life cycle assessment (S-LCA) for Zero emission vehicles (ZEVs) by Original Equipment Manufacturers (OEMs) in Europe, comprising the social impact from mining, refining, production, use, and end of life, the geographical scope of the study should cover the entire life cycle of the ZEV, including all the stages mentioned above. The study should consider the social impacts associated with each stage of the life cycle, such as the working conditions of the employees, the impact on the local community, and the social risks associated

Explanation	**Identification of social hotspots:** S-LCA can be used to identify social hotspots in a product system. Social hotspots are areas where the product system has a significant negative impact on social sustainability. By identifying social hotspots, companies can take action to improve their social performance and mitigate social risks. **Enhancing sustainability reporting:** S-LCA can be used to enhance sustainability reporting by providing a comprehensive assessment of the social impacts of a product system. By including S-LCA in sustainability reporting, companies can provide stakeholders with a more complete picture of the social sustainability of their products. **Comparing alternatives:** S-LCA can be used to compare the social sustainability of different alternatives. By evaluating the social impacts of different alternatives, decision makers can choose the most socially sustainable option.	It is preferable to use worker hours as the activity variable for social performance or social risk assessment in S-LCA for the following reasons: **Quantitative data:** Worker hours provide quantitative data that can be used to evaluate the social impacts of a product system. This data can be used to prioritize data collection and quantify the considered social inventory indicators. **Most common activity variable:** Worker hours are the most common activity variable used in S-LCA studies. This makes it easier to compare the social impacts of different product systems and to build targeted S-LCA models using existing databases such as the Product Social Impact Assessment (PSILCA) database and the Social Hotspot Database (SHDB). **Prioritization:** Worker hour data offers an additional and meaningful parameter to help prioritize further action such as additional data collection. Prioritization is a key activity for life cycle management, and worker hours can help identify the most intensive activities in a unit process.	14075 if we solely use PSIA, and we won't be considering anything quantitative either. Additionally, the UNEP Guidelines have attained a greater level of consensus that involves more organisations and businesses (see the nine pilots, which also include one developed by the Roundtable), rather than just a small number of companies (as it is for the PSIA).	with the production and disposal of the ZEV. The study should also consider the geographical location of each stage of the life cycle, as the social impacts may vary depending on the location.

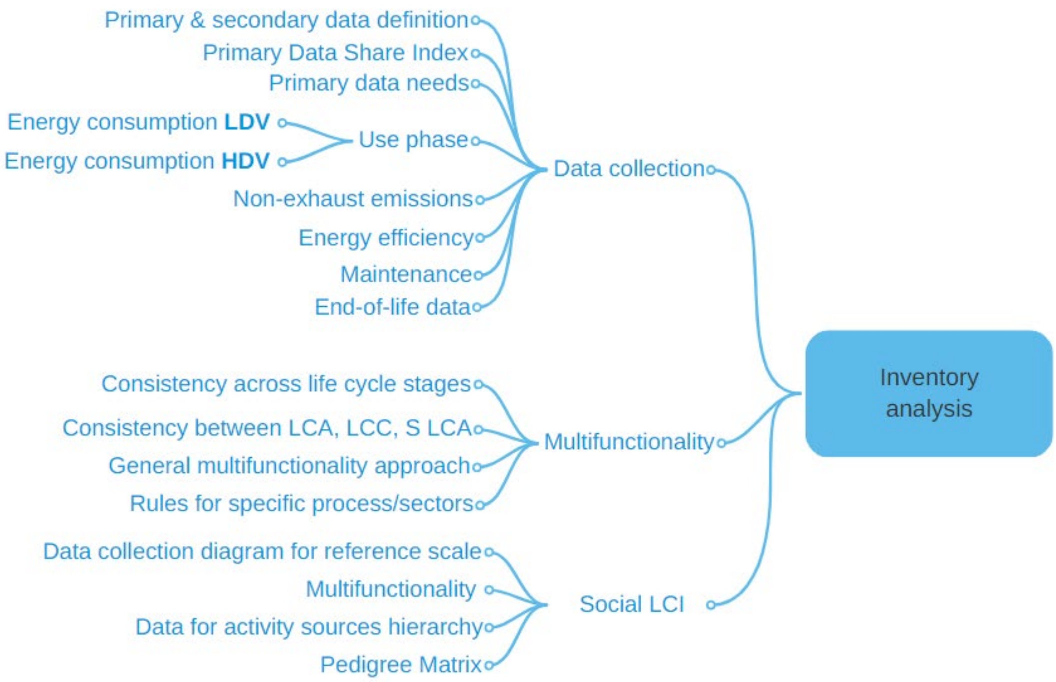
Explanation	**Supply chain management:** S-LCA can be used in supply chain management to evaluate the social sustainability of the entire supply chain. By evaluating the social impacts of the entire supply chain, companies can identify areas where social performance can be improved, and social risks can be mitigated. **Policy development and regulations:** S-LCA can be used to inform policy development and regulations related to social sustainability. By evaluating the social impacts of different products and product systems, policymakers can develop regulations that promote social sustainability.	**Reflects impact share:** Worker hours are related to 1 USD of process (or sector) output and can be used to measure process output and reflect the impact share (relative significance) of each unit process related to the product system. **Best available activity variable:** Worker hours are currently the best activity variable available for obtaining a measure of the scope each production activity represents in S-LCA. Therefore, worker hours are a preferred activity variable for social performance or social risk assessment in S-LCA due to their quantitative nature, common use, prioritization capabilities, and ability to reflect impact share.		

2.3 Inventory (Task 2.3)

This task aims at providing **guidelines and recommendations on how to address LCI and S-LCI** for ZEV, building on the knowledge obtained from WP1 (SoTA & Needs and gaps analysis). Task 2.3 is intended to provide recommendations on **primary/secondary data choices**, how data should **be collected**, and how to evaluate its **quality**. Moreover, guidelines related to **multifunctionality** of systems (like allocation rules) as well as choices related to **electric energy modelling are also discussed** and recommended due to their relevance to the ZEV field. The discussion aims to formulate draft actions and an approach to achieve recommendations avoiding multiple interpretations of requirements, guidelines and results, and increasing comparability of studies while ensuring comparability and consistency with non-ZEV LCA studies.

These first recommendations are based on WP1 findings but also WP2 partners' expertise. Live discussions, offline knowledge sharing through shared files were used to collect the partners thoughts and benefit from their expertise in the different areas.

Summary of recommendation & voting options:



Reminder: the voting questions below are meant for **"retrospective product LCA" as defined in Task 2.2 of this WP**. Adjustments to the choices/ new questions might be needed to address fleet-level and prospective LCA.

2.3.1 Subtask 1: Data collection & type

This subtask aims at determining what type of LCI data should be used in ZEV LCA studies and how this data should be collected. Given the big coverage of this subtask, and to facilitate the development of recommendations and voting questions, the UNECE level concept was utilized here. The UNECE working group that is currently working on a globally harmonized approach for vehicle LCAs, is applying and further developing the Level concept approach (TranSensus LCA - WP 2 - SG3_level concept illustration_v1(LCA-SG-03-03).pdf - Alle Dokumente (sharepoint.com))). For TranSensus, this level concept was adopted as well. The **Level concept** helps to establish transparency regarding the level of data quality used in a specific vehicle LCA (Table 2-17). This, in turn, gives an indication which vehicle LCAs (produced by different authors/companies/institutions) can be compared. For clarification: the LCA study authors should indicate themselves what the level of their LCA is (1-4). The TranSensus methodology can be applied by anybody – the data quality is just indicated by the respective level. The Level concept itself is still a work in progress in the UNECE working group **for all life cycle phases.** For example, the UNECE supply chain subtask will also develop a list of components necessary to reach Level 3.

For this voting session, **we focus on Level 3, thus recommendation and voting option will be proposed ONLY to fulfil level 3**.

Table 2-17: UNECE level concept approach for supply chain

SUPPLY CHAIN & PRODUCTION	Possible Comparison[1)]	Vehicle modelling	Representativeness[2)]
Level 1	General concept of drivetrains (e.g. BEV vs. ICEV)	Generic material composition & average vehicle curb weight	Global average / regional
Level 2	General concept of drivetrains (e.g. BEV vs. ICEV) based on exemplary „real" car vehicle model	BOM & Material information system (CMDS / IMDS[3)])	Global average / regional
Level 3	A representative vehicle of OEM A VS A representative vehicle of OEM B	BOM & Material information system (CMDS / IMDS) & „part-by-part" for hotspots	Regional & individual SC for hotspots
Level 4	e.g. OEM A's BEV model vs. OEM B's BEV model	BOM („part-by-part")	individual SC

The goal of this subtask is to address data collection, types and quality. Based on the Level Concept of UNECE, only recommendations and voting options will be given for the Level 3. Nine topics will be addressed in this report covering the whole life cycle of ZEV. Except for the definitions of primary/secondary data and the primary data share, all options are ranked as (2) for the first voting round.

Primary & Secondary data definitions

The following definitions are based on a quick literature review of definitions covering GBA, CATARC, Catena-x, PEF CR Batteries, CFB-EV, EPD Passenger Cars, e-LCAr; PFA, VDA Passenger Cars and the discussion in our subtask. See the Appendix for the definitions used in the mentioned standards.

The consortium recommends the following definitions of primary and secondary data:

Primary data:

"Primary data is data pertaining to a specific product and can be collected over its entire life cycle. It may take the form of measured activity data (e.g. kWh needed to produce a unit of X), emissions and emission factors. On a vehicle model level, the mass and material data (the BOM) sourced from e.g. IMDS is the prerequisite to gather primary data for the supply chain. On a process or activity level, data provided by suppliers is defined as "primary" if:

Input	Activity data	Source of activity data	Background dataset	Considered as
Material/Energy	X kg/ Y kWh	Literature	Secondary (LCI databank)	Secondary
Material/Energy	X kg/ Y kWh	Measured	Secondary (LCI databank)	Primary
Material/Energy	X kg/ Y kWh	Measured	Measured /proven (e.g. emissions of novel process for steel production)	Primary

Secondary data:

"Secondary data is data gathered from indirect sources such as databases. It may take the form of emission factors. On a vehicle model level, the mass and material data assumed by the LCA practitioner which is not the original BOM of the vehicle is also called "secondary". It is recommended to use the same LCI database throughout a study if possible. It is further recommended to use the more conservative secondary data set if the LCA practitioner has only restricted knowledge about a specific process/component and must therefore chose between several possible data sets."

NOTE: the information from guidelines on the definitions of primary and secondary data is available in the appendix. Furthermore, the recommendations from these guidelines regarding when/where to use primary or secondary data are also reported in the appendix.

Data collection per life cycle stages: what and how

Supply chain

Primary data needed to reach Level 3

Which level of guidance should TranSensus give, regarding the primary data needed to reach level 3 for supply chain inventory?			
	Option 1	***Option 2***	***Option 3***
Description	**No list of components is given. We give guidance on how to do the hotspot analysis (typical high impact components) and/or a threshold of primary material data needed (e.g. a percentage of BOM weight) and/or some mandatory material categories (e.g. platinum and REE).**	**Primary data requirements are set for the EV battery only (in 2024). <rest as for Option 1>**	**A list of components/ processes/guidance is provided by TranSensus for BEV/FCEV and LDV/HDV each. The list is defined in 2024.**
Pros	• more flexibility if hotspots are very different from one supply chain to another • applicable for technology development and vehicle types.	• provides consistency with emerging standards for batteries (especially for compliance under the Battery Regulation), improving comparability. • Other pros as for Option 1.	• allows comparability between LCAs • provides consistency with emerging standards for specific components – particularly for batteries (and especially for compliance under the Battery Regulation)
Cons	• Difficult to set guidelines for hotspot identification, these guidelines should be generic and specific enough. • Less comparability possible • The hotspot analysis should be provided to justify the components selected • The concept of threshold as a percentage of BOM has a big risk of overlooking some materials that have important impacts. Maybe a threshold as a percentage of environmental impacts would be a safeguard • Lack of harmonisation with emerging standards for batteries (particularly for compliance with the Battery Regulation)	• Cons, as for Option 1, except for batteries. • Risk of mis-representing non-battery components with materials having large spectrum of carbon footprint. For example, aluminium has emission factors ranging from 2-24 kgCO2eq/kg. • No apple-to-aple comparability	• difficult to agree on a specific list of hotspots, a deep knowledge is needed regarding ZEV manufacturing • Technology will change over time. A carbon intensive component today might not be carbon intensive in 10 years. Intensive components might change between vehicle type/categories. Tier 1 suppliers will face the same challenge as OEMs of not obtaining 100% primary data. Dividing components with and without primary data will not reflect the actual situation. • Hard to set components boundaries. Components

Which level of guidance should TranSensus give, regarding the primary data needed to reach level 3 for supply chain inventory?			
	Option 1	*Option 2*	*Option 3*
Descrip-tion	**No list of components is given. We give guidance on how to do the hotspot analysis (typical high impact components) and/or a threshold of primary material data needed (e.g. a percentage of BOM weight) and/or some mandatory material categories (e.g. platinum and REE).**	**Primary data requirements are set for the EV battery only (in 2024). <rest as for Option 1>**	**A list of components/ processes/guidance is provided by TranSensus for BEV/FCEV and LDV/HDV each. The list is defined in 2024.**
	• It is possible that the hotspot analysis is performed using unrepresentative secondary data and therefore lead to inaccurate hotspot identification.		might have multi functions, crash structures etc. • Not future proof/will require updating. Risk of missing important components for vehicles that has not been studied as much.
Possible consequences	Rejection of methodology by key stakeholders (particularly the EC) as not compliant with legislative requirements for batteries.	-	-
Recommendation of subtask	none		

Use stage

Energy consumption to use as standard scenario (LDV)

Here, we only focus on the technical input data for the use phase for LDVs: **the measured data regarding the energy consumption**. The voting for the respective electricity (mix) factor is prepared by another 2.3 sub-task. In this subtask we agreed that both the regulatory protocol (WLTP for LDVs) and a factor for real-world (RW) emissions should be included in an LCA study. Though, we could not find consent on whether the regulatory cycle alone or the regulatory cycle + RW correction factor would be favorable as the standard scenario. Therefore, the following voting options are presented.

Q: What energy consumption to use as standard scenario for LDV?

	Option 1	*Option 2*
Description & definition	*Standard scenario: Regulatory protocol for fleet reporting by authorities (WLTP for LDVs) [e.g. kWh/100km]* *Sensitivity analysis: Regulatory cycle + RW correction factor (factor tbd in 2024)*	*Standard scenario: Regulatory cycle + RW correction factor (factor tbd in 2024)* *Sensitivity analysis: Regulatory cycle for fleet reporting by authorities (WLTC for LDVs) [e.g. kWh/100km]*
Pros	• standard cycle already reported by OEMs. WLTP values are verified at the	• will provide better accounting for real-world effects. This will also be important for (inevitable) comparisons also between

	Option 1	*Option 2*
Description & definition	***Standard scenario: Regulatory protocol for fleet reporting by authorities (WLTP for LDVs) [e.g. kWh/100km]*** ***Sensitivity analysis: Regulatory cycle + RW correction factor (factor tbd in 2024)***	***Standard scenario: Regulatory cycle + RW correction factor (factor tbd in 2024)*** ***Sensitivity analysis: Regulatory cycle for fleet reporting by authorities (WLTC for LDVs) [e.g. kWh/100km]***
	highest level to be used for reporting to authorities. • simplest messaging to the consumer/customer. • standard for vehicle LCAs performed by German OEMs • recommend and aligns with several guidelines: PFA, VDA, JRC-CBF (WLTP used to obtain delivered energy (Wh/km)) • acknowledgement of the situation that is already widely known – i.e. that regulatory energy consumption does not fully reflect average real-world conditions. This will help improve trust in the results. • EC JRC are pursuing a real-world factor at UNECE-level, at least for Europpean perspective.	different powertrain types (i.e. also non-ZEVs) • There are already existing correction factors developed by EC JRC that could be used at least initially. EC JRC are pursuing a real-world factor at UNECE-level, at least for Europpean perspective. Also, likely to have the support of other vocal stakeholders, e.g. NGOs, and critical media • Real-world energy consumption is already monitored in most/all ZEV models, which could be used to inform improved correction factors for individual OEMs. European reporting of fuel consumption monitoring is likely to be extended to ZEVs in the future (LDV and HDV). • higher prominence given to RW consumption for customer information, which will on average better reflect the real-world situation • acknowledgement of the situation that is already widely known – i.e. that regulatory energy consumption does not fully reflect average real-world conditions. This will help improve trust in the results.
Cons	• WLTP does not represent real-world emissions • less prominence given to real-world performance for customer information. • EC JRC are pursuing a real-world factor at UNECE-level, at least for European perspective. • Potential for criticism from other vocal stakeholders, e.g. NGOs, and critical media	• Difficult to set and agree on a RW correction • As more information becomes available on WLTP vs Real-World performance this might mean updated RW scaling factors are developed reducing comparability for with previous analyses (but you could also say this for many other elements that are improved in LCA). • more complex messaging to the consumer/customer. • potential for reduced comparability with LCA for other regions? • The RW factors are still “only” factors, I.e. another complexity level that is being added. LDVs (other than HDVs) will still take several/many years until OEMs have access to real-world energy consumptions

	Option 1	*Option 2*
Description & definition	***Standard scenario: Regulatory protocol for fleet reporting by authorities (WLTP for LDVs) [e.g. kWh/100km]*** ***Sensitivity analysis: Regulatory cycle + RW correction factor (factor tbd in 2024)***	***Standard scenario: Regulatory cycle + RW correction factor (factor tbd in 2024)*** ***Sensitivity analysis: Regulatory cycle for fleet reporting by authorities (WLTC for LDVs) [e.g. kWh/100km]***
		collected over the whole life time of the vehicles. • potential to reduce trust in the regulatory cycle/results, leading to wider questions on its benefits.
Possible consequences	Proposed method may not be aligned with that recommended for EU application from UNECE work. • OEMs are likely to stop using WLTP as the standard scenario in their LCAs only if the legislator demands it. I.e. the TranSensus methodology would not be applied by OEMs if something else than the WLTP is demanded as a standard scenario.	
Recommendation of subtask	none	

Non-exhaust emissions

During the use phase, a Zero Emission Vehicle contributes to non-exhaust emissions: brake, tyre & road wear particles. “Tyre wear particles” emissions are a mix of rubber from tyre tread and minerals from the road surface mostly in cigar shaped from ~10 to ~500 µm length known as Tyre Road Wear Particles (TRWP).

Data on non-exhaust automobile tyre and brake wear emissions for road transport are available on European Monitoring and Evaluation Programme / European Environment Agency (EMEP/EEA) air pollutant emission inventory Guidebook https://www.eea.europa.eu/publications/emep-eea-guidebook-2019. Such information is based on literature surveys from early 2000’ using non-current technologies and under not real driving conditions and need to be updated.

The Particle Measurement Program (PMP), an informal working group of the United Nations Working Party on Pollution and Energy (UNECE – GRPE), has developed a new braking cycle representative of real-world braking events and conditions, the WLTP-Brake cycle. A new set of brake particles emissions data will be available leading to an update of EMEP/EEAG emission inventory Guidebook from 2024.

Regarding Tyre Road Wear Particles (TRWP) emissions, no direct measurements are available in the literature. Tyre emission factor values from EMEP Guidebook have either been derived experimentally from laboratory tests or have been estimated from average statistics. New abrasion rate definition methods on-road or in laboratory bench / drum developed by the tyre industry (Tire Industry Project – TIP) and JASIC (Japan Automobile Standards Internationalization Center) are under discussion at UNECE in 2022-2024 for regulatory purposes. Applying these methods will help to update TRWP emissions especially atmospheric contribution. However, more work is needed to establish more accurate values for tyre deposition to the road and microplastics emissions to water. No soil and water tyre microplastics from tyre emission inventory is available yet.

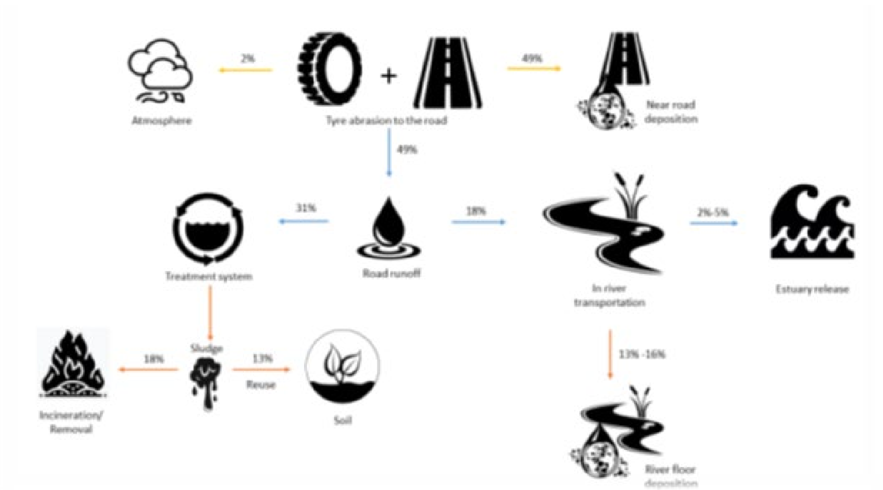


Figure 2-14 : The fate of TRWP in the environment (adapted from (Unice, 2019))

Q: How should TranSensus address non-exhaust emission?

	Option 1	*Option 2*	*Option 3*
Description & definition	**Non-exhaust emissions are all excluded from the methodology**	**Non-exhaust PM emissions from tyre and brake wear is included (basis/methodology to be determined in 2024). No other non-exhaust emissions is covered.**	**Include tyre and brake wear, as well as others (e.g. potentially hydrogen, refrigerant leakage, etc) on a list to be provided by TranSensus LCA for BEV/FCEV and LDV/HDV each. The list is defined in 2024.**
Pros	Simplest to apply	• alignment with currently proposed policy in this area • reduces potential for bias when comparing with non-ZEVs (i.e. also reducing potential for criticism) • methodologies to estimate tyre and brake wear already exist (e.g. used in inventories) that could be used until specific measurement standards are agreed	• alignment with currently proposed policy for tyre and brake wear emissions • captures also other potentially important impacts to provide a more objective (and future-proof) comparison between different powertrains • standard factors for mobile HVAC leakage rates are already available and used in national inventories (i.e. could be used as defaults where primary data was unavailable)
Cons	Failure to capture any potentially important non-exhaust impacts of ZEVs, leading to a bias in comparisons (between ZEVs, and with non-ZEVs) RIC:	• More complex • there are currently no established standardised measurement protocols for tyre and brake wear • potential to miss significant impacts from other non-exhaust emissions, creating potential for bias in comparisons • Require proposed default value or calculation methodology when specific data is missing	• more complex • there are currently no established standardised measurement protocols for tyre and brake wear • requires also gathering evidence on potential hydrogen or refrigerant leakage rates • Require proposed default value or calculation methodology when specific data is missing
Possible consequences	Not supported by EC as not aligned with policy – i.e. anticipated standards for non-exhaust PM in Europe under Euro 7.	-	-

Recommendation of subtask	The subtask does not recommend option 1 as relevant emission sources would be missing.

Use phase: Efficiency degradation factors

BEV : Capacity fade is predominately caused by the formation of a solid electrolyte interface (SEI) passivation layer at the anode-electrolyte interface due to its consumption of lithium ions. Moreover, surface layers on the anode and cathode play a barrier role in reactions with the electrolyte. This, in turn, causes an increase in cell impedance and a reduction in the charge/discharge cycling efficiency of the battery. These two effects lead to energy efficiency fade, which measures the ability of the fraction of energy that is stored in the battery compared to that delivered to the battery during charging. Energy efficiency fade has not been a significant concern in automotive applications as the cost of electrical energy to refuel a vehicle is so much less than the cost of the equivalent gasoline to refuel for an equivalent distance travelled. (link)

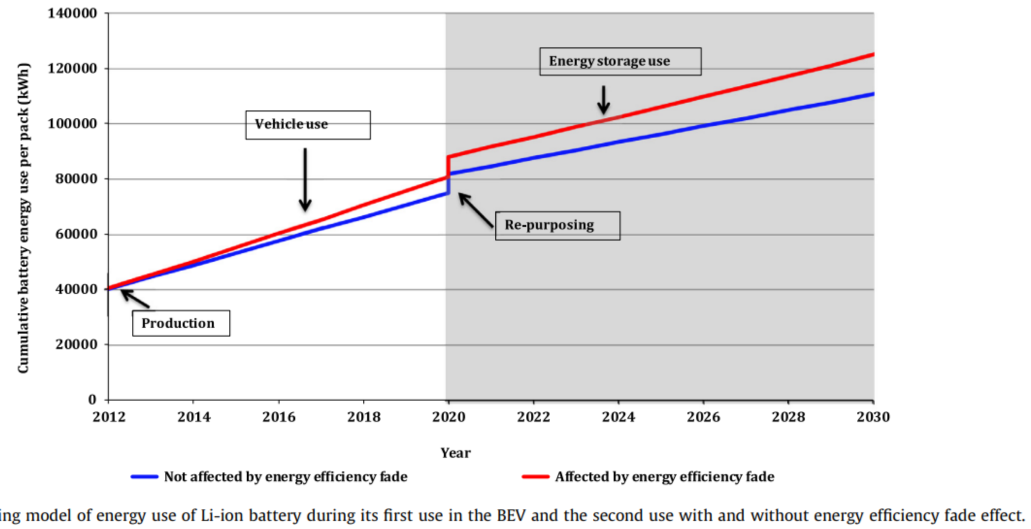


Figure 2-15 : Comparing model of energy use of Li-ion battery during its first use in the BEV and the second use with and without energy efficiency fade effect (Source below)

FCEV : Fuel cell efficiency gradually decreases over its lifetime of operation, which directly affects (i.e. increases) the amount of hydrogen (energy) consumed to power the vehicle; this reduction in efficiency over the lifetime of the vehicle is affected by the performance of the fuel cell itself, the vehicle configuration (e.g. sizing/power of the fuel cell versus energy balancing/storage). Different methods for assessing the durability of PEMFCs have been developed in the United States, the European Union, Japan, and China; according to the US Department of Energy, a metric is used until the cell/stack either accumulates a certain number of cycles or fails to meet a performance criterion, such as a cumulative 20% decline in power or a 10% loss

of average cell voltage from initial voltage under cycling conditions (Nguyen et al., 2021). The EC JRC has previously developed EU Harmonised test protocols for PEMFC durability testing for automotive applications, which includes definition of voltage loss (which directly impacts efficiency) ((JRC, 2015)).
Sources: https://www.mdpi.com/1996-1073/14/13/4048 , https://publications.jrc.ec.europa.eu/repository/handle/JRC99115

Fuel cell durability/lifetime is currently often characterized to be based on ~reaching 10% reduction in voltage/efficiency (i.e. EoL at this point). Ricardo analysis [not yet published] (based on an understanding of current and anticipated future PEMFC durability) suggests that only the highest utilization vehicles are expected to get reasonably close to this point, but that does still mean the effect could lead to a significant reduction in the lifetime average energy efficiency (i.e. increased energy consumption per km). The effect for LDVs may be relatively small (compared to higher activity heavy-duty applications), but not necessarily insignificant. Ricardo's analysis has shown that in higher activity heavy-duty applications, degradation over the use phase can lead to a significant loss in overall efficiency (i.e. close to the end-of-life point – i.e. 10% voltage/efficiency loss in some cases). Therefore a standardized way of accounting for this in LCA is expected to be important, to help understand and aid/incentivize improvement/optimization in technology development and system design for automotive applications, as well as providing more accurate comparisons between different vehicle products.

Q: How should TranSensus LCA address energy efficiency for BEV and FCEV?

	Option 1	*Option 2*	*Option 3*
Description & definition	**Do not include a calculation term for potential efficiency degradation factors in the methodology**	**Include a degradation factor in the formula/methodology applied, separate from other (e.g. RW) adjustment factors. The basis for this to be defined by TranSensus for BEV/FCEV and LDV/HDV each in 2024**	**Include Option 2 but as sensitivity analysis**
Pros	• simplest to apply	• including the option to provide accounting for degradation will future proof the methodology, and help reduce potential for bias • already being explored at the UNECE level • degradation factor could be set to 1 in most cases (except where there was evidence that it could be significant) • Test protocols are established for fuel cells	• No further complexity is added to the basic/reference scenario but the information is given to those who can put the results of the scenario in perspective. • Flexible option that address the issue and highlight its impact on the results and conclusions.

		• Will incentivise technology improvement and system optimisation	
Cons	• this is already being explored at the UNECE level • Will not provide a further incentive for fuel cell system optimization and technology improvement • Will reduce the accuracy of comparison of impacts between different products	• unclear if there is a standardised methodology for fuel cell durability that could be used to provide this information (or indeed other components that might affect this). • Adds complexity • if default factor are set; these may become redundant as technology improves (but of course this could provide additional incentive to measure and report primary data, improving competition)	• does not include a potentially significant effect by default, which risks creating a bias for the 'default' results, which are likely to be the focus for reporting and use in mainstream consumer information • Reduced incentive (versus inclusion by default) for fuel cell system/powertrain optimization and technology improvement
Possible consequences	-	-	-
Recommendation of subtask	none		

Energy consumption to use as standard scenario (HDV)

The **Vehicle Energy Consumption calculation Tool** (VECTO) is a HDV energy consumption simulation software developed by the European Commission for regulatory purposes. VECTO has been introduced in May 2017 in the European vehicle type-approval system as the official tool used in Europe to certify and monitor the fuel consumption and CO2 emissions from HDV, and its use is compulsory in Europe for CO2 certification of Heavy Duty Vehicles according to 2017/2400/EU. Beyond this use in policy implementation, VECTO can be used in any other phase of the policy cycle including impact assessment studies, analysis of the likely impact of specific technologies on fuel consumption and CO2 emissions, and formulation and analysis of future policy scenarios.

See e.g. https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/vehicle-energy-consumption-calculation-tool-vecto_en

The consortium recommends that the energy consumption to be used as a standard scenario for HDV should be based on results from the European HDV CO2/fuel consumption certification tool VECTO. Exact options (e.g., weighted av. Cycle only of also separate cycle) to be decided in 2024.

Justification:

- Proven to be representative
- Transparent
- Established and consistent with European legislation applied for the vast majority of HDVs sold in the EU (i.e. for fuel consumption certification, and for HDV CO2 regulations)

Maintenance

We developed two rather general voting options regarding data collection for maintenance modelling in the use phase. These options address whether or not TranSensus should provide a fixed list of included components and processes or not. Below, a summary of the findings in D1.1 is provided for context.

According to the literature reviewed in D1.1, maintenance modelling varies significantly between complete neglection, assumptions based on tests and fact sheets, and arbitrary assumptions. Furthermore, maintenance activities are the most subject to exclusion in the reviewed literature. According to D1.1, a reason could be that it is hard to foresee the impacts of that in the real life of the vehicle. Maintenance is also most often excluded in the scientific literature, generally justified by the low impacts relative to the vehicle life cycle. Among those studies that do include maintenance, there is a lack of detailed information regarding the methodology and data utilized. Typically, generic data sourced from LCI databases is utilized. Battery replacement has been also largely neglected despite its relevance to the life cycle impacts. Although some studies report that they included battery replacement, there is a lack of methodological transparency and data that are not clearly disclosed (with the exception of Ricardo's LCA study for the EC, where the methodology is outlined in detail in the D1.1 report Appendices). This is also reflected in the LCIA results where disaggregation of battery replacement impact hampers the proper interpretation of its impact. OEMs however, account for maintenance in a considerable number of studies. According to D1.1, this might be due to availability of data from tests and experience which can significantly improve estimations that can be modelled.

Maintenance (e.g., replacement of batteries) is considered in several standards and guidelines based on service intervals (RISE, VDA-PC, CATARC) or the road vehicle preventive maintenance program (PCR-Buses and coaches). The PFA report differentiates between two maintenance needs: i) regular maintenance (e.g., oil, filters, 12V battery, coolant, traction battery, air conditioning gas) and ii) replacement of wear parts (e.g., tyres, brake linings, and windscreen wipers). The second type heavily depends on the driving mode (e.g., frequency of tyres replacement) and, in consequence, it entails higher challenges to establish an harmonised approach. The recommendation is to assume the theoretical change frequencies as specified in the maintenance book. Typically, generic data sourced from LCI databases is utilized. Battery replacement has been also largely neglected despite its relevance to the life cycle impacts. Although some studies report that they included battery replacement, there is a lack of methodological transparency and data that are not clearly disclosed.

Q: How TranSensus LCA should address Maintenance ?

	Option 1	*Option 2*
Description & definition	**The LCA practitioner decides which components and processes should be included for the maintenance, to fulfil the FU. Special focus will be put on battery durability. TranSensus LCA will provide a guideline on how to identify these components/processes (tbd in 2024). Maintenance intervals should be OEM and model-specific.**	**A list of maintenance components and processes are given by TranSensus LCA (to be defined in 2024). Special focus will be put on battery durability. Additional components could also be included at OEM discretion, TranSensus LCA will provide a guideline on how to identify these additional components/processes. Maintenance intervals should be OEM and model-specific.**
Pros	• flexibility, adaptability (particularly for HDVs, which may have significant potential variability)	• provides for greater consistency and guarantees a good level of comprehensiveness. Does NOT need to be exhaustive – can be prioritized to areas of high frequency/significance. • list can potentially be expanded in the future; flexibility for adding additional items will likely be useful for more complex HDV variants
Cons	• definition of maintenance requirements is being discussed at UNECE level; there is a risk that not prescribing/considering at least a core mandatory list in TranSensus will bring out of alignment	• Increases data collection burden
Possible consequences	none	
Recommendation of subtask	-	-

EoL stage

Primary data needed to reach Level 3

Environmental impacts of EoL are determined by the burden of EoL treatments and the potentially avoided impacts from avoided virgin materials. EoL treatments comprises is recycling, energy recovery and disposal processes. The shares of vehicle components that will be treated by these processes and the recovery rate of recycling process also determine the overall EoL impacts.

At this current voting, we are addressing the **data of the environmental impacts** of the EoL treatment processes. The abovementioned shares and the recovery rate are not considered and will be addressed in 2024. The avoided impacts, the allocation of burden and credit (e.g. the options to use CFF or cut-off method) is also out of the scope of this voting.

Q: What type of data (primary or secondary) TranSensus LCA should recommend for EoL (recycling, energy recovery and disposal processes)?

	Option 1	*Option 2*
Description & definition	**Secondary data for recycling, energy recovery and disposal processes can be used for EoL modelling. Guidance on which processes must be covered will be developed in 2024.**	**A list of recycling, energy recovery and disposal processes that should be modelled with primary data is developed by TranSensus LCA (tbd 2024).**
Pros	• The exact EoL process of a vehicle at SOP cannot be known	• should provide a more accurate representation of likely EoL impacts • Incentivize OEMS and other actors to practice eco-design • Incentivize recyclers to improve their environmental impacts • Incentivize OEMS to use recyclers that promotes sustainable practices • OEMs already model EoL processes partly with primary data from representative EoL processes and e.g. scale these generally applicable models via the vehicle weight
Cons	• make sure that this data is available in the databases and define which secondary data to use • No incentive for OEMS and other actors to practice eco-design • No incentive for recyclers to improve their environmental impacts	• uncertainty regarding future EoL processes
Possible consequences	-	-
Recommendation of subtask	none	

Other topics

Primary Data Share

In the process of developing this voting option we discussed the idea of **a primary data share index**. The WP2 did not include this option. The reason is that in order to calculate the primary data share the whole supply chain must be transparent. A primary data share of only a certain/unknown percentage of the overall e.g. GWP result is not helpful in judging the data quality of an LCA and does not establish a better comparability between studies. As we do not only focus on GWP but also on other environmental impacts, another open question would be whether a primary data share of only the overall GWP result would be enough.

The consortium does not recommend a Primary Data Share index.

2.3.2 Subtask 2: Multifunctionality

This subtask is concerned with providing recommendations on how to address multifunctionality, in its broader definitions. Allocation rules, substitution or system expansion, co-production, recycling, and energy recovery from waste were all discussed here in the context of ZEVs and batteries.

In brief words, a multifunctionality issue emerges when a system provides an additional function other than the one defined in the functional unit.

The objective of the subtask is to provide clear guidance on how to solve multifunctionality problems in each of the life cycle stages in a scientifically-sound and practical way.

In this section, only multifunctionality at production level will be addressed. Multifunctionality at use phase (such as 2nd life of V2G) will be addressed in 2024.

The goal of this subtask is to address multifunctionality (in all life cycle phases). There will be questions of two different sets (bottom up + top down) concerning handling multifunctionality in general as well as in specific sectors or for specific processes. In this report only multifunctionality at production phase and EoL phase will be addressed.

STEP 1: description of the main findings and learnings from WP1 & partners expertise & SotA

Multifunctionality

The definition of multifunctionality in a nutshell was given in the introduction to the sub task (see above)

Paragraph: Before diving deeper into the work done on multifunctionality in both WP1 and WP2 so far, it is probably wise to revisit the definitions of some basic terms and concepts that will be mentioned frequently in the following text. These terms are:

- Subdivision: *subdividing involves disaggregating multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. The process is investigated to see whether it may be subdivided. Where subdivision is possible, inventory data should be collected only for those unit processes directly attributable to the products/services of concern. This is the definition provided* **by PEF**. **ISO 14044** on the other hand briefly defines it as *dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes.*
- Substitution: It basically assumes that the secondary function of the system under study substitute (at least partially) a primary function of another system (e.g. secondary materials availability reduces the demand on primary materials) hence the system producing the secondary materials gains environmental credits. Substitution is not equal to system expansion as provided by ISO 14044. System expansion is a different concept which means expanding the system understudy to include the additional functions related to the co-products. This is not widely applied and it is criticized for violating the original function of the system under study.
- Allocation: It refers to 'partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems. Allocation and partitioning term are often used interchangeably.

Input from WP1 (SotA and consultation activities):

WP1 showed that Multifunctionality is dealt with in different ways for processes at different stages of the life cycle of a vehicle or battery. Specifically speaking:

1. Raw Material Acquisition and processing (Particularly in the context of batteries)
2. Components manufacturing when facilities are shared (also emphasized in case of batteries due to facilities being shared- so how to deal with energy allocation)
3. EoL or more specifically recycling and recycled content. This is the most discussed and elaborated part.

Multifunctionally Upstream to EoL

Input from Review for upstream multifunctionality:

- Guidelines and standards tend to claim to be consistent with ISO and PEF (at least most of them). However, some of them provide certain deviations in recommendations. The hierarchy of the different guidelines can be seen in Table 1 below.

- The most significant remark here is prioritizing economic allocation for co-production of metals based on the price ratio. The ratio 4 is provided by GBA and CBF as the border to decide whether to apply economic allocation or not. How to determine the price is also another question since it varies over time.
- See below in the table also that apart from battery-specific guidelines, the guidelines tend to report ISO hierarchy without further detailing.
- Substitution is absent in many guidelines however this may be due to the material in scope cannot be produced from a primary route (which is mandatory to apply substitution)

Table 2-18: Hierarchy of options in reviewed guidelines (hierarchy is represented by the numbers)

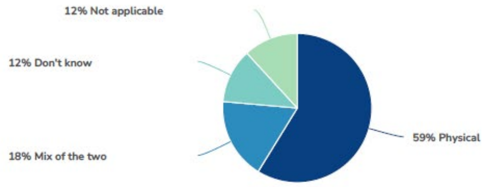
Guidelines and standards reports	Material of subject if specified	Break down unit processes into mono functional unit sub-processes	Substitution		Partitioning	
				economic	physical	other
Batteries						
GBA	graphite and metals	2	3	1*	4	4
	sulfuric acid, ammonium sulfate, sodium sulfate, and chlorine by-products	2	1	4	3	4
	By-product salts from brine processing	2	3	4	1**	4
	other materials	1	2	4	3	4
GRB-CFB-EV (in the final draft released in June 2023)	metals	2	-	1*	3	4
	other materials	1	-	3***	2	4
PEFCR-Batteries		1	2		3 (mass)	
vehicles						
CATARC		-	-	-	-	-
Catena-X		1	2	3	3	3
eLCAr		1	2	3	3	3
PCR-B&C		1		3	2	
RISE-LCA				1	1	1
VDA-PC		1		2	2	2
PFA				1	1	1

*Economic allocation is the first option unless price ratio of the co-products is less than or equal to four. In this case theoretically, the user should follow the ISO hierarchy.
** Mass allocation as a first choice unless the price ratio between co-products is greater than 4.
*** Economic allocation becomes the first preferred option when the price ratio is greater than four.

Input from Survey for upstream multifunctionality:

NO specific questions were asked regarding this except a general question on applying conventional allocation without specifying at which point it takes place in the supply chain:

66. If conventional allocation is applied, what is the allocation approach applied?



Value	Percent	Responses
Physical	58.8%	10
Mix of the two	17.6%	3
Don't know	11.8%	2
Not applicable	11.8%	2
		Totals: 17

Figure 2-16 : Input from Survey for upstream multifunctionality

Distribute the burdens & credits from EoL phase [Multifunctionality in the EoL stage]

Multifunctionality in the EoL is quite common due to the possibility of recycling and energy recovery activities which means the production of new secondary products. Therefore it is of utmost importance to have a clear framework on how to allocate the burdens of recycling/energy recovery processes between the current system understudy and the subsequent system which will use the secondary products from the first system. The same applies to credits, in the form of questions like should we consider credit system?, if yes, which system gets the credits.

Input from Review for EoL:

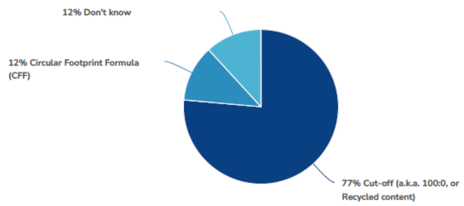
Five main approaches are identified here to deal with multifunctionality in the end-of-life (please refer to section 3.2.1.4 in D1.1 (TranSensus LCA, 2023)for more details and explanations):

Table 2-19: Main 5 approached used to deals with multifunctionality (D1.1)

Approach	Cut-off approach (100:0)	Avoided burdens	50:50	APOS	Circular Footprint Formula
Brief Explanation	this approach considers the full environmental impacts of the primary material supply chain, while secondary materials come free of burdens	This approach applies substitution . secondary materials partly substitute primary materials hence give environmental credits to the producer of the secondary materials	it divides the burdens and benefits of recycling between the producer and user of secondary materials on a 50:50 basis. Sort of in between the previous two with arbitrary 50% ratio	this approach performs economic allocation between the primary and secondary usage of materials. This method is usually associated with the APOS system model used in ecoinvent v3. (for more details on the method please refer to section 3.2.1.4 in the databases part). Allocation in its core. How and where allocation is done depends on the type of material.	the Circular Footprint Formula (CFF) from PEF which is a formula that tries to allocate burdens and credits between supplier and user of recycled materials. And gives credits for energy recovery if it comes from waste. It also includes a part for disposal burdens it applies a mix of both allocation and substitution.

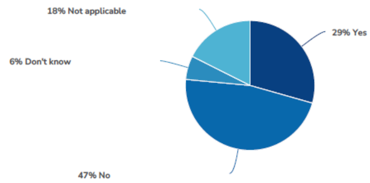
Input from Survey for EoL:

63. Which EoL allocation method is used in your LCA?



Value	Percent	Responses
Cut-off (a.k.a. 100:0, or Recycled content)	76.5%	13
Circular Footprint Formula (CFF)	11.8%	2
Don't know	11.8%	2
		Totals: 17

64. Is the quality of recycled materials accounted for in the calculations?



Value	Percent	Responses
Yes	29.4%	5
No	47.1%	8
Don't know	5.9%	1
Not applicable	17.6%	3
		Totals: 17

Figure 2-17 : Input from Survey regarding recycling approach used

Input from WP2:

Building on WP1 outcomes, Further analysis from the working group of MF subtask was done via a number of meetings and offline materials. New feedback was collected in a form of table. The table starts with level 1 (life cycle stage), level 2 (specific processes or substances) and each partner is required to provide his preferred hierarchy between:

- Subdivision
- Substitution
- Allocation (physical or economic or other)

While this seems like following the ISO hierarchy, it is worth noting that ISO refers to "System expansion" as the first option if subdivision is not possible. In practice, system expansion is not the same as substitution. Since system expansion is not a useful option for our context, we explicitly mention only substitution instead.

For the EoL, and in addition to these options, the partners are given extra choices:

- Cut-off
- CFF
- No special approach

The partners were also required to provide why they preferred a specific method and what the pros and cons they see. This table represented the primary material to provide the final voting questions and answers

> Multifunctionality is literature is usually dealt with in different ways depending on where it occurs in the supply chain. A distinction can be seen between EoL stage and upstream processes from raw materials acquisition until the final product manufacturing. The latter is addressed with allocation whether physical or economic. EoL issues like recycling and energy recovery are addressed via five identified variations ranging between allocation and substitution concepts. For the voting some of these variations are not presented due to impracticability and limited diffusion in community.

Multifunctionality STEP 2: selection of 2-4 pertinent methodological options

For the voting session arranged for 2023, it was decided to provide two sets of voting questions: first **top-down questions** (i.e. General guiding questions: "should we use a same approach across all life cycle stages or across LCA, S-LCA and LCC ?"), second **bottom-up questions** (i.e. questions on the certain processes/sectors: " **What approach would you recommend to a specific sector**").

It is obvious that the two levels are interlinked, since the voting on the top-down questions will impact the decisions taken in the bottom-up questions and conflicts may emerge, therefore, we ask the voters to think wisely about their vote in the two sets of questions and its possible consequence on the final recommended methodology to deal with multifunctionality. The decision tree on the next page was designed to help explain the logic behind the questions. Furthermore, when relevant, guidance is provided per question.

2 set of questions will be asked: 1/ top down and 2/ bottom up questions. We recommend to the voter to be as consistent as possible when addressing these 2 types of questions.
(e.g. if the voter want an harmonized approach through all life cycle stages, it should be reflected in its vote).

After the two set of questions are provided separately for voting in 2023, the harmony of two sets will be explored more in 2024 in which the top-down questions voting results will indicate if the questions in the bottom-up approach need to be removed/modified/more questions to be added. Then based on the voting received on the detailed bottom-up questions, the most-voted answers can be further refined in 2024 with more details or if the top-down questions imply certain modifications to the voted answer to the specific bottom-up questions.

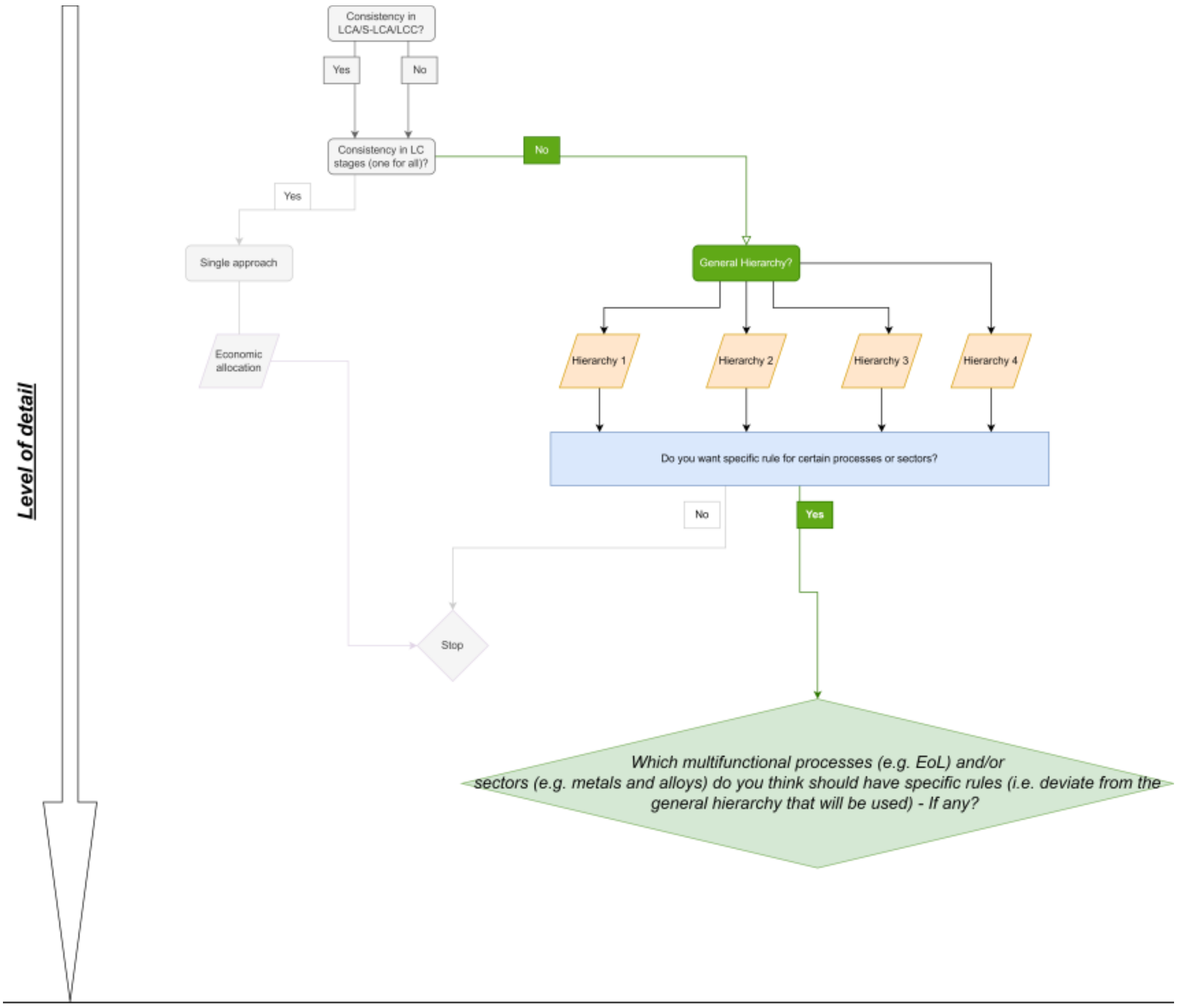


Figure 2-18 : Decision tree of multifunctionality voting questions

Top-down questions

The consortium recommends that consistency should NOT be achieved across all life cycle stages, i.e. dealing with multifunctionality using a one-for-all single method in both upstream (raw material acquisition & manufacturing), use, and downstream (EoL) MF processes.

Justification

- An approach can make more sense to deal with multifunctionality in a certain life-cycle stage and not the other
- This division is usually followed in battery guidelines

Q: Which general approach do you prefer to solve multifunctionality?

*NOTE: **If in the question above you to disagree, then the only option for you here is economic allocation**. However, we welcome your vote in the bottom-up questions if you want (it will be taken into account if people vote for the concept of exceptions).*

	Option 1	*Option 2*	*Option 3*	*Option 4*	*Option 5*
	Hierarchy 1 (ISO)	***Hierarchy 2***	***Hierarchy 3***	***Hierarchy 4***	***Economic allocation***
Description & definition	1. Subdivision 2. System expansion (via substitution) 3. Allocation, physical 4. Allocation, other (e.g. economic)	1. Subdivision 2. Substitution 3. Allocation, economic 4. Allocation, physical	1. Subdivision 2. Allocation, economic 3. Allocation, physical 4. Substitution	1. Subdivision 2. Allocation, physical 3. Allocation, economic 4. Substitution	Intermediate and elementary flows of a multifunctional unit process are allocated based on the economic revenues/cost/price generated by the functional flows of that unit process. This approach is consistently applied to all multifunctional processes across all life cycle stages.

Pros	Supported by ISO	Substitution in general is preferred over allocation according to ISO	Considers economic allocation as preferred approach (which we argue that it is theoretically always applicable) but in a softer way which provides some flexibility to the LCA practioner to move to physical allocation or substitution depending on personal judgement.	Preferred allocation order of ISO.	The most versatile and the only possible way if a one-for-all method is required.
Cons	ISO is quite vague regarding the difference between system expansion and substitution which are two different concepts from which almost only substitution is used.	-	-	-	Cons of economic allocation found in the bottom-up questions apply here
Possible consequences	Further explanation of what is meant by system expansion will be required in order to be clearer.	Clear deviation from ISO	Clear deviation from ISO	Clear deviation from ISO	Possible consequences of economic allocation found in the bottom-up questions apply here.
Official position of stakeholders if any	-	-	-	-	-
others	Pros and Cons of each method in the hierarchy can be found in the next questions.	Pros and Cons of each method in the hierarchy can be found in the next questions.	Pros and Cons of each method in the hierarchy can be found in the next questions.	Pros and Cons of each method in the hierarchy can be found in the next questions.	-

Q: Should the TranSensus LCA method to solve multifunctionality issues be consistent across the three pillars of sustainability, i.e. consistency across LCA, S-LCA and LCC? (if LCC included in the method)

	Option 1	*Option 2*
Description & definition	***Yes***	***No***
Pros	This will add a lot of credibility and simplicity to the TranSensus methodology. Facilitates future merging of sustainability indicators (not part of TranSensus)	Takes into account the different nature of the different analyses. Ignores the gap in the level of development of each methodology (LCA is more established than S-LCA) therefore no rushed adaptation will be required from S-LCA developers. For example, S-LCI background databases are relatively recent. Therefore, asking the developers of these data to adapt to the approach chosen in LCA might not be realistic.
Cons	The same approach in one methodology (e.g. LCA) might not make sense in another methodology (e.g. S-LCA)	Will require providing specific rules per each pillar Might reduce the possibilities of future combination of results to obtain for example a sustainability score as credits and burdens (whether economic or social) will be differently calculated for multifunctional processes.
Possible consequences	It has to be approved by S-LCA and LCC experts in the consortium if they agree on generalizing what is decided in LCA. If consistency is sought between the three methodologies, then this should not be limited to the issue of multifunctionality but should be kept in mind for every choice we make Can require too much work on S-LCA and LCC that might be out of scope for TranSensus	-
Official position of stakeholders if any	-	-
others	-	-

Do you think there should be specific rules for multifunctional processes (e.g. EoL) and/or sectors (e.g. metals and alloys) that deviate from the general hierarchy that will be used?

2.3.3 Subtask 3: Social LCI

The topics discussed in this subtask are the Collection of data for creating the REFERENCE SCALES, Multifunctionality, Database & Software, data for activity variable, collection of data for the different STAKEHOLDER GROUPS and the different SUBCATEGORIES and Data Quality Assessment.

S-LCI STEP 1: description of the main findings and learnings from WP1 & partners expertise & SoTA

Collection of data for creating the REFERENCE SCALES: For every indicator used, reference scales should be created, with each scale level having an explicit objective. For the best development, it is advised to draw upon in-depth knowledge of the sector and location (including local legislation) to be evaluated. During the Inventory phase, reference scales are created. It is an essential first step in arranging the collection of inventory data and in carrying out an impact assessment. Reference scales are ordinal scales with 1 to 5 levels, typically, and each level corresponds to a performance reference point (PRP). PRPs are thresholds, targets, or objectives that establish various social risk or performance levels and enable estimation of the scope and importance of potential social impacts related to companies in the product system. The PRPs are context-dependent and frequently based on normative reference points, such as international standards, local laws, or industry best practises. When appropriate inventory indicator data is compared to these levels, it is possible to determine whether the obtained data points to a negative or positive performance. But there is not any attempt to develop a reference scale from international or national standards for transport sector.

Multifunctionality: Sometimes a system under study produces many co-products or serves multiple purposes, for as when a cow is raised for milk, meat, and leather. It could be required to narrow the system limits or only assign a portion of the social consequences to this product when evaluating the social and socioeconomic effects of just one of these items. Due to the nature and scope of social data, this is not always necessary or simple. Allocation and partitioning in S-LCA are sometimes not relevant. This is the case, for instance, when evaluating indicators and repercussions that are not evaluated at the product level, such as external effects (delocalization of local communities, disregard for indigenous rights), or systemic issues like the right of employees to strike. The hierarchy outlined by ISO 14040-14044 2006 should be primarily followed where allocation is relevant, such as for product-specific (e.g., in case of TranSensus), quantifiable consequences like working hours or wages.

Data for activity variable stakeholders and impact subcategory: To define worker hours as the activity variable for social life cycle assessment (S-LCA), several types of data are required. Firstly, modelling data is necessary to ensure that the assessment captures the entire life cycle and provides quantitative metrics that can assist when justifying the study boundaries and scoping choices. Secondly, social impact data is necessary to evaluate the social impacts associated with each stage of the life cycle, such as the working conditions of the employees, the impact on the local community, and the social risks associated with the production and disposal of the product. The Social Hotspots Database (SHDB) and the Product Social Impact Life Cycle Assessment (PSILCA) database are examples of databases that provide social impact data. Finally, working time data is necessary to calculate the worker hours for each process in the life cycle. Worker hours are selected for all indicators, and this variable determines the working time (in hours) required to produce the reference product. The SHDB also uses worker hours as the activity variable. Therefore, to define worker hours as the activity variable for S-LCA, modelling data, social impact data, and working time data are required. These data can be used to evaluate the social impacts associated with each stage of the life cycle and prioritize further action to improve social performance and mitigate social risks.

Database & Software: Dedicated databases currently available for S-LCA on the market are Social Hotspot Database (SHDB) and Product Social Impact Life Cycle Assessment (PSILCA) database. The SHDB and PSILCA databases provide access to large amounts of social data on the country-specific sector (CSS) level, which enables practitioners to assess social risks or performance associated with certain sectors and product systems. The two main functions of these databases are to complete a study. or provide screening of social risks prior to an in-depth study i. e., identify hotspots that will be studied further. SHDB and PSILCA databases are based on three main building blocks: An Input-Output model, a Worker-Hours model, and a database on social aspects. However, it`s important to be aware of the differences. The Input-Output models underlying both social LCA databases differ: SHDB is based on the GTAP Input-Output model, but PSILCA is based on EORA/MIRO Input-Output model. Both databases have applied different methodologies for calculating the worker-hour model. The main social data sources used to create social risk tables are shared among the databases, however, methodologies used to assign risk levels may differ. Other database available are GaBi Life Cycle Working Environment (LCWE), RepRisk, Sedex, EcoVadis and Maplecroft other than statistical database like Organization for Economic Cooperation and Development (OECD) database, international Labour Organization (ILO) database, United Nations (UN), The World Bank Group (WBG).

Data Quality Assessment: It is advised to specify other pertinent characteristics of data quality, such as timeliness, geographical or technological compliance of the datasets with the activity under research, etc., in order to evaluate the quality of the data obtained itself. The defined indicators and criteria, such as reliability, timeliness, geographic match, etc., can be rated by ordinal evaluation rules, with scores from 1 to 5 corresponding to a qualitative assessment of the data, for a structured evaluation of the quality of both the measurement methods and the collected data.

S-LCI STEP 2: Recommended approach

Collection of data for creating the REFERENCE SCALES:

The consortium recommends the following process to establish a S-LCA reference scale:

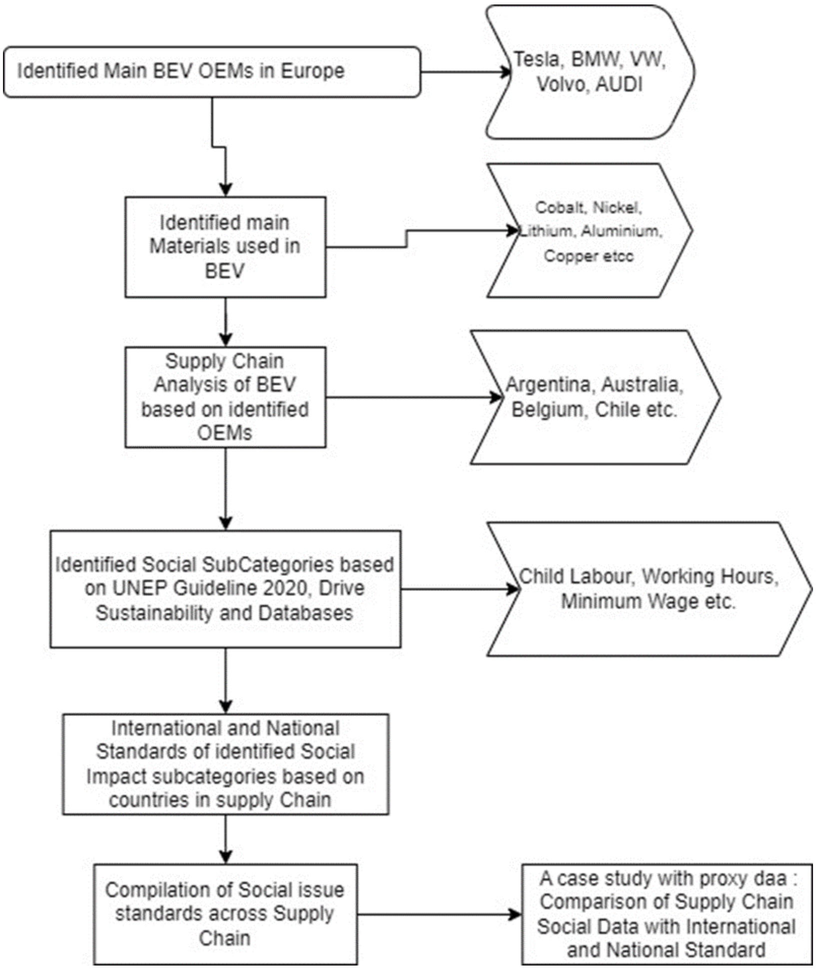


Figure 2-19 : TranSensus S-LCA Data collection diagram for reference scale

To establish a reference scale for Zero Emission Vehicles (ZEVs), it is crucial to have a comprehensive understanding of both international and national regulations, standards, and norms pertinent to the countries participating in the entire ZEV supply chain, spanning from the extraction of raw materials to the product's end-of-life phase. This understanding serves as the foundation for conducting a social life cycle impact assessment using the reference scale methodology.

The process of formulating this reference scale for ZEVs commences with the identification of key ZEV models available in the European market, including those manufactured by Tesla, BMW, VW, Volvo, and Audi. Subsequently, a meticulous analysis is performed to track and identify the materials and components utilized in these vehicles, as well as pinpointing the primary countries and regions involved in the upstream production and usage phases. Notably, due to the unavailability of precise data concerning the end-of-life stage of these materials, this aspect is not factored into the development of the reference scale.

Following the identification of countries participating in the ZEV supply chain, the next step involves the exploration and collation of both international and national regulations that pertain to social indicators and impact subcategories. These regulations are then synthesized to form the conclusive Reference Scale for ZEVs.

Multifunctionality:

The consortium recommends to follow ISO 14040-14044:

1. In general, allocation should be avoided by dividing activities into segments and acquiring particular information for producing of each co-product independently;
2. If subdivision is not possible, or if we assess rather generic systems (e.g., an industry sector like "textiles"), expand the system to include the additional products and activities substituted by the dependent by-products and associated social issues;
3. For combined products where the relative amount produced can be independently varied, relevant risks and impacts can be allocated causally (what ISO calls "in a way that reflects the underlying physical relationships") to the process output. In S-LCA a causal relationship might be established via the activity variable. For example, one could argue that in an agricultural process, more working time is needed to cultivate and harvest asparagus than carrots, hence a higher share of overtime or number of foreign, discriminated workers can be assigned to asparagus cultivation.
4. If causal modelling is not possible or desired, i.e., when the Goal and Scope is to trace a specific issue in the value chain, process impacts can be allocated based on the share of revenue coming to the process for each of its product outputs. For example, in cow husbandry, the production of meat generating higher revenue than milk can be associated with a corresponding higher share of quantifiable effects, e.g., the positive effect of fair wage.

Data for activity variable stakeholders and impact subcategory:

Three approaches are recommended by the consortium to collect activity variables data:

1. Through site-specific data collection;
2. Use of an S-LCA dedicated database (SHDB or PSILCA);
3. Through input-output or other databases

Data Quality Assessment: *Pedigree Matrix*

The following Pedigree Matrix is recommended by WP2, based on REF.

Indicator	Scores				
	1	2	3	4	5
Reliability of the source(s)	Statistical study[23], or verified data from primary data collection from se-veral sources.	Verified data from primary data collection from one single source or non- verified data from primary sources, or data from recognized secondary sources.	Non-verified data partly based on assumptions or data from non-recognized sources.	Qualified estimate (e.g. by an ex-pert).	Non-qualified es-timate or unknown origin.
Completeness conformance	Complete data for country-spe-cific sector/ country.	Representative selection of country-spe-cific sector/ country.	Non-representa-tive selection, low bias.	Non-represen-tative selection, unknown bias.	Single data point/ completeness unknown.
Temporal confor-mance	Less than 1 year of difference to the time period of the dataset.	Less than 2 years of difference to the time period of the dataset.	Less than 3 years of difference to the time period of the dataset.	Less than 5 years of difference to the time period of the dataset.	Age of data unknown or data with more than 5 years of difference to the time period of the dataset.
Geographical conformance	Data from same geography (country).	Country with similar condi-tions or average of countries with slightly different conditions.	Average of coun-tries with different conditions, geography under study included, with large share, or country with slightly different conditions.	Average of coun-tries with different conditions, geo-graphy under stu-dy included, with small share, or not included.	Data from unknown or distinctly different regions.
Further technical conformance	Data from same technology (sec-tor).	Data from similar sector, e.g. within the same sector hierarchy, or average of sectors with similar tech-nology.	Data from slightly different sector, or average of different sectors, sector under study included, with large share.	Average of different sectors, sector under study included, with small share, or not included.	Data with unknown tech-nology/sector or from distinctly different sec-tor.

Figure 2-20 : Pedigree Matrix recommended by WP2.

2.4 Impact Assessment (Task 2.4)

In conducting a life cycle assessment (LCA), it is important to identify and prioritize impact categories and life cycle impact assessment (LCIA) methods. Similarly, for Social Life Cycle Assessment(S-LCA), it is important to identify impacts sub-categories and stakeholder categories that need to be assessed in S-LCA. This is in line with the goal and scope and inventory modelling. The identified impact categories, stakeholder categories, and impact subcategories will be used to assess environmental and social impacts. LCIA methodological guidance will be provided to assess environmental and social performance, including the use of material resources, circularity, innovative concepts, critical materials, social issues. The choice, modelling, and evaluation of impact categories will be established to reduce subjectivity in the impact assessment phase. The impact assessment guidelines will ensure the collection of indicator values for the various impact categories, which together constitute the impact assessment profile for the product system. Guidance for normalization choices, grouping, and weighting will also be established. Recommendations will be formulated to identify significant impact categories in the various value chains of the electromobility value chain, particularly zero-emission vehicles, through impact hotspot analyses.

Summary of recommendation & voting options:

2.4.1 Subtask 1: Pre-selection of a non-restrictive set

The goal of this subtask is to pre-select a non-restrictive set of relevant Impact categories, category indicators, LCIA methods for TranSensus LCA.

Non restrictive set STEP 1: description of the main findings and learnings from WP1

Two key findings were highlighted in the WP1 TranSensus deliverables regarding Life Cycle Impact Assessments methods (LCIA):

- 1 : "the LCIA **set of impact categories and characterization factors by EF (3.0 and 3.1)** is going to be the **recommended standard** for Life Cycle Impact Assessment. However, the review of the OEM reports, scientific literature and prospective LCA studies shows that, until now, **these studies do not seem to follow the LCIA method of EF as** (most often) recommended in the guidelines and standards".
- 2 : there is a need for a "**clear and unique set of impact categories** associated with methods, covering env, social & resource issues, potentially including aspects as circularity, impacts on biodiversity & ecosystem services, criticality".

Several additional or alternative impact categories or indicators (environmentally, socially –related or not) were also mentioned:

- The **Cumulative Energy Demand CED** (considered by VDA & PFA guidelines): which assesses the quantity of energy content of all different energy sources, both renewable and non-renewable, used throughout the Life Cycle of a product
- **Resource dissipation** is an interesting alternative for the impact categories "abiotic resource depletion of elements". This indicator better captures circularity and resource uses issues.
- **Criticality**: as part of life cycle sustainability assessment (including social and economic aspect), this indicator reflects the (geopolitical) environment on the product system.
- **Circularity indicator**: which allow Circular Economy strategies measurements and assessments
- **Biodiversity indicator**: assesses biodiversity losses (decrease in the number of local species, decrease in the number of individuals per specie), both locally and globally, due to the processes under study through the 5 pressures identified in the Millennium Ecosystem Assessment (2005): land use (habitat change), pollutions, climate change, invasive species, overexploitation of species.

Non restrictive set STEP 1: Analysis from WP2

Based on these WP1 guidelines and findings, several questions were raised during WP2 discussions:

- *1: Should EF set be recommended and why? Or should TranSensus select its own set of IC, indicators and characterization methods?*
- *2: Should alternative and/or additional (to EF) impact categories be recommended and why?*

To answer these questions a clear distinction should be made between different levels of indicators (Figure 2-22).

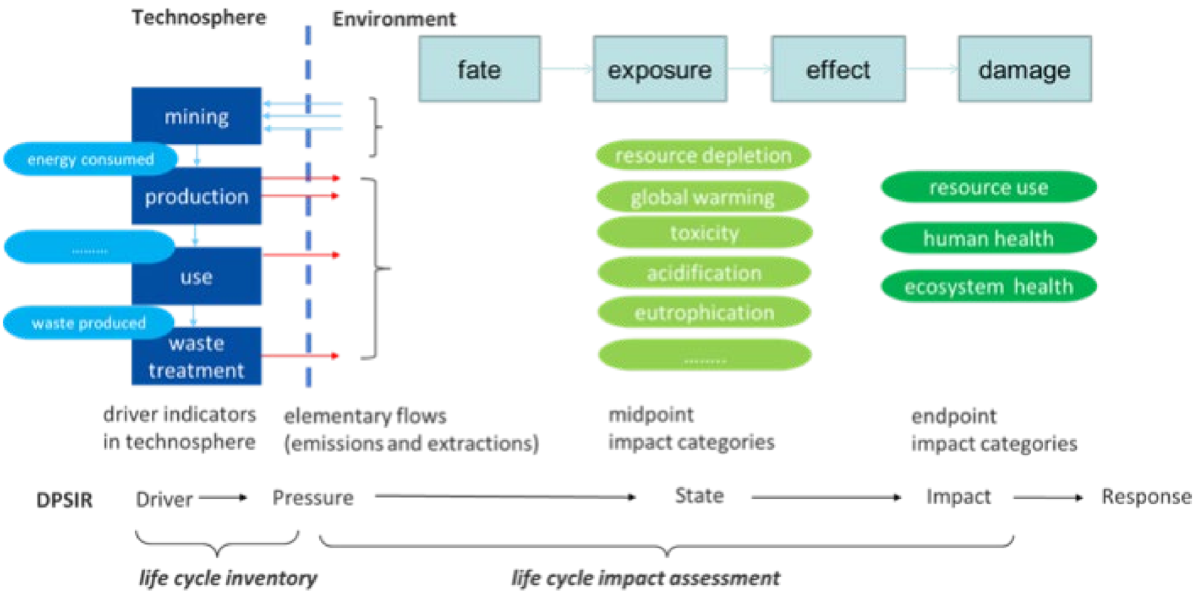


Figure 2-21 : Level of Indicators

Figure 2-22 describes the relationship between the two systems that are distinguished in LCA, the technosphere, or economic system, and the environment. The *Life Cycle Inventory* deals with modelling the processes in the technosphere, all economic flows (goods and wastes) are traced back to the elementary flows (i.e. emissions and extractions) that cross the system boundary between Technosphere (economy) and Environment. The *Life Cycle Impact Assessment* starts with these emissions and extractions. The aim of the environmental impact assessment is to aggregate these elementary flows into a more limited group of environmental impacts. To do this, characterization models are used that might consider several processes in the environment (distribution/fate, exposure, effects etcetera).

Indicators for environmental impact categories can be distinguished into midpoint and endpoint indicators. In terms of DPSIR (drivers, pressures, state, impact, and response) indicators, the midpoint indicators are at the level of the state indicators while the endpoint indicators are at the level of the impact indicators. Now, taking this reasoning further, indicators based on economic flows in the technosphere (e.g., total materials consumed, total energy consumed, total waste produced, total waste recycled etcetera) are at the level of the drivers (i.e., human activities that might have impacts on the environment).

Driver-indicators can be used to monitor changes in the technosphere (for example due to policy measures) and therefore might be useful. Driver-indicators describe some state of the technosphere. However, following the LCIA framework these are NOT environmental indicators, which after all take elementary flows as a starting point for the environmental assessment. The economic flows (goods and (final and recycled) wastes) are flows within the technosphere and are already dealt with in the Inventory.

When presenting, discussing, and interpreting indicators, the indicators SHOULD be on the same level in the DPSIR chain. This is to avoid overlap, redundancy or double counting. After all, also the midpoint and endpoint indicators are always discussed as two different sets of indicators, presented separately, and are not combined. Thus, also driver indicators (like CED) should be treated separately and should not be combined with environmental indicators on the state or impact level.

Should EF set be recommended and why? Or should TranSensus select its own set of IC, indicators and characterization methods?

To answer these questions, the WP2 partners gathered in Table 2-20 the main advantages and drawbacks of using EF set of impacts categories and characterization factors.

Table 2-20 : Advantages and drawback of EF set of impact categories, indicators & characterization methods

Advantages of recommending the use of EF set	Identified drawbacks of EF
EF set is an outcome of a harmonization process involving expert consortiums	Low robustness of some Impact Categories (tox/ecotox, resource use, land & water use) – leading to difficult interpretation
EF set is recommended by the European Commission	Some environmental issues are missing (e.g. impact on biodiversity partly covered)
EF set includes some of the Recipe and CML indicators, used by OEM (*e.g.* climate change, ozone layer depletion, eutrophication (fresh water and marine), abiotic resource depletion)	The relevance of some EF impact categories for the automotive sector could be questionable
	EF is not recommended in other region of the world

The robustness and relevance of some EF impacts categories are questionable (*e.g.* tox/ecotox, resource use, land & water use, biodiversity …). However, EF set has been developed by expert consortium and is strongly recommended by the European Commission. Moreover, some indicators used by OEMs (*e.g.* abiotic resource depletion and climate change) are already included into the EF set.

The consortium recommends the inclusion of a nonrestrictive set of relevant impact categories, category indicators, LCIA methods:

- **the impact categories, indicators and characterization methods of EF (EF3.0 & EF3.1)**

Should alternative and/or additional (to EF) impact categories be recommended and why?

Cumulative Energy Demand

The cumulative energy demand (CED) assesses the quantity of energy content of all different energy sources, both renewable and non-renewable, used throughout the Life Cycle of a product. The aim of this section on Cumulative Energy Demand (CED) is to assess the usefulness and feasibility to include energy[1] indicators in Life Cycle Impact Assessment for vehicles.

The most recent review of characterization methods on Cumulative Energy Demand is the paper by (Frischknecht R. W., 2015). The paper gives an overview of existing life cycle-based energy indicators, concluding that there is no harmonized approach to calculate the CED of a system. Therefore, the paper also aims to provide a consistent approach to develop characterization factors for a Cumulative Energy Demand indicator, the harvested energy approach. This approach is nowadays the most widely used CED-approach and implemented in Ecoinvent (and other databases).

In the paper of Frischknecht (2015), the cumulative energy demand is considered to be an impact category indicator and thus belongs to the life cycle impact assessment. In Frischknecht et al. (2015), the problem definition of energy use is defined based on an assumed **intrinsic value of energy**. This means energy is worth saving, because it has a value of its own, independent of a defined usefulness for humans or a function for supporting ecosystems. Different types of energy sources are considered in the CED_harvested_energy_approach, both renewable (biomass, wind, solar, geothermal and waterpower), and non-renewable (fossil fuels, nuclear energy from uranium and primary forest).

CED_total (both renewable and non-renewable) gives insight into the energy efficiency of an economic system, which is considered an important indicator for policy. The indicator relates to the following problem on energy resource use: “Energy resources are valued by humans

[1] The CED indicator focusses on the supply of energy by energy resources. It does not refer to methods based on exergy content, surplus energy and surplus costs related to mining of abiotic resources as a total (both energy and mineral or element resources).

for their functions used (by humans) in the technosphere. Energy may originate from both non-renewable resources (fossil, nuclear, primary forest) and renewable (solar, wind, hydro, biomass) resources."

CED_non-renewable (fossil, nuclear, primary forest) is an indicator for the depletion of non-renewable energy resources. The indicator relates to the following problem on energy resource use: The decrease of accessibility on a global level of non-renewable resources over the very long term (LT: e.g. 500 years) or short term (ST: 25 years). It basically follows the same problem definition as the Impact Category 'abiotic resources fossil fuels', which is presently used in EF, but includes uranium and primary forest as other depletable energy resources, next to fossil fuels.

Table 2-21 shows some of the advantages and drawbacks of the CED approach of Frischknecht et al. (2015).

Table 2-21 : Advantages and drawbacks of the CED approach of Frischknecht et al. (2015)

	CED
Advantages	- reflects the overall energy efficiency of a product system - high policy relevance - useful indicator on the diver-level of DPSIR - The partial indicator, CED_non-renewable, might be considered a good alternative for the impact category 'abiotic resources fossil fuels', which is presently recommended in EF, because it also takes into account energy from nuclear power and primary forests.
Drawbacks	- based on an assumed intrinsic value of energy, while the consensus tends to be that energy resources are valued by humans for their functions used (by humans) in the technosphere - energy use as such, is not an environmental impact category, i.e., the link of renewable energy sources to environmental problems is weak - definition of what is the *harvested energy* is not always clear and aligned, particularly a problem for renewable and nuclear energy resources - interpretation of CED (driver indicator) together with impact categories (state indicators) should be performed cautiously.

Based on this analysis, our conclusion and recommendations are:

The consortium recommends to include in the non-restrictive set of relevant Impact categories, category indicators, LCIA methods :

- CED_total, based on aggregation of different energy sources by equal weighting, might be considered an interesting additional indicator on the driver level

  However, CED_total, as such, should not be recommended as an Environmental Impact Category, because of the weak link of the renewable energy flow to an environmental problem defined in terms of safeguarding energy as such.

  Indicators on driver level and environmental impact level should be interpreted cautiously when presented and discussed together. Because the different indicators measure effects of economic activities on different levels in the DPSIR framework, there might be overlap in indicated effects.

- CED_non-renewable, based on aggregation of different non-renewable energy sources by equal weighting, might be recommended as an alternative indicator for the impact category 'abiotic resources fossil fuels'.

  Downside is that the assumed amount of harvested energy from uranium is quite variable between different literature sources, leading to high uncertainty for this item of the CED_non-renewable.

  TranSensus flags that this CED indicator for nuclear energy is less robust and more research is recommended to develop consensus on which value for harvested energy flow should be used.

- The consortium recommends using characterization factors for CED_non-renewables and CED_renewables as defined by Frischknecht (2015) which is most widely used and implemented in Ecoinvent (and other databases).

Criticality

The concept of material "criticality" varies according to the context and lacks a universally accepted definition (Frenzel et al., 2017; Jin et al., 2016; Terlouw et al., 2019). In mechanics, ISO 13372 (ISO, 2012) defines it as the index reflecting the severity of an effect and its expected frequency, while in management, ISO 22300 (ISO, 2018) describes it as a process for systematically evaluating organizational assets. In the context of supply-chain analysis, criticality assigns importance to high-demand materials but lacks a standardized framework (Mancini et al., 2015).

Material criticality generally includes dimensions such as supply risks and vulnerability to supply disruptions, which are influenced by geopolitical factors, trade barriers, and environmental regulations (Dewulf et al., 2016; Knobloch et al., 2018; Sonderegger et al., 2020b). Various standards and organizations offer their definitions. For instance, the British standard CLC/TR 45550 (CEN, 2020) defines CRMs (Critical Raw Materials) as economically important materials with high supply risk. The European Commission (European Commission, 2017) echoes this by emphasizing the economic importance and high supply risk of CRMs.

An added dimension to criticality is the environmental implication of material processing, as suggested by Graedel et al. (2012). This approach aligns with Life Cycle Thinking (LCT) and uses a Life Cycle Impact Assessment (LCIA) approach for criticality assessment. While there is no consensus on the definition of criticality, some authors associate vulnerability with scarcity and abundance rather than economic importance (Adibi et al., 2017; Klinglmair et al., 2014). This perspective, however, often overlooks the role of recycling as a strategy to mitigate supply risk, a factor considered by the Raw Materials Initiative (RMI) in Europe.

Criticality indicators in LCA primarily focus on supply risks rather than resource depletion, yet their inclusion provides valuable complementary information for understanding material criticality (Drielsma et al., 2016; Klinglmair et al., 2014). While scientific consensus is lacking on the optimal methodology for evaluating criticality, either generally or within a product life cycle context, there is a pressing need for guidelines like those recommended by the Joint Research Centre (JRC) for Product Environmental Footprint (PEF)/Organisation Environmental Footprint (OEF) assessments (Schrijvers et al., 2020b; Zampori & Pant, 2019).

It is also important to note that criticality assessment is different to Impact Assessment (IA). In IA one assesses the impacts of a product system on the environment. In criticality assessment one assesses the impact of the Environment, i.e., geopolitical factors (including R/P), on the product system. The criticality assessment method (of EU) only focuses on supply risks on the level of mining and refining, while processes can be hampered on any other level in the process chain. Also, the criticality assessment method focuses on resources that finally end up in the product as components whereas, the elementary flow of resource extraction in LCIA relates to all resources used during the production, use and disposal of a resource, both components as also other consumed auxiliary materials. It's debatable whether criticality should be part of the environmental impact assessment, it's basically more an economic and even social assessment of supply risks. Maybe criticality does not belong to the environmental assessment in the LCIA but should be considered as part of LCSA because it includes more and more economic and social issues as safeguard area instead of environmental considerations.

Table 2-22 : Advantages and drawbacks of adding criticality indicator to the non-restrictive list of impact categories of TranSensus LCA.

	Criticality
Advantages	- Criticality analysis highlights the scarcity of crucial materials such as lithium and cobalt, which are essential for battery production, and the geopolitical and supply chain risks associated with these materials. - By understanding the criticality, policymakers and industry stakeholders can make informed decisions and strategies regarding resource management, recycling, and sourcing. - Awareness of the criticality of materials can stimulate innovation in the sector, encouraging the development of alternative materials and technologies that are less dependent on scarce or geopolitically sensitive resources.
Drawbacks	- The criticality of materials may change over time due to geopolitical changes, new reserve discoveries or changes in technology, which can quickly make the analysis obsolete. - It requires extensive data collection, expertise and resources to conduct a thorough analysis. - There may be limitations in the availability and accuracy of data relating to material reserves, mining impacts and recycling rates that may affect the accuracy and reliability of the criticality analysis.

Based on the evaluation conducted by the ORIENTING project, which used the RACER methodology to rank criticality assessment methodologies, the consortium recommends including criticality in the non-restrictive set of relevant Impact categories, category indicators, LCIA methods. We recommend using the GeoPolRisk method based on its robustness, acceptance, credibility, ease of use, and relevance; when the characterization factors will be provided by the ORIENTING project.

Circularity

Circular Economy (CE) is defined by the underdevelopment ISO standard as “an economic system that uses a systemic approach to maintain a circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development” (ISO/DIS59004). Circular Economy (CE) is often associated to “reduction”, “reusability”, “recovery” and “recycling” principles (Julian Kirchherr, 2017), called circularity aspects. To access Circular Economy strategies, a large variety of circularity indicators has been developed, they can be classified at micro- meso- or macro-level (from product level to company level)((Rigamonti, 2021), and measure one or more circularity aspects. The MCI (Material Circularity Indicator) for example, from Ellen MacArthur Foundation (Foundation), indicates how much the product materials circulate and provides information on the utility of the product. The Recycled Content (RC) indicator simply described the fraction of secondary resource (scrap) in the total resource input (primary and secondary). The EoL Recycling Rate (EoL-RR) gives the fraction of the total waste flow of a resource that enters the recycling process and that is recycled (the recycled flow of a resource that is the output of the recycling process).

However, CE and environmental/social sustainability are not directly and necessary linked:

- First, circularity is not an environmental problem as such, as it is not based on assessment of elementary flows, but is linked to economic flows in the Technosphere (waste flows, secondary goods …)
- Second, CE strategies do not necessary provide environmental benefits and could lead to shifting and rebound effects (Claudio Sassanelli, 2019). Several articles even demonstrated that the most circular solutions are not necessary the best environmental options (Rigamonti, 2021).

The Table 5-4 gives the advantages and drawbacks of adding circularity indicator to the non-restrictive list of impact categories of TranSensus LCA.

Table 2-23: Advantages and drawbacks of including circularity indictor in TranSensus methodology

	Circularity indicators
Advantages	- reflects circularity aspects and efficiency of a product system - high policy relevance (linked to Ecodesign for sustainable Products Regulation) - useful indicator on the driver-level of DPSIR
Drawbacks	- large variety of indicators, which reflect only partial aspect of circularity - ISO norms not finalized yet - circularity is not an environmental or social impact (it is not based on assessment of elementary flows) - it is a way to enhance sustainable use of resources and should be properly modelled in the LCI (% recycled content, mass, recyclability …)

As they measure circularity aspects, circularity indicators can be powerful tools to improve circular decision making. In line with the Eco-design for Sustainable Products Regulation (Commision), these indicators have high policy relevance. However, it is necessary to highlight that circularity is not an environmental problem as such, thus circular indicator cannot be considered as environmental or social impact category. Circularity aspects relates to flows (waste, secondary goods …) which belong to the Technosphere and are not elementary. Thus, circularity aspects should be properly modelled in the LCI, distribution of burdens/benefits regarding recycling/recycled content should be addressed with EoL allocations (CFF, cut off …) and present impact categories, like abiotic resource depletion or resource dissipation, already differentiate between system with high or low circularity. As many circularity indicators exist, each addressing only partial aspects of circularity, and as the ISO/DIS 59004 is still under development, WP2 TranSensus LCA recommendations are:

The consortium recommends NOT including 'circularity indicators and aspects' into the non-restrictive set of relevant Impact categories, category indicators.

Biodiversity

Human activities have an impact on our planet biodiversity through the 5 pressures identified in the Millennium Ecosystem Assessment (2005): land use (habitat change), pollutions, climate change, invasive species, overexploitation of species. Each of these 5 pressures are detrimental to our planet biodiversity because of the decrease in the number of local species and the decrease in the number of individuals per specie they are responsible for.

Several biodiversity indicators exist to take into account the impact of a given human activity on our planet biodiversity. Among them, two are the most advanced and take into consideration the whole life cycle of the impacting processes: the GBS (Global Biodiversity Score) and the PBF (Product Biodiversity Footprint).

The GBS indicator sets a particular focus on investments and aims to be used by financial institutions. It relies on money expenditures that are converted to biodiversity losses through models and databases, considering the 5 pressures the money expenditures are responsible for. Such models and databases are still in the process of being completed. It is possible to complete the indicator with more specific data (local practices…).

The PBF indicator also considers the 5 environmental pressures on biodiversity, with different tools: an LCA will give information on the land use (habitat change), pollutions (photochemical oxidation, eutrophication and acidification) and climate change impacts on biodiversity linked to the process under study through the LC-Impact method/tool. The results from the LCA will be completed by qualitative data reflecting local practices on biodiversity preservation that are related to: species habitat change (land occupation, land transformation and water stress), invasive species and species overexploitation.

The Table 2-24 gives the advantages and drawbacks of adding biodiversity indicator to the non-restrictive list of impact categories of TranSensus LCA.

Table 2-24 : Advantages and drawbacks of biodiversity indicators calculation

	Biodiversity method 1: GBS	Biodiversity method 2: PBF
Advantages	- Easy to compute (only financial data are needed)	- LCA approach completed with local data so that to reflect the impacts on biodiversity of the 5 pressures
Drawbacks	- Sectorial approach - Not easy to differentiate between companies of a given sector - Databases relating financial investments to the 5 pressures need to be completed	- LC-Impact model still in development - Qualitative approach for local actions - Shows improvements better than absolute values

The consortium recommends NOT including biodiversity impact in the non-restrictive set of relevant Impact categories, category indicators, LCIA methods, because of the lack of maturity and robustness of the existing 2 main indicators (GBS and PBF).

Dissipation of Mineral Resources

The potential damage to current and future generations induced by the use, or improper use, of mineral resources in a product or a system over its life cycle has long been addressed in LCA. Existing LCIA methods have been classified in four categories according to their underlying impact mechanisms by the task force (TF) mineral resources of the United Nations Environment Programme (UNEP) Life Cycle Initiative, in the context of the Global Guidance for Life Cycle Impact Assessment Indicators and Methods (GLAM2): depletion, future efforts, thermodynamic accounting, and supply risk methods (Sonderegger et al., 2020).

Methods related to the potential *depletion of mineral resources* address the reduction and subsequent potential exhaustion of a certain stock (of these mineral resources). They assume that the extraction of mineral resources from the ecosphere reduces the natural (geological) stock, making these resources less available (Sonderegger et al., 2020). Availability of a resource here concerns its physical presence (Schulze et al., 2020). The abiotic depletion potential method (ADP, ultimate reserves; Guinée et al., 2002; van Oers et al., 2002) is in particular recommended in the GLAM2 context, for use by LCA practitioners interested in the relative contribution of a product system to the depletion of mineral resources and with a long-term perspective (Berger et al., 2020). As a mirror to this set of recommendations from the UNEP Life Cycle Initiative, the European Commission (EC) similarly recommends the use of ADP characterization factors (CFs) in the context of the Product and Organization Environmental Footprint (PEF/OEF; Zampori and Pant, 2019; EC, 2021) when assessing impacts associated with mineral and metal resource use. Eventually the depletion-based ADP method has been and is extensively implemented in daily LCA practice, in particular thanks to adapted standard LCI databases (e.g., ecoInvent©) and LCA software (e.g., SimaPro©) that enable easy calculations.

In addition to providing recommendations on some impact assessment methods, the UNEP Life Cycle Initiative welcomed the introduction of the concept of *resource dissipation* in LCIA and called for the definition of dissipative resource use and for its integration in future method developments. This requires i) LCIs to account for dissipative losses or flows and ii) LCIA methods to be adapted or developed (Berger et al., 2020). The EC also further encouraged and initiated research on resource dissipation in LCA (Zampori and Sala, 2017). It has indeed been argued that mineral resources, especially for what concerns metals, are transformed, but do not "disappear", and hence cannot be depleted. Instead, they are transferred from some stocks to some others, with various degrees of quality and/or accessibility (Stewart and Weidema, 2005; Dewulf et al., 2021). Dewulf et al. (2021) in particular distinguish six compromising actions that alter the "ability to access and make use of (the instrumental value of) a resource" (i.e., its accessibility): emitting to environment, landfilling, disposal of tailings, abandoning, hoarding, and downcycling. Part of these compromising actions contribute to resources dissipation. Beylot et al. (2020) reviewed 45 publications to describe the status of resource dissipation in life-cycle based studies, discussing how resource dissipation is usually defined, which temporal perspective is considered, which compartments of dissipation are distinguished, and which approaches (including the implementation of parameters) are considered to assess resource dissipation in a system. Building on insights from this review, they then proposed the following definition:

"Dissipative flows of abiotic resources are flows to sinks or stocks that are not accessible to future users due to different constraints. These constraints prevent humans to make use of the function(s) that the resources could have in the technosphere. The distinction between dissipative and non-dissipative flows of resources may depend on technological and economic factors, which can change over time" (Beylot et al., 2020)

These dissipative flows (or "losses") of mineral resources "negate circularity" (Charpentier Poncelet et al., 2022a).

In the recent years, in parallel to, or after, the GLAM2 review and recommendation work, several methods have been developed to address reduction of resource accessibility and resource dissipation (i.e. full inaccessibility) in LCA, both at the LCI and LCIA levels, adopting different scopes, (e.g., short term, long term); namely EDP (van Oers et al., 2020b), ARP (Owsianiak et al., 2021), ADR/LPST (Charpentier Poncelet et al., 2021; 2022b), and JRC-LCI (Beylot et al., 2021), complemented by JRC price-based (Ardente et al., 2023) to capture value loss. Comparatively, methods related to depletion, future efforts, thermodynamic accounting, and to a lower extent supply risks, received in the meanwhile less emphasis from the scientific community (in scientific literature and conferences), and from standardization/harmonization initiatives (e.g., in the PEF context, towards potentially delivering new recommendation).

Table 2-25: Synthesis of main characteristics of six methods to address mineral resource use in LCA

Method	Reference	Concept captured	Compromising actions covered	Practical implementation*	Temporal scope	LCI resource flows to which CFs apply
ADP ultimate reserves	Last update in van Oers et al., 2020a	Depletion	NA	CFs multiplied by inventory flows	Very long term to infinite	Resources from ground
ARP	Owsianiak et al., 2021	Dissipation	Emitting to environment	Classification of dissipative flows in LCI	Very long term to infinite	NA
JRC-LCI	Beylot et al., 2021	Dissipation	Emitting to environment	Addition and classification of dissipative flows in LCI	Short-term	NA
			Landfilling			
			Disposal of tailings			
			Downcycling			
EDP	van Oers et al., 2020b	Dissipation	Emitting to environment	CFs multiplied by inventory flows	Very long term to infinite	Emissions to environment
ADR and LPST	Charpentier Poncelet et al., 2022	Dissipation (midpoint)	Emitting to environment	CFs multiplied by inventory flows	Short-term and long-term	Resources from ground
			Landfilling			
		Value Loss (endpoint)	Disposal of tailings			
			Downcycling			

JRC price-based	Ardente et al., 2023	Value Loss (when combined with JRC-LCI)	NA	CFs multiplied by inventory flows	Short-term	Dissipative resource flows as in JRC-LCI method

*In this column the terms "inventory flows" are understood in a large sense, potentially including i) elementary flows and ii) flows within technosphere. Elementary flows (i.e., extractions and emissions) are in a 'conventional' LCA the basis for the Impact Assessment, while dissipative flows in the technosphere have not been, so far.

The table below gives the advantages and drawbacks of adding dissipation resources indicator to the non-restrictive list of impact categories of TranSensus LCA.

Table 2-26 : Advantages and drawbacks of including mineral resource dissipation in TranSensus LCA methodology

	Resource dissipation
Advantages	- dissipation better captures the problem of resource use. It looks very promising for LCAs to be truly supportive of more resource-efficient products and systems. - CFs have been developed, and for some of them are operable with standard LCA tools and LCI databases. E.g., ADR/LPST methods, whose CFs are available in standard LCA software (e.g., SimaPro©) and that may be used with current approaches for mineral resources flows compilation in LCI ("extracted from ground"), as e.g., in ecoinvent© or EF databases. And the EDP method, whose CFs are available for the emissions inventoried in the LCI database of ecoinvent© or any other database. - LCIs may need to be adapted, depending on the approach undertaken (which is a pro and a con – see below): resource flow analysis at the basis of the JRC-LCI method enables improved quality of LCIs, in terms of completeness (more flows covered, including better coverage of emissions to environment) and consistency of resource flows over the life cycle of products and systems (coherent mass balances of resources, which is classically not the case in standard LCI datasets, e.g. in ecoinvent©).
Drawbacks	- many developments, but characterization models and characterization factors only tested to few case studies, so far; - LCI datasets may need to be adapted, depending on the approach undertaken: dissipative flows may need to be added, elemental composition of materials may need to be known, ideally process data shall follow mass balance principle (IN=OUT). - Software tools may need to be adapted, depending on the approach undertaken, to extract the relevant dissipative flows from the technosphere matrix and relate them to the appropriate CFs. - several understandings of dissipation, essentially different as per their time frame (short-term versus long-term) and the parameters assumed to be relevant in the characterization model (e.g., dissipative flows only, dissipative flows in relation to stocks (in environment and technosphere), economic market mechanisms, or any others). This requires a common understanding of the concept of dissipation, and agreement onthe selection of a temporal perspective.

- **Regarding Resource dissipation**: TranSensus LCA consortium acknowledges the relevance of the concept of mineral resource dissipation, and the limitations of the concept of mineral resource depletion, and of the associated depletion-based method as recommended e.g., in the PEF (ADP method). **The TranSensus LCA consortium recommends to explore to shift from the concept of depletion to the concept of dissipation; for possible recommendation in the TranSensus LCA method based on further work to be performed in 2024.**
- **WP2 favours the recommendation of a new impact assessment method *if, through tests to be performed in 2024,* this is found to be relevant building on application to case studies.** Two candidate methods were identified as potentially relevant: **EDP (long-term temporal perspective) and ADR (short-term temporal perspective).** The test period in 2024 may conclude on **whether EDP or ADR may be recommended and may accordingly substitute for the ADP method** regarding the indicator "resource use, minerals and metals".
- **the consortium recommends that the TranSensus LCA method enables (setting it as *an option*), and even incentivizes, the consideration of dissipative flows of mineral resources in LCI following the JRC-LCI method.**
- **the consortium recommends to revise the final TranSensus LCA recommendations on mineral resource dissipation at the latest within 5 years.** New recommendations within 5 years shall take advantage of future developments and improvements (e.g., consideration of dissipative resource flows in LCI databases)

Non restrictive set STEP 2: WP2 pre-recommendations

WP2 TranSensus LCA pre-recommendations, regarding the non-restrictive set of relevant impact categories, category indicators and LCIA methods, are the following:

The consortium recommends the inclusion of a non-restrictive set of relevant impact categories, category indicators, and LCIA methods:

- the impact categories, indicators and characterization methods of **EF (EF3.0 & EF3.1)**
- **CED-total** based on aggregation of different energy sources by equal weighting, as driver level indicator
- **CED_non-renewable**, based on aggregation of different non-renewable energy sources by equal weighting, as an alternative indicator for the impact category 'abiotic resources fossil fuels'.

  - characterization factors for CED_non-renewables and CED_renewables as defined by Frischknecht (2015) which is most widely used and implemented in Ecoinvent (and other databases).

- **Criticality:**

  Based on the evaluation conducted by the ORIENTING project, which used the RACER methodology to rank criticality assessment methodologies, the TranSensus LCA consortium recommends including criticality in the non-restrictive set of relevant Impact categories, category indicators, LCIA methods. It recommends using the GeoPolRisk method based on its robustness, acceptance, credibility, ease of use, and relevance.

- **Mineral resource dissipation**:
  - The TranSensus LCA consortium recommends to explore to shift from the concept of depletion to the concept of dissipation; for possible recommendation in the TranSensus LCA method based on further work to be performed in 2024.
  - WP2 favours the recommendation of a new impact assessment method if, through tests to be performed in 2024, this is found to be relevant building on application to case studies. EDP and ADR methods will be tested, and compared with ADP.
  - the consortium recommends that the TranSensus LCA method enables (setting it as an option), and even incentivizes, the consideration of dissipative flows of mineral resources in LCI following the JRC-LCI method.
  - the consortium recommends to revise the final TranSensus LCA recommendations on resource dissipation at the latest within 5 years.

The consortium **recommends to NOT include** in the non-restrictive set of relevant Impact categories, category indicators, LCIA methods:

- **circularity indicators and aspects**
- **biodiversity impacts**

2.4.2 Subtask 2: Restrictive set of Impact Categories

The goal of this subtask is to address the reporting of a restrictive set of Impact Categories.

Restrictive set STEP 1: description of the main findings and learnings from WP1 & WP2 analysis

The analysis of WP1 shows that most OEMs report a restrictive set of impact categories, mainly GWP, Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential. This restrained list is often arbitrary chosen, inspired by the review of other published product LCAs. Two opposite needs are highlighted in D1.2 : 1/ the need for a comprehensive set of method, including circularity, biodiversity, criticality aspect, 2/ the need for a simple and easy to use set of impact categories, based on the most relevant and reliable indicators.

The use of a restrictive set of the most reliable and robust impacts categories could facilitate the interpretation and reporting. Not all impact categories and indicators are relevant for the ZEV sectors, and the low robustness of some indicators could lead to misinterpretation and biased decision-making. On the other hand, the PEF recommends the reporting of all EF set, limiting impact transfer. Also, a set of the most relevant and reliable indicators could be difficult to define without involving subjectivity.

Table 2-27 : Advantages and drawbacks of recommending a restrictive set of indicators

	Should we recommend a restrictive set of indicators?
Pros	• Simpler and easier to interpret & report • Not all EF impact categories are relevant for the ZEV sector • Low robustness ICs are difficult to interpret
Cons	• PEF recommends the reporting of all EF set • Impact transfer should be analysed • How to define a relevant restrictive set of IC without subjectivity

Restrictive set STEP 2 : WP2 pre-recommendations

Q: Should TranSensus recommend a restrictive set of the most relevant impacts categories, indicators and LCIA methods (based on the non-restrictive set) ?”

> The consortium recommends a restrictive set of the most **relevant impact categories, indicators and LCIA methods,** based on the **non-restrictive set.**
>
> **Guidance will be given in 2024 on how to analyse, report and communicate these sets.**

2.4.3 Subtask 3: Normalization and weighting

The goal of this subtask is to address normalization and weighting: should TranSensus LCA recommend normalizing and weighting results of impacts?

Normalization & Weighting STEP 1: description of the main findings and learnings from WP1 & WP2 analysis

Normalization aims at expressing each category-specific environmental impact indicator in terms of its relative magnitude when compared to a reference impact for that same category, in a specified geographic area and year. Normalized LCIA indicators are therefore expressed as dimensionless ratios.

Weighting aims at combining different weighted impact indicators by means of value-based weighting factors, to arrive at a single-score "super-indicator" of "overall" environmental impact. Weighted LCIA indicators are also dimensionless.

Multiple guidelines, standards and scientific literature address normalization and weighting, but in very different ways:

- **ISO 14044** (2006) states that Normalization is an OPTIONAL step of LCIA, and it also warns that it "can change the conclusions drawn from the LCIA phase". That is because whereas pre-normalization, mid-point LCIA indicators are absolute and express a quantitative estimation of potential environmental impact (e.g., in the case of Acidification: total moles of H+-eq), post-normalization they become relative indicators, which can be interpreted as some sort of "distance to reference". Hence, if for instance the (updated) estimate of the overall impact for a particular impact category (e.g., Acidification) in the reference region and year chosen for Normalization purposes is higher in absolute terms (vs. for some other region or year), then the corresponding Normalized LCIA indicator for the product or system under assessment will be discounted more heavily (i.e., divided by a larger normalization factor), and it will end up being expressed by a lower dimensionless ratio, all else being equal. As a result, Normalization tends to give prominence to those impact LCIA indicators that refer to impacts that contribute to impact categories for which the chosen reference region is comparatively less severely compromised already.
  ISO 14044 also warns that "Weighting steps are based on value-choices and are not scientifically based". Because of this, according to ISO, not only is Weighting also an OPTIONAL step of LCIA, but it "shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public". It is noteworthy that, arguably, the vast majority if not all of the LCAs that fall under the scope of this project entail a comparative element, whether explicitly or implicitly, since the prime purpose of

TranSensus LCA is precisely to provide harmonized recommendations to make LCAs more comparable.

- The **ILCD Handbook**, published in 2011, does not provide explicit recommendations on Normalization.

  The **original Product Environmental Footprint (PEF) guidelines**, published in 2012, were in alignment with ISO 14044 in stating that both Normalization and Weighting were to be OPTIONAL steps in LCIA.

- The guidelines also mandated that, if these steps were optionally applied, the ensuing normalized results "shall" be reported separately under "additional environmental information", with all methods and assumptions documented. The guidelines were also explicit in requiring that "*Normalized results shall not be aggregated as this implicitly applies weighting*" (with all weighting factors equal to 1), and in acknowledging that "*Weighting requires making value judgements as to the respective importance of the EF impact categories considered*".

- Selected **scientific literature** on Normalization was reviewed. Specifically:
  - The review by **Moltu Johnsen and Lokke (2013)** found that "*the weighting step seems to be inadequately understood in the LCA community, and its workings appear to be regarded as somewhat mystical*" [DOI:10.1007/s11367-012-0491-y]
  - The later paper by **Pizzol et al. (2017)** identified four main approaches to Weighting: (I) distance to policy target; (II) distance to scientific target; (III) Monetization; and (IV) Panel weighting. All approaches have shortcomings: (I) may not reflect how serios a problem actually is, since policy may be influenced by costs and other political considerations; (II) is affected by potential lack of robust scientific data and evidence; (III) is extremely subjective since it fundamentally relies on "willingness to pay" concepts and on the assumed monetary value of human life; (IV) is likewise affected by subjectivity, and can easily be skewed by the personal characteristics and possible preconceptions of the panelists. [DOI:10.1007/s11367-016-1199-1]

- The European Commission Joint Research Centre (JRC) attempted to develop a standardized approach to Weighting and an ensuing set of agreed-upon weighting factors for use in LCIA [Sala et al., 2018], while at the same time explicitly acknowledging that "nevertheless, the identification of the 'right' perspective to be adopted (I.e., the 'right' weighting approach) cannot stem from 'objective evaluations', as subjectivity plays a fundamental role."

  Be that as it may, the JRC-recommended Weighting factors were developed using a combination of two approaches, namely: (I) a hybrid evidence-based and expert-judgement approach, partly relying on "distance to scientific target" criteria; and (II) a panel-based approach, combining the responses obtained from a webinar with selected LCA experts and an on-line sample of 400 internet users between 18 and 65 years of age, with no prior knowledge of LCA.

- The updated Product Environmental Footprint (PEF) guidelines, published in 2021, made a U-turn on Normalization (and weighting) and changed the recommendation from OPTIONAL to MANDATORY for both. At the same time, though, the updated PEF guidelines still acknowledged that "normalized EF results do not indicate the severity or relevance of the respective impacts" (because of the shift in focus from absolute to relative, as discussed above), and they still required that "normalized results shall not be aggregated as this implicitly applies equal weighting". Finally, the updated PEF guidelines mandate that "characterized results shall be reported alongside the normalized results" and that "the results of the EF impact assessment prior to weighting (I.e., characterized and normalized) shall be reported alongside weighted results".

Even if recommendations vary dramatically between guidelines, standards and scientific literature, they all agree that **Normalization** shifts the focus of LCIA from absolute to relative impact (the latter only being interpretable vs. the backdrop of a specific reference region and time), and that **Weighting** always, inescapably, entails subjective value judgements and it can never be scientifically based. The following table shows the advantages and drawbacks of normalizing and weighting.

Table 2-28: Advantages and drawbacks of normalization and weighting

	Normalization	Weighting
Advantages	Allows contextualizing LCIA results in terms of the pre-existing cumulative impact in a specific region and timeframe, within each impact category.	Simplifies communication.
Drawbacks	Shifts the focus from absolute to relative impacts. Does not indicate (absolute) severity or relevance of impact. Entails additional uncertainty.	Not scientific. Always subjective. Hides detail and potential impact shifting between different impact categories.

Normalization & weighting STEP 2: consortium recommendations

Q: The consortium recommends providing factors for normalization.

The consortium recommends that normalisation and weighting are optional and reported separately. Factors will be recommended only for normalisation and not for weighting.

Guidance will be given in 2024 on how to analyse, report and communicate these sets.

2.4.4 Subtask 4: S-LCA and LCIA

The S-LCA subtasks consists of two tasks: 1) relevant impact sub-categories and stakeholder categories (Section 5.4.1); and 2) Methodology for hotspot assessment (Section 5.4.2).

Relevant Impact sub-categories and Stakeholder categories for S-LCIA

The goal of this subtask is to select and recommend a set of relevant Impact sub-categories, and Stakeholder Categories for S- LCIA for TranSensus LCA.

S-LCA STEP 1: description of the main findings and learnings from WP1 & WP2 analysis

The objective of conducting a thorough analysis of social and socio-economic impacts in social life cycle assessment (S-LCA) studies gives rise to the requirement for prioritizing social life cycle impact subcategories. Prioritizing impact subcategories enables a more specialized evaluation of the social impacts connected to a process or product (Bouillass, Blanc, & Perez-Lopez, 2021). Since Battery Electric Vehicles (BEVs) (since informations on other ZEV are not available the list is made according to BEV) are in the path of replacing the conventional vehicles across the globe, it becomes necessary to conduct S-LCA to identify its social impacts. Prioritizing social life cycle impact categories for a battery electric vehicle (BEV) before performing a Social Life Cycle Assessment (S-LCA) is important for several reasons:

I. Comprehensive assessment: Prioritizing social impact categories allows for a more comprehensive assessment of the BEV's overall sustainability performance. S-LCA evaluates the social aspects of a product's life cycle, including its social impacts on workers, communities, and society as a whole. By prioritizing impact categories, such as human rights, labour practices, community well-being, and social equity, the assessment can focus on the most relevant and significant social issues (Sharma & Manthiram, 2020).

II. Identifying hotspots: Prioritizing social impact categories helps identify the areas of the BEV's life cycle that have the most significant social impacts. This can help guide decision-making and resource allocation towards addressing and mitigating these impacts. By understanding the hotspots, stakeholders can work towards improving the social performance of the BEV and ensuring that it aligns with sustainability goals (Sharma & Manthiram, 2020).

III. Transparency and accountability: Prioritizing social impact categories promotes transparency and accountability in the assessment process. By clearly identifying the social impact categories that are being assessed, stakeholders can understand the scope and focus of the S-LCA. This transparency helps build trust and credibility in the assessment results and allows for meaningful comparisons and benchmarking across different BEVs (Ahamed, Nazzal, Darras, & Deiab, 2023).

IV. Stakeholder engagement: Prioritizing social impact categories involves engaging relevant stakeholders in the assessment process. Stakeholders, such as workers, local communities, and advocacy groups, can provide valuable insights and perspectives on the social impacts of the BEV. Engaging stakeholders ensures that their voices are heard and considered in the assessment, leading to more robust and meaningful results (Ahamed, Nazzal, Darras, & Deiab, 2023).

In summary, prioritizing social life cycle impact categories for a battery electric vehicle before performing a S-LCA is essential for a comprehensive assessment, identifying hotspots, promoting transparency and accountability, and engaging relevant stakeholders. By prioritizing these impact categories, the assessment can focus on the most significant social issues and drive improvements in the social performance of the BEV.

The methodology used is a three-step filtration process. Primarily, a materiality assessment proposed by the European Financial Reporting Advisory Group (EFRAG) is done by identifying the main impact subcategories based on the frequency in which they are reported in the relevant policies and frameworks related to Battery Electric Vehicles. Similarly, the Sustainability Assessment Questionnaire (SAQ) from Drive Sustainability was analysed to pick the impact categories which are aligned with the UNEP. These two lists are then compared to get the final set of impact set categories. The PSILCA and SHDB databases were used to find out the KPIs and impact scales for each of the subcategory. The impact subcategories which has got KPIs to measure from the databases are considered mandatory and rest of them as recommended while performing a SLCA for a BEV.

Materiality Assessment:

Understanding the context and defining the Stakeholders

The S-LCA framework calls for a stakeholder approach that considers potential effects on various stakeholder categories. This is similar to how managing both positive and negative impacts on people (stakeholders) is a key component of social sustainability. Stakeholder categories are used to categorize social impacts in order to help operationalize and ensure that the framework is comprehensive. A S-LCA assessment's foundation is its stakeholder categories because they are the ones on which justification for inclusion or exclusion in the scope must be given (UNEP, 2020). The (UNEP, 2020) have published the updated version of the S-LCA guidelines and have defined the relevant stakeholder categories along with its impact subcategories. The different stakeholder categories identified are Workers, Local Community, Value Chain Actors, Consumer, Society and Children

Identification of the potential material impacts

The potential impacts on each of these stakeholder categories can be classified into a number of impact sub-categories depending on the issues of concern that are potentially affected. The identified impact subcategories will cover a wide range of social and socio-economic aspects related to the product.

Table 2-29: Impact sub-categories, potential impacts on each of these stakeholder categories (Benoît Norris, Traverso, & Neugebauer, 2020)

UNEP Stakeholder Categories	Worker	Local community	Value chain actors (not including consumer)	Consumer	Society
UNEP Impact Subcategories	1. Freedom of association and collective bargaining 2. Child labour 3. Fair salary 4. Working hours 5. Forced labour 6. Equal opportunities/discrimination 7. Health and safety 8. Social benefits / social security 9. Employment relationship 10. Sexual harassment 11. Smallholders including farmers	1. Access to material resources 2. Access to immaterial resources 3. Delocalization and migration 4. Cultural heritage 5. Safe and healthy living conditions 6. Respect of Indigenous rights 7. Community engagement 8. Local employment 9. Secure living conditions	1. Fair competition 2. Promoting social responsibility 3. Supplier relationships 4. Respect of intellectual property rights 5. Wealth distribution	1. Health and safety 2. Feedback mechanism 3. Consumer privacy 4. Transparency 5. End-of-life responsibility	1. Public commitments to sustainability issues 2. Contribution to economic development 3. Prevention and mitigation of armed conflicts 4. Technology development 5. Corruption 6. Ethical treatment of animals 7. Poverty alleviation

Hence, the outcome of this step is the definition of list of potential material matters (topics and subtopics) and their related impact.

Determination of the final list of material matters based on an assessment of the materiality of the impacts

This is the step of the materiality assessment process whose outcome is the list of material impacts. The methodology used for the materiality assessment is to prioritize the impacts related to BEV by considering it as a whole and in granular level i.e., raw material level by taking the scope from cradle to grave. Then find out how the various policy documents and frameworks connected to BEVs have addressed the different impact sub-categories related to different components of BEV in all the different stages such as the Extraction, Manufacturing, Distribution, Use and EoL. The count of the number of reporting is considered as the factor to rank the impact sub-categories. The tables of prioritization are given below for each of the stakeholder categories.

Table 2-30: Tables of prioritization for each of the stakeholder categories.

Stakeholder Categories	Impact Subcategories	Extraction	Manufacturing	Distribution	Use	EoL	Total Reportings
Workers	**Health and safety**	IIIIIIII	IIIII	I	IIIIIIIII	I	24
	Equal opportunities/discrimination	IIIIII	IIII	II	I	NA	13
	Child labour	IIIIII	IIIII	I	NA	NA	12
	Forced labour	IIIII	IIII	II	NA	NA	11
	Freedom of association and collective bargaining	IIII	III	II	NA	NA	9
	Working hours	III	III	II	I	NA	9
	Fair salary	IIIII	I	I	I	NA	8
	Social benefits/social security	II	II	I	I	NA	6
	Sexual harassment	II	II	II	NA	NA	6
	Employment relationship	I	II	NA	I	NA	4
	Smallholders including farmers	NA	NA	NA	NA	NA	NA
Local community	**Delocalization and migration**	III	NA	I	I	NA	5
	Respect of indigenous rights	III	II	NA	NA	NA	5
	Community engagement	IIII	NA	NA	NA	I	5
	Cultural heritage	II	NA	I	NA	NA	3
	Safe and healthy living conditions	NA	II	NA	I	NA	3
	Access to material resources	I	NA	NA	I	NA	2
	Access to immaterial resources	NA	NA	NA	II	NA	2
	Secure living conditions	NA	I	NA	I	NA	2
	Local employment	NA	NA	NA	NA	NA	NA
Value chain actors	**Wealth distribution**	I	I	I	II	NA	5

	Promoting social responsibility	I	NA	NA	II	NA	3
	Fair competition	I	I	NA	NA	NA	2
	Respect of intellectual property rights	I	NA	NA	NA	NA	1
	Supplier relationships	NA	NA	NA	NA	NA	NA
Consumer	**Health and safety**	IIII	II	NA	IIIIIII	I	14
	Consumer privacy	I	II	NA	I	NA	4
	Transparency	NA	NA	NA	I	NA	1
	End-of-life responsibility	NA	NA	NA	NA	I	1
	Feedback mechanism	NA	NA	NA	NA	NA	NA
Society	**Corruption**	III	II	I	NA	NA	6
	Prevention and mitigation of armed conflicts	III	NA	NA	NA	NA	3
	Contribution to economic development	I	NA	NA	NA	NA	1
	Technology development	I	NA	NA	NA	NA	1
	Poverty alleviation	NA	I	NA	NA	NA	1
	Public commitment to sustainability issues	NA	NA	NA	NA	NA	NA
	Ethical treatment of animals	NA	NA	NA	NA	NA	NA

The main impact sub-categories for each stage across the entire lifecycle are marked in bold. NA represents the Impact sub-category which is not at all addressed in that stage from the collected sources. The different sources and documents used for finding the impact addressal in each stage of the life cycle are:

Table 2-31: Different sources used for finding the impact addressed in each stage of the life cycle

Extraction	• Aluminium Stewardship Initiative (ASI) Principles • Global Reporting Initiative (GRI) Mining Standards • JRC Technical Report- European Commission • International Council on Mining and Metals (ICMM) Principles • International Labor Organization (ILO) Mining Standards • OECD Guidelines for Multinational Enterprises on Responsible Business Conduct. • ISO 26000 • Sustainability Accounting Standards Board (SASB) Standards • United Nations Global Compact (UNGC Principles) • EU Batteries Directive and Regulations
Manufacturing	• Fair Labor Association Manufacturing Standards • Global Reporting Initiative (General) • EU Battery Directive • Global Battery Alliance (GBA) • Automotive Industry Action Group (AIAG) • International Labour Oorganization (Automotive Sector) • Batteries Scientific Studies • European Financial Reporting Advisory Group
Distribution	• International Labour Organization (Transport Sector) • United Nations Human Rights Council (Transport Sector) • EU Transport Directive 2022
Use	• Society of Automobile Engineers International • European Automobile Manufacturers Association • United Nations Economic Commission for Europe • European Road Safety Observatory • Federal Highway Administration • European Financial Reporting Advisory Group • European Commission • Sustainable Development Goals • Capgemini Invent Research Studies • National Cooperative Highway Research Program • Market Report by European Commission • Journal of Advanced Research in Economics and Administrative Sciences • Scientific Studies • World Bank
	• External Source

End of Life	• Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection

Identifying the relevant Impact Sub-Categories from SAQ

Drive Sustainability has developed a Sustainability Assessment Questionnaire (SAQ) for the automotive suppliers with aim of achieving some targets among which one of the main goals is to Introduce key supplier performance indicators on the environmental, social and governance (ESG) topics that are prioritised by the OEM members of the Automotive Partnership (Drive Sustainability, 2023). Hence for this, they have introduced a set of impact sub-categories or topics which are relevant to certain areas or stakeholder categories to map the potential social risks. After a careful comparison of these topics with the UNEP guidelines, the common ones were in the following table.

Table 2-32: Common impact sub-categories or topics relevant to map the potential social risks and common to UNEP and Drive Sustainability

Stakeholder Categories	Worker	Local community	Value chain actors (not including consumer)	Consumer	Society
Impact Sub-categories	Freedom of association and collective bargaining Child labour Fair salary Working hours Forced labour Equal opportunities/discrimination Health and safety Social benefits / social security Sexual harassment	Cultural heritage Respect of Indigenous rights	Fair competition Supplier relationships Respect of intellectual property rights	Health and safety Consumer privacy Transparency	Prevention and mitigation of armed conflicts Corruption Ethical treatment of animals

A shortlisting process for the impact subcategories was carried out by matching the Table 5-14 with the impact subcategories which are reported more than or equal to 5 times (highlighted in black) from Table 2-33. The final list of impact categories is:

Table 2-33: The final shortlist of impact sub-categories for S-LCA.

Shortlisted Impact Subcategories	
Freedom of association and collective bargaining	Social benefits / social security
Child labour	Sexual harassment
Fair salary	Respect of Indigenous rights
Working hours	Consumer Health and safety
Equal opportunities/discrimination	Worker Health and safety
Forced labour	Corruption

Identifying and Matching the Indicators in Databases with shortlisted Impact Sub-Categories

The goal of the S-LCA's social impact assessment phase is to quantify, comprehend, and assess the potential social impacts of a product system over the course of the product's life cycle. It can be used to forecast future potential social impacts of an evolving or non-existent system or to analyse past and present potential social impacts connected with a system. It's important to keep in mind that S-LCIA primarily focuses on assessing potential social impacts, rather than actual social impacts. Remember that potential social impact is the likelihood that a social impact will occur as a result of an organization's actions or inactions throughout the course of a product's life cycle or from the use of the product itself. The word "potential" is crucial because it implies relativism. A variety of rigorous but constrained hypotheses are used to support the assessment of potential impacts. (UNEP, 2020)

In order to assess the impact on the subcategories from Table 5-14, indicators can be used as the main metric or tool which can provide valuable information and insights on decision making for the OEMs. Hence, to find the indicators, the SHDB (Social Hotspot Database) and PSILCA (Product Social Impact Life Cycle Assessment) databases were used. They provide access to large amounts of social data on country-specific sector (CSS) level including the reference scales for each indicator since this study is following the Reference Scale Impact Assessment Approach, which enables practitioners to assess social risks associated with sectors and product systems. Both SHDB and PSILCA databases are based on three main building blocks: An Input-Output model, a Worker-Hours model, and a database on social aspects. However, it's important to be aware of the differences. The Input-Output models underlying both social LCA databases differ: SHDB is based on GTAP Input-Output model, but PSILCA is based on EORA/MIRO Input-Output model (Indrane, 2019).

STEP 2: WP2 pre-recommendations

The shortlisting of impact subcategories was done according to the methodology and have been classified as mandatory and recommended based on the availability of indicators and impact scales from databases such as PSILCA and SHDB. Orange represents mandatory impact subcategories whereas the green represents recommended. The impact subcategory "Fair Competition" is **marked separately because after applying the methodology, there were no subcategories coming under the "Value Chain Actors". Since it is required to include all stakeholders, "Fair Competition "was selected to be added due to the fact that it was most reported subcategory.

Table 2-34: The final list of impact sub-categories for S-LCA.

Stakeholder Categories	Worker	Local community	Value chain actors (not including consumer)	Consumer	Society
Impact Subcategories	Freedom of association and collective bargaining Child labour Fair salary Working hours Health and safety Social benefits / social security Sexual harassment	Respect of Indigenous rights	**Fair competition	Health and safety	Corruption

Methodology for Hotspot Assessment for S-LCIA

The goal of the social impact assessment phase in S-LCA is to evaluate, comprehend, and assess the potential social impacts of a product system over the course of the product's life cycle (derived from ISO 14040). It can be used to estimate future potential social consequences of an emerging or nonexistent system or to analyze past or present potential social impacts connected with a system. The goal of this task is to recommend the S-LCIA method to be used for TranSensus LCA.

<u>S-LCIA STEP 1: description of the main findings and learnings from WP1 & WP2 analysis</u>

The social life cycle impact assessment is conducted using one of two techniques, as per the UNEP/SETAC guideline for S-LCA:

- Reference scale – social life cycle impact assessment method (RS S-LCIA)
- Impact pathway – social life cycle impact assessment method (IP S-LCIA)

These two methods are also known as characterization models.

A reference scale is an ordinal scale that typically consists of grades 1 through 5, with each grade corresponding to a performance reference point (PRP). PRPs are thresholds, goals, and objectives that set different levels of social performance or social risk and assess the magnitude and significance of potential social impacts associated with organizations and products within production systems. PRPs are contextual and often based on international standards, local laws, or industry best practices. It can also be based on comparing relevant stock index data to these values, it is possible to identify whether the collected data indicate negative or positive developments. RS S-LCIA methods are selected when the impact assessment aims to find out the social risk or social performance of the product system. According to UNEP/SETAC, (2020), social performance refers to the evaluation of business activities against established benchmarks or standards. It involves measuring the company's performance using specific data relevant to that organization. This approach recognizes the unique context and characteristics of each company. On the other hand, social risks are assessed by considering the extent of social impacts experienced by stakeholders due to a company's activities throughout its life cycle and business relationships. These risks can also arise because of unexpected incidents or events. Social risk evaluations typically incorporate generic or sector- and country-level data to assess the potential social effects and their significance. In summary, social performance assessment involves measuring a company's activities against specific standards, utilizing company-specific data. In contrast, social risk evaluations consider the rate of social impacts on stakeholders throughout the life cycle and business relationships, and they often rely on more general data at the sector or country level. RS S-LCIA also known as the Type-1 model, doesn’t consider any causal relationships (cause-effect) and summarizes each model according to the scoring system such as multi-level scores for indicators or two levels of score.

The main target of the impact pathway approach is to assess and develop a model which consists of the relations between the cause and effect. The impact pathway assessment is based on the social mechanisms, and it belongs to certain impact subcategories. IP S-LCIA approaches do not strongly focus on the stakeholder groups but will give the impact results of a social issue through midpoint and endpoint indicators. Midpoint indicators are used to measure intermediate social impacts that occur because of a product's life cycle activities. These indicators focus on specific cause-effect relationships within the impact pathway. They are often based on quantitative data and can provide insights into the magnitude or intensity of the social impacts. Endpoint indicators could include measures like overall social well-being, social contribution to society, or the level of social sustainability achieved throughout the life cycle. These indicators are useful for comparing different products or services, identifying hotspots or areas of concern, and supporting decision-making processes (UNEP/SETAC, 2020). According to the UNEP/SETAC guideline, there are two types of impact pathways, those are qualitative pathways and quantitative pathways. Qualitative pathways usually identify social topics of interest or concern such as fair wages and child labour and it is described and combines different disciplines of natural and social sciences. The quantitative pathway approach is more focused on measurable numbers and target explanations of one or more phenomena. The quantitative approach is further divided into two, pathways following a mechanistic modelling approach oriented on E-LCA and pathways following a regression-based modelling approach (UNEP/SETAC, 2020).

S-LCIA STEP 2: WP2 pre-recommendations

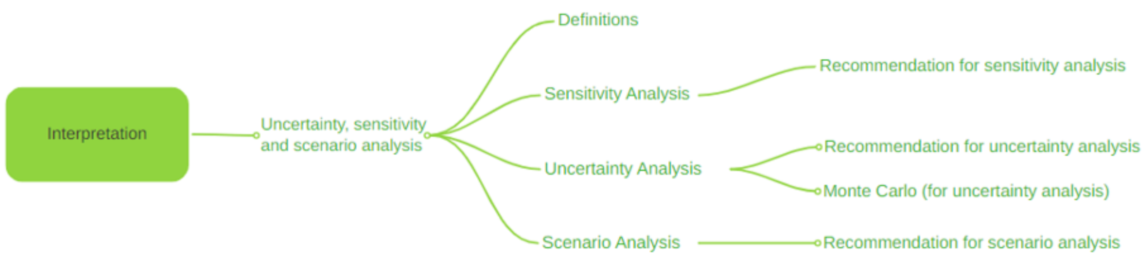
The reference scale approach is in common use rather than the impact pathway approach in social life cycle assessment (S-LCA) because it is more advanced. The reference scale approach uses performance reference points (PRPs) which are defined as thresholds or targets that set different levels of performance. In contrast, the impact pathway approach assesses the consequences resulting from the product system through one or multiple characterization models that employ cause-effect relationships for evaluating impact categories that are comparable to environmental life cycle assessment (E-LCA). The reference scale approach is more advanced because it focuses on the past or current social performance or social risks related to the behaviour of the organizations involved in the product system along its life cycle stages. Additionally, the current development of characterization models within the impact pathway S-LCIA is limited to potential social and socio-economic impacts, and for a very restricted number of impact subcategories.

The consortium recommends to use the most commonly used Reference Scale Approach (RS S-LCIA) for Hotspot Analysis/Risk/Performance Assessment.

2.5 Interpretation, Decision making and Frontloading concept (Task 2.5)

Within this task, the approach for the interpretation step for LCA and S-LCA will be defined. Recommendations for conducting sensitivity analysis, scenario analysis and uncertainty analysis will be proposed, considering user behaviour, electricity mix, value chain scenarios (V2G, circular loops), and other identified parameters from Tasks 2.1-2.4 and findings from Task 1.2. In view of the overall objective to pave the path towards an LCA-driven product development, this task will also conceptualise how decision-making and frontloading processes can be easily implemented into industrial product development processes along the supply chain. The goal is to enable engineers and managers according to their profile (industry, RTO, academia, policy, regulation, etc.) to select solutions and technologies (both existing and emerging) based on their environmental and social impacts, while balancing all other requirements. Furthermore, to enable informed decisions to be made within the constraints of the LCA and S-LCA results following the proposed approach, recommendations on how to report the results to the decision-maker in a clear, consistent and transparent way will be proposed.

Summary of recommendation & voting options:



2.5.1 Subtask 1: Uncertainty, sensitivity and scenario analysis

This subtask has the goal to elaborate a definition respectively description for the terms uncertainty analysis, sensitivity analysis and scenario analysis. As a main result of this subtask recommendations for conducting an uncertainty, sensitivity and scenario analysis are available.

Definitions of sensitivity, uncertainty and scenario analysis

To issue recommendations on how to conduct an uncertainty, sensitivity and scenario analysis, certain requirements must be met. A particularly important point here is the development of a common understanding of the various terms of analysis. To this end, various sources from science, standards and legislation were consulted. The following short and long descriptions of the terms uncertainty, sensitivity and scenario analysis were created within the subtask and were agreed upon with the partners in Task 2.5 and represent a finding.

Sensitivity analysis

The consortium recommends the following definition for sensitivity analysis:	
Short version	The sensitivity analysis focuses on the influence each parameter has on the result (e.g., OAT on location of the electricity mix).
Long version	Most guidelines refer to sensitivity as a 2-step-process. First step (“check”, “analysis”) is changing parameters like inventory data, used methods, impact categories or assumptions to be able to evaluate the influence these changes have on the final results of the LCA. According to the ISO 14040 this can be done in **absolute numbers** or a **variation in %.** The aim of the second step (“evaluation”) is to assess the results concerning their relevance for final conclusions and suggestions. This step is an iterative process along all steps of the LCA and should also incorporate expert knowledge and prior experiences. The most commonly used approach is the **local sensitivity analysis (LSA)** which evaluates the variation caused by one input around its reference point as opposed to **global sensitivity analysis (GSA)** which evaluates the variation of outputs caused by all input parameters.

Uncertainty analysis

The consortium recommends the following definition for uncertainty analysis:	
Short version	The uncertainty analysis focuses on how well we know the absolute value of the result (e.g., Monte Carlo).
Long version	Uncertainty analysis, in general, is carried out to investigate the accuracy and reliability of the LCA model of a product or a process, which has developed with various underlying variables and assumptions as the basis of LCA. Particularly applied to comparative LCA, uncertainty analysis must be applied to estimate and report any statistics differences in the results reported for the different variables. Where not possible, a thorough evidence-based justification of the preference of one system over the other.

Scenario analysis

The consortium recommends the following definition for scenario analysis:	
Short version	A scenario represents a storyline that determines a variation of key parameters/assumptions (applies well where parameters are correlated) of the model.
Long version	Most guidelines refer to sensitivity as a 2-step-process. First step (“check”, “analysis”) is changing parameters like inventory data, used methods, impact categories or assumptions to be able to evaluate the influence these changes have on the final results of the LCA. According to the ISO 14040 this can be done in **absolute numbers** or a **variation in %.** The aim of the second step (“evaluation”) is to assess the results concerning their relevance for final conclusions and suggestions. This step is an iterative process along all steps of the LCA and should also incorporate expert knowledge and prior experiences. The most commonly used approach is the **local sensitivity analysis (LSA)** which evaluates the variation caused by one input around its reference point as opposed to **global sensitivity analysis (GSA)** which evaluates the variation of outputs caused by all input parameters.

General approach to address sensitivity, uncertainty and scenario analysis in TranSensus LCA

Local sensitivity analysis (LSA) involves examining how one specific input changes when it is adjusted from its reference point, while keeping all other inputs at their normal, or nominal, values. The most straightforward method is called one-at-a-time (OAT) or perturbation analysis (as described by Heijungs and Kleijn in 2001[2]). In OAT, the sensitivity of a particular input parameter is calculated as the ratio between how much the model's results change and how much the specific parameter is adjusted. OAT is simple to use in any Life Cycle Assessment (LCA) software tool. Various strategies can be employed to adjust input parameters. In some cases, a uniform variation (e.g., ± 20%) is applied to all uncertain data, which avoids the need to gather more data but introduces bias into the results because it doesn't account for the varying uncertainty levels of different inputs. This leads to an overestimation of sensitivity for parameters with low uncertainty and vice versa[3].

Global sensitivity analysis (GSA) is a technique used to understand how the outputs of a system are influenced by changes in the entire range of input values. A basic GSA method involves examining correlations within the results obtained from uncertainty propagation methods, like Monte Carlo sampling, where a wide range of input values is considered[4].

Sampling methods / Monte Carlo Method:

Sampling methods aim to create simulations of various possible outcomes. By sampling the probability distributions of input variables, we can statistically estimate the distribution of results. In Life Cycle Assessment (LCA), the most commonly used approach for this purpose is the Monte Carlo method, as seen in works such as Maurice et al. (2000), Huijbregts et al. (2003), and Sonnemann et al. (2003). This random sampling technique is integrated into most LCA software, except for Umberto LCA+. However, it requires a substantial number of simulations to generate reliable results, often involving 1000 to 10,000 runs, which can take several hours to compute. Unfortunately, it's challenging to predict the exact number of simulations needed, and sometimes results may not converge to stability. As a general practice, many LCA analysts use a rule of thumb of 10,000 iterations to ensure a stable estimation of variance[5].

Understand the habits from partners:

To find out which methods are used for the analysis by different partners from industry and academia, a questionnaire was handed out. In the following section the evaluation of this consultation is presented. To conduct a sensitivity analysis various stakeholder were asked which methods are used and why they are used.

[2] Heijungs and Kleijn in 2001
[3] Igos
[4] Igos
[5] Igos (todo: also cite other sources within)

The results of the questionnaire were very consistent: All participants claimed that they perform sensitivity analysis and that they use one at a time (OAT) as the preferred method. The stated reasons were that the method is easy to apply and understand and that if more than one parameter is changed, dependencies are harder to prove. Other mentioned methods were Global Sensitivity Analysis (GSA) using sobol indices and delta-independent approach.

After answering the previous question, stakeholders were asked what methods were used in the context of uncertainty analysis. First of all, it is important to note that not all partners perform uncertainty analysis. By default, most of them do not perform uncertainty analysis, the focus is usually put on sensitivity/scenario analysis. However, when they perform uncertainty analysis, they unanimously agree on doing a Monte Carlo analysis. The Monte Carlo analysis is the only method used when uncertainty analysis is performed.

To gain insight into the methods used in connection with the scenario analysis, the partners were interviewed. For scenario analysis, the stakeholders agreed on saying that there aren't specific mathematical methods defined as in sensitivity or uncertainty analysis. However, they proceed according to one or more storylines that match specific criteria. It can be a storyline in line with decision making and target setting, client expectations, possible futures or in line with future policies. Sometimes there is a reference scenario, a more conservative one for example considering actual policies and technologies. For the stakeholders, it is important to have coherent and relevant scenarios to explore alternative options.

Q: What type of sensitivity analysis, TranSensus should recommend?

The consortium recommends that the following **sensitivity analysis** should be **MANDATORY**: **One at a time (OAT)**. Prioritized sensitivities to include to be discussed/developed in 2024.

Justification:

- Common approach
- Easy to implement
- Easy to understand
- The influence of one specific parameter can be visualized

Uncertainty analysis

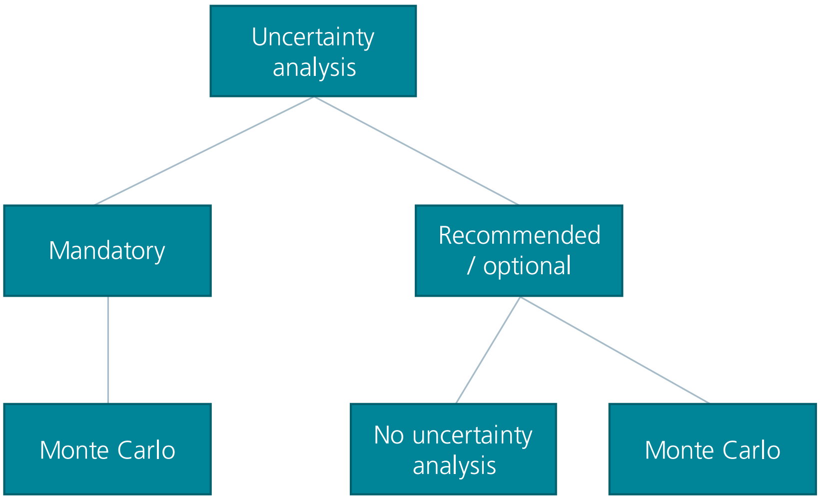


Figure 2-22: Decision tree for the voting options of uncertainty analysis

Q: Should TranSensus make uncertainty analysis mandatory or optional/recommended? (details on parameters/ use cases/... will be determined in 2024)

	Option 1	**Option 2**
Description & definition	**Uncertainty analysis should be mandatory**	**Uncertainty should be recommended / optional**
Pros	-Adds credibility and reliability to the results -The results can be compared from one LCA to another -Provides information about the robustness of the data used -Ensures an exhaustive analysis -Incites LCA practitioners to use reliable and robust data	-No effort -More accessible for all LCA practitioners
Cons	-Less accessible for all LCA practitioners -Workload increases -Not all LCA software is equipped with uncertainty tools -This analysis is not always required -Some uncertainty methods require additional information about the data used	-No information about uncertainty -Hard to compare results -Low credibility of results

WP2 recommends for uncertainty analysis to use Monte Carlo Analysis. Monte Carlo is the most common approach in the LCA community (when uncertainty analysis is performed), the questionnaire sent to the partners confirms this tendency. This method is already implemented in some softwares which makes it easy to use and saves some time. Other than for practical reasons, Monte Carlo should be used as it provides exhaustive information on the quality of the results by calculating the combined influence of all input uncertainties. This method also allows comparability between two products. WP2 recognizes the workload required to do such an analysis. However, for now, there is no other method that provides this amount of information and that is already frequently used in the community and implemented in LCA softwares.

Scenario analysis

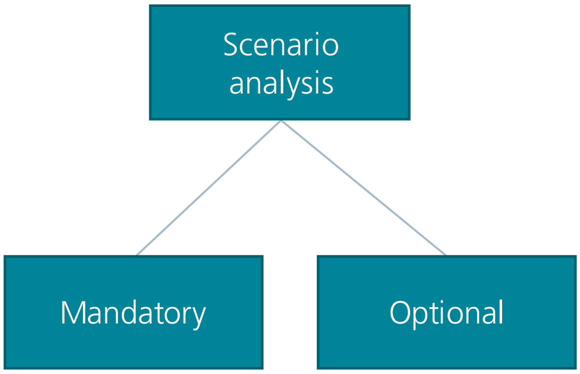


Figure 2-23: Decision tree for the voting options of scenario analysis

Q: Should TranSensus make scenario analysis mandatory or optional ?

	Option 1	Option 2
Description & definition	**Optional dedicated scenario analysis (included in uncertainty / sensitivity analysis) (Guidance /recommendations on these to be discussed/developed in 2024)**	**Mandatory scenario analysis by comparing different storylines or what-if-scenarios (Guidance /recommendations on these to be discussed/developed in 2024, if selected)**
Pros	-No effort needed - No multiplication of analysis so the interpretation of the results is easier	-Comparison of future scenarios for decision making during development -More information about correlated parameters -Most detailed insight about scenarios - Provides safeguards and objectivity on the result - Has been requested in other subtasks
Cons	-No information about possible future events and decisions -No visualization of interdependencies - Lack of objectivity	-Most effort needed -No standardized process for scenario analysis -Limited information about the influence of various interconnected parameters on the result - Multiplication of scenarios can make the interpretation of results complicated

3. Documentation to support second round of voting

3.1 Task 2.2: Goal & Scope

3.1.1 List of questions submitted to the 2nd voting by Task 2.2

Summary of TranSensus LCA recommendation & voting options.

Table 3-1: List of questions submitted by task 2.2 to 2nd voting of spring 2024

TranSensus LCA recommends for task T2.2 Goal & Scope:	Status
Technology coverage	
• Shall light means of transport (e-scooters and e-bikes) be excluded from the technology coverage or be included with limited guidance?	*(2)*
System boundary	
• TranSensus LCA recommends to exclude second use from the system boundary. It will be addressed as part of a sensitivity/ scenario analysis.	*(1)*
Functional unit	
• TranSensus LCA recommends the following general hierarchy for the default values in the functional unit:	*(1)*
• TranSensus LCA recommends the model-based values from PRIMES-TREMOVE for the default values of passenger cars and LCVs (light commercial vehicle) because of the consistency in the assumptions.	*(2)*
• For HDVs, TranSensus LCA recommends to use the segmentation provided by the Commission regulation (EU) 2017/2400 which is also implemented in VECTO.	*(1)*
• For two-wheelers, TranSensus LCA recommends to follow the segmentation and the default values for each segment provided by the European Parliament and of the Council in the Regulation (EU) No 168/2013.	*(1)*

3.1.2 Technology coverage

Q1 – Light means of transport

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA, Manufacturer fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting:

Shall light means of transport (e-scooters and e-bikes) be excluded from the technology coverage or be included with limited guidance?

Although light means of transport add to a more comprehensive picture, are relatively easy to model and will probably become relevant in new regulations, they cannot be included in TranSensus LCA methodologies to the full extent for several reasons:

- The light means of transport have a quite different purpose and mode of transport compared to the other vehicles. This limits the comparability.
- Due to the different mode of transport, the functional unit could be different to what is defined in this project.
- There is no industry partner in consortium to define detailed guidance from an industry perspective (e.g. on default values in the FU)
- The project is quite limited with the time available to detail the guideline. Therefore, we should focus on core topics.

This can be changed and updated in future versions of the guidelines.

Voting options	Exclude light means of transport	Include light means of transport with limited guidance
Description	Light means of transport will be excluded from the technology coverage.	Light means of transport will be included in the technology coverage. However, there will not be full detailed guidance on them in each step.
Pros	- Consistency in guideline – no technologies included for which no detailed guidance is provided	- More comprehensive picture in the technology coverage
Cons	- Less comprehensive picture in the technology coverage	- Inconsistency throughout guideline with level of guidance provided

Background

The technology coverage was voted on in the first voting period in October. TranSensus LCA includes already passenger cars, light commercial vehicle, heavy duty vehicle (Trucks, urban busses and coaches) and motorcycles and mopeds. On light means of transport, no consensus could be reached – within WP2 and with the Advisory board. The topic was discussed again in the working group and two options to solve the issue were developed. The work since the first voting showed new limitations and constraints (e.g., availability of default values for light means of transport) regarding including light means of transport. Therefore, a full inclusion of them is not feasible at the moment.

3.1.3 System boundary

Q2 – Second use

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA recommends excluding second use from the system boundary. Second use will be addressed as part of further analysis (e.g., sensitivity, scenario analysis).

While second use can be relevant, it is not sure at the moment if it will become a state of the art. With the limited time in the TranSensus LCA project, the working group recommends to focus on the core life cycle stages in the system boundary. Second use of batteries shall be addressed in further analysis (as sensitivity and scenario analysis) and with guidance to be developed in WP2.5. The developed guidance will be presented by WP2.5 in the third voting.

Possible answers: **Agree/ Disagree/ No preference**

Background

In the first voting, it was decided that the system boundary is cradle-to-grave. Second use was addressed in the first voting as well. No consensus was reached. WP2 was close to a majority for excluding it, while the advisory board was in favour of including it. The voting results were readdressed in the WP2.2 meetings and the meetings with the Advisory Boards.

3.1.4 Functional Unit

Q3 – General hierarchy

Overview

Type of LCA concerned by the question: **Product LCA**

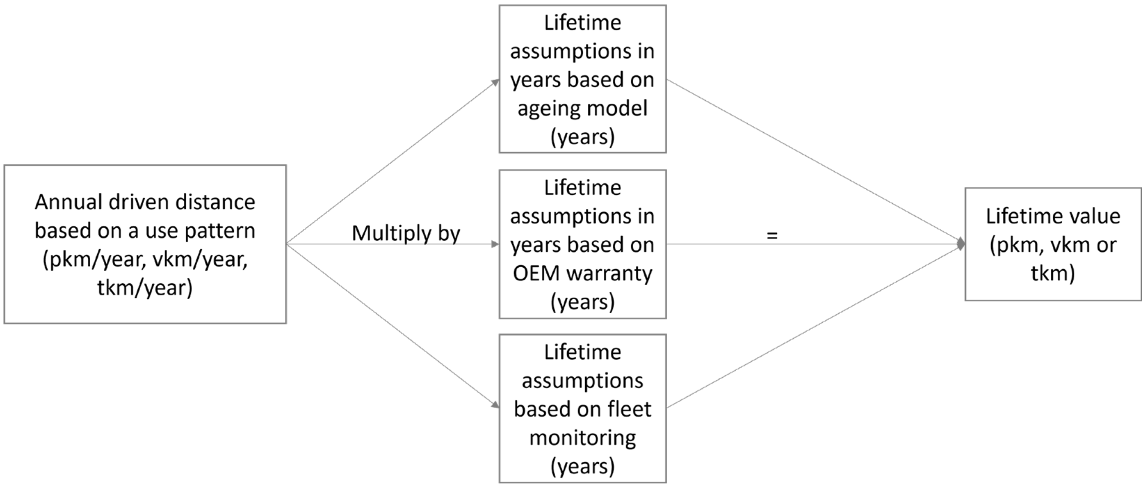
Complete question submitted to voting

TranSensus LCA recommends the following general hierarchy for the default values in the functional unit:

1. TranSensus LCA generally **mandates *("SHALL")* lifetime kilometers on a segment basis** (the respective default values and segment description criteria are provided in the next voting questions). Based on our statistical analysis, this modelling approach is deemed to be the most realistic and most likely to approximate the actual environmental emissions and impacts accruing over the full service life of the vehicle.

Comparisons between vehicles and segments are to be made on a km basis (vkm/ pkm as decided in the first vote)

2. TranSensus LCA allows for ("MAY") lifetime assumptions that are different from the default values if they are sufficiently justified. Comparisons are to be made as described in option 1. The following process is recommended to justify the values:



First, an annual driven distance has to calculated based on a specific use pattern of this vehicle. This includes the typical trips made, the length of the trips and the frequency. This can also include payload and passengers. The annual driven distance has to be multiplied with the lifetimes in years to obtain the full driven distance over the lifetime. There are different ways (no order among the options) to justify the lifetime in years:

- Based on an ageing model
- Based on the OEM warranty
- Based on fleet monitoring

The combination of a use pattern and an ageing model leads to the use of a mission profile. A mission profile is created as follows:

a. List the different typical trips performed by the user (e.g., work commute, week-end excursion, holidays)

Then for each kind of trip:

b. Define its typical length in km

c. Define the number of times this trip is performed per year

d. Define a typical speed profile (can look like a WLTP cycle, but on the full length of the trip)

e. Define the type of charging after the trip (charging power, charged once every x trips, state of charge (SoC) limit)

f. For long trips, define the type of charging during the trip (charging power, SoC limits)

g. Consider the climate where the car operates, define the external temperatures at which the trip is performed (e.g., x times at 0°C, y times at 10°C, z times at 20°C,...)

3. TranSensus LCA acknowledges that OEMs have to steer complex corporate environmental programs including a wide range of vehicle models and regions (and even separate brands) for which vehicle LCAs are a crucial data source. Moreover, OEMs must provide straightforward and legally-proof information regarding the environmental impacts caused over the lifecycle of their vehicles for their customers and other stakeholders. It is therefore **deemed permissible ("MAY") that OEMs opt to use a more generic approach instead, whereby a generic lifetime (see next voting question) is assumed for passenger cars of all segments.**
   Like this, comparisons between segments can be performed on a lifecycle-basis (i.e. environmental impact/total driven distance) or based on the approach described in 1 (environmental impact/1km).

4. Regardless of the chosen modelling approach (points 1., 2. and 3. above), TranSensus LCA **mandates ("SHALL") that the same approach be used in all instances of explicitly comparative LCAs**, which are aimed at making "comparative assertions" (i.e. either option 1, option 2 or option 3)

Possible answers: **Agree/ Disagree/ No preference**

Background

In the working group, it was agreed that while default values are necessary it should also be possible for the LCA practitioner to use different assumptions for the lifetime if they are sufficiently justified. This process was defined in the working group. In general, the working group favoured default values per segments of passenger cars. To adapt to the needs raised by the OEMs, step 3 was added to the general approach.

Q4 – Default lifetime activity values for passenger cars and LCV

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA recommends the model-based lifetime activity values from PRIMES-TREMOVE for the default values of passenger cars and LCVs (light commercial vehicle) because of the consistency in the assumptions.

Two options for vote remain since the values could be differentiated per powertrain or be aggregated for all powertrains.

The PRIMES-TREMOVE (model PRIMES-TREMOVE - PRIMES-TREMOVE Transport Model | Modelling Inventory and Knowledge Management System of the European Commission (MIDAS) (europa.eu)) was chosen by the working group because it includes values for all passenger car segments and has therefore consistent assumptions for all the different segments which would not be the case if values were taken from different sources.

For the applications the options would mean the following:

- Option 1: The default values are based on vehicle segments and powertrains.
- Option 2: The default values are only based on vehicle segment.

Differentiated lifetime activity values for passenger cars and LCV based on PRIMES-TREMOVE.

Lifetime activity, km	Passenger car					LCV		
	Small A/B	Lower medium C	Upper medium D	Large Others	All*	Small	Medium	Large
BEV	155,000	177,000	184,000	213,000	**175,000**	107,000		
REEV/FCEV	225,000	221,000	221,000	273,000	**227,000**	241,000		

Aggregated lifetime activity values for passenger cars and LCV based on PRIMES-TREMOVE

Lifetime activity, km	Passenger car					LCV		
	Small A/B	Lower medium C	Upper medium D	Large Others	All*	Small	Medium	Large
All powertrains	**190,000**	**202,000**	**205,000**	**257,000**	**203,000**	**236,000**		

*Basis for generic value for step 3 in general hierarchy described in the previous question: Instead of 203,000 km the round-down value of 200,000 km can be used by OEMs as is partly already common practice (e.g. BMW & Volkswagen).

Voting options	Differentiated values	Aggregated values
Description	Different values per powertrain are provided.	Aggregated values per segment are provided.
Pros	• Higher level of detail	• Less uncertainty in the assumptions
Cons	• Information not available for all powertrains • Brings a new level of uncertainty in the assumptions – all values are derived from ICEV and it is not sure how the difference between the powertrains will be	

Background

In the first voting, it was agreed to use km-based functional units and a segmentation for passenger cars. Therefore, default lifetime activity values per segment need to be provided. To get to the values, current guidelines, legislations and studies (VDA, PFA, Ricardo analysis, Directive 2009/33/EC) were analysed. All existing values are based on statistics for petrol and diesel vehicles.

Q5 – Default values for lifetime activity for HDV

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> For HDVs, TranSensus LCA recommends using the segmentation provided by the **Commission regulation (EU) 2017/2400** (Regulation - 2017/2400 - EN - EUR-Lex (europa.eu)) which is also implemented in VECTO (Vehicle Energy Consumption calculation TOol - VECTO - European Commission (europa.eu)).

VECTO provides yearly driven distances for each segment in the EU legislation. These yearly-driven distances are scaled to lifetime driven distances by using scaling factors derived from an internal Scania/MAN study based on a real fleet monitoring. The default values for the lifetime assumption therefore are:

- For trucks: Yearly distance from VECTO x 12
- For buses: Yearly distance from VECTO x 15

Possible answers: **Agree/ Disagree/ No preference**

Background

In the first voting, it was agreed to use km-based functional units. It was decided to follow the segmentation by the EU because this is widely established and accepted. To get the default values, current guidelines, legislations and studies were analysed. None of the existing values were following the segmentation by the EU. Therefore, these values cannot be taken as guidance for TranSensus LCA. Therefore, default values were developed from VECTO and the MAN/Scania study on real fleet monitoring.

Q6 – Default values for lifetime activity for two-wheelers

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

For two-wheelers, TranSensus LCA recommends following the segmentation and the default values for each segment provided by the European Parliament and of the Council in the Regulation (EU) No 168/2013

(https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:060:0052:0128:en:PDF).

The segments and default values shall be updated in line with the Regulation.

Possible answers: **Agree/ Disagree/ No preference**

Background

In the first voting, it was agreed to use km-based functional units. To get the default values, current guidelines, legislations and studies were analysed. It was decided to follow the segmentation and the matching default values by the EU because this is widely established and accepted.

3.2 Task 2.3: Inventory

3.2.1 List of questions submitted to the 2nd voting by Task 2.3

Summary of TranSensus LCA recommendation & voting options.

Table 3-2: List of questions submitted by task 2.3 to 2nd voting of spring 2024

TranSensus LCA recommends for task T2.3:	Status
Electricity modelling	
• **Production phase:** Which approach should we recommend to deal with electricity modelling for the production phase?	*(2)*
• **Use phase:** TranSensus LCA recommends the following approach to model the electricity input to the use phase of BEVs	*(1)*
• **End of life (EoL) phase:** TranSensus recommends to use the same electricity modelling approach for the EoL phase as for the use phase	*(1)*
• **On-site electricity production:** Do we need guidance for on-site electricity production modelling (to be defined later)?	*(1)*
• **Market-based electricity modelling:**	
- In case the market-based electricity option is voted for which hierarchy should we use for market-based electricity modelling?	*(2)*
- In case the market-based electricity option is voted for do we need safeguards for Energy Attribute Certificate (EAC) related to additionality (to be discussed later)?	*(1)*
- In case the market-based electricity option is voted for do we need safeguards for Energy Attribute Certificate (EAC) related to a production/consumption physical link (to be discussed later)?	*(1)*
- In case the market-based electricity option is voted for do we need safeguards for Energy Attribute Certificate (EAC) related to production/consumption time synchronization (to be discussed later)?	*(1)*
- In case the market-based electricity option is voted for do we need a safeguard for Energy Attribute Certificate (EAC) saying that the excess of production that is not consumed by the vehicle should not be counted as negative emissions/impacts?	*(1)*
- In case the market-based electricity option is voted for do we need other safeguard(s) for Energy Attribute Certificate (EAC) (to be discussed later)?	*(1)*
- Bonus question: What can we propose to deal with inconsistencies within electricity modelling approaches for Product LCA?	*(2)*
Multifunctionality	
• Transensus LCA recommends following approach regarding consistency between LCA, S-LCA and LCC:	*(1)*
• **The General Hierarchy for multifunctionality:** TranSensus LCA recommends the following hierarchy to deal with Multifunctionality in environmental LCA	*(1)*

• **Exceptions from Hierarchy:** TranSensus LCA recommends no exceptions from this Hierarchy except for the End of Life	*(1)*
• **Multifunctionality in the EoL**: Which approach do we use to deal with Multifunctionality in the EoL stage (allocation of credits and burdens between two successive system)?	*(2)*
Data	
• TranSensus LCA recommends the adoption of the data definitions of the JRC battery carbon footprint draft to be used for full vehicle LCA studies	*(1)*
• TranSensus LCA recommends making the following minimum cradle-to-gate data requirements mandatory to reach Level 3 for a BEV Light-Duty Vehicle and Heavy-Duty Vehicle product LCA	*(1)*
• TranSensus LCA recommends using the regulatory protocol for fleet reporting by authorities (WLTP for LDV's) [e.g. kWh/100km] as standard scenario and the regulatory cycle x RW correction factor for sensitivity analysis.	*(1)*
• How TranSensus LCA should address non-exhaust emissions during the use phase?	*(2)*
• TranSensus LCA recommends providing the practitioner with a recommended non-exhaustive list of parts/ processes (tbd. in 2024). Building on that, the OEM needs to provide a complete list with frequency of maintenance (OEM and model specific). Emission factors and processes may stem from secondary data sources.	*(1)*
• If end of life processes are already part of the operations of an OEM (e.g. already recollecting vehicles) they should include company-specific data for those processes. TranSensus LCA recommends using secondary data for recycling, energy recovery and disposal when modelling EoL.	*(1)*

3.2.2 Electricity modelling

Production phase electricity modelling

There are 2 main approaches to tackle electricity modelling within a product LCA: the location-based approach and the market-based approach. These two approaches cannot be used simultaneously if there is to be a coherence between the emissions reported in the GHG inventories and the emissions to the atmosphere.

TranSensus LCA has to recommend either the location-based approach or the market-based approach for the product production phase electricity modelling, if dual reporting cannot be an option (see bonus question).

Q7 – Electricity modelling for the production phase

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

Which approach should we recommend to deal with electricity modelling for the production phase?

The location-based electricity modelling approach is based on the physical average consumption mix of a country or region electricity-consuming facilities. The geographical scope of the electrical mixes to be considered should be national (i.e., country-specific electricity mix), or, if not possible, regional (i.e., EU grid mix).

The market-based electricity modelling approach uses contractual agreements, guaranteeing a unique claim for electricity from specific energy sources, such as Renewable Energy Sources, to model electricity consumption. For processes for which a contractual agreement has been concluded, the consumed electricity will be modelled according to the mix that is described in the agreement. For processes for which no contractual agreement has been concluded, the consumed electricity will be modelled using the national residual mix (i.e., country-specific), or, if not possible, regional (i.e., EU) residual mix. A residual electricity mix shows the sources of the electricity supply that is not covered via an Energy Attribute Certificate (EAC) tracking system. The location-based and market-based approaches cannot be combined within a product production phase LCA because of double counting issues, therefore the need to choose only one of them.

Voting options	Location-based approach	Market-based approach
Description	Every electricity consumption process will be modelled using either a national grid mix (i.e., country-specific electricity mix) or, if not possible, a regional mix (i.e., EU grid mix).	Every electricity consumption process will be modelled using either processes that reflect the electricity mix purchased via specific contractual instruments related to the considered process or, if no contract exist for the given process, country or, if not possible, regional residual mixes.
Pros	• Easy to use method because national and regional location-based mixes are available from most LCA databases. Incorporated in all production processes (of e.g. steel, aluminium) in secondary data bases. • Relies on a physical approach of electricity production and consumption; close to real-world representativeness (geographically speaking) and reflects real impacts linked to global electricity production and consumption. • Encourages energy efficiency and/or energy savings measures throughout the ZEV value chain. • By a systematic choice of the location-based method, there is no risk of double counting. The average mixes of the location-based approach are a way to have a simple and consistent accounting of electricity. But TranSensus cannot force every LCA practitioner to use its methodology. Double counting will arise when different companies, within or outside TranSensus, will, for some, use the location-based approach, and for others, use the market-based approach. • Very few accusations of greenwashing. • Easy to use for sensitivity and scenario analyses, when comparing production plants in different locations.	• Electricity consumers from anywhere in the ZEV value chain can actively choose to buy renewable electricity and take credit for the electricity they sign up for. • By increasing the demand for contractual instruments that can prove the additionality of their production, electricity consumers would give additional incentives for building new power plants. • Contractual instruments (Guarantee of Origin in Europe or other EAC such as REC in other parts of the world) are accessible to large and small companies alike. • Encourages energy efficiency and/or energy savings measures throughout the ZEV value chain within companies that want to do more than buying EACs (going neutral for instance). • When used systematically, for all consumers in a given bidding zone, the correct modelisation of EAC-backed contracts combined with residual grid mixes, avoid double-counting. But TranSensus cannot force every LCA practitioner in a given bidding zone to use its methodology. Double counting will arise when different companies, within or outside TranSensus, will, for some, use the location-based approach, and for others, use the market-based approach. • Can be used for sensitivity and scenario analyses, when comparing contractual energy sourcing options.
Cons	• Not considering the reality of the electricity market that is already using EAC and is anticipated to do even more so in the future. • No impact on the grid electricity decarbonization. • No incentive for companies to support renewable electricity projects outside of their boundaries.	• Contractual mixes need to be modelled, as well as, in the cases where the residual grid mixes are not available from LCA databases, the residual mixes; many LCA databases provide location-based processes, therefore the need to modify them to be compliant with a market-based approach. All this provides additional work.

	• As location-based modelling results in an average, attributed uniformly to all actors in the same geographical area, actors engaged in a voluntary individual approach to purchasing electricity from renewable energy producers, and who seek to promote their development, do not derive any credit from it	• Relies on financial instruments related to electricity production and consumption that open the way, for instance, in the case of unbundled EAC, to decoupling reported GHG emissions for products using EAC from GHG emissions to the atmosphere related to the same products. • Market based instruments break physical constraints: electricity can be transmitted over distances longer that a few hundreds of kilometres (which is not really the case), and can even be consumed when no physical connexion exist between the producer and the consumer (i.e. GO from Iceland can be used in continental Europe). • Impacts on the grid electricity decarbonization is not proven, but the GO system is not meant as a lever for the development of RES, at least in Europe. The development of RES is carried out through other mechanisms: voluntarism of governments which organize calls for tenders to achieve international production mix objectives, taxes on carbon energies, etc. • As not all players are obliged to buy AECs, it important that the consumers in the same bidding zone where the EACs are bought, and that do not buy those EACs use the residual grid mix in their LCAs as prescribed by the market-based approach. This is especially crucial in countries with a big difference between the location-based and the market-based electricity emission factor (for example Norway). • Nowadays, in Europe, the price of GOs is too low to reflect the real cost of building power plants and producing the electricity. Prices may increase according to the balance between the number of companies that will want to use GOs and the GOs available. • In practice, it may be difficult to know every amount of contracted electricity all along the product value chain. Approximations may have to be made, either inconsistent (double counting if using average mixes) or conservative (if using systematically residual mixes). • Potential accusations of resource shuffling (see definition below). Potential accusations of double counting if not done properly. Potential accusations of greenwashing and lower credibility to the LCA results if not done with safeguards.

Background

Definitions

An **Energy Attribute Certificate (EAC)** is the official documentation to prove renewable energy consumption. Each EAC represents proof that 1 MWh of renewable energy has been produced and added to the grid.

Global EAC standards for renewable claims are primarily **Guarantees of Origin** (GO) in Europe, **Renewable Energy Certificates (RECs)** in North America and **International RECs (I-RECs)** in a growing number of countries in Asia, Africa, the Middle East and Latin America.

Attributes for EACs

Each MWh of produced electricity has its unique characteristics associated with it, such as:

- time and date of production
- location of the generation device
- generation technology (eg. wind turbine, hydropower plant etc.)
- age of a production device

These characteristics are called attributes, and the EAC market offers a tool for trading these attributes.

At its most basic level, the EAC system works as follows:

- a producer of (renewable) electricity generates 1 unit of electricity (generally this is 1 megawatt-hour (MWh))
- for each MWh of power they inject into the grid the producer requests an EAC from the *issuer*; the EAC, which is an electronic certificate, contains factual information *attributes* about the specific unit of electricity such as the technology used to generate the power and where it is located.
- the EAC can be traded between market participants through *registries* with the ultimate claim of selling it to a consumer (also known as an end-user).
- The end-user or their representative consumes the EAC by cancelling it so that it cannot be used again – without cancellation, there is a risk that one EAC can be used twice (known as double counting)
- the consumer can then *claim* to have consumed the unit of power that was represented by the EAC.
- The EAC market is separate to the electricity market. Even though each EAC is associated with a specific unit of electricity, EAC markets are not about allocating the electricity but

are about allocating its *attributes*. Most often these are “renewable attributes” so that the electricity consumer can claim the consumption of renewable power.

Energy attribute certificate systems prevent the double sale or consumption of the attributes of a particular unit of electricity. *All* consumption of energy attributes should have the associated EAC cancelled, as there are no other means to ensure the prevention of double issuance or claiming.

Source: RECS

Bundled versus Unbundled GO

A GO can be sold either together with the underlying energy, or separately from it. When the GO and the underlying energy are traded in a contract together, it is described as “bundled.” When the GO and underlying energy are traded in separate contracts, it is described as “unbundled.” In either case, the basic principles of buying renewable electricity through the GO system apply.

Source: Guarantees of Origin and Corporate Procurement Options. RE-Source Platform, October 2021

A **residual electricity mix** is defined as a mix which is not documented via an Energy Attribute Certificate (EAC) tracking system.

The Association of Issuing Bodies (AIB - Home | AIB (aib-net.org)) develops, uses and promotes a European, harmonised and standardised system of energy certification for all energy carriers: the European Energy Certificate System - "EECS".

The AIB is issuing residual mixes for European countries.

A **Power Purchase Agreement (PPA)**, or electricity power agreement, is a long-term contract between an electricity generator and a customer, usually a utility, government, or company. PPAs may last anywhere between 5 and 20 years, during which time the power purchaser buys energy at a pre-negotiated price.

Whether the electricity producing plant is located on the site of the customer (on-site PPA model) or connected to the customer site via a purpose-built direct or ‘private’ wire which is typically less than 10 km (private-wire PPA model), the electricity generated by the renewable energy installation is sold and consumed by the customer, and power surplus is fed to the grid. GOs are not generated for the power that is consumed by the customer behind the meter. Surplus power that is exported to the grid, and metered, would receive a GO certificate to prove that the power comes from a renewable energy source.

The off-site PPA models, whether Physical (i.e. with a physical transmission of electricity via the electricity grid) or Financial (i.e. with no physical transmission of power between the producer and the customer (hence the name of Virtual or Synthetic PPA for this model) which allows the PPA to be signed across national borders), involves the signature of a contract or a series of contracts between a producer and a consumer. GOs are bundled (linked) with the power sold and transmitted from the installation owner to the consumer as part of the contract(s).

Source: Introduction to Corporate Sourcing of Renewable Electricity in Europe. RE-Source. January 2020.

RE-Source-introduction-to-corporate-sourcing.pdf (windeurope.org)

To be noted: GOs bundled with physical PPAs are typical of virtuous additivity: customer is responsible, by a long-term contractual commitment, of the building of a new low carbon facility. Although electricity is delivered through the grid, contract is a specific arrangement between producer and customer, optimizing production on consumption needs, and is very similar to a private line PPA.

Characteristics of the market-based approach

The market-based approach is designed to allow an energy consumer to declare it has made the choice of supporting the production of a renewable or low-carbon source by creating a direct link to a producer. This is explicit in the Renewable Energy Directive (RED II): « Guarantees of origin issued for the purposes of this Directive have the sole function of showing to a final customer that a given share or quantity of energy was produced from renewable sources. ».

Main findings and learnings from WP1

The debate about the choice of a market based or location-based modelling is still an open debate. In practice, D1.1 notes that in general, the most popular choices are the national or regional (i.e., Europe) average electricity mixes based on secondary data from a LCI database. It also mentions that the GHG protocol Scope 2 guidance requires for corporations to report their scope 2 GHG emissions for both location-based approach and market-based one approach, in a so-called dual reporting and that guidance such as the Catena-X, PEFCR-Batteries, and CFB-EV suggest to use emission factors appropriate for renewable energy consumed based on their source, by describing the EAC-type contractual instruments that can be invoked, such as RECs and GOs.

D1.1 mentions the difference which is made between bundled and unbundled RECs. Bundled RECs allow economic operators to claim “additionality” as a means of showcasing direct investment into new renewable energy generation plants and its added decarbonization contribution to the overall grid.

This bundled property is also identified in D1.2, as a key differentiating factor. It also warns against the risk of greenwashing associated with GOs and mentions that some advocate stricter requirements to strengthen the credibility of renewable energy claims based on Guarantees of

Origin (GOs), including stricter time consistency criteria between energy generation and use and a stricter geographic link consistency criteria between energy generation and use.

Recommended approach/possible options description and justification

Electricity basics

At every moment, electricity consumption and production should be at an equilibrium through the grid, otherwise the grid would collapse. Electricity supply from the grid is the result of a complex collaboration of various actors to ensure the balance between production and consumption, subject to strong physical constraints.

The electricity Transmission and Distribution systems act in a way that the physical consumption cannot be traced back to a production. The physical reality of the electric grid means that electrons cannot be traced: it is impossible to differentiate the consumption of two actors on the same bidding zone. Therefore, the physical tracing of electrons is not performed in existing grids.

The electricity travels on average short distances (100 km in the French transport network for instance).

Furthermore, the generalization of contractual instruments will fragment the electricity market, which could lead to deoptimization of the system. Nonsensical situations could arise, typically, if the consumer has no need for the electricity for any given reason (for example breakdown of a factory), does this mean the renewable production should stop, or be stored for the specific consumer site? The production asset could be forced to accommodate the needs of the client and not those of the system in its production schedule, which may endanger the equilibrium of the grid.

Main arguments in favour of location-based electricity modelling

The market-based approach amounts to determining rules to allocate energy production from a specific site to a specific consumer. Because electrons are not traceable in the network, and therefore consumption on site cannot be differentiated, these rules are necessarily arbitrary and lead to questionable results. LCA reports should reflect the environmental impacts caused by a product as accurately as possible, and in this respect stay as close as possible to real GHG emissions, when considering its impacts on climate change. The market-based approach presents the risk of decoupling GHG inventory emissions from GHG emissions to the atmosphere. The most accurate way to assess the environmental footprint of electricity is to calculate its geographical average.

To decarbonize or not to decarbonize, that is the question.

Both the location-based and the market-based approach are facing accusations of not decarbonizing, either the electricity from the grid or the product itself:

Location based approach	Market-based approach
By using national or regional electricity mixes, the location-based approach is accused of not helping to decarbonize the national or regional electricity grid mixes because it does not incentivize investments in renewables.	By using GOs with no safeguards, the market-based approach is accused of not decarbonizing the national / regional electricity grid mixes because the overall emissions of a country / region would be the same with and without the use of GOs.
	The market-based approach is accused of not decarbonizing products, but of showing decarbonization for given products while attributing all the "bad" emissions to other products for which there is little or no reporting that is done.

There is no clear evidence of a tangible impact of market-based approaches as a driver of decarbonization of the electric grid. Multiple studies have shown that contractual instruments used in the context of the Scope 2 market-based method have proved inefficient in that they are very unlikely to lead to additional renewable electricity generation, whose price is currently too low to provide additionality. The lack of impact stems from the low prices due in part to the flexibility of current spatial, temporal and additionality criteria: GOs from old renewable installations such as Norwegian dams can be used to decarbonate an installation in southern Europe during a winter night. Furthermore, Bjørn et al.[6] have shown that GOs represent a major part of mitigation efforts made by companies validated by SBTi. The main contribution to additional generation has been State subsidies. The need for privately funded renewable generation, when they exist, can be challenged, considering that the States are responsible for reaching decarbonization targets and would therefore most likely have funded the additional generation had they had to.

Double counting

There is no risk of double counting with a systematic and consistent approach, using either a location-based electricity modelling or a market-based electricity modelling.

Double counting arises when within a given value chain, some electricity consumptions are modelled using EAC while others are modelled using a national or regional electricity mix, as shown in figure 3 of the article from Peter Holzapfel, Vanessa Bach and Matthias Finkbeiner (Technische Universität Berlin, Institute of Environmental Technology, Chair of Sustainable Engineering): "Electricity accounting in life cycle assessment: the challenge of double counting", published in April 2023, in The International Journal of Life Cycle Assessment.

[6] Bjørn, A., Lloyd, S.M., Brander, M. et al. Renewable energy certificates threaten the integrity of corporate science-based targets. Nat. Clim. Chang. 12, 539–546 (2022)

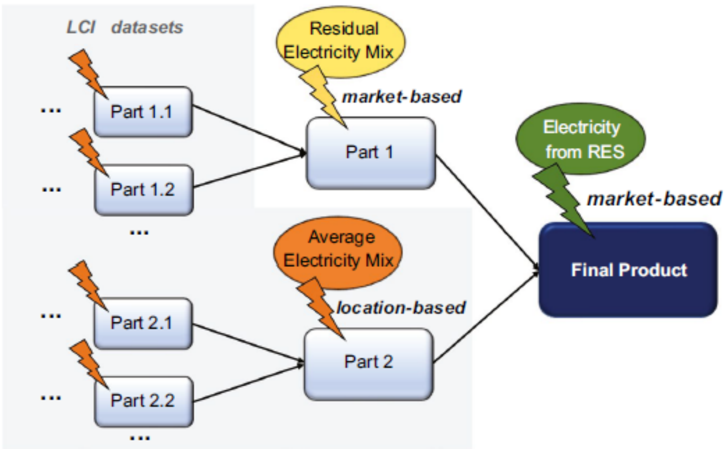


Fig. 3 Overview of simplified example illustrating the parallel use of location- and market-based electricity mixes in one LCA and GHG accounting, when including both market-based electricity and average LCI datasets with location-based electricity inputs

With the choice of the market-based method, the risk of double counting can be limited to zero if residual mixes are systematically used when no information is available about the origin of the electricity consumed.

Let's illustrate the issue of double counting through the example a country, with a total production of 125 MWh and with only 2 electricity consumers, one using EAC while the other one is using the national grid mix, which is 20% renewable and 80% fossil:

	Consumer A	Consumer B
National production	125 MWh	
National mix composition	25 MWh from renewables + 100 MWh from fossil = 20% renewable + 80% fossil	
Energy consumed	25 MWh from EAC	100 MWh from the grid ⇨ 20 MWh from renewables ⇨ 80 MWh from fossil
Total accounted energy mix	45 MWh from renewables + 80 MWh from fossil 36% renewable + 64% fossil	
Double counted energy	25 MWh from renewables is consumed by A and B!	

To avoid double counting Consumer B should use its national residual mix (100 MWh fossil) and not its national average mix (20 MWh from renewables + 80 MWh from fossil).

This mechanism is illustrated by Peter Holzapfel, Vanessa Bach and Matthias Finkbeiner in the figure 2 of their article (situation highlighted with a red dotted line):

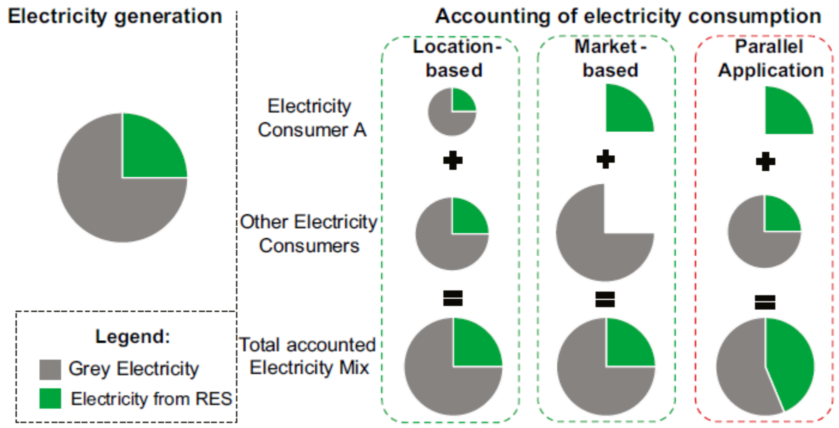


Fig. 2 Illustration of challenges of double counting electricity from specific energy sources due to a parallel application of location-based and market-based electricity accounting method, based on a hypothetical region

<u>Resource shuffling</u>

A definition of resource shuffling is proposed by the European Roundtable on Climate Change and Sustainable Transition (ERCST - [2021120914_P2R4-v11.pdf (ercst.org)](ercst.org)): Resource shuffling occurs when clean foreign production is re-routed toward export to the EU, and dirty foreign production is sold elsewhere, leaving foreign production patterns ultimately unchanged.

Why it is a risk for now:

- There is a large difference between the carbon intensity of high carbon and low carbon electricity (factor 10),
- It is very easy to switch from high carbon to low carbon (just purchase the right certificates or PPA without any physical change in the factory nor in the supply chain),
- Only a small fraction of any country electricity production will be dedicated to products subject to EU regulation, therefore it is very easy to direct the clean electricity towards this product production and dirty electricity to other consumers not subject to similar regulation, without any effect on the total country emissions.
- The price of these certificates is around 5€/MWh, this indirectly shows that their effect is limited. Indeed, if these certificates were inducing real efforts towards more low-carbon electricity production instead of only inducing resource shuffling, they would be more expensive.

The components that are mostly at risk are the electricity and electricity-intensive materials such as aluminium and steel.

As resource shuffling is a way to circumvent carbon regulations that is inherently linked to the use of specific emission values, one solution may be to enforce the use of generic national or regional consumption mixes.

Main findings and learnings from WP1

D1.2 reminds some pros and cons of both approaches:

Location based pros / market-based cons	Location based cons / market-based pros
"real-life" approach and pushes towards lower carbon electricity contents at country/regional levels.	Location based does not account for the capacity of some suppliers that are located in contexts of "bad" electricity mixes to afford purchasing renewable energy.
When choosing a market-based approach, there is the need to carefully address the risk of double counting…	… and this is why residual mixes must be evaluated and systematically used when no specific contracts can be invoked.
Not all countries outside the EU and the US have such contractual instruments as RECs or GOs…	… but this is currently being pursued in China, UK and South Korea
There is a need to overcome potential "greenwashing" accusations when using a market-based approach. For instance: unbundled RECs can lead to a simple reshuffling of the pre-existing GHG emission quotas.	

Contractual instruments evolution

In the longer term, other instruments may allow a higher degree of confidence, such as PPA contracts, however, under the following conditions:

- Seller and buyer identities are disclosed,
- The quantity of electricity and the contract duration are disclosed,
- Any type of electricity generator is allowed, as long as it is identified together with the associated carbon content,
- A mechanism ensures that the electricity is consumed by the factory during the same 1h timestep as it is produced by the generator (temporal consistency),
- The factory and the generator are located in the same bidding zone (geographical consistency)

However, such contracts do not cancel the risk of resource shuffling.

Use phase electricity modelling

Electric vehicle use-phase is a particularly energy / electricity-intensive phase, accounting for ~90% total electricity consumed over an average electric vehicle's life cycle (Ecoinvent, 2000). Having established the significance of this life cycle phase, it is of utmost importance recommending scenarios that reflect the most representative assumptions of the real world. Two ways of modelling the electricity have been identified here (with underlying location-based principle):

(i) 'static current mix' and

(ii) 'conservative future dynamic mix'.

In light of the expected evolution of the grid mix composition in the real world, the use of a 'static' mix for the entire use phase is methodologically questionable and would inevitably lead to inaccurate results. Also, such practice would hinder the TranSensus LCA methodology's alignment with key existing and evolving policies and their assessment strategies, including REDIII and Car and Van CO2 regulations. Therefore, the recommendation to use 'dynamic' mix for the TranSensus product use-phase. Nevertheless, because OEMs are legally responsible for all published values and claims regarding their vehicles, TranSensus will allow the use of a "static" mix for OEMs: the market- and year-specific electricity mix at date of production can be used to model the electricity input throughout the entire use phase of BEVs.

Q8 – Electricity modelling for the use phase

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

> TranSensus LCA recommends following approach to model the electricity input to the use phase of BEVs:

1. TranSensus LCA **SHALL use a "dynamic" modelling approach, informed by a reputable energy futures scenario (to be determined - e.g., IEA WEO STEPS) in order to model the electricity input to the use phase of BEVs**. This modelling approach is deemed to be the most realistic and most likely to approximate the actual environmental emissions and impacts accruing over the full service life of the vehicle.
2. However, TranSensus LCA acknowledges that OEMs are legally responsible for all published values and claims regarding their vehicles, and that therefore **OEMs MAY opt to use a more conservative "static" modelling approach instead**, whereby the market- and year-specific electricity mix at date of production is used to model the electricity input throughout the entire use phase of BEVs. (Further recommendations and/or requirements on the adoption of alternative modelling approaches by way of Sensitivity Analysis will be decided upon at a later date, within WP2.5).

3. Regardless of the chosen modelling approach (points 1. and 2. above), in TranSensus LCA **the same approach SHALL be used in all instances of explicitly comparative LCAs**, which are aimed at making “comparative assertions”, as defined by ISO 14044. (This latter principle is not limited to electricity modelling, but applies to TranSensus LCA as a whole).

Possible answers: **Agree/ Disagree/ No preference**

Background

European electricity grid mixes show an historical decrease of heir GHG emissions during the last decades, see figure below:

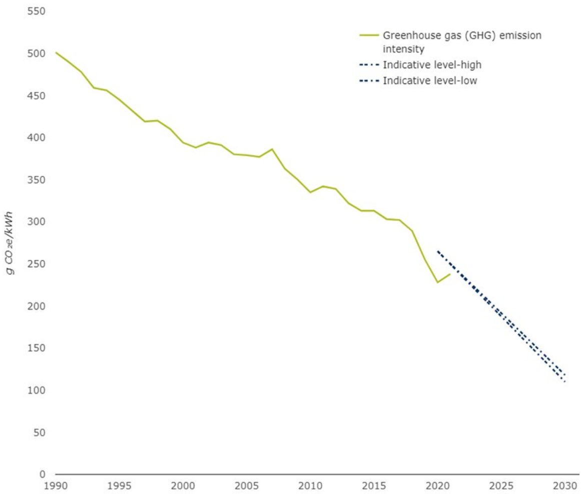


Figure 3-1: Greenhouse gas intensity of electricity generation in Europe (europa.eu) – historical record and projected trends

Most of the internationally established scenarios for the future evolution of the electricity grid mixes also reflect a future decrease in GHG emissions, due to the modification of the energy sources used to produce electricity.

Consideration of evolving grid decarbonization and future grid mixes is essential for accurate estimation of use-phase emissions. In a context where the lifetime of a vehicle can last until 10-20 years, changes in the electricity grid mix may influence the impact of any process or life cycle stage that is not occurring “now” (typically the use and end of life phases).

To get a better accuracy for the estimation of use-phase vehicle emissions, a future dynamic mix can be used. Nevertheless, every future dynamic mix is subject to a given degree of uncertainty.

The presence of different scenarios is reflective of the inevitable uncertainty about the future, and more specifically about the rate of decarbonization of the grid mix over the vehicle’s use phase. However, adopting a “static current” grid mix would not make such uncertainty disappear, but instead misleadingly replace a range of reasonable dynamically derived estimates (e.g., one "default" plus a series of Sensitivity Analyses) with a single value that is outside of that range and already known to be far more likely to be incorrect.

Using some future dynamic mixes may lead to underestimated results. Therefore, the proposition of using a 'conservative future dynamic mix', to get both accuracy and certainty as much as possible.

The term 'conservative' here refers to the use of most-conservative measures applicable to facilitate the decarbonisation of energy grid, for example, the "Stated-Policies" (STEPS) scenarios published by the International Energy Agency (IEA).

There is an important distinction to be made here, between "certainty" and "accuracy". Using a static grid mix composition from the past to model a use phase that occurs in the future would entail using data that are indeed more "certain" (i.e., known with high confidence and good precision at this current time), but which at the same time are also almost certain to be inaccurate (i.e., NOT representative for the time frame that is being modelled, and hence ultimately wrong). In such circumstances, it is therefore much preferable to accept an inevitable degree of uncertainty (i.e., by using a projected dynamic mix, which is by nature influenced by some assumptions), which is however also much more likely to lead to more accurate results (i.e., results which will eventually prove to be closer to the real values).

A work-around to address perceptions of insufficient "certainty" would entail (a) relying on reputable grid mix evolution scenarios by internationally recognized bodies such as the IEA (or the European Commission, should this be officially published in the future), and (b) ensuring transparency on the underlying assumptions and sensitivities.

Recommended approach/possible options description and justification

Pros and cons for using a static current mix

Stated Pros	Stated Cons	Ricardo's interpretations
Conservative approach and easy to implement, since historical data are 'known and certain'	*"Conservative but likely inaccurate approach"; Does not keep pace with the LCA methodological evolution, particularly for "accuracy building"*	-
Customers can be sure that LCA results are not "greenwashed" therefore providing immunity from "greenwashing claims"	-	Estimated GHG emissions calculated using this approach may be more "precise", but are almost guaranteed to be inaccurate (i.e., they would be "precisely wrong"), and in fact significantly higher than the average case in the real-world. There is no such thing as a static mix, as the historical record shows (e.g., already 52% GHG emission reduction since 1990 in the EU, and 38% reduction just in the last 15 years), and significant future emission reductions are guaranteed through existing EU policy (e.g. RED, EU ETS, etc) and national policy/commitments. *Please see appendix for information on the noted reduction in the carbon intensity of EU average grid mix from the 1990s.* Using high quality, agreed and referenceable sources for conservative projections (such as from the IEA), backed up also by historical evidence on trends should not be viewed as 'greenwashing' by the consumer.
Static current mix values can be used for public reporting for CDP and the financial market	*From a scientific perspective, particularly in the context of establishing a cutting-edge LCA methodology for zero-emission vehicles, this approach is already widely rejected as a 'bad' option; highly likely to be subject to significant criticism, also by other stakeholders, undermining credibility of the overall TranSensus LCA methodology*	Static grid mix is 'explicitly' **NOT ALIGNED** with the current policies or established practices in policy impact assessment. E.g. the EU-ETS suggest that "*it caps emissions from the sectors within its scope, including power generation, and therefore ensures (i) that the additional electricity consumption from the zero-emission vehicles does not lead to additional upstream emissions, and (ii) that the **electricity used in zero-emission vehicles is decarbonised over time**"*

Pros and cons for using a conservative future dynamic mix

Stated Pros	Stated Cons	Ricardo's interpretations
Most accurate/ realistic representation of an evolving grid over the lifetime of the vehicle *Three scenarios, varying by the level of NZ ambitions are put forwards by IEA* *1. Stated-Policies (STEPS) – most conservative.* *2. Announced Pledges (APS) – Intermediate* *3. Net Zero (NZE) – most ambitious*	*Due to this being a newer approach, forecasted data are not "known".* *Consensus on which particular scenario to be adopted should be reached.*	- Projected electricity/ energy mix available for various countries, closely following their net-zero goals, policy pledges and likelihood of achieving milestones, through three different scenarios. TranSensus LCA can flexibly adopt those projected electricity/ energy mix and implement them into third-party LCA tools. Please see appendix section 1.7 for guidance on how this can be done with both in-house and third-party LCA modelling tools. Only in the complete absence of any robust agreed projections for future grid evolution (expected to only be the case in specific niche assessments in minor geo-territories and regions), might the use of a static mix be defensible.
Modelling approach in line with policies currently in force	*Use of IEA projections may lead to "greenwashing"*	Time and time again, past IEA projections on the deployment of renewable energies have so far tended to be too conservative (vs. the historical track record), rather than too optimistic. Hence, any potential accusations that the use of these projections may lead to "*greenwashing*" lacks credibility. An example of ***EU-ETS's*** reference to consideration of decarbonising grid mentioned under Ricardo's *interpretation section* for "*static current mix*". Accounting for policy in place (and critically evolution of the grid mix) is an accepted fundamental part of all EC (and national) policy analyses. It should also be expected that any methodology developed for vehicle LCA under the CO_2 regulations would inevitably include accounting for future changes in electricity grid mix based on policies in place.

Stated Pros	Stated Cons	Ricardo's interpretations
		Guidance to ***Carbon Border Adjustment Mechanism***, pg 11, recommends that indirect emissions related to commodities covered in the scope of the CBAM be calculated using EC's default emission factors based on IEA data or other location-specific grid mix emission factors. Similarly, the ***regulation for monitoring and reporting of data relating to GHG emissions from passenger cars and light commercial vehicles*** provides that for estimating the evolution of real world performance of vehicles over their estimated lifetime, data shall be collected for the period of 15 years for the same vehicle, powered by electricity (…among other fuels). This provision, therefore, established the expected best practice and the need for the most representative estimates to be used for the calculating the real-world performance of vehicles over their service life. Additionally, the ***new EPD for passenger cars*** (currently under development) proposes the use of IEA datasets for modelling future dynamic grid mix to estimate use phase emissions. However, it is crucial to note that this guidance is still under development.
	OEMs have to realize less reduction measures in order to reach their decarbonization targets as the projected mixes are less CO2-intensive than the current ones.	It is a misconception to assume that future grid mix is recommended merely as a means of creating an opportunity to "reduce a vehicle's emissions, adopting projected low carbon electricity mix". Future dynamic mix is meant to represent the most representative/ realistic trends in energy decarbonisation that have been demonstrated since the 1990s and as acknowledged/ demanded as a part of policy-driven assessment of adopted targets/ milestones within the aforementioned policies and regulations. Instead, adopting a "static current" mix goes against the core scenarios adopted in these EU policy proposals and regulations. This could severely undermine model consistency, representativeness, and ultimately the credibility of the overall TranSensus LCA methodology proposed.

Considerations about accusations of greenwashing

Reiterating the interpretations listed in the pros and cons tables, "using accurate and realistic forecasted grid mix" may coincidentally yield CO2 savings over the vehicle use phase. From a scientific perspective, this must be viewed as an 'inevitable' real-world impact of a decarbonising grid and not to be interpreted as a "route to greenwashing".

A work -around to greenwashing claims could include clear and transparent specification of use-phase modelling parameters, underlying assumptions and scenarios for both public and corporate reporting or potential inclusion of these aspects as a detailed technical annex, as almost all specifications (except, vehicle energy consumption data) are open-source information.

EoL phase electricity modelling

The end of Life (EoL) of the vehicles will occur after their use phase. As a consequence, and to avoid major discrepancies within TranSensus product LCA methodology, the same reasoning should apply for electricity modelling choice for the EoL phase as for the use phase.

Q9 – Electricity modelling for the EoL phase

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

TranSensus LCA recommends using the same electricity modelling approach for the EoL phase as for the use phase.

Possible answers: **Agree/ Disagree/ No preference**

Recommended approach/possible options description and justification

For the "End of Life" phase, TranSensus recommends the use of specific average grid mix of the country or region where the vehicle is expected to be decommissioned, estimated at the year of disposal (i.e., equal to year of manufacturing + expected service life), on the basis of the scenario used to calculate the vehicle use phase electricity mix.

On-site electricity production modelling

Q10 – Guidance for on-site electricity production modelling

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

Do we need guidance for on-site electricity production modelling (to be defined later)?

There may be some electricity production systems (e.g., solar panels, wind turbines) within the boundaries of the Product system. This would be the case for instance for an electricity production system that is located within the premises of the factory considered and/or directly connected to the factory but not connected to the grid.

The way this electricity production is taken into account for TranSensus product LCAs needs to be clarified and harmonized. The way on-site electricity production is handled does not depend on whether the location-based or the market-based approach is chosen for TranSensus product LCA electricity modelling.

Possible answers: **Agree/ Disagree/ No preference**

Specifications for the market-based electricity modelling approach

Products GHG emissions are under scrutiny, by consumers, NGOs, national government, national Energy Agencies… Without clear rules, the EU decided to ban carbon neutrality claims so as not to give any misguidance to consumers. The market-based electricity modelling approach has been criticized for its ability to underestimate the GHG emissions of a product, as compared to a location-based approach. The same reasoning can apply to other LCA environmental impact categories and indicators.

Because most market-based method rely on classic EACs, which remain very unrestrictive in terms of activation time (one year) or compatibility with the physical transmission of current associated with these contracts, they open the way to all the "generic arguments against the unbundled contractual instruments" (mainly accusations of greenwashing).

To respond to the main criticisms related to the market-based approach (i.e. accusations of greenwashing), additional guidelines and safeguards can be used, for instance to guarantee additivity, bundling with production, synchronicity, …

Q11 – Priority list for market-based electricity modelling

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

In case the market-based electricity option is voted for which hierarchy should we use for market-based electricity modelling?

Specifying that the market-based approach should be used for electricity modelling is not enough to provide enough harmonization for TranSensus product LCAs, because different market-based approaches use different priority lists for electricity processes.

Many of the documents existing today that provide specifications on how to apply the market-based approach (PEF, JRC CFB, GHG Protocol scope 2 guidance, GBA GHG Rulebook) propose a hierarchy relying on the level of knowledge related to the origin of the consumed electricity. To provide a harmonized market-based electricity modelling methodology, TranSensus should propose its own hierarchy (whether copied or adapted from another international document).

Voting options	Option 1	Option 2
Descrip-tion	The following hierarchy should be used for each electricity consuming process of the LCA: 1. Supplier-specific contracts 2. Supplier-specific total mix 3. Residual mix in the country 4. Regional residual mix	Another hierarchy should be specified (to be discussed later)
Pros	• Strict methodologically sound approach • Will address accusations of greenwashing	• Option 1 is not satisfactory
Cons	• Need to calculate country and/or regional residual mix if they are not included in available LCA databases	

Q12 – Safeguards for Energy Attribute Certificate (EAC) related to additionality

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

In case the market-based electricity option is voted for do we need safeguards for Energy Attribute Certificate (EAC) related to additionality (to be discussed later)?

If no additivity constraint is imposed, a large part of GO can be generated by production units that have already made a profit. They are only a windfall effect, contribute to low prices, and do not encourage the development of new RES.

Possible answers: **Agree/ Disagree/ No preference**

Background

Some Energy Attribute Certificate (EAC) rely on electricity producing assets that were built some time ago. Some, like in France, can be rather old. Using such old assets, has no influence on the decarbonization of electricity mixes nor on the product LCA.

Recommended approach/possible options description and justification

The whole purpose of Energy Attribute Certificate (EAC) is to promote decarbonization through the construction of new low carbon electricity production plants. If the EAC that are used for TranSensus LCAs are coming from old power plants, then their decarbonization effect can be questioned (the GHG emissions of the consumed electricity will be the same, whether or not the product under study uses such EAC, since the plants are already there since a long time).

Q13 – Safeguards for Energy Attribute Certificate (EAC) related to a production/consumption physical link.

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

In case the market-based electricity option is voted for do we need safeguards for Energy Attribute Certificate (EAC) related to a production/consumption physical link (to be discussed later)?

Some Energy Attribute Certificate (EAC) rely on electricity producing assets that may not belong to the same biding zone. Some may not even be connected physically to the processes that consume electricity within the product value chain. This is for instance the case of Iceland electricity that cannot be physically consumed anywhere else than in Iceland. Taking advantage of Iceland electricity production for products made and used in Europe is questionable.

Possible answers: **Agree/ Disagree/ No preference**

Q14 – Safeguards for Energy Attribute Certificate (EAC) related to production/consumption time synchronization

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

In case the market-based electricity option is voted for do we need safeguards for Energy Attribute Certificate (EAC) related to production/consumption time synchronization (to be discussed later)?

Some Energy Attribute Certificate (EAC) rely on electricity producing assets that may produce electricity at times when the product for which the LCA is conducted does not consume electricity. This may be the case for renewable energy plants (like wind and solar) which times of production are determined by natural conditions and not by human exploitation schedules.

Taking advantage of such production, without any synchronisation with the product consumption is questionable. Therefore, using such assets without any safeguards may lead to accusations of greenwashing, since the produced electricity is in reality not used for the product.

Possible answers: **Agree/ Disagree/ No preference**

Background

At every moment, electricity consumption and production should be at an equilibrium through the grid, otherwise the grid would collapse.

As power produced by renewables depends on the weather, it is possible that there is not a perfect mismatch between production and consumption, as illustrated by the following figure, which is Figure 3-2: Typical daily solar generation curve and load curve from the GBA GHG Rulebook:

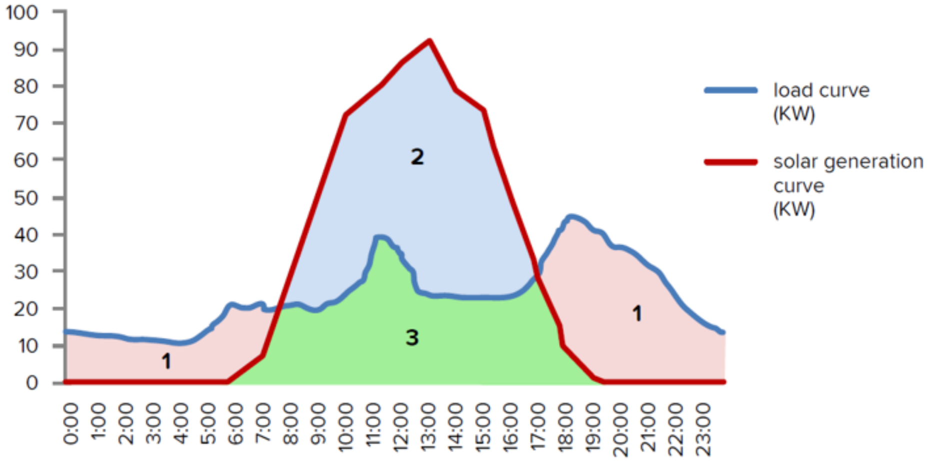


Figure 3-2: Typical daily solar generation curve and load curve from the GBA GHG Rulebook

In this chart, only area #3 (in green) can be counted as consumed by the product. The energy of area #2 is cannot physically be consumed by the product.

Recommended approach/possible options description and justification

It is not physically correct to attribute the electricity production of both area 2 and 3 of the above figure to the product.

Q15 – Safeguards for Energy Attribute Certificate (EAC) related to the excess of production that is not consumed by the vehicle.

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

In case the market-based electricity option is voted for do we need a safeguard for Energy Attribute Certificate (EAC) saying that the excess of production that is not consumed by the vehicle should not be counted as negative emissions/impacts?

Some Energy Attribute Certificate (EAC) rely on electricity producing assets that may produce electricity at times when the product for which the LCA is conducted does not consume electricity. This may be the case for renewable energy plants (like wind and solar) which times of production are determined by natural conditions and not by human exploitation schedules.

Counting the excess of production of the EAC that is not consumed by the vehicle as negative emissions /impacts is questionable. Therefore, the need, in TranSensus, to exclude the use of negative emissions /impacts related to the excess of electricity production that is not consumed by the vehicle.

Possible answers: **Agree/ Disagree/ No preference**

Background

Negative emissions is a very controversial topic.

Recommended approach/possible options description and justification

As power produced by renewables depends on the weather, it is possible that there is not a perfect mismatch between production and consumption, as illustrated by the following figure, which is Figure 3-3: Typical daily solar generation curve and load curve from the GBA GHG Rulebook:

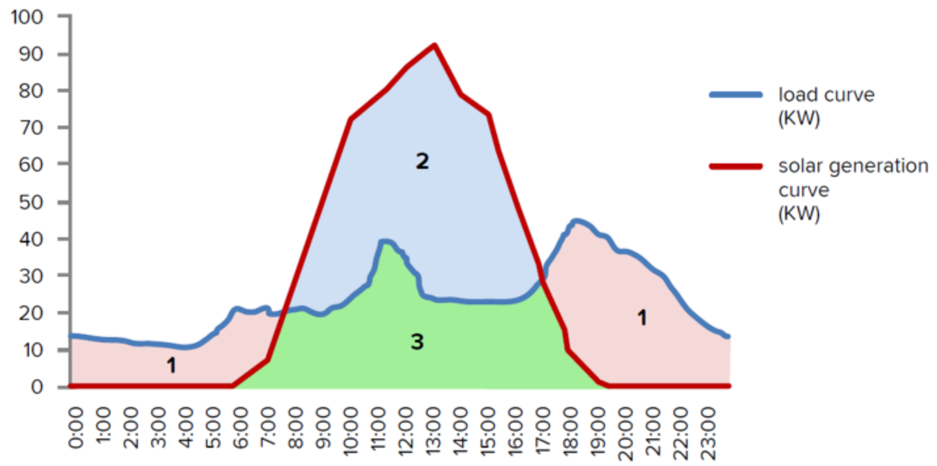


Figure 3-3: Typical daily solar generation curve and load curve from the GBA GHG Rulebook

In this chart, only area #3 (in green) can be counted as consumed by the product. The energy of area #2 is not consumed by the product. It can either be wasted or injected to the grid. In the latter case, the question would be: should this amount of energy generate or not negative emissions?

Q16 – Other safeguards for Energy Attribute Certificate (EAC).

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

In case the market-based electricity option is voted for do we need other safeguard(s) for Energy Attribute Certificate (EAC) (to be discussed later)?

Possible answers: **Agree/ Disagree/ No preference**

Bonus question

In case a marked-based electricity modelling approach is chosen for the production phase, whereas a location-based electricity modelling approach is chosen for both the use phase and the EoL phase, then the overall product LCA will show some inconsistencies, as well as possible double counting, which may lead to results that may be misleading.

Q17 – How to deal with inconsistencies with electricity modelling approaches within one Product LCA?

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

What can we propose to deal with inconsistencies within electricity modelling approaches for Product LCA?

Voting options	Option 1	Option 2	Option 3
Description	Dual reporting	Sensitivity analysis on location-based electricity modelling	No need to propose additional guidelines
Pros	• Consistency • Results with more added value • More robust results	• Consistency • Results with more added value • More robust results	• Easiest • Only one result will be best for consumers
Cons	• Additional work • Will not give clarity to customers	• Additional work • Will not give clarity to customers	• Less robust results • Accusations of greenwashing for choosing the best possible electricity modelling options instead of relying on consistency

Background

In groups seeking to harmonize the environmental impacts linked to the consumption of electricity supplied by the grid, the positions in favour of a contractual approach, accounting for the individual purchases of the actors, on the one hand, and the supporters of an approach more physical, analysis of average electron flows, on the other hand, have not always been able to find common ground. This is why the GHG protocol scope 2 guidance, or the GBA GHG Rulebook, ultimately recommended double reporting, by not cutting corners, and by highlighting the benefit of the complementarity of approaches.

Recommended approach/possible options description and justification

In this electricity modelling subtask, no one has supported the systematic performance of two calculations as a recommended approach. But there is a risk that, if everyone's positions remain fixed, the only possible convergence will be dual reporting.

3.2.3 Multifunctionality

After extensive discussions and rounds of group work, it was decided to provide a detailed and comprehensive hierarchy to deal with multifunctionality as the chief objective of this subtask (Q19). In addition, with this hierarchy the need for exceptions is very limited.

Q18 – Consistency between LCA, S-LCA and LCC

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA, Manufacturer fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting.

TransensusLCA recommends following approach regarding consistency between LCA, S-LCA and LCC:

TranSensus LCA recommends:

- "In case the TranSensus methodology is applied for the 3 aspects of sustainability in the same case study:
    1) Environmental-LCA (E-LCA) multifunctionality choices are decided for each MF process first
    2) On unit process level, and for the corresponding process, the S-LCA and LCC practitioner checks if the same choices of E-LCA are suitable to apply in Social-LCA (S-LCA) and Life cycle Costing (LCC). If yes, then these rules shall be applied.
    3) If it is unfeasible, unrealistic or any other reason that prevents following the exact same rules of E-LCA, the S-LCA or LCC practitioner shall deal with the MF issue in the way he/she considers it as appropriate **AFTER** providing solid justifications on why it is not possible to follow the E-LCA recommendations for this specific MF process.
- In case the TranSensus LCA methodology is only applied for S-LCA or LCC or both and there is an E-LCA for the same system available (Conducted with the TranSensus LCA Methodology), same recommendations above should be followed.
- In case the TranSensus LCA methodology is only applied for S-LCA or LCC or both and there is **NO** E-LCA (Conducted with TranSensus Methodology) for the same system available: The S-LCA or LCC practitioner shall deal with the MF issue in the way he/she sees appropriate. The approach chosen to deal with multifunctionality shall be unambiguously reported."

Possible answers: **Agree/ Disagree/ No preference**

Background

The question originated from an endeavour to create some sort of consistency between LCA, S-LCA, LCC so that we would have harmony in the overall methodology. From the first voting, it was clear that this will not be easy, however we understood that the proposal to have this harmony was at least appealing. Therefore, we came up to the recommendation here as a middle ground between consistency, and flexibility to accommodate for the difference between the three methodologies which is the main issue in having such harmony.

Q19 – General Hierarchy

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

TranSensus LCA recommends the following hierarchy to deal with Multifunctionality in environmental LCA

See *MF Hierarchy Proposals - Proposal 1-To GROUP - V6-1.docx* in Annex V.3.5

Possible answers: **Agree/ Disagree/ No preference**

Background

This is the core argument in this subtask on Multifunctionality in LCA. This has evolved a lot since the first voting. In the first voting, different options of this hierarchy were provided in a very abstract way and the idea was that in addition to this hierarchy, the methodology will include sector/processes specific exceptional rules (addressed previously in what we called "bottom up" questions). For more information, please refer to the previous voting supporting document page 74.

Later, the working group orientation changed towards creating a robust detailed and comprehensive general hierarchy and refrain from reporting many exceptions as this may weaken the hierarchy. This transition in our view was born in the last project general assembly in Germany, where the project partners (in their majority) expressed a preference of not including many exceptions since some of them are not necessary and can be addressed by a good general hierarchy. Therefore, we took it from there and worked on it.

This hierarchy tries to find the balance between the validity of ISO hierarchy (which was the preference of voters from previous voting) and the practicality of guidelines provided by initiatives like Catena X which we based our proposal on when we started. Nevertheless, the hierarchy in its current status is the evolution of this attempt to find a balance, which means it has gone through a lot of modifications and iterations for improvements within our Multifunctionality working group, and it is a unique TranSensus proposal now.

We believe this text is of good quality to be disclosed as the final text in the methodology if consensus threshold is achieved. Nonetheless, Improvements can still take place after the voting, but they will be limited and won't affect the core of it.

Recommended approach/possible options description and justification

The current hierarchy is the product of these elements:

- First Voting results (leaning towards an ISO-compliant hierarchy)
- Concerns raised regarding how ISO hierarchy is very abstract and does not provide enough guidance
- Finding synergies with other important initiatives in Europe like Catena X
- The scientific knowledge and experience of the subtask working group

An important first step was to clearly link the right notions to the right terms in order to have the same understanding of the used terms. We provide clear distinction between system expansion and substitution which are often confused. Since ISO mentions only "system expansion" we put it as ISO in the second place in the hierarchy however we pointed out that it might not be a useful solution in most cases. Although substitution is not part of ISO, it is very popular and applied in practice and so it couldn't be ignored. Therefore, we included it in our hierarchy and restricted it with conservative conditions for application. These conditions were formed carefully to tackle the critique that is always directed against substitution as a concept. This critique includes its suitability only in consequential modelling approach. This however does not cancel the reality that substitution is heavily applied in attributional LCA, and there are other voices advocating its role in attributional LCA. Thus, we reported substitution as a substitution in attributional context but limited its usage with conservative conditions.

We also provided clear allocation rules that again take into account the complications of the real world. We adopted the economic allocation trigger when the economic value difference is very high. This considers the fact that economy is the driver of the systems (in most cases), the nature of certain systems where the value/mass is extremely inconsistent (e.g. base metal and precious metals co production). This is done in many guidelines in certain cases either naming the process like in JRC battery carbon footprint guidelines, or a general trigger of a certain ratio like in Catena X and our hierarchy here. We support our approach by clear definition of economic value, how to choose price, or other economic properties to decide the best allocation approach and apply it.

Q20 – The need for exceptions from the Hierarchy in Q19

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

TranSensus LCA recommends no exceptions from this Hierarchy except for the End of Life

Possible answers: **Agree/ Disagree/ No preference**

Background

As reported in the description of the general hierarchy. This is to confirm our conclusion on not needing exceptional rules for certain sectors/processes, in the light of the detailed hierarchy we are proposing now. The initially proposed sectors/processes can be found in the first voting document (page 88). The only exception that will exist is for the EoL since this is a controversial topic and has implications not only on the system understudy but also on the successive system to the one under study. See the next question.

Q21 – Dealing with Multifunctionality in the end-of-life stage

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

Which approach do we use to deal with Multifunctionality in the EoL stage (allocation of credits and burdens between successive systems)?

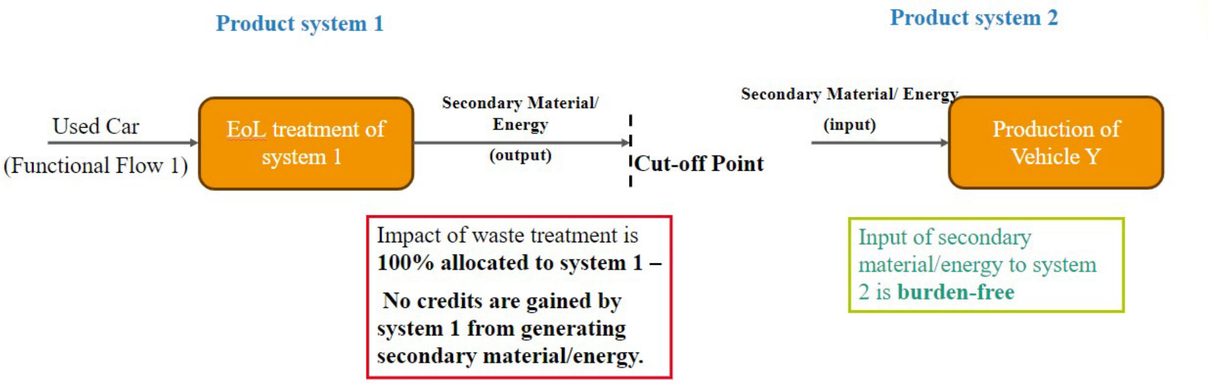


Figure 3-4: Cut-off approach

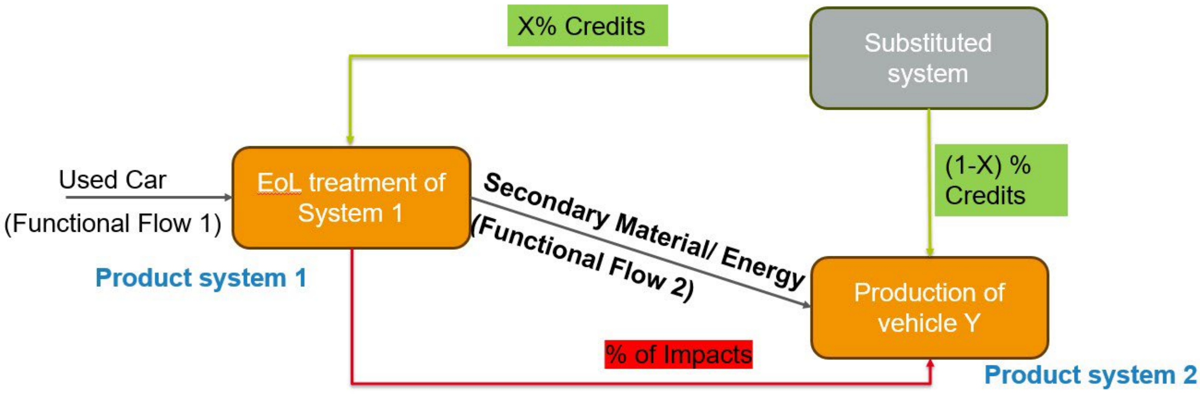


Figure 3-5: Circular Footprint Formula (CFF) approach

Voting options	Circular Footprint Formula (CFF) as in PEF	Cut-off approach.
Description	The Circular Footprint Formula (CFF) from PEF which is a formula that tries to allocate burdens and credits between supplier and user of recycled materials. And gives credits for energy recovery if it comes from waste. It also includes a part for disposal burdens it applies a mix of both allocation and substitution. Modified versions of CFF appears guidelines like (PCR for batteries by recharge), however here we mean refer the original formula in PEF.	This approach considers the full environmental impacts of the primary material supply chain, while secondary materials come free of burdens. No credit is given to the producer of secondary material/energy.
Pros	• Recommended by PEF and all PEF-based guidelines like CFB & PCR batteries • It distributes the credits and burdens in a more realistic and fair way	• It is simple, easy to apply, conservative approach. • It heavily encourages increasing the recycled content in the inputs to the processes since it is burden free. • No need to make assumptions and take credits on downstream use that might/might not take place. • It also avoids making assumption in the far future. • Avoids any attempt of gaining credits by overfeeding the market of secondary material.
Cons	• Very complex to apply especially if there are many materials streams. • The allocation factors for allocating burdens and credits are the coefficients “A” and “B” for materials and energy (in case of energy recovery) respectively. Need some revision since they are seen by some experts rather arbitrary than based on solid basis.	• the producer of waste does not get credits for generating recyclable materials hence might not be very encouraging for producers to work on better designs for re-cycling for example. • Not PEF or any PEF-based guidelines compliant.

	• CFF is not implemented in any database (and software) which hampers its usability in real full studies. • In some case, a step of allocation might still be needed for example: • Let's assume a simple battery recycling that leads to CoSO4 and NiSO4: the CFF does not provide any guidance on how to solve the allocation of burden of the recycling process between these too, yet you have to use the footprint of the individual material recycling in the formula	

Background

The options here were decreased from five options in the first survey (page 98 in the first voting document) to only two options which are the top discussed and argued.

For further information on this topic, please refer to TranSensus Deliverable 1.1 "Review of current practices on life cycle approaches along the electromobility value chain" page 93, and Battery Passport [EoL allocation approaches] with a special focus on batteries.

3.2.4 Data

Q22 – Company specific and secondary data

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

TranSensus LCA recommends the adoption of the data definitions of the JRC battery carbon footprint draft to be used for full vehicle LCA studies (https://eplca.jrc.ec.europa.eu/permalink/battery/GRB-CBF_CarbonFootprintRules-EV_June_2023.pdf).

'**Company-specific data'** refers to directly measured or collected data from one or multiple facilities (site-specific data) that are representative for the activities of the company. It includes company-specific activity data and elementary flows. It is synonymous to 'primary data' or 'supply-chain specific data' or 'manufacturer-specific' data.

'**Secondary data**' means data not from a specific process within the supply-chain of the company performing a life cycle assessment. This refers to data that is not directly collected, measured, or estimated by the company, but sourced from a third party, LCI database or other sources. Secondary data includes industry average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and may also be based on financial data, and contain proxy data, and other generic data.

Since TranSensus LCA has a broader scope, for the definition of secondary data the working group recommends swapping out the term "carbon footprint study" for "life cycle assessment".

Possible answers: **Agree/ Disagree/ No preference**

Background

Having the same understanding of the differences in data quality is crucial for the overall task of data collection.

Recommended approach/possible options description and justification

In the process of developing this voting option we discussed controversially whether the distinction between company specific and secondary data, made by the JRC, is sufficient. Part of the group had the impression that, especially by the synonymous use of the terms company specific and primary data, there might be information lost, or in the worst case uncertainty created about what is actually the data quality ("what looks at first glance like company specific data, and therefore primary data, might be a composition of primary and secondary data in reality" – so the assumption). Ultimately, these doubts could be dispelled. It could not be proven that the definitions made by the JRC are misleading or can lead to a loss of information. In fact it proved itself to be very precise and we highly recommend using their definitions of company specific (primary) data and secondary data. Furthermore, the adoption of those definitions promotes the harmonization of TranSensus LCA and JRC battery carbon footprint draft which we strongly support.

Q23 – Minimum data requirements for Level 3 LCA

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

TranSensus LCA recommends making the following minimum cradle-to-gate data requirements mandatory to reach Level 3 for a BEV Light-Duty Vehicle and Heavy-Duty Vehicle product LCA:

- OEMs shall choose vehicle parts that cause in total a minimum of 20% of the production stage Global Warming Potential (GWP) in addition to the battery system that the EU Battery Regulation Article 7 is covering with data requirements

- The chosen parts shall be modelled with company-specific data for at least their tier-1 suppliers, while secondary data may be used to cover the rest of the parts' supply chain
- OEMs shall provide a list of the parts chosen to fulfil these requirements (e.g. car body, rims)

Possible answers: **Agree/ Disagree/ No preference**

Background

- The *level concept* refers to the UNECE LCA typology (Table V-3) which was adopted by TranSensus LCA in the last voting. *Level 3* can only be reached by an OEM with access to a complete Bill of Materials (BOM) and supplier-specific information. Level 3 LCAs of two representative vehicles of different OEMs may be compared to each other if the same LCA methodology is applied (e.g. TranSensus LCA) and the same minimum data requirements are used to define *Level 3*.

Table 3-3: Level concept as proposed by the UNECE working group and as adopted by TranSensus LCA (see SG4 - 3nd meeting - Transport - Vehicle Regulations - UNECE Wiki) – Check out the annex for higher resolution

SUPPLY CHAIN & PRODUCTION	Possible Comparison[1)]	Vehicle modelling	Representativeness[2)]	Supply chain modelling	OEM manufacturing Processes	Supplier manufacturing process	Individual decarbonisation measures
Level 1	General concept of drivetrains (e.g. BEV vs. ICEV)	Generic material composition & average vehicle curb weight	Global average / regional	generic footprint per kg of vehicle curb weight			none
Level 2	General concept of drivetrains (e.g. BEV vs. ICEV) based on exemplary „real" car vehicle model	BOM & Material information system (CMDS / IMDS[3)])	Global average / regional	global secondary data material footprints (incl. generic information for production processes)			none
Level 3	A representative vehicle of OEM A VS A representative vehicle of OEM B	BOM & Material information system (CMDS / IMDS) & „part-by-part" for hotspots	Regional & individual SC for hotspots	primary information for the vehicle hotspot parts	Optional: primary data for OEM's inhouse hot spot processes	primary information for the manufacturing of vehicle hotspot parts	included
				secondary information for the rest	Secondary information for the rest or average values per vehicle from OEM's Scope 1 & 2 emissions	secondary information for the rest	
Level 4	e.g. OEM A's BEV model vs. OEM B's BEV model	BOM („part-by-part")	individual SC	regional or primary data based part (& material) footprints	included	included	included

- The proposed data requirements only apply to BEVs (LDV & HDV). FCEV minimum data requirements might be part of the next voting.
- **'Company-specific data'** refers to directly measured or collected data from one or multiple facilities (site-specific data) that are representative for the activities of the company. It includes company-specific activity data and elementary flows. It is synonymous to 'primary data' or 'supply-chain specific data' or 'manufacturer-specific' data.

- ‘**Secondary data**’ means data not from a specific process within the supply-chain of the company performing a life cycle assessment. This refers to data that is not directly collected, measured, or estimated by the company, but sourced from a third party, LCI database or other sources. Secondary data includes industry average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and may also be based on financial data, and contain proxy data, and other generic data.
- The EU Battery Regulation covers the whole battery system i.e. the component that causes ca. 50% of the production stage Global Warming Potential (GWP) of a Light-Duty Vehicle (LDV). It is still under review but will take effect in 2025. The data requirements in the current draft of the Battery Regulation are depicted in our decomposition tree. TranSensus LCA partners with access to the Sharepoint, please, see ProdBEV_decomposition_tree_w_bat_reg_rqrts.html) , Advisory Board members and others, please see Figure 3-9 and Figure 3-10.

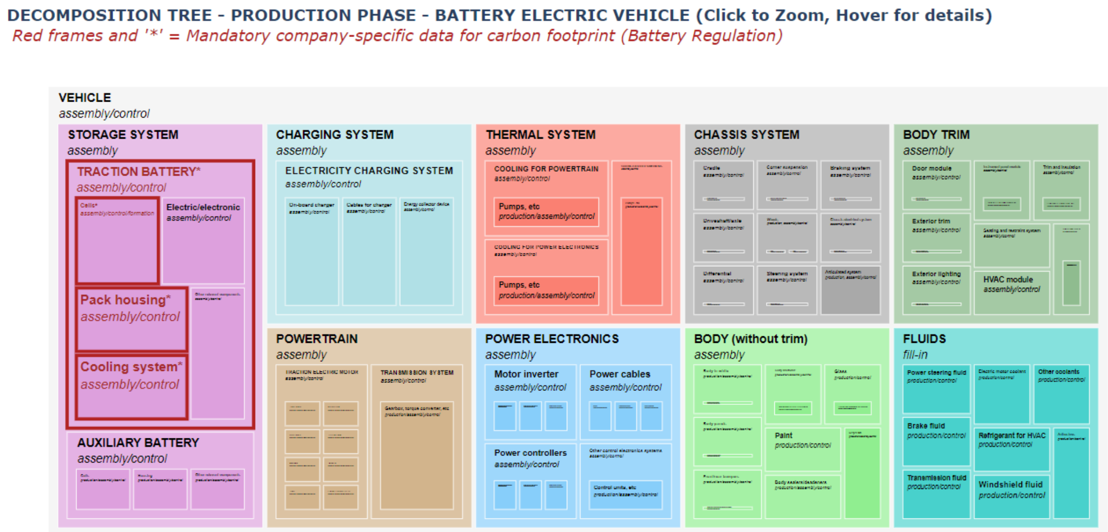


Figure 3-6: Decomposition tree for battery electric vehicle at production phase showing company-specific data required by the Battery Regulation (carbon footprint) draft in a red frame.

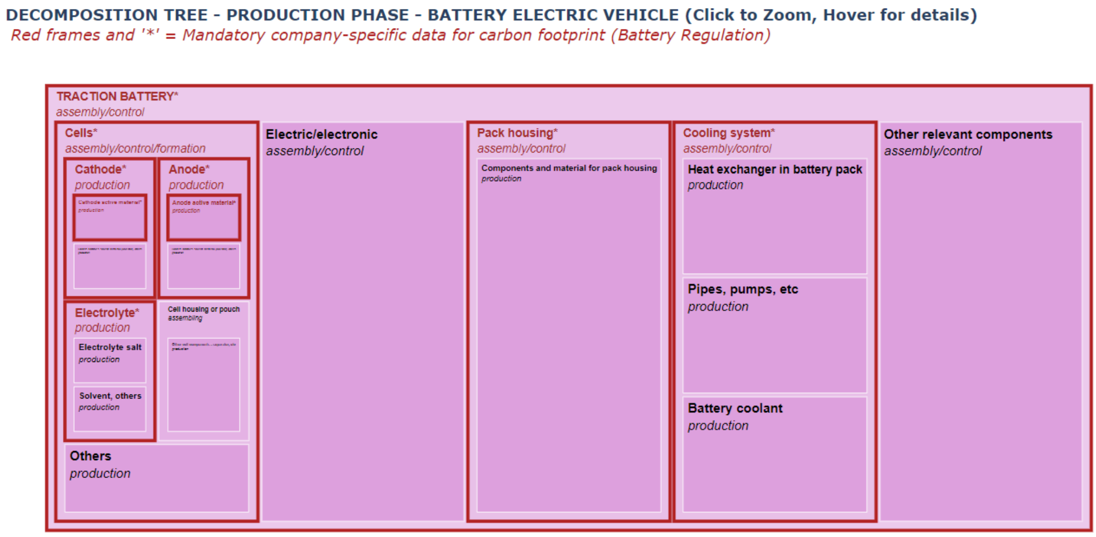


Figure 3-7: Decomposition tree (zoom on the traction battery with Battery Regulation data requirements requirements)- Check out the annex for higher resolution.

- OEMs have a complete parts list available for each of their vehicles. Via the system IMDS, the material composition of each part is known to the OEM. The OEM LCA practitioner then (semi-) automatically translates the provided materials list into the OEM's material typology and attaches the respective secondary data. The structure of a BOM, the denomination of parts and the secondary data used can differ between OEMs. Each vehicle part has a specific part number. Each part (number) can be sourced from different suppliers at the same time.
- Usually, OEMs are only in contact with their tier-1 suppliers. The manufacturing depth between OEMs can differ though: one OEM may buy the car body while another has their own press. The tier-structure therefore differs between OEMs (Figure 3-11).
- OEMs' own company-specific data (their in-house production) is measured and collected in Environmental Information Systems (EIS). It is used for their scope 1 and scope 2 emissions reporting and as a data source for vehicle LCAs. This data is, however, only process-specific for hotspots like e.g. the press and paint shop and mostly added to the vehicle LCA as an average per vehicle as a whole.
- Collecting company-specific data for vehicle parts on a regular basis is relatively new for OEMs. The IT environment to facilitate this complex exchange of information is currently being built (see figure 3-11). As the current focus is put on GWP data exchange, TranSensus LCA also focuses on GWP for the time being. This does not mean that other impact categories should be considered less; it is just a starting point.

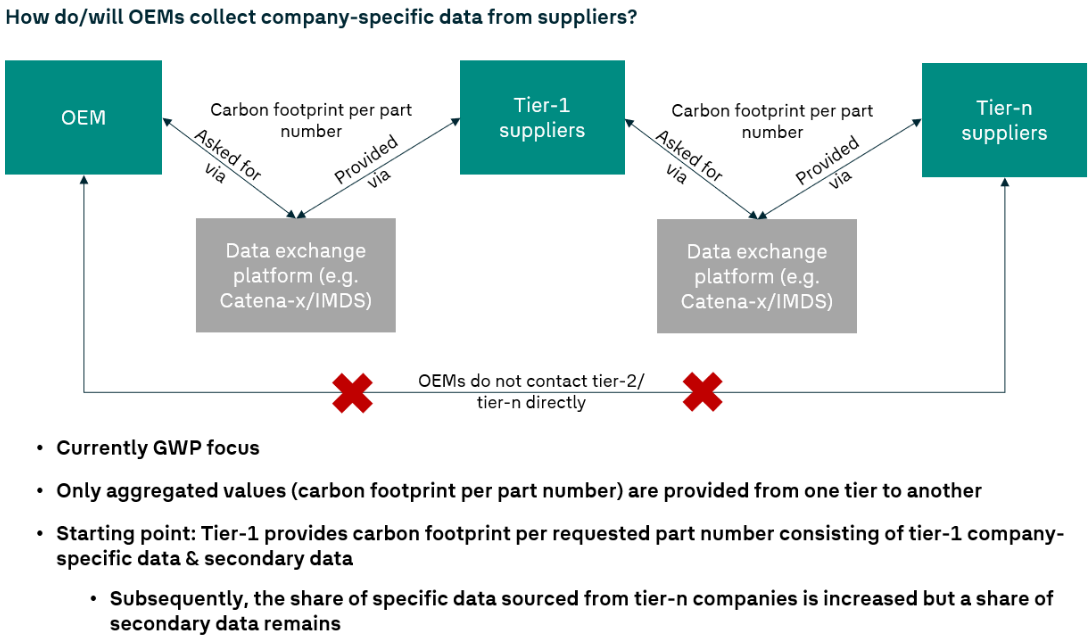


Figure 3-8: Current/future data exchange between OEMs and suppliers respectively between suppliers and suppliers.

- The iterative approach for OEMs to fulfil the Level 3 data requirements proposed here looks as follows (Figure 3-12):

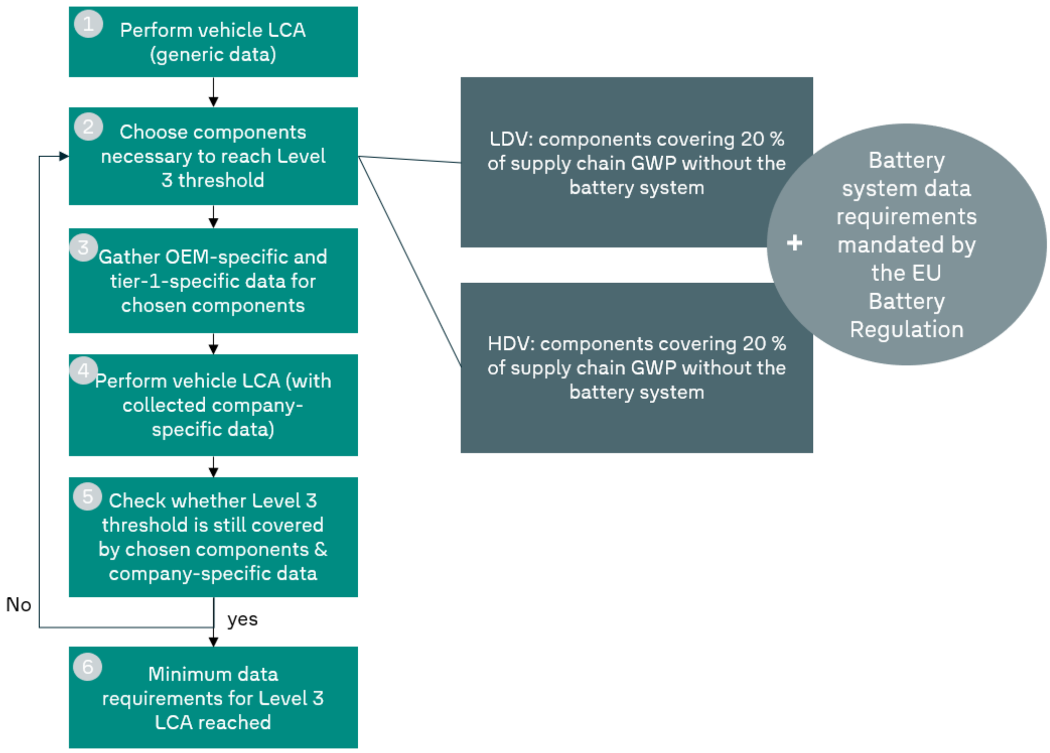


Figure 3-9: Iterative approach to fulfil the TranSensus LCA Level 3 minimum data requirements.

- The 20% minimum threshold to be covered by the TranSensus LCA Level 3 data requirements does **not** mean that 20% of the supply chain GWP is covered with company-specific data. The threshold only serves as a guideline to choose the hotspot components that are, as a first step, to be modelled with tier-1 company-specific data. Secondary data will always be a part of the supply chain impact modelling, its share will just be lowered by exchanging specific data between the tiers (see Figure 3-13 below)

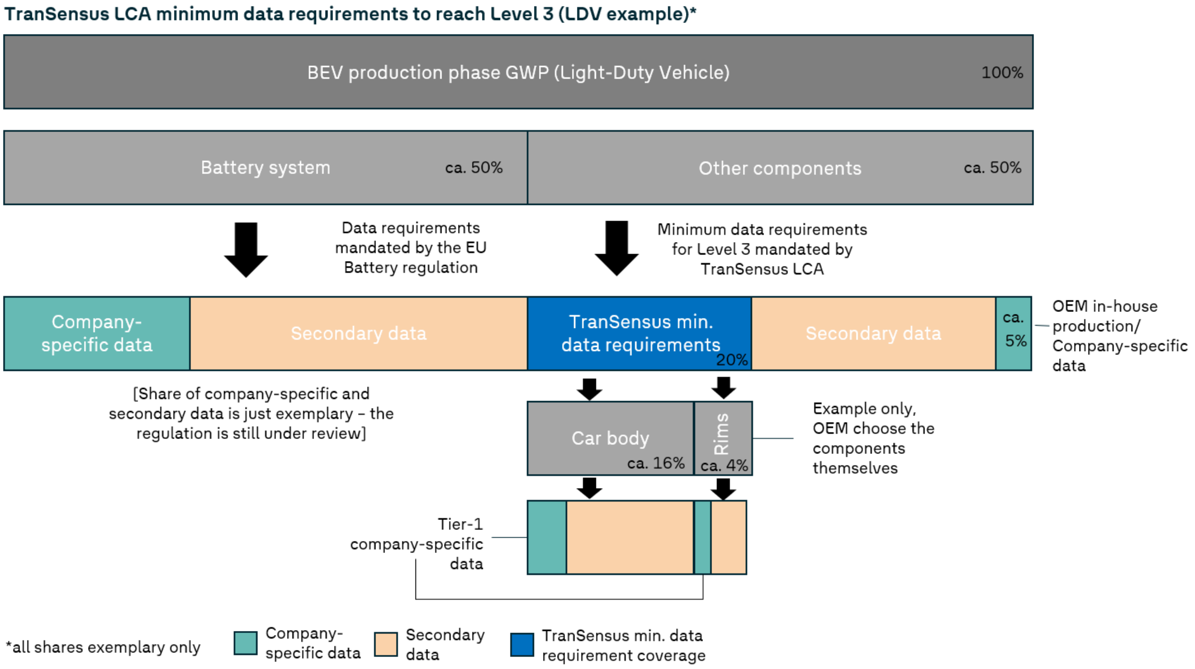


Figure 3-10: Overview of the shares of company-specific and secondary data in supply-chain LCA modelling when following the Level 3 minimum data requirements.

- Another way to depict the tier-1 company-specific data requirement for components that in total make up for a 20% share of the BEV production stage apart from the battery system is shown below (Figure 3-14).

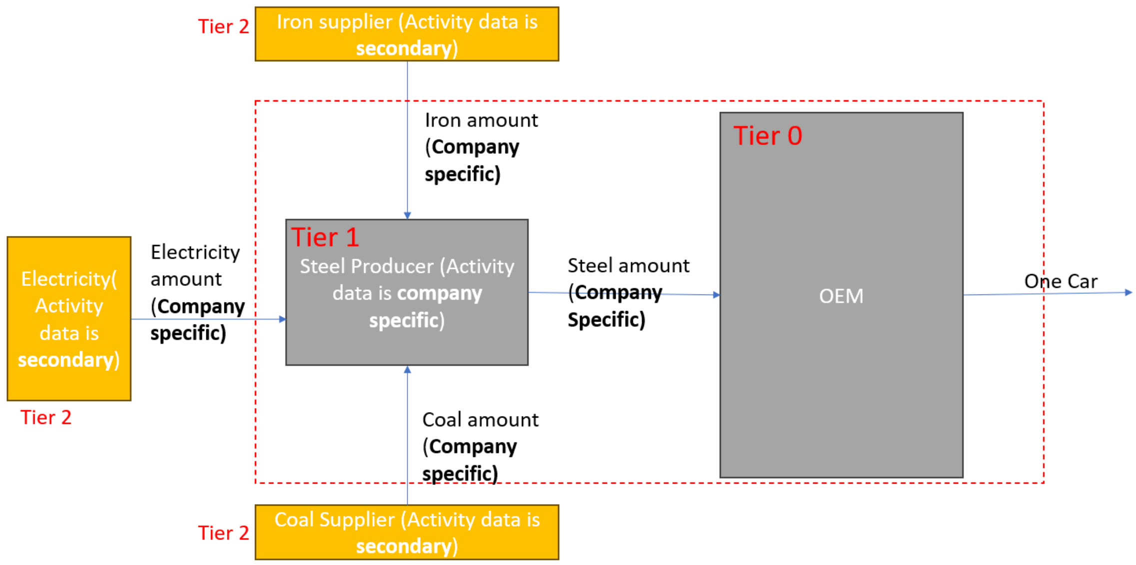


Figure 3-11: Tier-1 company-specific data as requested for a Level 3 LCA: Tier-1 activity data is company-specific (i.e. directly measured) while tier-2/tier-n data can remain secondary (i.e. sourced from databanks).

- The 20% minimum threshold was developed by the TranSensus LCA partners, mainly by the involved OEMs Scania, BMW, Renault and Volkswagen. The threshold is based on the OEMs' perception of the current state of OEM-supplier data exchange initiatives (i.e. going in the right direction but still being complex) and their internal evaluation of hotspot GWP parts apart from the battery system. Those hotspot parts include the car body, tires and electronics. The OEMs describe the supplier network structure of electronic parts as very complex and small-scale and thus unlikely to be in the focus for the next time regarding data exchange with suppliers. Even more large-scale parts like the car body and tires have relatively complex supplier structures (several different tier-1 suppliers per part) but are deemed more realistic for an OEM-tier-1-supplier data exchange regarding carbon footprint information in the near future. As these hotspot parts apart from the battery system (e.g. car body, tires) make up for roughly 20% of the production stage GWP (to differing degrees among the OEMs), this final threshold was agreed on.
- OEMs must be in touch with their suppliers to decrease the environmental footprint of their supply chains anyways. Only by increasing data transparency can environmental requirements be put on suppliers and these requirements subsequently be tightened. The minimum Level 3 data requirements are meant to serve as guidance for OEMs and for non-OEMs to gain insight about the data collection process.
- An inherent incentive to add more parts to the list of parts being modelled with at least tier-1 company specific data for an OEM is that as soon as company-specific data for a part is

collected and reduction measures are requested, the GWP share of this part decreases. This means that more parts must be added to the list in order to meet the 20% threshold.

- The data requirements proposed here for Level 3 are the minimum requirements. In the current Catena-x terminology (see the rulebook here https://catena-x.net/fileadmin/user_upload/Standard-Bibliothek/Update_September23/CX-0029-ProductCarbonFootprintRulebook-v2.0.0.pdf), these Level 3 minimum requirements would be identified as a 0% primary data share because directly measured company-specific tier-1 data can be coupled with secondary data in the TranSensus LCA requirement (see figure below). Until a completely harmonised terminology is used by all initiatives and stakeholders it is necessary to translate the different terminologies.

Catena-x versus TranSensus LCA data terminology and requirements

Table 3: Definition of primary and secondary data.

Approach	Direct emission measurement			
Primary data, if	Source of emission is within company boundaries and is measured			
Approach	Activity data source		Emission factor source	
	Energy	Material	Energy	Material
Primary data, if	Consumption measured (primary)		For on-site production ▪ Emission measured (primary) ▪ For supplier-specific electricity ▪ Primary with guarantee of origin	Measured and reported as a share by supplier
Secondary data, if	Consumption/production measured (primary)		Secondary databases, data proxy	

TranSensus LCA minimum data requirement for Level 3 LCA for tier-1

Figure 3-12: The TranSensus LCA minimum data requirement for a Level 3 LCA results in a 0% primary data share when applying the current Catena-x terminology (adapted from CX-0029-ProductCarbonFootprintRulebook-v2.0.0.pdf (catena-x.net).

- An open point/risk discussed in the working group is that OEMs hand the responsibility of data quality over to the suppliers. Especially, the secondary datasets used by the suppliers should be harmonised in order to guarantee comparability. This issue is discussed in other initiatives (e.g. in the Catena-x working groups) and will not be solved within TranSensus LCA. Nonetheless, we want to point out the importance of harmonised secondary datasets.

Q24 – Which energy consumption to use as standard scenario for LDV?

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

TranSensus LCA recommends using the regulatory protocol for fleet reporting by authorities (WLTP for LDV's) [e.g. kWh/100km] as standard scenario and the regulatory cycle x RW correction factor for sensitivity analysis. However, should the application of a RW correction factor be applied as standard in accordance with the UNECE A-LCA guidance under development or the European Commission for the methodology to be developed under the CO2 regulations for cars and vans, this will become the default setting for TranSensus LCA (with WLTP becoming the sensitivity analysis). In addition, the formula shall be expanded to include the degradation factor as soon as the UNECE or European Commission releases a value for it.

(The basis for the default RW correction factor will be further explored in the 2024 work programme for WP2).

The degradation factor was included in this question because it is redundant to deal with this parameter separately. In addition, it simplifies alignment with the UNECE and thus harmonization.

Possible answers: **Agree/ Disagree/ No preference**

Background

Here, we only focus on the technical input data for the use phase for LDVs: the measured data regarding the energy consumption. The voting for the respective electricity (mix) factor is prepared by another 2.3 sub-task.

Recommended approach/possible options description and justification

It was agreed that both the regulatory protocol (WLTP for LDVs) and a factor for accounting real-world (RW) emissions/energy consumption should be included in an LCA study. Though, in the first voting round consensus could not be found on whether the regulatory cycle alone or the regulatory cycle + RW correction factor would be favourable as the standard scenario, the working group now favours the regulatory protocol for fleet reporting by authorities as standard scenario as long as there is no clear guidance on how to develop the RW correction factor. As soon as this changes and the UNECE or EC come up with a methodology on the definition of the RW correction factors, the working group recommends using the regulatory cycle x RW correction factor as standard scenario and the regulatory protocol for fleet reporting by authorities (WLTP) as sensitivity analysis. Therefore, it is guaranteed to start with a working methodology, even if it does not adequately reflect real emissions, but at least the procedure paves the way for a more precise approach, which is urgently needed to take real emissions into account more accurately.

Another important parameter to mirror real world emissions is the degradation factor. This parameter was dealt with in a separate question during the last voting. Due to the latest developments under the UNECE A-LCA guidance we decided to integrate it and furthermore recommend expanding the formula by the degradation factor as soon as values are provided by the UNECE or the European Commission (regulatory cycle x RW correction factor x degradation factor).

Q25 – How TranSensus LCA should address non-exhaust emissions during the use phase?

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

How TranSensus LCA should address non-exhaust emission during the use phase?

Voting options	Option 1	Option 2
Description	Non-exhaust PM emissions from tyre and brake wear are included (basis/methodology to be determined in 2024). No other non-exhaust emissions covered.	Include tyre and brake wear, as well as others (e.g. potentially hydrogen, refrigerant leakage, etc.) on a list to be provided by TranSensus LCA for BEV/FCEV and LDV/HDV each. The list is defined in 2024.

Recommended approach/possible options description and justification

A clear trend emerged during the last voting towards one of the three options (Option 1: 4.54%; Option 2: 22.73%; Option 3: 63.64%; No answer: 9.09%) though consensus could not yet be reached. Therefore, we recommend stripping the three options down to two (keeping option 2 and 3) and repeat the voting. In the UNECE A-LCA sub-group on the use phase (SG4), there is already general agreement that all significant non-exhaust emissions should be included within the scope (i.e. Option 2), but likely subject to cut-off criteria (to be defined/decided) and that certain potential fugitive emissions from the vehicle may not currently be easily defined or have no standardised testing protocol yet (e.g. hydrogen). Suitable methodologies and/or interim default values may need to be defined in such cases, which would need to be discussed further.

Q26 – How TranSensus LCA should address Maintenance?

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

TranSensus LCA recommends providing the practitioner with a recommended non-exhaustive list of parts/ processes (tbd. in 2024). Building on that, the OEM needs to provide a complete list with frequency of maintenance (OEM and model specific). Emission factors and processes may stem from secondary data sources.

Possible answers: **Agree/ Disagree/ No preference**

Background

Maintenance is most often excluded in the scientific literature, generally justified by the low impacts relative to the vehicle life cycle. Nonetheless, it is good practice in the industry to include maintenance in in the use-phase.

Recommended approach/possible options description and justification

The maintenance parts may be very different regarding an LDV or HDV, or even different models inside one category. Therefore, the lists of parts and consumables to consider will need to take into account differences in vehicle types and powertrains. At present most of the automotive OEMs already recommend a list of consumables/maintenance parts in owner's manual (including frequency) – e.g. Table 3-5. The development of a fully exhaustive list seems unrealistic, but nevertheless it is feasible to provide a non-exhaustive list as starting point and guidance for the practitioner. Building on the non-exhaustive list from TranSensus LCA, the manufacturer would be obliged to provide a complete list with frequency of maintenance (OEM and model specific). However, due to the low impact of some maintenance items, emission factors and processes may be taken from secondary data sources in some cases. An example of the draft list of maintenance parts currently under discussion in the UNECE Automotive LCA Informal Working Group is provided in Table 3-6 (draft developed by OICA/Renault and Ricardo in discussion with SG4 of the IWG).

Table 3-4: Example of maintenance and servicing requirements for a passenger car (check out the Annex for a higher resolution) Source: UNECE A-LCA IWG: SG4 - 7th meeting - Transport - Vehicle Regulations - UNECE Wiki

Passenger car example

	M1	Tracks	moto
Oilfilter	○	○	○
air cleaner element	○	○	○
fuel filter	○	○	○
timing belt	○	○	○
spark plug	○	-	○
Disk Pad (Front Wheel)	○	○	○
Brake shoe (rear wheel)	○	○	○
MT Clutch Plate	-	○	-
Regulator	-	○	-
Chain for driving vehicle body side	-	-	○
engine oil	○	○	○
brake fluid	○	○	○
Long Life Coolant	○	○	○
Tires	○	○	○
Auxiliary Battery (Lead Battery)	○	○	○
MT Mission Oil	-	○	-
AT Oil	-	○	-
differential oil	-	○	-

	BEVs		Gasoline ICEVs		Diesel ICEVs	
Maintenance Request	Mileage	Time	Mileage	Time	Mileage	Time
Passenger Air Filter	36,000 km	2 years	36,000 km	2 years	72,000 km	2 years
Electric Drive Unit Fluid	72,000 km	-	-	-	-	-
Hood Lift Support Gas Struts	161,000 km	10 years	161,000 km	10 years	-	-
Body Lift Support Gas Struts	161,000 km	10 years	161,000 km	10 years	-	-
Coolant Circuits	240,000 km	5 years	-	-	-	-
Brake Fluids	-	5 years	-	5 years	156,000 km	5 years
Air Conidtioning Desiccant	-	7 years	-	7 years	-	7 years
Engine Filter	-	-	12,000 km	12 months	12,000 km	12 months
Engine Oil	-	-	12,000 km	12 months	12,000 km	12 months
Engine Air Filter	-	-	12,000 km to 24,000 km	-	72,000 km	4 years
Automatic Transmission Fluid	-	-	72,000 km	-	-	-
Automatic Transmission Filter	-	-	72,000 km	-	-	-
Spark Plugs	-	-	96,000 km to 156,000 km	-	-	-
Transfer Case Fluid (if 4WD)	-	-	161,000 km	-	72,000 km	24 months
Rear Axle Fluid (if AWD)	-	-	240,000 km	-	-	-
Engine Cooling System	-	-	240,000 km	6 years	240,000 km	6 years
Fuel Filter	-	-	-	-	36,000 km	2 years
Front Axle Oil	-	-	-	-	96,000 km to 156,000 km	12 months
Front Axle Bearing Grease	-	-	-	-	156,000 km	12 months
Power Steering Fluid	-	-	-	-	144,000 km	-
Power Steering Filter	-	-	-	-	144,000 km	-
Windshield Wiper Blades	-	-	-	-	12,000 km	6 months

Table 3-5: Example of a draft list maintenance and servicing requirements for a passenger car being developed under the UNECE Automotive LCA IWG

		Gasoline	Diesel	CNG	NOVC-HEV	OVC-HEV	Pure EV	FCHV	OVC-FCHV	H_2-ICE	...
Consumables	*Engine Coolant*	✓	✓	✓	✓	✓	-	-	-	✓	
	Engine Lubricant	✓	✓	✓	✓	✓	-	-	-	✓	
	Screen Wash	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Break fluids	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Electric Drive Unit Fluid	-	-	-	✓	✓	✓	✓	✓	-	
	Transmission fluid	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Refrigerant	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	AdBlue/Urea	-	✓	-	-	-	-	-	-	-	
Maintenance parts	*Passenger Air Filter*	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Engine Filter	✓	✓	✓	✓	✓	-	-	-	-	
	Spark plug	✓	-	✓	✓	✓	-	-	-	-	
	Windshield Wiper Blades	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Tires	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Brake linings	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	SLI Battery (12V)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Aftertreatment	✓	✓	✓	✓	✓	-	-	-	-	
	Traction Battery	-	-	-	✓	✓	✓	✓	✓	-	
	Fuel cell	-	-	-	-	-	-	✓	✓	✓	

Under discussion

Source: UNECE A-LCA IWG: [SG4 - 7th meeting - Transport - Vehicle Regulations - UNECE Wiki]

Q27 – What type of data (company specific or secondary) should TranSensus LCA recommend for EoL (recycling, energy recovery and disposal processes)?

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting.

If end of life processes are already part of the operations of an OEM (e.g. already recollecting vehicles) they should include company-specific data for those processes. TranSensus LCA recommends using secondary data for recycling, energy recovery and disposal when modelling EoL.

Possible answers: **Agree/ Disagree/ No preference**

Background

Environmental impacts of EoL are determined by the burden of EoL treatments and the potentially avoided impacts from avoided virgin materials. EoL treatments comprise recycling, energy recovery and disposal processes. The shares of vehicle components that will be treated by these processes and the recovery rate of the recycling process also determine the overall EoL impacts.

At this current voting, we are addressing the data of the environmental impacts of the EoL treatment processes. The abovementioned shares and the recovery rate are not considered and will be addressed in 2024. The avoided impacts, the allocation of burden and credit (e.g. the options to use CFF or cut-off method) is also out of the scope of this question, but it is addressed in the multifunctionality section.

Recommended approach/possible options description and justification

EoL processes are usually outside the control of an OEM and lie in the future. For this reason, the use of company-specific data seems currently unrealistic. Nevertheless, the trend is moving in the direction of gaining control over that part of the supply chain. Therefore, in the future EoL processes might be more transparent and company-specific data more accessible, but for now the working group recommends using secondary data, unless OEMs already possess partnerships or their own facilities in that field.

3.3 Task 2.4: Impact assessment

3.3.1 List of questions submitted to the 2nd voting by Task 2.4

Summary of TranSensus LCA recommendation & voting options:

Table 3-6: List of questions submitted by task 2.4 to 2nd voting of spring 2024

TranSensus LCA recommends for task T2.4	Status
Normalisation	
• TranSensus recommends to mandatorily calculate the midpoint impact assessment results and then the normalized results as optional	*(1)*
• TranSensus recommends to use Global Planetary Boundary based normalization factors	*(1)*
Prospective and Fleet Level LCIA	
• TranSensus found Goal and Scope and Inventory phases has differences in Prospective and Fleet Level LCA compared to Product LCA but not on Impact Assessment phase. All characteristics (Impact Categories, LCIA methods, indicators) applicable for conventional product level LCIA is also applicable for Prospective and Fleet level LCIA	*(1)*
Comparison of Software's	
• In Deliverable 2.3, LCA for Experts (LCA FE; formerly known as GaBi) and SimaPro will be compared since they are the most commonly used ones, but recom-mendation to use a particular software will not be made in TranSensus.	*(1)*
Mandatory set of LCA-Impact Category	
• TranSensus LCA recommends including the impact Climate Change in the mandatory list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA recommends excluding the impact Depletion of abiotic resources in the mandatory list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA recommends excluding the impact Land use in the mandatory list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA recommends including the impact Photochemical ozone formation in the mandatory list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA recommends excluding the impact Human toxicity & Ecotoxicity in the mandatory list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA recommends excluding the impact Water scarcity in the mandatory list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA recommends including the impact Acidification in the mandatory list of TranSensus LCA impact categories – (with restrictions to be defined in next voting session)	*(1)*
• TranSensus LCA recommends including the impact Freshwater eutrophication & to exclude the impact Marine eutrophication in the mandatory list of TranSensus LCA impact categories	*(1)*

• TranSensus LCA recommends including the impact Particulate matter in the madatory list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA recommends excluding the impact Ozone depletion in the mandatory list of TranSensus LCA impact categories	*(1)*

3.3.2 Normalisation

The goal of this topic is to Recommend a set of Normalization factors, that should be used by LCA practitioners following the TranSensus LCA guidelines. But Normalization will be recommended as an optional step and not mandatory.

Q28 – Midpoint impact assessment results and normalized results

Overview

Type of LCA concerned by the question: Product LCA

Complete question submitted to voting

TranSensus recommends to mandatorily calculate the midpoint impact assessment results and then the normalized results as optional

We decided during the first vote round to suggest normalization factors in TranSensus LCA; conversely, since weighting is not recommended under any circumstances, no recommendations are given either on any specific weighting factors.

Possible answers: **Agree/ Disagree/ No preference**

Background

Normalization is an optional step under ISO 14044:2006, however there is no prescribed calculation measure to be followed while considering this criterion. Normalization transforms an indicator result by dividing it by a selected reference value. The normalization of the indicator results can change the conclusions drawn from the LCIA phase. ISO 14044 mentioned that normalization (& weighting) are optional, while VDA recommended to not consider normalization (& weighting) as it is subjective; PEF mandates normalization in LCA, and other guidelines do not mention Normalisation in their framework (D1.1 TranSensus).

Recommended approach/possible options description and justification

Normalization is advised for TranSensus LCA as an optional feature for a variety of reasons. One reason is that no guideline, other than the PEF, recommends it as mandatory. Furthermore, there are several discrepancies between the application of normalization factors in various software packages. Following normalization, some impact categories (ICs) are emphasized or downplayed. As a result, the normalization elements and their assessment are not deemed mature enough to make it obligatory. Also, when reporting LCAs following TranSensus LCA, midpoint impact data should always be reported before normalized values.

Q29 – Global Planetary Boundary based Normalization Factors

Overview

Type of LCA concerned by the question: Product LCA

Complete question submitted to voting

TranSensus recommends to use Global Planetary Boundary based normalization factors

Global planetary boundaries-based normalization factors recommended here are based on the paper https://doi.org/10.1016/j.jenvman.2020.110686 . Also note that the Global planetary boundaries-based normalization factors are not mature yet. So, practitioners must be following the updates regarding this normalisation factor.

Possible answers: **Agree/ Disagree/ No preference**

Background

There are different kinds of normalization: Internal, External and Absolute normalization (De Laurentiis, 2023). Although internal normalization allows to overcome issues of compensability and ensures consistency within the study, it is also very context-dependent and as such cannot be used with generic weighting. This type of normalization was left aside in the workgroup as it prevents comparability between studies. Then for the remaining two typologies of normalization, 5 normalization sets were found and compared, i.e.: Global production-based, European production-based, European consumption-based, process-based LCA, European consumption-based, input/output, Global planetary boundaries.

The European consumption-based input/output set of normalization factors is adapted for Economic input/output LCA and not for process-based LCAs which is why it was also set aside in the workgroup. The others European sets of normalization factors are not fit for systems with international supply chains, in the case of TranSensus the zero-emission vehicles come from international supply chains so only Global sets of normalization factors are relevant.

Recommended approach/possible options description and justification

The advantages of using Global Planetary Boundary based normalization factors are: First and foremost, this provides an absolute basis for normalization (instead of relative), which makes the normalized results dependent on absolute thresholds ("boundaries"), instead of on total previous impact (which is always a moving target); this also avoids potentially controversial interpretation if/when an impact contributes to a category already affected by significant overall impact globally. Other advantages are: Adapted for international supply chains, no inverse proportionality, Bias more transparent, cannot be affected by data coverage issues. But it has also several disadvantages such as: Not applicable to all LCIA impact categories, potential issues with upscaling local environmental pressures to global level (some impact categories are context-specific and more relevant on a local scale).

The benefits and Limitations of other normalization factors are mentioned in the table below.

	Benefits	Limitations
Global production-based		Extrapolations and the assumptions made for that. Coverage of data. Inverse proportionality.
European production-based	Covers the whole economy.	Biased because of the internationality of supply chains. Coverage of data. Inverse proportionality.
European consumption-based, process based LCA	Same data source for system under study and normalization reference (=> consistency)	Coverage of activities (efficiency level and technologies in countries from which EU imports goods). Only household consumption. Inverse proportionality. Limited to EU studies.
European consumption-based, input/output		Biased and unfit for normalization regarding ecotoxicity. Lower granularity. Limited coverage of elementary flows. Inverse proportionality. High level of aggregation of industrial sectors in IO analysis and of inventories.

3.3.3 Prospective and Fleet Level LCIA

The goal of this topic is to Identify the difference of prospective and fleet level LCIA to Retrospective LCIA

Q30 – Differences to Product LCA/Retrospective LCA

Overview

Type of LCA concerned by the question: **Product LCA, Prospective, Fleet Level LCA**

Complete question submitted to voting

TranSensus found Goal and Scope and Inventory phases has differences in Prospective and Fleet Level LCA compared to Product LCA but not on Impact Assessment phase. All characteristics (Impact Categories, LCIA methods, indicators) applicable for conventional product level LCIA is also applicable for Prospective and Fleet level LCIA

Possible answers: **Agree/ Disagree/ No preference**

Background

A number of literatures have been reviewed to understand the differences in Prospective and Fleet Level LCA compared to Product LCA/Retrospective LCA based on the characteristics of LCIA such as selection of impact categories, LCIA methods, Indicators, normalisation and weighting factors etc. but none of the literature mention about the differences that to be considered in LCIA phase. But when we did the brainstorming in WP2 several partners pointed out possible differences in the framework for Prospective and Fleet Level LCA compared to Product LCA/Retrospective LCA.

Recommended approach/possible options description and justification

Since we couldn't find any differences from the literature review and brainstorming discussion within task meetings, we are not proposing any differences in the framework for Prospective and Fleet Level LCA compared to Product LCA/Retrospective LCA.

3.3.4 Comparison of Softwares

This chapter aims to pinpoint the causes of variations in LCIA outcomes while utilising various software packages, hence educating LCA practitioners about software particularities that may occur during LCIA execution.

Q31 – Differences in LCIA Calculation

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

In Deliverable 2.3, LCA for Experts (LCA FE; formerly known as GaBi) and SimaPro will be compared since they are the most commonly used ones, but recommendation to use a particular software will not be made in TranSensus.

Possible answers: **Agree/ Disagree/ No preference**

Background

- Differences in LCA FE and SimaPro: The names used for impact categories in the LCIA methods (Simapro and LCA FE) are different (e.g. GWP in SimaPro, Climate change in LCA FE). SimaPro shows total results for some of the impact categories, while LCA FE shows individual and total results (e.g. Climate change – total, biogenic, fossil, landuse and land use change). In both softwares, characterization, normalization and weighting factors for an impact category in a LCIA method are not completely the same.
- Relevant issues to consider:
  1) Differences in names, initial emission compartments (e.g. air, high population density; water, fresh; soil, agricultural) and CAS numbers. Different naming conventions are used to refer to the same elementary flows, the same elementary flow name bears different meaning in the database and in the different methods.
  2) Individual substance emissions versus substance group emissions.
  3) The LCI database and LCIA database does not provide complete elementary flows and characterization factors of a particular Impact Category in an Impact Assessment method which makes difficulties in linking LCI and LCIA database.
  4) Assumptions of flows (e.g. Oxidation states - Metal emissions are usually given including their oxidation states (for example, Cadmium II). However, where this is not the case or where it explicitly states "ion" as it could refer to two different oxidation states

(for example, Copper I or Copper II)), assumptions of Compartments (There is no general rule for sub-compartment mapping between LCI databases and the different methods. Because fate and exposure of emissions are highly dependent on the compartment of an emission, it is not appropriate to use the CFs of another compartment to characterize an exchange), assumptions of Assessment for long-term emissions (Attribute the same CF to both short term and long-term emissions, leading to an overestimation of the impacts), assumptions of Emissions (The impact category "climate change: biogenic" in "IPCC 2021" only considers "Methane, non-fossil" . Even if original datasets are carbon balanced, LCIs are rarely carbon balanced due to the unavoidable distortions introduced by allocation. In these conditions, using negative CFs for carbon uptakes and positive CFs for non-fossil carbon emissions would lead to unreliable GWP scores, particularly for agriculture and wood products.), assumptions of Natural resources (The Cumulative Energy Demand (CED) method implemented since a long time in ecoinvent is based on HHVs. The standard EN 15804:2012+A2:2019 (CEN/TC 350 2019) implemented in the EF v3.0 EN15804 method, on the other hand, uses LHVs for the calculation of CFs. Following the latter, LHVs are implemented in methods assessing energy resources if no other CFs are given), assumptions of Regionalization (LCI databases sometimes does not yet consider regionalized EFs and hence no regionalized, but only global CFs are implemented. Implementation of global CFs can affect results a lot and regionalized results using a software allowing this should be used for studies where impact categories with regional differences such as land and water use are important).

Recommended approach/possible options description and justification

Even if LCA practitioners follow all of the TranSensus Guideline's recommendations, the final LCIA results will differ from study to study because the softwares, LCI database, and LCIA database used vary by case.

3.3.5 Mandatory set of LCA-Impact Category

TranSensus LCA first 2023 building blocks (deliverable D2.2) provides guidance for the impact assessment on indicators to be considered in optional set advised by the methodology, the question of the integration of a mandatory set and S-LCA. Optional set building blocks recommends the inclusion of EF method, CED-total, CED_non-renewable, criticality and resource dissipation as well as the exclusion of biodiversity impact and circularity indicators and aspects.

In 2024, WP2.4 partners have analysed a list of existing LCA impact categories and evaluated the relevance of each impact for zero emission vehicles (ZEVs) life cycle assessment. This evaluation has been performed by scoring each impact regarding a set of 5 criteria:

- Science based criteria: 1) robustness of the impact, and 2) relation to planetary boundaries.
- Other criteria: 3) importance for ZEVs, 4) data availability, and 5) easy-to-use.

Based on this analysis, we have proposed a list of impacts categories mandatory meaning that this set of impacts has to be calculated.

Impacts not included in this list are either optional with TranSensus LCA recommendation of calculation or not recommended for calculation according to details below.

For information, here we will not give recommendation on LCA impact categories need of publication only on the selection of impacts categories to be calculated. The reporting of TranSensus LCA impacts categories will be performed in the following months and proposed for the next voting session in September 2024.

The identification of impact categories for the assessment of ZEVs and their environmental impacts is based on extensive research conducted through various reports, frameworks and directives at European, national and international levels. This systematic approach ensures that the chosen categories are not only relevant, but also based on recognized standards and guidelines that reflect the latest in environmental policy and scientific knowledge.

By aligning the assessment criteria with the impacts contained in key documents, such as European Union directives, national policy frameworks and international environmental agreements, the methodology benefits from a solid foundation. This alignment ensures that the assessment remains relevant to current environmental priorities and challenges, while facilitating comparisons and benchmarking against set objectives and targets. In addition, it helps identify data gaps or areas where ZEVs could make a more significant contribution to mitigating environmental impact.

The thorough cross-referencing process is carried out to match the chosen impact categories with the concerns and priorities outlined in the aforementioned policy documents. These cross-references not only reinforce the credibility of the selected impact categories, but also ensure that the assessment framework is comprehensive and covers a wide range of environmental aspects, from emissions to resource use and beyond. It is relevant to mention that the majority of the identified impact categories are part of the PEF methodology.

The evaluation of the shortlisted impact categories relevant to ZEVs was structured into two main components: scientific basis and other criteria. The science component focuses on the robustness of the impact categories and their correlation to planetary boundaries, emphasizing an approach based on measurable and objective environmental science. The other criteria component addresses factors crucial to the practical deployment and understanding of the ZEVs. These include the importance of each criterion to the ZEVs, the ease of use, and the availability of data needed for a comprehensive assessment of the impact category.

The scoring system used for the evaluation is designed with a range of "A" to "E", where "A" represents the highest possible score, indicating the most favorable assessment or the highest level of compliance with the criteria evaluated. Conversely, "E" denotes the lowest score, reflecting significant deficiencies or areas in need of improvement. This hierarchical system of letter grades is intuitive, as it is based on rating systems known from educational contexts and allows for quick and clear comparisons and decision-making processes.

In the context of a quantitative analysis or further statistical evaluation, these letter grades are converted into numerical values. Specifically, "A" equals a score of 5, reflecting the highest compliance or the most favorable conditions. A score of 4 is assigned to a "B" grade, indicating a high but not optimal level of compliance. "C" equates to a score of 3, denoting moderate compliance and average in terms of performance. "D" is given a value of 2, showing a lower level of compliance, while "E", with a score of 1, signals the lowest level of compliance. This numerical conversion of letter grades allows scores to be aggregated and simplifies the calculation of averages, identification of trends, and benchmarking across categories or entities under assessment. This structured approach ensures a methodical and transparent assessment process. When the scores for several criteria are added together to calculate an average, the resulting figure does not always perfectly match the integer numbers. To address this problem and maintain the integrity of the assessment, a more granular rating scale was used for averages that fall between the standard letter grades. This refined rating scale introduces "+" and "-" modifiers to the basic letter grades, creating subdivisions that more accurately represent nuanced differences in performance or compliance levels. For example: an average score >4.7 is classified as "A+"; a score >4.3 up to 4.7 is designated as "A"; and a mean score above 4 but up to or equal to 4.3 is labeled "A-", representing the lower end of the "A" spectrum but maintaining a high overall level of compliance. This pattern continues down the grading scale, with "B+", "B", "B-", etc., allowing for more precise differentiation within each grade level.

The Robustness criteria was assessed based on the JRC levels I, II, and III. However, in this unique application of the criteria, evaluators assigned ratings only from a narrowed selection of grades: “A”, “C”, and “E”. “A” signifies the highest level of robustness, aligning with JRC level I, indicating comprehensive compliance and exceptional performance. “C” reflects a moderate level of robustness, equivalent to JRC level II. “E”, corresponding to JRC level III, represents the lowest robustness, indicating minimal compliance.

The evaluation of the Data Availability criteria was designed to assess how readily available and accessible the required data is to assess the impact categories in the ZEVs context. “A”, already available or normally collected by OEMs; “B”, partially collected but easy to collect missing data; “C”, not fully collected and complicated to collect, time consuming; “D” not collected and time and costly to Gather; “E”, complicated to collect, highly time consuming, and costly.

In the case of the Planetary Boundaries (PBs) criteria, the Climate Change and Particulate Matter categories, the PBs is exceeded by a factor 8. For Land Use, it is by a factor 60. This supports an "A" scoring as they are well above the limit and represent a high risk relative to PBs. The scoring of the other impact categories consisted in "A", "B", "C", "D" and "E" grades.

The correlation between life cycle assessment and planetary boundaries (PBs) is extremely interesting to consider as it provides an absolute limit to which the results of the LCIA can be compared. The Joint Research Center has worked on this subject for several years and have managed to establish a link between LCA and PBs through different methods, mapping most of the EF impact categories to the planetary boundaries[7,8]. Their papers show on two scales (global and European) the results for each impact category, some of them exceed the limit no matter the scale and the method and find themselves in the high-risk zone. In this workgroup, we considered that such impact categories are of the utmost importance to integrate in the TranSensus methodology. Thus, we provided a rating for the impact categories considering how many times they were found in the safe operating space (“E”), the zone of uncertainty (“D”, “C”) or the high-risk zone (“C”, “B”, “A”).

The particulate matters (PM), climate change (CC) and land use (LU) impact categories exceed the limit by a factor 8 for PM and CC and a factor 60 for LU. That’s why they were given the highest rating as they are considered urgent to address in LCA.

[7] Esther Sanyé-Mengual, Serenella Sala; Life Cycle Assessment support to environmental ambitions of EU policies and the Sustainable Development Goals; Integrated Environmental Assessment and Management — Volume 18, 2022, Number 5—pp. 1221–1232; DOI: 10.1002/ieam.4586

[8] Serenella Sala, Eleonora Crenna, Michela Secchi, Esther Sanyé-Mengual; Environmental sustainability of European production and consumption assessed against planetary boundaries; Journal of Environmental Management, Volume 269, 2020, 110686, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2020.110686

Table 3-7: Impact category and planetary boundary limits

Impact Category	Global limit exceeded	EU27 limit exceeded eval e)	EU27 limit exceeded eval a)	Consumption Footprint per capita	Rating
Particulate Matters	XXX	XXX	XXX	XXX	**A**
Climate Change	XXX	XXX	XXX	XXX	**A**
Land Use	XXX	XXX	XXX	XXX	**A**
Resource use, fossils	X	XXX	X	XXX	**B**
Resource use, mineral, metals	X	XXX		X	**B**
Human toxicity, non cancer		XXX			**C**
Human toxicity, cancer				X	**D**
Eutrophication, freshwater	X		X	X	**C**
Photochemical Ozone Formation		X			**D**
Eutrophication, marine		X			**D**

A synthetic table of the impact categories evaluation can be found below. Details regarding evaluation can be found within each dedicated impact category paragraph.

Table 3-8: Impact categories evaluation by TranSensus LCA

	Science based criteria		Other criteria			
Impact category	**Robust-ness**	**Relation to planetary bounda-ries**	**Im-portance for ZEVs**	**Easy to use**	**Data availabil-ity**	**Score**
Climate change	A+	A+	A+	A+	A+	A+
Depletion of abi-otic resources	C-	B	A+	A+	A-	B+
Land use	D+	A+	C+	B	B	B
Photochemical ozone formation	B-	D+	A-	A	A+	B+
Human toxicity	D+	C+	B+	B+	B+	B
Ecotoxicity	C-	D	B+	B	B+	B-
Water scarcity	C-	D	B+	C+	C+	C
Acidification	B	D	A	A	A	B
Freshwater eu-trophication	B	B-	B-	A	A+	B+
Marine eutrophi-cation	B	C-	C+	C+	C+	C+
Particulate mat-ter	A	A+	A	A+	A	A
Ozone depletion	A-	D	C	A	A	B
Biodiversity	D-	C+	B	D	C-	C-
Criticality	D-	E+	B+	C	C	C-

WP2.4 has decided to propose as mandatory impact categories, those reaching which reached a total score of A+, A or B+. Below this threshold limit, it is understood that impact considered is non-mature enough, methodology or data are not available yet. The concerned impact may be a priority for R&D activities in order to include it as mandatory within a future revised TranSensus LCA methodology for ZEV.

This voting session will focus on the list of impact categories to be mandatory in TranSensus LCA methodology, recommended LCIA methods will be proposed for the next voting session of September 2024.

Q32 – Integration of climate change as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA recommends including the impact "Climate Change" in the mandatory list of TranSensus LCA impact categories.

Climate change impact category is considering all inputs and outputs that result in greenhouse gas (GHG) emissions. The consequences include increased average global temperatures and sudden regional climatic changes.

The method of calculating the impact of a product on the environment, Life Cycle Assessment, already standardizes climate change impact. For the assessment of Climate change the characterization factors developed by IPCC (i. e., GWPs) are by far the most used in all vehicle LCAs. This impact is expressed in kg CO_2 equivalents (kg CO_2-eq) over 100 years. Most of the studies focus on climate change given that it is a main driver of road electrification. The prioritization of this impact category for ZEV LCA was obvious in the reviewed work.

Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Climate change	A+	A+	A+	A+	A+	A+

The characterization factors express the relative contribution of an emission or extraction to the impact category. The quality of characterisation methods is well described within ILCD handbook from Joint Research Center (International Life Cycle Data System, JRC 2011[9]. The recommended characterisation methods (models and associated characterisation factors) are classified according to their quality into three levels: —I (recommended and satisfactory), —II (recommended but in need of some improvements) or —III (recommended, but to be applied with caution).

For climate change, the characterisation method has been classified by the JRC into a Level I: recommended and satisfactory. Moreover, climate change impact category exceeds the planetary boundaries limit by a factor 8, as mentioned in the beginning of this paragraph, therefore it receives a A+ grade. Climate change impact is also rated to A+ score for its ease to use, data availability as well as high relevance to ZEVs assessment.

Q33 – Exclusion of depletion of abiotic resources as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA.**

Complete question submitted to voting

TranSensus LCA recommends excluding depletion of abiotic resources in the mandatory list of TranSensus LCA impact categories.

Depletion of abiotic resource addresses the use of non-renewable abiotic natural resources (minerals and metals: copper, potash, rare earths, sand, etc.).

A new indicator "dissipation of abiotic resources" might be proposed instead of "depletion of abiotic resources". TranSensus LCA will recommend its inclusion in the list of impact categories based on on-going method-testing with available life cycle inventories. The recommendation will be provided ahead of the next voting session in September 2024.

Possible answers: **Agree/ Disagree/ No preference**

[9] European Commission-Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook- Recommendations for Life Cycle Impact Assessment in the European context. First edition November 2011. https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-Recommendations-for-Life-Cycle-Impact-Assessment-in-the-European-context.pdf

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Depletion of abiotic resources	C-	B	A+	A+	A-	B+

The depletion of abiotic resources impact received a B+ score reflecting its importance in the broader context of environmental science and policy. Its ease to use is highlighted by a A+ score. It should be noted that data are relatively available, which led to a A- grade.

A previous review on this impact presented in deliverable D1.1 "Review of current practices on life cycle approaches along the electromobility value chain" lead to the conclusion that an interesting alternative for this indicator is the dissipation of abiotic resources. A dissipation model also might better address circularity issues, since it could help identify hotspots in which resources are not recovered. However, methods to assess dissipation of resources are in development and potentially not yet operational. Work on this topic is on-going within the TranSensus LCA project and will be presented before the next voting session (September 2024).

Therefore, TranSensus LCA recommends to exclude depletion of abiotic resources impact in the mandatory list of impact in TranSensus LCA methodology.

A new indicator "dissipation of abiotic resources" might be proposed for evaluation and potential integration into the optional list of impact categories for next voting session in September 2024. As proposed in our previous deliverable D1.1 "Review of current practices on life cycle approaches along the electromobility value chain" on p125.

Q34 – Exclusion of land use as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA recommends excluding Land use in the mandatory list of TranSensus LCA impact categories.

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

Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Land use	D+	A+	C+	B	B	B

Land use impact is rated B with a great relevance to planetary boundaries relation according to JRC studies. Indeed, for this indicator, planetary boundaries are exceeded by a factor 60. This grade signifies a positive assessment of the usefulness of the indicator. However, the JRC has also rated the robustness of the land use category at lowest level III, moreover data are not always available or easy to use. The land use impact assessment for ZEV seems also be quite low. This evaluation makes this impact not mature enough to be recommended within TranSensus LCA methodology.

Q35 – Integration of photochemical ozone formation as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA.**

Complete question submitted to voting

TranSensus LCA recommends including photochemical ozone formation in the mandatory list of TranSensus LCA impact categories.

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

Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Photochemical ozone formation	B-	D+	A-	A	A+	B+

Photochemical ozone formation impact got a B+ score. This grade signifies a positive assessment of the usefulness of the indicator, reflecting its relative importance to ZEVs. Data are available and quite easy to use. The JRC has rated the robustness of the photochemical ozone formation category at level II and only low relation to planetary boundaries.

For this reason, TranSensus LCA recommend the integration of photochemical ozone formation in the mandatory list of impact category of TranSensus LCA methodology.

Q36 – Exclusion of toxicity as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

TranSensus LCA recommends excluding toxicity in the mandatory list of TranSensus LCA impact categories.

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

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

Freshwater ecotoxicity addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Ecotoxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.

Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Human toxicity	D+	C+	B+	B+	B+	B
Ecotoxicity	C-	D	B+	B	B+	B-

The emission of some substances, such as heavy metals, can have impacts on the ecosystem. Assessment of toxicity has been based on maximum tolerable concentrations in water and land for ecosystems. This indicator is not yet very robust as it covers a wide range of pollutants, and their emissions are not very well monitored nor documented in LCA databases.

Human toxicity and ecotoxicity impact categories received a B and B- scores. These two impacts are of interest to ZEV life cycle assessment. But, the JRC has rated the robustness of both toxicity categories at level III. This rating indicates a low level of confidence in the methodologies used to assess toxicity impacts. Moreover, low relation to planetary boundaries have been highlighted. Due to this lack of confidence, TranSensus LCA recommends excluding toxicity from the mandatory set of impact categories of TranSensus LCA methodology. But it might be interesting to address these impacts, at least ecotoxicity, in a future updated version of the proposed LCA methodology in order to be compliant with the next CSRD (Corporate Sustainability Reporting Directive) relative to ESRS#4 (European Sustainability Reporting Standards) on biodiversity.

Q37 – Exclusion of water scarcity as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

> **TranSensus LCA recommends excluding Water scarcity in the mandatory list of TranSensus LCA impact categories.**

Water scarcity is a LCA impact category that represents the relative available water remaining per area in a watershed, after demand from humans and aquatic ecosystems has been met. It assesses the potential for water deprivation, to either humans or ecosystems, based on the assumption that the less water remaining available per area, the more likely it is that another user will be deprived.

> Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Water scarcity	C-	D	B+	C+	C+	C

Water scarcity impact category received a C score. The JRC has rated the robustness of the water scarcity category at lowest level III. This rating indicates a low level of confidence in the methodologies used to assess water scarcity impacts. Moreover, when specifically assessed for its relationship to planetary boundaries, the water scarcity indicator received a relatively low score, with a grade of D.

On the other hand, this indicator receives a score of C+ for its ease of use. This relatively low score indicates that the tools and approaches available for calculating water scarcity are not mature enough. In addition, the availability of the data needed for these calculations also receives a low grade, with a C+. Also, the relative relevance of the water scarcity category for the assessment of ZEVs is highlighted with a grade of B+.

Q38 – Integration of acidification as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA.**

Complete question submitted to voting

TranSensus LCA recommends including acidification in the mandatory list of TranSensus LCA impact categories

Acidification contributes to the decline of coniferous forests and increased fish mortality. Acidification can be caused by emissions that reach the air, water and soil. The most important sources are combustion in electricity production, heating and transportation. The contribution to acidification is highest when fuels contain a high level of sulphur. The potential impact of substances contributing to acidification is converted into the equivalent moles of hydrogen (mol H+ eq).

This recommendation needs to be completed with more details regarding the list of exclusion of substances and recommendation to appropriated method for the next voting session in September 2024.

Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Acidification	B	D	A	A	A	B

The scoring of the acidification impact category reveals its applicability and relevance for ZEVs. This indicator received a B score. This grade signifies a positive assessment of the usefulness of the indicator, reflecting its importance in the broader context of environmental science and policy. The JRC has rated the robustness of the acidification category at level II. This rating indicates a moderate level of confidence in the methodologies used to assess acidification impacts, suggesting that while the methods are well established, there may still be room for improvement or further validation to increase their accuracy and reliability. However, when specifically assessed for its relationship to planetary boundaries, the acidification indicator received a relatively low score, with a grade of D.

On the other hand, this indicator receives a score of A for its ease of use. This high score indicates that the tools and approaches available for calculating acidification impacts are straightforward and can be easily applied in a variety of environmental assessment contexts. In addition, the availability of the data needed for these calculations also receives a high grade, with an A. Similarly, the relevance of the acidification category for the assessment of ZEVs is underlined with a grade of A.

Q39 – Integration of freshwater eutrophication and exclusion of marine eutrophication as mandatory impact category

Overview

Type of LCA concerned by the question: **Product LCA.**

Complete question submitted to voting

TranSensus LCA recommends including freshwater eutrophication and exclude marine eutrophication in the mandatory list of TranSensus LCA impact categories

Eutrophication affects ecosystems due to substances containing nitrogen (N) or phosphorus (P). If algae grow too fast, they can leave the water without enough oxygen for fish to survive. Nitrogen emissions to the aquatic environment are largely due to fertilizers used in agriculture, but also to combustion processes. The most important sources of phosphorus emissions are urban and industrial effluent treatment plants and leaching from agricultural land. The potential impact of substances contributing to freshwater eutrophication is converted into kilograms of phosphorus equivalent (kg P eq). The potential impact of substances contributing to marine eutrophication is converted to kilograms of nitrogen equivalent (kg N eq).

Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Freshwater eutrophication	B	B-	B-	A	A+	B+
Marine eutrophication	B	C-	C+	C+	C+	C+

The scoring system was applied to evaluate both freshwater and marine eutrophication indicators.

The JRC ranked the robustness of both impact indicators at level II. This ranking suggests a moderate level of confidence in the reliability and accuracy of the methodologies used to assess these impacts, indicating that the methods are well developed but may still benefit from further refinement or validation.

In terms of their relationship to planetary boundaries, the eutrophication indicators, although not directly related to this framework, are considered relevant. The relevance of these indicators to ZEVs highlights the importance of considering a wide range of environmental impacts in vehicle life cycle assessments. While ZEVs focus primarily on reducing greenhouse gas emissions, the assessment of eutrophication impacts warrants a more holistic view of environmental performance, emphasizing the need to address nutrient runoff and its effects on aquatic ecosystems in the production and operation of ZEVs.

These eutrophication impacts received grades of B+ for freshwater eutrophication and only C+ for marine eutrophication. These scores reflect the accessibility and applicability of the methods and data needed to assess freshwater eutrophication impacts, making them practical tools for environmental impact assessments. However, improvement is still needed for marine eutrophication environmental assessment.

Q40 – Inclusion of particulate matter as mandatory impact category

<u>Overview</u>

<u>Type of LCA concerned by the question:</u> **Product LCA**

<u>Complete question submitted to voting</u>

TranSensus LCA recommends including particulate matter in the mandatory list of TranSensus LCA impact categories.

This Impact category assesses the Impact on human health the potential incidence of disease due to particulate matter emissions. The impact category is measured in terms of Disease incidence based on PM model (Fantke et al., 2016 in UNEP 2016).

<u>Possible answers:</u> **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Particulate matter	A	A+	A	A+	A	A

For the particulate matter, the characterization method has been classified by the JRC into highest Level I: recommended and satisfactory. This rating indicates a relatively high level of confidence in the methodologies used to assess particulate matter impacts. In the case of this impact, the planetary boundaries are exceeded by a factor 8. Data needed for these impact calculations is quite available and easy to use, which led to a respective A and A+ grade. In addition, the relevance of the particulate matter category for the assessment of ZEVs is underlined with a grade of A.

Q41 – Exclusion of ozone depletion as mandatory impact category

<u>Overview</u>

<u>Type of LCA concerned by the question:</u> **Product LCA**

<u>Complete question submitted to voting</u>

TranSensus LCA recommends excluding ozone depletion in the mandatory list of TranSensus LCA impact categories

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

Possible answers: **Agree/ Disagree/ No preference**

Background

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Ozone depletion	A-	D	C	A	A	B

The scoring system was applied to evaluate ozone depletion indicator. The JRC ranked the robustness of this impact at level I. This ranking suggests a high level of confidence in the reliability and accuracy of the methodologies used to assess this impact. Data required for ozone depletion calculations are available and easy to use. However, this impact doesn't exceed planetary boundaries limit and only low contribution to ozone depletion is attributed to ZEV production and usage[10]. These two criteria are rated respectively D and C grade.

[10] Mikosch, N.; Dettmer, T.; Plaga, B.; Gernuks, M.; Finkbeiner, M. Relevance of Impact Categories and Applicability of Life Cycle Impact Assessment Methods from an Automotive Industry Perspective. Sustainability 2022, 14, 8837. https://doi.org/10.3390/su14148837

3.4 Task 2.5: Interpretation, Decision making and frontloading concept

3.4.1 List of questions submitted to the 2nd voting by Task 2.5

Summary of TranSensus LCA recommendation & voting options:

Table 3-9: List of questions submitted by task 2.5 to 2nd voting of spring 2024

TranSensus LCA recommends for task T2.5:	Status
Mandatory analysis of parameters	
• Usage - consumption : TranSensus LCA recommends performing a mandatory analysis on the quantity of energy consumed during the use phase using real world factors (to be defined).	*(1)*
• Quantity value :TranSensus LCA recommends performing a mandatory analysis on the quantity value for certain components/materials/flows leading to hotspots (a list is to be defined later).	*(1)*
• Usage - lifetime : TranSensus LCA recommends performing a mandatory analysis on the vehicle life-time (usage).	*(1)*
• Usage - geographical variation of energy mix consumption: TranSensus LCA recommends performing a mandatory analysis on geographical variation of the energy consumed (electricity mix or H2 mix) during usage.	*(1)*
• Future mix: use phase electricity/H_2 mix: TranSensus LCA recommends performing a mandatory analysis on the future electricity/H2 mix for the use phase.	*(1)*
Recommend analysis of parameters	
• Choice of secondary data: TranSensus LCA recommends performing a recommended analysis on the choice of secondary data for the components/materials/flows that are deemed relevant, e.g., leading to hotspots (to be defined).	*(1)*
• Location of the value chain: electricity mix: TranSensus LCA recommends the partners to perform a recommended analysis on the location of the value chain and how it affects the electricity mix.	*(1)*
• Supply chain improvements: recycled vs. primary materials: TranSensus LCA recommends the partners to perform a recommended analysis on process improvements with respect to the use of recycled vs. primary materials.	*(1)*
• Usage - maintenance & wearing: TranSensus LCA recommends the partners to perform a recommended analysis on maintenance & wearing during usage.	*(1)*
• Usage - payload/number of passengers : TranSensus LCA recommends the partners to perform a recommended analysis on the payload/number of passengers during usage.	*(1)*
• Usage - temperature: TranSensus LCA recommends the partners to perform a recommended analysis on the ambient temperature during usage.	*(1)*
• Future mix - EoL electricity/fuel mix : TranSensus LCA recommends the partners to perform a recommended analysis on the EoL electricity/fuel mix modelled with a future mix (whether static or dynamic).	*(1)*
• Second use : TranSensus LCA recommends the partners to perform a recommended analysis on the second use.	*(1)*

Optional analysis of parameters	
• <u>Supply chain improvements - supplier choice</u>: TranSensus LCA recommends the partners to perform an optional analysis on the supplier choice with respect to supply chain improvements.	*(1)*
• <u>Location of the value chain - fuel mix, transport distance & means:</u> TranSensus LCA recommends the partners to perform an optional analysis on the location of the value chain with respect to inbound logistics (fuel mix, transport distance & means).	*(1)*
• <u>Process improvements</u>: TranSensus LCA recommends the partners to perform an optional analysis on process improvements (e.g., waste management, upstream recycling processes, packaging, on-site electricity production, fluids and consumables, materials consumption).	*(1)*
• <u>Process improvements - energy consumption:</u> TranSensus LCA recommends the partners to perform an optional analysis on process improvements with respect to energy consumption.	*(1)*

In order to increase comparability and create a common basis for the LCA, we would like to use this voting to find out which parameters should be analysed in more detail. Following this vote, we will clarify which methods should be used to carry out a sensitivity and/or uncertainty and/or scenario analysis. The voting differentiates between which parameters are mandatory, recommended and optional.

The voting is split into 3 sections:

- Mandatory analysis of parameters: An analysis of these key parameters is mandatory to calculate in order to perform a LCA following the TranSensus LCA methodology to achieve a harmonized outcome. The type of reporting (i.e. mandatory/recommended/optional) for mandatory parameters will be defined in another subtask after this voting.
- Recommended analysis of parameters: Task 2.5 recommends analysing these parameters to achieve a comprehensive and comparable LCA. The type of reporting (i.e., mandatory/recommended/optional) for recommended parameters will be defined in another subtask after this voting.
- Optional analysis of parameters: If one or more of the parameters are important for the involved stakeholder with respect to their business, the parameters can be analysed in depth, further increasing the informative value and the needed effort of the LCA. The type of reporting (i.e., mandatory/recommended/optional) for optional parameters will be defined in another subtask after this voting.

3.4.2 Mandatory analysis of parameters

Within this section, TranSensus LCA would like to get your input on which parameters should be subject to mandatory analysis of sensitivity and/or uncertainty and/or scenario. The type of analysis to perform on each parameter will be defined in another subtask after the second voting. A mandatory analysis of these parameters implies a mandatory calculation of the results. The type of reporting (i.e., mandatory/recommended/optional) for mandatory parameters will be defined in another subtask after this voting.

Q42 – Usage: consumption

Overview

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA recommends performing a mandatory analysis on the quantity of energy consumed during the use phase using real world factors (to be defined).

"Mandatory" means that TranSensus LCA mandates these parameters to be analysed. The type of analysis to perform on each parameter will be defined after the voting (i.e., sensitivity analysis/uncertainty analysis/scenario analysis).

The baseline/default value being the one provided by e.g., Worldwide harmonized Light vehicles Test Procedure (WLTP) or Vehicle Energy Consumption calculation Tool (VECTO).

Possible answers: **Agree/ Disagree/ No preference**

Background

It was decided in the task 2.3 that a sensitivity analysis on vehicle energy consumption using real world factors (to be defined) was to be performed.

Recommended approach/possible options description and justification

Energy consumption during the use phase is one of the most important contributors to the overall life cycle impacts which is why it must be modelled as closely to the reality as possible. If the default value used in the model come from WLTP or VECTO models, then a sensitivity analysis on the energy consumption during the use phase using real world factors must be performed to evaluate the system as close to real conditions as possible.

Q43 – Quantity value

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

> **TranSensus LCA recommends performing a mandatory analysis on the quantity value for certain components/materials/flows leading to hotspots (a list is to be defined later).**

Definition for the analysis of quantity values leading to hotspots: This is the amount of component/material/flow that is put in the LCI. For supplier specific data, the quantity is known and measured and thus comes with uncertainty on measurement. For secondary data, the quantity is either provided by literature/databases and thus can come with uncertainties (e.g., ecoinvent datasets) or the quantity is not known (e.g., battery/vehicle lifetime) and an assumption is made, a sensitivity is then needed on that value.

Definition of hotspot: it is specific component within a process or value chain where the environmental impacts are notably significant. A check list of known hotspots for ZEVs will be provided in task 2.3 Data Collection and could be used here also.

"Mandatory" means that TranSensus LCA mandates these parameters to be analysed. The type of analysis to perform on each parameter will be defined after the voting (i.e., sensitivity analysis/uncertainty analysis/scenario analysis).

> Possible answers: **Agree/ Disagree/ No preference**

Q44 – Usage: lifetime

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

> **TranSensus LCA recommends performing a mandatory analysis on the vehicle lifetime (usage).**

Definition for the analysis of vehicle lifetime (usage): This parameter aims to study the sensitivity of the vehicle lifetime regarding its use phase. Indeed, depending on the end-user (e.g., family, taxi driver...) and how the vehicle is driven the lifetime of the vehicle will be significantly affected.

This analysis should be performed in case:

- A default value provided by TranSensusLCA is used in the general assumptions (determined in task 2.2),
- Another value is used and thus must be justified with a sensitivity analysis.

"Mandatory" means that TranSensus LCA mandates these parameters to be analysed. The type of analysis to perform on each parameter will be defined after the voting (i.e., sensitivity analysis/uncertainty analysis/scenario analysis).

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the lifetime depending on how/by whom the vehicle is driven (e.g., taxi car or family car).

This is one of the key assumed parameters and it has a great impact on the overall results which is why it should be mandatory to study. It covers a life cycle phase that lies in the future at the time when the LCA is performed so it is unknown, as such it is uncertain and should be subject to a sensitivity/uncertainty/scenario analysis.

Q45 – Usage: geographical variation of energy mix for consumption

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

TranSensus LCA recommends performing a mandatory analysis on geographical variation of the energy consumed (electricity mix or H2 mix) during usage.

Definition for the analysis of geographical variation of energy consumed: This parameter aims to study the sensitivity on the use phase of the energy mix consumed depending on where the vehicle is driven.

This sensitivity should be performed regardless of whether a static or dynamic mix is used in the initial model.

Example: If an electric car is driven and charged in Norway it has a different electricity mix, than a car driven and charged in Poland, which has an enormous impact on the emitted greenhouse gases.

"Mandatory" means that TranSensus LCA mandates these parameters to be analysed. The type of analysis to perform on each parameter will be defined after the voting (i.e., sensitivity analysis/uncertainty analysis/scenario analysis).

<u>Possible answers:</u> **Agree/ Disagree/ No preference**

Background

Sensitivity analysis on the use phase geographical variation of the electricity mix (regardless of whether static or dynamic) or H2 mix used depending on where the vehicle is driven.

This is one of the key assumed parameters and it has a great impact on the overall results which is why it should be mandatory to study. It covers a life cycle phase that lies in the future at the time when the LCA is performed so it is unknown, as such it is uncertain and should be subject to a sensitivity/uncertainty/scenario analysis.

Q46 – Future mix: use phase electricity/H2 mix

Overview

<u>Type of LCA concerned by the question:</u> **Product LCA**.

<u>Complete question submitted to voting</u>

TranSensus LCA recommends performing a mandatory analysis on the future electricity/H2 mix for the use phase.

Definition for the analysis of future mix: This is one of the options to model the electricity mix during the use phase as it lies in the future at the start of production (SoP). This future mix can be modelled thanks to projections established by recognized bodies (e.g., IEA) provided that corresponding datasets are available in databases (e.g., LCA for experts, ecoinvent).

This analysis should be performed regardless of whether:

- A static mix is used in the initial model for the use phase (e.g., the mix of the SoP year).
- A dynamic mix (to be defined in task 2.3 Electricity modelling) is used in the initial model (e.g., a baseline scenario to be defined).

"Mandatory" means that TranSensus LCA mandates these parameters to be analysed. The type of analysis to perform on each parameter will be defined after the voting (i.e., sensitivity analysis/uncertainty analysis/scenario analysis).

<u>Possible answers:</u> **Agree/ Disagree/ No preference**

Background

Sensitivity on use phase electricity mix/H2 mix using a dynamic future electricity mix (e.g., based on IEA scenarios).

This is one of the key assumed parameters and it has a great impact on the overall results which is why it should be mandatory to study. It covers a life cycle phase that lies in the future at the time when the LCA is performed so it is unknown, as such it is uncertain and should be subject to a sensitivity/uncertainty/scenario analysis. What's more the projections used to model the baseline scenarios are also subject to uncertainty which is why the sensitivity should be performed e.g., using a range of scenarios like optimistic/pessimistic.

As it was established in task 2.3, using a dynamic future mix for the electricity/H2 ensures a more realistic modelling of the use phase.

Recommended analysis of parameters

Within this section, TransSensus LCA would like to get your input on which parameters should be subject to recommended analysis of sensitivity and/or uncertainty and/or scenario.

These parameters have been identified as important to study as they could potentially lead to hotspots. Reporting won't be mandatory on all the following parameters.

Q47 – Choice of secondary data

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

> **TranSensus LCA recommends performing a recommended analysis on the choice of secondary data for the components/materials/flows that are deemed relevant, e.g., leading to hotspots (to be defined).**

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: This choice arises when the LCA practitioner uses a database to model their system and several datasets are available to represent one component/material/flow and they don't know which one suits their model best. Thus, the decision to use one dataset rather than another one is arbitrary and leads to uncertainty in the results.

Possible answers: **Agree/ Disagree/ No preference**

Background

If the LCA practitioner has the choice between two datasets to model one component and no knowledge on which one to use, e.g., 2 alloys possible.

This wouldn't have to be done for all secondary datasets, maybe only for those leading to hotspots (e.g., steel / aluminium).

Q48 – Location of the value chain: electricity mix

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA**.

Complete question submitted to voting

TranSensus LCA recommends the partners to perform a recommended analysis on the location of the value chain and how it affects the electricity mix.

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: The location of some of the suppliers along the value chain might not be known to the LCA practitioner (i.e., no supplier-specific data available) and thus the electricity mix used (whether location or market-based) for some process/components/materials is also unknown.

This analysis doesn't have to be performed for all suppliers along the value chain, only for relevant process/suppliers e.g., leading to hotspots or energy intensive processes (to be defined).

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the production regional electricity mix (whether market or location-based) depending on where the factories are located.

This can be relevant in the case of improvement of the existing value chain or for prospective LCA.

Q49 – Supply chain improvements: recycled vs. primary materials

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA**.

Complete question submitted to voting

TranSensus LCA recommends the partners to perform a recommended analysis on process improvements with respect to the use of recycled vs. primary materials.

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: This parameter is linked to the decision of the OEM or supplier to use recycled materials instead of primary.

This analysis doesn't have to be performed on all materials but only those deemed relevant by the LCA practitioner.

Possible answers: **Agree/ Disagree/ No preference**

Background

This parameter comes from the decision of the OEM/supplier to choose to use recycled material X instead of primary material X.

Q50 – Usage: maintenance & wearing

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

TranSensus LCA recommends the partners to perform a recommended analysis on maintenance & wearing during usage.

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: This is another parameter linked to the way the vehicle will be driven and by whom. A more intensive use might lead to more maintenance and wearing of some parts/components.

Maintenance includes tasks such as tire rotations, fluid checks, and other routine inspections. Wear include wear on tires, brake pads, and other mechanical components. Wear is a natural part of a car's lifespan and may require maintenance or replacement.

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the maintenance depending on how/by whom the vehicle is driven (e.g., taxi car or family car).

Q51 – Usage: payload/number of passengers

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

TranSensus LCA recommends the partners to perform a recommended analysis on the payload/number of passengers during usage.

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: This is another parameter linked to the way the vehicle will be driven and by whom (e.g., family of 6 or single person).

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the payload/number of passengers depending on how/by whom the vehicle is driven (e.g., taxi car or family car).

This is one of the key assumed parameters that will have an important influence on the results if the functional unit is expressed in p*km/t*km. The agreed functional unit in TranSensus LCA is km-based, it was agreed in the previous voting in task 2.2 that the functional unit is ton*km for freight vehicles and passenger*km for buses and passenger cars.

Q52 – Usage: temperature

Overview

Type of LCA concerned by the question: **Product LCA**.

Complete question submitted to voting

> **TranSensus LCA recommends the partners to perform a recommended analysis on the ambient temperature during usage.**

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: This is another parameter linked to the way the vehicle will be driven and where (e.g., in Spain or in Norway). The ambient temperature will affect the ageing, the range and the performance of some parts/components like the battery for example.

Example: A car driven in Norway experiences cold temperatures especially in winter. This may cause a reduced efficiency and a decrease in its overall range. While a car driven in Spain in summer needs cooling for the passengers and the battery which results in a higher energy consumption.

> Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the temperature depending on where the vehicle is driven (e.g., Spain or Norway).

Q53 – Future mix: EoL electricity/fuel mix

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA**

Complete question submitted to voting

> **TranSensus LCA recommends the partners to perform a recommended analysis on the EoL electricity/fuel mix modelled with a future mix (whether static or dynamic).**

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: This is one of the options to model the electricity mix during the end-of-life as it lies in the future at the SoP. This future mix can be modelled thanks to projections established by recognized bodies (e.g., IEA).

This analysis should be performed whether:

- A static mix is used in the initial model for the end-of-life (e.g., the mix of the SoP year).
- A dynamic mix is used in the initial model (e.g., a baseline scenario to be defined).

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on EoL electricity mix/fuel mix using a dynamic future electricity mix (e.g., based on IEA scenarios).

This parameter was deemed of lesser importance by task 2.5 which is why it is recommended and not mandatory. It covers a life cycle phase that lies in the future at the time when the LCA is performed so it is unknown, as such it is uncertain and should be subject to a sensitivity/uncertainty/scenario analysis. What's more the projections used to model the baseline scenarios are also subject to uncertainty which is why the sensitivity should be performed e.g., using a range of scenarios like optimistic/pessimistic.

As it was established in task 2.3, using a dynamic future mix for the electricity/H2 ensures a more realistic modelling of the end-of-life.

Q54 – Second use

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA**

Complete question submitted to voting

TranSensus LCA recommends the partners to perform a recommended analysis on the second use.

"Recommended" means that TranSensus LCA recommends these parameters to be analysed. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting will be decided after this voting.

Definition: This parameter evaluates the impacts of adding a second use to the initial system. The task 2.5 encourages to perform such analysis if a business case exists.

Please note that adding a second use will change the functional unit, the results won't be comparable anymore.

Possible answers: **Agree/ Disagree/ No preference**

Background

Study the effects on the results to have a second use. The task 2.5 encourages the LCA practitioner to evaluate the effects of a second use on the overall results. It is important to note that adding a second use to the system will change the functional unit and thus the results won't be comparable anymore. Due to the increasing importance of second use in the context of zero-emission road transport, a more in-depth analysis is highly recommended and encouraged by the Advisory Boards.

3.4.3 Optional analysis of parameters

Within this section, Task 2.5 would like to get your input on which parameters should be subject to an optional analysis of sensitivity and/or uncertainty and/or scenario.

These parameters might be of interest for internal studies and/or prospective LCA. The type of reporting will be addressed after this voting.

Q55 – Supply chain improvements: supplier choice

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA.**

Complete question submitted to voting

TranSensus LCA recommends the partners to perform an optional analysis on the supplier choice with respect to supply chain improvements.

"Optional" means that TranSensus LCA leaves the choice to perform an analysis over these parameters with the LCA practitioner. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting . The type of reporting (i.e., mandatory/recommended/optional) will also be discussed after this voting.

Definition: This parameter is linked to the decision of the OEM to change supplier(s) for some parts/materials/components.

This analysis doesn't have to be performed on all suppliers along the value chain but only those deemed relevant by the LCA practitioner.

Possible answers: **Agree/ Disagree/ No preference**

Background

It could be interesting to see how the choice of supplier affects the overall results whether the value chain is completely known or not by the LCA practitioner.

An example of this parameter is: What if the OEM chooses to use Li coming from spodumene instead of brine?

Q56 – Location of the value chain: fuel mix, transport distance & means

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA**.

Complete question submitted to voting

TranSensus LCA recommends the partners to perform an optional analysis on the location of the value chain with respect to inbound logistics (fuel mix, transport distance & means).

"Optional" means that TranSensus LCA leaves the choice to perform an analysis over these parameters with the LCA practitioner. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting (i.e., mandatory/recommended/optional) will also be discussed after this voting.

Definition: This is another parameter linked to the location of the value chain and the different suppliers. Changing the location of suppliers or factories will affect the fuel mix, the transport distance and means between each step of the value chain.

Once again, this analysis might not be relevant to perform on all suppliers/factories but only those deemed relevant to the LCA practitioner.

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the inbound logistics with regards to production fuel mix, the transport distance and transportation means depending on where the factories are located.

Q57 – Process improvements (e.g., waste management, upstream recycling processes, packaging, on-site electricity production, fluids and consumables, materials consumption)

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA**.

Complete question submitted to voting

TranSensus LCA recommends the partners to perform an optional analysis on process improvements (e.g., waste management, upstream recycling processes, packaging, on-site electricity production, fluids and consumables, materials consumption).

Example: What if the OEM decides to have on-site electricity production by installing solar panels on their factory?

"Optional" means that TranSensus LCA leaves the choice to perform an analysis over these parameters with the LCA practitioner. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting . The type of reporting (i.e., mandatory/recommended/optional) will also be discussed after this voting.

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the process improvements (e.g., waste management, upstream recycling processes, packaging, on-site electricity production, fluids and consumables, materials consumption) depending on the OEM strategic decisions.

This analysis could be relevant in the case of prospective LCA for example.

Q58 – Process improvements: energy consumption

Overview

Type of LCA concerned by the question: **Product LCA, Prospective LCA**.

Complete question submitted to voting

TranSensus LCA recommends the partners to perform an optional analysis on process improvements with respect to energy consumption.

Definition: This parameter covers process improvements and optimization regarding the energy consumption.

Example: A company decides to improve the insulation in buildings and production areas to reduce heat transfer and minimize the need for heating or cooling. Energy saving is the main result of this process improvement. Another example could be to use the heat lost in one process to heat another process in the factory, this way the overall energy consumption of the factory is reduced.

"Optional" means that TranSensus LCA leaves the choice to perform an analysis over these parameters with the LCA practitioner. The type of analysis (i.e., sensitivity/uncertainty/scenario analysis) to perform on each parameter will be defined after the voting. The type of reporting (i.e., mandatory/recommended/optional) will also be discussed after this voting.

Possible answers: **Agree/ Disagree/ No preference**

Background

Sensitivity on the energy consumption by processes along the supply chain.

This could be done for relevant processes leading to hotspots (e.g., process that are energy intensive).

4. Documentation to support third round of voting

4.1 Task 2.2: Goal & Scope

4.1.1 List of questions submitted to the 2nd voting by Task 2.2

Summary of TranSensus LCA propositions & voting options.

Table 4-1: List of questions submitted by task 2.2 to 3rd voting of September 2024

TranSensus LCA proposes for task T2.2 Goal & Scope:	Status
Functional unit	
• TranSensus LCA proposes updating the segments and the default values for lifetime distance driven in km for two-wheelers based on the SIBYL model by EMISIA:	*(1)*
• TranSensus LCA proposes updating the default values for lifetime distance driven in km for heavy-duty vehicles in the following way:	*(1)*
• TranSensus LCA proposes the following default values for lifetime in years: passenger cars=15, LCV=15, HDV/urban busses=13, HDV/Trucks=16, HDV/coaches=15 motorcycles = 25, mopeds = 21	*(1)*
OEM fleet LCA	
• TranSensus LCA proposes the following approach for the OEM fleet LCA for passenger cars...	*(1)*
• TranSensus LCA proposes the following approach for the OEM fleet LCA for heavy-duty vehicles...	*(1)*
• TranSensus LCA proposes the following approach for the OEM fleet LCA for two-wheelers...	*(1)*
Prospective LCA	
• TranSensus LCA proposes the following guidance regarding goal and scope definition for the prospective LCA...	*(1)*
Macro Fleet LCA	
• TranSensus LCA proposes the following guidance regarding goal and scope definition for the macro fleet LCA:	*(1)*

4.1.2 Functional unit

Default values for the functional unit are defined in this subtask based on expertise of the different partners and available sources.

Q1 – Default values for two-wheelers

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes updating the segments and the default values for lifetime distance driven in km for two-wheelers based on the SIBYL model by EMISIA:

	Motorcycles				Mopeds	
	2 stroke > 50cm^3	4 stroke < 250cm^3	4 stroke 250 – 750cm^3	4 stroke > 750cm^3	2 stroke < 50cm^3	4 stroke < 50cm^3
Lifetime in km	75.000				45.000	

Possible answers: Agree/ Disagree/ No preference

Background

In the last voting, default values based on an EU regulation were recommended. Based on the feedback received after the voting, these values were quite conservative. To be more consistent with the sources of default values for the other vehicle types (models and real-world data and not regulations), further data sources were explored and values based on the SIBYL model are suggested. The SIBYL model is based on the best available statistical data, such as new vehicle registrations, vehicle stock, average vehicle age, data from technical inspections and other relevant parameters. These values have been applied in numerous European studies (f.e., Study on new mobility patterns in European cities - Publications Office of the EU (europa.eu)) and are frequently referenced by policymakers. However, it is important to acknowledge the inherent uncertainty in these results, which can fluctuate significantly from year to year and between Member States.

Q2 – Default values for heavy-duty vehicles

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes updating the default values for lifetime distance driven in km for heavy-duty vehicles in the following way:

VECTO provides yearly driven distances for each segment in the EU legislation. These yearly-driven distances are scaled to lifetime driven distances by using scaling factors derived from an internal Scania/MAN study based on a real fleet monitoring. The default values for the lifetime assumption therefore are:

- For urban buses: Yearly distance from VECTO x 15
- For coaches: Yearly distance from VECTO x 18

Possible answers: Agree/ Disagree/ No preference

Background

In the last voting, the scaling factors were only differentiated for trucks and busses. Further analysis showed however, that different scaling factors for urban busses and coaches are necessary.

Q3 – Lifetime: default values for service life in years

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes the following default values for lifetime in years:

	Passenger cars	Light Commercial Vehicle (LCV)	Heavy Duty Vehicles (HDV)			Motorcycles	Mopeds
			Urban busses	Coaches	Trucks		
Lifetime in years	15	15	13	15	16	25	21

The values may need to be updated in the future to reflect the growing service lifetime of vehicles and also need to be updated should robust data specific for ZEV becomes available (where this is expected to be meaningfully different for equivalent vehicles). Other values can be used if these are documented and justified.

The values are derived as follows:

- Passenger cars and LCVs are based on analysis information from OEM datasets, average fleet ages and analysis of national licencing statistics from a range of major European countries. In the light of evidence on the growing vehicle fleet ages, the recommendation for an update of the lifetime in the future is made.

- HDV is based on real fleet monitoring by Scania and methodology for the estimation by Scania and MAN. The number of years before the lifetime driven distance is reached is varying between VECTO vehicle groups. For trucks 16 years is considered to be representative. For buses, it is suggested to differentiate between urban and coach bus groups where 13 years is valid for urban buses and 15 years for coaches.
- Two-wheelers (motorcycles and mopes) is based on the SIBYL model by EMISIA, such as the driven distance for two-wheelers.

Possible answers: Agree/ Disagree/ No preference

Background

The lifetime in years is needed to support calculations for two important areas: (1) the dynamic modelling of the use phase and EoL energy mix (i.e. where the electricity or hydrogen supply mix varies over time), and (2) the calculated impacts of maintenance and component replacements (e.g. where these may be determined by a time-based replacement schedule, rather than km activity).

Information on the expected actual service lifetime of current and new vehicles is difficult to determine precisely, particularly for heavy-duty vehicles, as there are relatively few studies that have analysed this specifically across a significantly representative and broad range of vehicles.

For passenger cars, estimates from TranSensus LCA OEMs based on data from their dealerships is around 10 years; however, these figures are not consistent with previous analyses of national vehicle licencing datasets (i.e. covering all registered vehicles), nor with broader industry statistics on the average AGE of vehicles in the fleet from ACEA (e.g. Figure IV-1), which is already higher than this[11].

[11] The average vehicle age accounts for numbers of vehicles of different ages across the fleet, so there are vehicles much newer and much older included. It does NOT represent the average service life therefore, which will be significantly higher than this, depending also on a range of other factors.

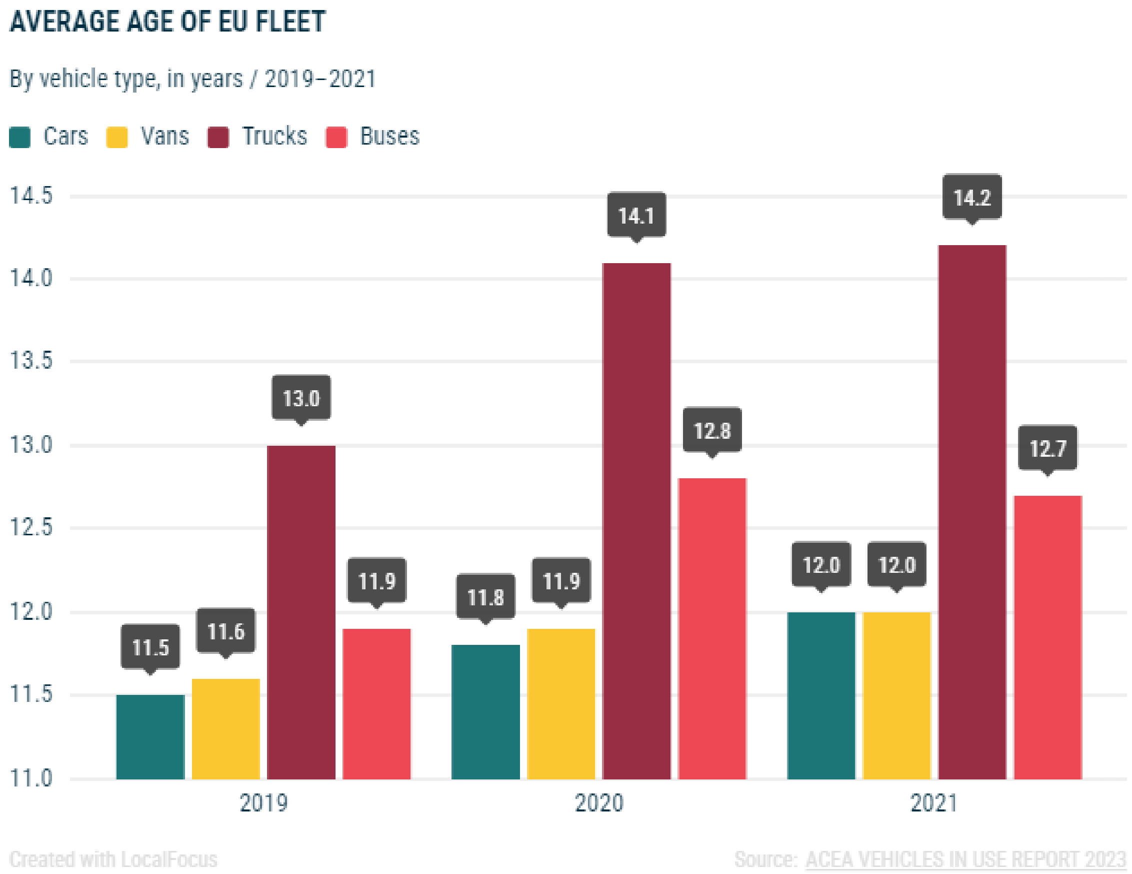


Figure 4-1 : ACEA statistics on average of the EU fleet by vehicle category for 2019-2021

Source: [Average age of the EU motor vehicle fleet, by vehicle type - ACEA - European Automobile Manufacturers' Association]

Previous analysis by Ricardo analysis of UK VDA licencing statistics (Ricardo-AEA, 2014a)[12], found the average service lifetime of cars in 2013 to be around 14-15 years (having risen from by around 1 year over the preceding 6 years). More recent analysis of UK licencing statistics by (Nguyen-Tien, Elliott, Strobl, & Zhang, 2024)[13] suggests the average retirement age could have reached over 18 years by 2024. This is also consistent with other analyses on end-of-life vehicles by (Oeko-Institut, 2018)[14] for ACEA, which concluded that the average age of ELVs was between 17 and 20 years. Similar figures have also been reported for other major European countries as referenced by ICCT in the UNECE IWG A-LCA – Sub-Group 4 (ICCT, 2024)[15],

[12] Ricardo, Improvements to the definition of lifetime mileage of light duty vehicles, A project by Ricardo-AEA for the European Commission, DG Climate Action, 2014.
[13] A novel way to estimate car longevity shows that electric vehicles' life mileage is increasing fast
[14] Öko Institute, https://www.oeko.de/fileadmin/oekodoc/ACEA-DecaBDE-final-report.pdf
[15] ICTT, A-LCA-SG4-10-04 SG4 Service life discussion 08 04 2024, UNECE IWG A-LCA SG4 10th Meeting, 2024

with data for Germany (17-18 yrs in 2016, from (BMUV, 2021)[16]), France (19 yrs in 2018, from (MTES, 2019)[17]), Poland (20 yrs in 2015, from (Oeko-Institut, 2018)[14]) and Portugal (20 yrs in 2015, from (Oeko-Institut, 2018)). These figures also correlate with other similar data available in non-European regions for the US and Brazil, as reported by ICCT.

Currently, there is no robust statistical data available on the service life of modern electric vehicle models, however a calendar lifetime for lithium ion batteries of 15-20 years has previously been reported (Ricardo, 2019)[18]. A more conservative estimate of the service life for ZEVs of 15 years compared to available information on average ELVs (end-of-life vehicles) might therefore be justified on this basis. Previous analysis by Ricardo (Ricardo-AEA, 2014a)[12] has also shown that the lifetimes of light commercial vehicles/vans is similar to those of passenger cars.

For heavy duty vehicles, no equivalent analysis of licencing statistics has been identified. However, Scania, together with MAN, have previously conducted an analysis of extensive data they hold on their in-use vehicles. This dataset is the base for the method (VECTO x factor) to get a representative lifetime driven distance for the FU. The same dataset has been used to investigate how many years in operation it takes for a vehicle in average to reach its lifetime driven distance. Since the results show a wide range depending on vehicle type (VECTO group), it is challenging to set one single default value representing all vehicle types. The suggestion is to use 16 years for trucks, 13 years for urban buses and 15 years for coaches, as these numbers can be considered reasonable for service life. For the trucks the service life assumption has a tilt towards representing long haul more than urban trucks. Long haul is the bulk in trucks sales and total travelled kilometers and transported tonnes.

If a dynamic approach for emission factors is to be used for HDV, it is important that a reasonable driven distance distribution (expected driven distance year 1, 2, 3 … X) is also applied. An even distribution assumption will significantly underestimate the GHG footprint for the use phase because the effect of high driven distances in later years will be multiplied with lower emission factors, especially for trucks. An even distribution of driven distance is not at all supported by real fleet monitoring data. Even if differences in total lifetime driven distance can be observed for different truck types, the distribution of driven distance over the years are quite uniform for all truck groups. For trucks the driven distance pattern can be described as a steady decline. For urban buses this driven distance decline comes several years later. Coaches shows a driven distance pattern as a mix of the urban bus and trucks´ pattern. Due to these fleet

[16] https://www.bmuv.de/download/jahresberichte-ueber-die-altfahrzeug-verwertungsquoten-in-deutschland/
[17] MTES, https://www.actu-environnement.com/media/pdf/news-34355-prime-vehicule-2018.pdf
[18] Ricardo, Circular Economy Perspectives for the Management of Batteries used in Electric Vehicles, Final Report for the European Commission, Joint Research Centre, 2019

monitoring insights the suggestion is to apply three types of default driven distance distributions, one for trucks and two for buses (urban and coach), see table below:

Default DD distribution																
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Truck	9,6%	9,1%	8,6%	8,2%	7,7%	7,3%	6,8%	6,3%	5,9%	5,4%	5,1%	4,7%	4,4%	4,0%	3,7%	3,2%
Urban bus	8,0%	8,0%	8,0%	8,0%	8,1%	8,1%	8,1%	8,1%	8,1%	7,6%	7,1%	6,6%	6,2%			
Coach	8,1%	8,0%	7,8%	7,6%	7,5%	7,3%	7,1%	7,0%	6,8%	6,4%	6,0%	5,7%	5,3%	4,9%	4,5%	

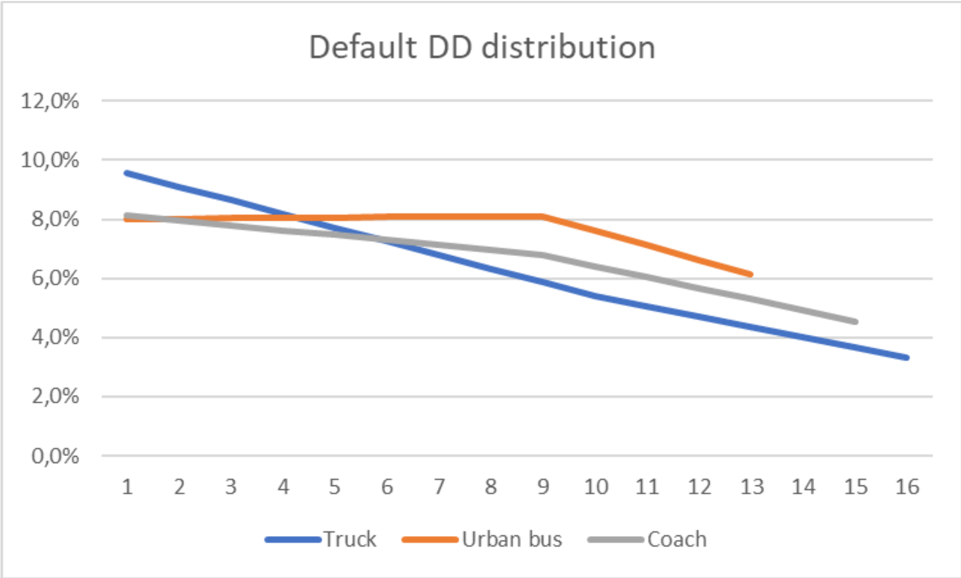


Figure 4-2 : Default driven distance distribution by vehicle type over 16 years

4.1.3 OEM fleet LCA

Q4 – Proposed approach for OEM fleet LCA Goal and Scope for passenger cars

Executive summary

Type of LCA concerned by the question: **OEM fleet-level LCA**

Complete question submitted to voting

> TransensusLCA proposes the following approach for the OEM fleet LCA (Coverage: Passenger cars, retrospective, Worldwide):

The OEM fleet LCA can be used by OEMs to report the lifecycle carbon emissions of their fleet in a specific year and geographical area. It can be tracked and reported in absolute CO_2 emissions (t CO_2) or in t CO_2/average vehicle. The OEM fleet LCA includes the production phase, the use phase and the End-of-Life phase. The use phase is modelled based on the fleet reporting to authorities, by using the consumption values for WLTP interpolation families. The fleet emissions are based on the sales numbers of the OEM in a specific year and market and include all powertrains in the fleet. The overall fleet emission value of the OEM, i.e. the tank-to-wheel (TTW) emissions, is thus an average of all the sold vehicles: BEVs with 0 gCO_2/km, ICEs with e.g. 103 gCO_2/km etc. The OEM fleet modelled is thus based on the sales numbers in a given year and geographic area accounting or the lifecycle emissions/environmental impacts within one reporting year. Thus, the approach described here does not account for a rolling stock. The well-to-tank (WTT) emissions are modelled with the time and market-specific fuel and electricity supply chain emission factors from secondary databases. The overall WTT value in t CO_2/average OEM vehicle being a weighted average of the vehicles' consumption values. The production and the EoL phase are modelled based on the available vehicle LCA data of an OEM (minimum criteria are proposed below). A detailed description, numerous modelling possibilities and background for an example of OEM fleet LCA reporting can be looked up in Neef et al. 2023[19].

Here, only minimum criteria for the OEM fleet LCA are defined. One refinement possibility is for the OEM to use their time and market specific in-house production emissions from their environmental information systems instead of e.g. outdated energy consumption averages from one single production site that is generically used for all vehicle LCAs included in the vehicle LCAs. OEMs can refine their modelling approach step-by-step with the most reliable data available to them.

Specific vehicle LCAs are not available for all vehicle models in the OEM fleet. Therefore, a minimum criterium to conduct an OEM fleet LCA is to have one vehicle LCA per powertrain-segment combination of the most sold model with respective equipment.

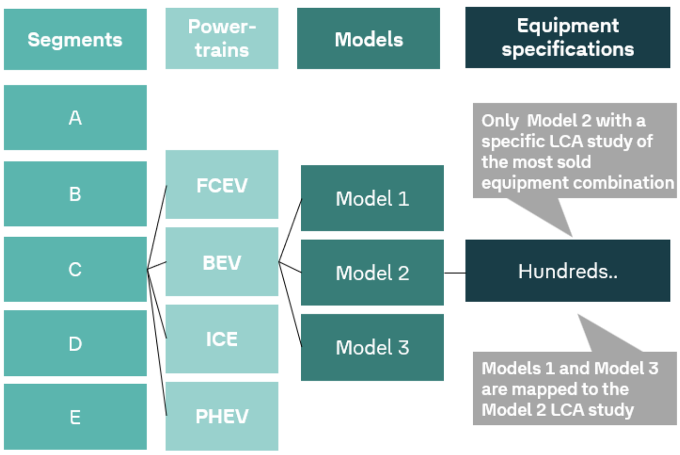


Figure 4-3 : Minimum criteria to conduct an OEM fleet LCA

[19] Neef *et al.*, Decarbonisation Index (DCI): an LCA-based key performance indicator for the automotive industry | The International Journal of Life Cycle Assessment (springer.com)

Vehicles without a specific LCA are mapped to existing ones with the following hierarchy. OEMs can adapt and expand this hierarchy basing on their fleet characteristics. The term “derivative” refers to different car body types produced for one model e.g. a sedan and a coupé version. The term “brand” refers to different car brands owned by one OEM Group, e.g. AUDI and PORSCHE are part of the VW Group and are therefore also part of the VW Group fleet level LCA.

i. Region - segment - powertrain - derivative - brand - model name - generation (model name specification)

ii. Region - segment - powertrain - derivative - brand - model name

iii. Region - segment - powertrain - derivative - brand

iv. Region - segment - powertrain - derivative

v. Region - segment - powertrain

Figure 4-4 : OEM’s hierarchy based on fleet characteristics

The modelling results for the production and EoL phases are then adjusted based on curb weight differences, as shown in an example below:

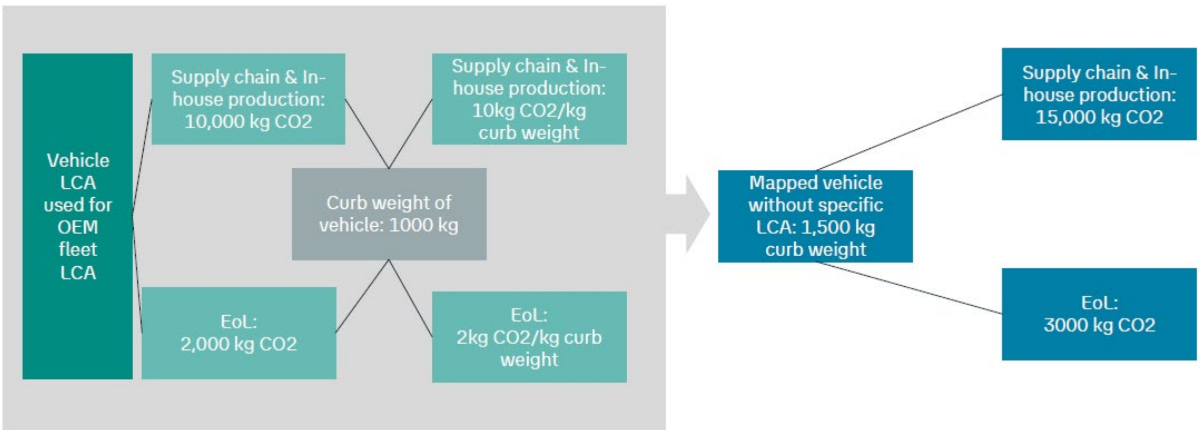


Figure 4-5 : Example of CO2eq calculation for the production and EoL phases based on curb weight differences

To sum it up, the following process is used to reach the OEM fleet level:

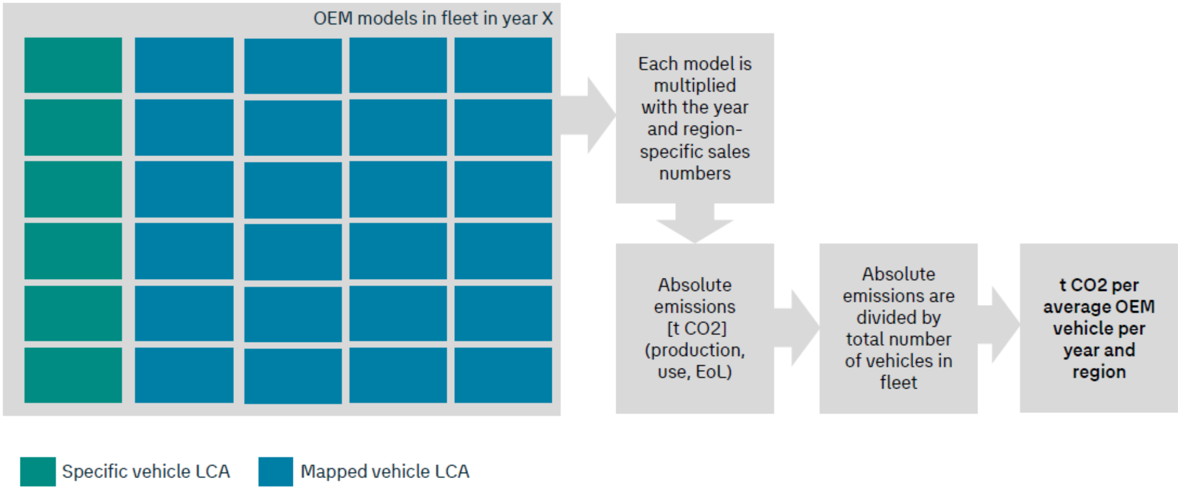


Figure 4-6 : Process to reach the OEM fleet level

Possible answers: Agree/ Disagree/ No preference

Background

The work builds on the definition of the OEM fleet LCA from the first voting.

LCA type	Definition	Reason	User of the LCA	Target audience
Retrospective vehicle LCA	A Product LCA aims to evaluate environmental impacts slightly before or after the start of production. A nearly finalised bill of materials of all parts is available to the OEM.	• Reporting + compliance • Calculation base for sustainability report • Identification of hot-spots • Target setting • Comparison between vehicles	• LCA experts within the R&D department / product department • External consulting firms	• Customers • Internal stakeholders (decision makers, product developers) • Auditors • Policy makers
Prospective vehicle LCA	A prospective LCA is conducted in the development stage and aims to estimate environmental impacts before the start of production (several years). The TRL is low (TRL<6) and the BOM is not completely defined.	• Research and development (eco-design) • Target setting • Identification of levers to reach targets • Comparison between vehicles	• R&D department • Purchase department (targeting supply chain) • External consulting firms • Researchers (universities and RTOs)	• Internal stakeholders (decision makers, strategy developers) • Policy makers (informative) • Scientific community
OEM fleet LCA	An OEM fleet LCA aims to evaluate the weighted environmental impact of a series of different products	• Corporate reporting of fleet emissions	Same as retrospective/prospective vehicle LCA	Managers for target tracking + general public (infos in Annual and

	introduced by a single manufacturer. Typically, it is based on an extrapolation of vehicle LCAs.	• Inform future decarbonisation strategy • Fleet portfolio optimisation		Sustainability report), CDP, sustainability ratings, financial ratings
Macro level fleet LCA	Macro level fleet LCA is conducted at the sub, national or international level to support economy-scale strategies. Fleet is typically generic, i.e. representative of a variety of manufacturers	• Inform policy decision making • Strategic & sustainability planning • Evaluation of consequences of large scale decisions	• Research institutes • Consultancies • Governmental agencies	• Policy makers • Scientific community • General public

Q5 – Proposed approach for OEM fleet LCA Goal and Scope for Heavy-Duty Vehicles

Executive summary

Type of LCA concerned by the question: **OEM fleet-level LCA**

Complete question submitted to voting

TranSensus LCA proposes to apply the same process for cradle-to-gate as for passenger cars.

The use phase emissions will be modelled with highly granular energy consumption data, e.g., fleet monitoring data on chassis number level. As a second option the energy consumption in use phase can be assessed with extrapolation of a limited set of representative energy consumption values. Adaptions can be made where necessary with sufficient documentation and justification.

Possible answers: Agree/ Disagree/ No preference

Q6 – Proposed approach for OEM fleet LCA Goal and Scope for Two-Wheelers

Executive summary

Type of LCA concerned by the question: **OEM fleet-level LCA**

Complete question submitted to voting

TranSensusLCA proposes to apply the same process as for passenger cars to Two-Wheelers. Adaptions can be made where necessary with sufficient documentation and justification.

Possible answers: Agree/ Disagree/ No preference

4.1.4 Prospective LCA

The subtask deals with necessary deviations in the goal and scope definition from the product LCA for the prospective LCA. TranSensusLCAs' aim for prospective LCA is to provide some guidance for practitioners instead of strict guidelines as for the product LCA.

Q7 – Proposed guidance

Executive summary

Type of LCA concerned by the question: **Prospective LCA**

Complete question submitted to voting

TranSensusLCA proposes the following guidance regarding goal and scope definition for the prospective LCA:

Goal definition

The nature of the prospective LCA is predictive, explorative or normative. The goals in the context of TranSensusLCA are defined in the LCA types (reasons for carrying out the study).

Technology coverage

The technology coverage in the prospective LCA is open for all new and emerging technologies as long as they meet the definition of the ZEV.

System boundary

The system boundary remains cradle-to-grave. If deemed relevant for the future market secondary functions such as second use, vehicle to grid or other processes can be included in the system boundary. This needs to be documented.

Cut-off rules and processes to include and exclude remain the same. If the system boundary is adapted, the processes to include and excluded can be revised. Any changes need to be justified and documented.

Functional unit

The functional unit stays the same as for the product LCA. The default values for the reference flow can be adapted following the general process for the product LCA. If additional functions are considered in the system which affect the lifetime of the vehicle (such as the usage of vehicle to grid), this needs to be reflected in the reference flow used. [How to deal with the multifunctionality from additional functions is described in the inventory]. The chosen reference flows need to be justified and documented.

Possible answers: Agree/ Disagree/ No preference

Background

The work builds on the definition of the prospective LCA from the first voting.

LCA type	Definition	Reason	User of the LCA	Target audience
Retrospective vehicle LCA	A Product LCA aims to evaluate environmental impacts slightly before or after the start of production. A nearly finalised bill of materials of all parts is available to the OEM.	• Reporting + compliance • Calculation base for sustainability report • Identification of hot-spots • Target setting • Comparison between vehicles	• LCA experts within the R&D department / product department • External consulting firms	• Customers [2] • Internal stakeholders (decision makers, product developers) • Auditors • Policy makers
Prospective vehicle LCA	A prospective LCA is conducted in the development stage and aims to estimate environmental impacts before the start of production (several years). The TRL is low (TRL<6) and the BOM is not completely defined.	• Research and development (eco-design) • Target setting • Identification of levers to reach targets • Comparison between vehicles	• R&D department • Purchase department (targeting supply chain) • External consulting firms • Researchers (universities and RTOs)	• Internal stakeholders (decision makers, strategy developers) • Policy makers (informative) • Scientific community
Manufacturer fleet LCA	A manufacturer fleet LCA aims to evaluate the weighted environmental impact of a series of different products introduced by a single manufacturer. Typically, it is based on an extrapolation of vehicle LCAs.	• Corporate reporting of fleet emissions • Inform future decarbonisation strategy • Fleet portfolio optimisation	Same as retrospective/prospective vehicle LCA	Managers for target tracking + general public (infos in Annual and Sustainability report), CDP, sustainability ratings, financial ratings
Macro level fleet LCA	Macro level fleet LCA is conducted at the sub, national or international level to support economy-scale strategies. Fleet is typically generic, i.e. representative of a variety of manufacturers	• Inform policy decision making • Strategic & sustainability planning • Evaluation of consequences of large scale decisions	• Research institutes • Consultancies • Governmental agencies	• Policy makers • Scientific community • General public

4.1.5 Macro fleet LCA

The subtask deals with necessary deviations in the goal and scope definition from the product LCA for the macro fleet LCA. TranSensusLCAs' aim for macro fleet LCA is to provide some guidance for practitioner instead of strict guidelines as for the product LCA.

Q8 – Recommended guidance

Executive summary

Type of LCA concerned by the question: **Macro-level fleet LCA**

Complete question submitted to voting

TranSensusLCA proposes the following guidance regarding goal and scope definition for the macro fleet LCA::

Goal definition

The goals in the context of TranSensusLCA are defined in the LCA types (reasons for carrying out the study).

Technology coverage

The technology coverage does not change.

System boundary

The system boundaries remain cradle-to-grave. The cut off rules remain the same. Processes regarding capital goods and charging stations/hydrogen refuelling stations should be included in the macro fleet LCA.

Functional unit

The functional unit needs to be adapted to reflect the aim of the study. One potential functional unit is:

- Operation of a total fleet of vehicles in a given region over a given time period (i.e. one year or full lifetime of the vehicle)

Possible answers: Agree/ Disagree/ No preference

Background

The work builds on the definition of the macro fleet LCA and the definition of the technology coverage from the first voting.

LCA type	Definition	Reason	User of the LCA	Target audience
Retrospective vehicle LCA	A Product LCA aims to evaluate environmental impacts slightly before or after the start of production. A nearly finalised bill of materials of all parts is available to the OEM.	• Reporting + compliance • Calculation base for sustainability report • Identification of hot-spots • Target setting • Comparison between vehicles	• LCA experts within the R&D department / product department • External consulting firms	• Customers • Internal stakeholders (decision makers, product developers) • Auditors • Policy makers
Prospective vehicle LCA	A prospective LCA is conducted in the development stage and aims to estimate environmental impacts before the start of production (several years). The TRL is low (TRL<6) and the BOM is not completely defined.	• Research and development (eco-design) • Target setting • Identification of levers to reach targets • Comparison between vehicles	• R&D department • Purchase department (targeting supply chain) • External consulting firms • Researchers (universities and RTOs)	• Internal stakeholders (decision makers, strategy developers) • Policy makers (informative) • Scientific community
Manufacturer fleet LCA	A manufacturer fleet LCA aims to evaluate the weighted environmental impact of a series of different products introduced by a single manufacturer. Typically, it is based on an extrapolation of vehicle LCAs.	• Corporate reporting of fleet emissions • Inform future decarbonisation strategy • Fleet portfolio optimisation	Same as retrospective/prospective vehicle LCA	Managers for target tracking + general public (infos in Annual and Sustainability report), CDP, sustainability ratings, financial ratings
Macro level fleet LCA	Macro level fleet LCA is conducted at the sub, national or international level to support economy-scale strategies. Fleet is typically generic, i.e. representative of a variety of manufacturers	• Inform policy decision making • Strategic & sustainability planning • Evaluation of consequences of large scale decisions	• Research institutes • Consultancies • Governmental agencies	• Policy makers • Scientific community • General public

Technology coverage

A zero-emission vehicle (ZEV) is defined as a vehicle without any GHG tailpipe emissions. This includes 5 powertrains and 6 vehicle types.

List of powertrains:

- BEV – Battery electric vehicles

- FCEV – Fuel cell electric vehicles
- FC-REEV – Fuel cell range extended vehicles
- BEV-ERS – Battery electric vehicles with dynamic charging operation on Electric Road Systems (e. g. includes BCEV = battery catenary electric vehicles, as well as vehicles operating on dynamic wireless/inductive charging, or rail conductive charging)
- H_2 ICE – Hydrogen fuelled internal combustions engine vehicle

List of vehicle types:

- Passenger car
- Light commercial vehicle/ van
- Lorry/ truck
- Urban bus
- Coach
- Motorcycle/ Moped

4.2 Task 2.3: Inventory

4.2.1 List of questions submitted to the 2nd voting by Task 2.3

Summary of TranSensus LCA propositions & voting options.

Table 4-2: List of questions submitted by task 2.3 to 3rd voting of September 2024

TranSensus LCA proposes for task T2.3 Inventory:	Status
Electricity modelling	
• Time period matching for electricity consumption processes for all phases	*(1)*
• Electricity consumption modelling approach for the production phase (decision tree)	*(1)*
• Safeguards for the use of Energy Attribute Certificate (EAC) related to additionality	*(2))*
• Safeguards for the use of Energy Attribute Certificate (EAC) related to a production/consumption physical link	*(2)*
• Safeguards for the use of Energy Attribute Certificate (EAC) related to production/consumption time synchronization	*(1)*
• Other safeguards for the use of Energy Attribute Certificate (EAC)	*(1)*
• Safeguards for the use of Energy Attribute Certificate (EAC) related to the excess of production that is not consumed during the production phase	*(1)*
• Guidance for residual mixes modelling for the product production phase	*(1)*
• Guidance for the use phase electricity consumption modelling	*(1)*

• Guidance for on-site electricity production modelling for the production phase	*(1)*
• Guidance for on-site electricity production modelling for the use and EoL phases	*(1)*
• General guidance for electricity modelling for Fleet level LCA	*(1)*
• Guidance for on-site electricity production modelling for Fleet level LCA for the use phase	*(1)*
• Guidance for electricity modelling for the production, use and EoL phases in Prospective LCA	*(1)*
• General guidance for on-site electricity production modelling for Prospective LCA	*(1)*
Multifunctionality	
• Do you agree with this final version of multifunctionality hierarchy?	*(1)*
• Do you agree with the EoL approach as it is now?	*(1)*
• Do you agree with prospective LCA recommendations below?	*(1)*
• Do you agree with fleet LCA recommendations?	*(1)*
Data collection and type	
• Energy consumption - subquestion 1: Realword emission factor	*(1)*
• Energy consumption - subquestion 2: Fuel cell degradation	*(1)*
• Non-exhaust emissions: Proposed methodology for estimating hydrogen leakage.	*(1)*
• Proposed approach for modelling hydrogen supply mix during the vehicle use phase	*(1)*
• Proposed approach for calculating impacts from maintenance, wear and consumables	*(1)*

4.2.2 Electricity modelling

General guidance for electricity modelling for all phases

Q9 – Guidance for time period matching for electricity consumption processes

Executive summary

Type of LCA concerned by the question: **Product LCA, Fleet level LCA, Prospective LCA**

Complete question submitted to voting

> When performing a Product LCA or a Fleet level LCA or a Prospective LCA, TranSensus LCA proposes that the consumption electricity processes / datasets that are used for the life cycle phases of the subject under study correspond as much as possible to the time period of the life cycle phases of the subject under study as defined in the goal and scope of the study.

Possible answers: Agree/ Disagree/ No preference

Background

LCA databases datasets for electricity consumption may be related to different time periods.

Proposed approach/possible options description and justification

This recommendation relies on basic LCA practice.

Production phase electricity modelling method

There are two main approaches to tackle electricity consumption modelling within a product LCA production phase: the location-based approach and the market-based approach.

The location-based electricity modelling approach is based on the physical average consumption mix of a country or region electricity-consuming facilities. The geographical scope of the electrical mixes to be considered should be sub-national (to be as precise as possible), national (i.e., country-specific electricity mix), or, if not possible, supra-national (i.e., EU grid mix).

The market-based electricity modelling approach uses contractual agreements, guaranteeing a unique claim for electricity from specific energy sources, such as Renewable Energy Sources, to model electricity consumption. For processes for which a contractual agreement has been concluded, the consumed electricity will be modelled according to the mix that is described in the agreement. For processes for which no contractual agreement has been concluded, the consumed electricity will be modelled using the sub-national residual mix (if available, to be as precise as possible), the national residual mix (i.e., country-specific), or, if not possible, a supra-national residual mix (i.e., EU residual mix). A residual electricity mix reflects the sources of the electricity supply that are not covered via an Energy Attribute Certificate (EAC) tracking system. In the absence of a residual mix, as a conservative option, residual mixes can be modelled as national mixes from which all the renewable production (hydro, wind, PV and biomass) and nuclear production has been taken out.

The location-based and market-based approaches are so different that they cannot be used simultaneously within one LCA if there is to be a coherence between the emissions reported in the GHG inventories and the emissions to the atmosphere: it is crucial to be consistent in the modelling approach to avoid double counting the renewable energy generation and accurately represent environmental impact of the product. Double counting will arise when, within a given LCA, both approaches are mixed (i.e. national grid mixes are used along with mixes associated with contractual instruments). In such a case, the share of renewable energy power plants is over-estimated because it is double counted. And as a consequence, the share of fossil fuels power plants is under-estimated (see a fictitious example in the following section).

To be noted: When used systematically, for all consumers in a given bidding zone, the correct modelling of EAC-backed contracts combined with residual grid mixes, avoids double-counting. Similarly, when the location-based approach is used systematically, for all consumers in a given bidding zone, then there is no risk of double counting. However, TranSensus cannot force every LCA practitioner in a given bidding zone to use only one electricity modelling approach.

Double counting will also arise when some companies, within or outside TranSensus, use the location-based approach while others use the market-based approach.

A third and mixed modelling approach is proposed here, based on OEMs experience. It relies on the use of the available location-based production processes in the databases as generic default while being able to use (market-based) specific electricity sources from suppliers or within the OEM's factories. It makes possible for OEMs to track their decarbonisation process while being transparent about the insufficient data availability and risk of double counting.

All 3 approaches have limitations and merits associated with those (see Annex for a table of PROs and CONs for all 3 approaches).

In conclusion, in order to satisfy both the entities that would like to use the location-based approach and those that would prefer to use the market-based one, and to propose a solution for companies that have difficulties implementing a 100% market-based approach, the electricity modelling subtask members agreed to propose a decision tree that would allow to choose between the following 3 options: a location-based approach, a 100% market-based approach and a mixed-method approach.

It is to be noted that evolution will probably occur both in terms of better traceability of electricity and modelling and use of residual grid mixes, which could bring a solution for most cons listed for the three methods above (see Annex). Once these evolutions are achieved and commonly accepted, TranSensus LCA rules for electricity modelling regarding the market-based approach could be re-evaluated.

Q10 – Electricity consumption modelling approach for the production phase

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

When performing a **Product LCA**, TranSensus LCA proposes using the following decision tree for the Product LCA **production phase** electricity consumption modelling:

- Does the entity have Energy Attribute Certificates (EACs) and want to use it for a Product LCA production phase electricity consumption modelling?
    - If No, then use a location-based approach, in which every electricity consumption process is modelled using either a sub-national consumption grid mix (i.e. for the USA and China, for more accuracy) or a national consumption grid mix (i.e., country-specific),

or, if both national and sub-national consumption grid mixes are not available, a supra-national consumption grid mix (i.e., EU grid mix).

- If Yes
  - Does the entity have enough data (i.e. secondary databases using residual consumption mixes for every process in the upstream value chain of the product) to complete a 100% marked-based approach?
  - If Yes, then use a 100% marked-based approach, in which every electricity consumption process is modelled using either processes that reflect the electricity mix purchased via specific contractual instruments related to the considered process and including losses during transmission and distribution of the purchased electricity. Or, if no contract exist for the given process, a residual consumption mix related to it, which can be derived either at a national level (i.e., country-specific residual consumption mix related to the process) or at a sub-national level (i.e. for the USA and China, for more accuracy) or, if both national and sub-national residual consumption mixes are not available, at a supra-national level (i.e. EU residual consumption mix).
  - To be noted: TranSensus LCA recommends that the contractual instruments that are used comply with some specific safeguards (see following questions).
  - To be noted: market-based residual consumption mixes and production processes using them are mostly not yet readily available for OEM global supply chains, and in practice it is not feasible (time consuming, data availability) for the OEMs to use market-based residual consumption mixes throughout their entire value chain, which is required by a 100% market-based approach, for electricity consumption that is not covered by an Energy Attribute Certificate (EAC).
  - If No, then use the following mixed-method approach that is currently widely practiced in the OEM industry to model production phase impacts: use the available location-based production processes in the databases as generic default while being able to use (market-based) specific electricity sources from suppliers or within the OEM's factories.
  - To be noted: TranSensus LCA recommends that the contractual instruments that are used comply with some specific safeguards (see following questions).

Whatever the approach chosen for modelling the Electricity consumption during the production phase, it shall be clearly justified and documented openly (type of approach, electricity mixes used for foreground and background processes). This allows for comparisons of Product LCA results using the same approach and the countries / regions where double counting of renewable power plant emissions occur (i.e. in countries / regions where no residual consumption mixes are used) are transparent to the recipients of the LCA reports."

Possible answers: Agree/ Disagree/ No preference

Background

Definitions

An **Energy Attribute Certificate (EAC)** is the official documentation to prove renewable energy consumption. Each EAC represents proof that 1 MWh of renewable energy has been produced and added to the grid.

Global EAC standards for renewable claims are primarily **Guarantees of Origin (GO)** in Europe, **Renewable Energy Certificates (RECs)** in North America and **International RECs (I-RECs)** in a growing number of countries in Asia, Africa, the Middle East and Latin America.

Attributes for EACs

Each MWh of produced electricity has its unique characteristics associated with it, such as:

- time and date of production
- location of the generation device
- generation technology (eg. wind turbine, hydropower plant etc.)
- age of a production device

These characteristics are called attributes, and the EAC market offers a tool for trading these attributes.

At its most basic level, the EAC system works as follows:

- a producer of (renewable) electricity generates 1 unit of electricity (generally this is 1 megawatt-hour (MWh))
- for each MWh of energy they inject into the grid the producer requests an EAC from the *issuer*[20]; the EAC, which is an electronic certificate, contains factual information *attributes*[21] about the specific unit of electricity such as the technology used to generate the power and where it is located.
- the EAC can be traded between market participants through *registries*[22] with the ultimate claim of selling it to a consumer (also known as an end-user).

[20] https://recs.org/public-information/#Issuers
[21] https://recs.org/public-information/#Trading attributes
[22] https://recs.org/public-information/#Registries

- The end-user or their representative consumes the EAC by cancelling it so that it cannot be used again – without cancellation, there is a risk that one EAC can be used twice (known as double counting)
- the consumer can then *claim*[23] to have consumed the unit of energy that was represented by the EAC.
- The EAC market is separate to the electricity market. Even though each EAC is associated with a specific unit of electricity, EAC markets are not about allocating the electricity but are about allocating its *attributes*[21]. Most often these are "renewable attributes" so that the electricity consumer can claim the consumption of renewable power.

Energy attribute certificate systems prevent the double sale or consumption of the attributes of a particular unit of electricity. *All* consumption of energy attributes should have the associated EAC cancelled, as there are no other means to ensure the prevention of double issuance or claiming.

Source: RECS[24]

Bundled versus Unbundled GO

A GO can be sold either together with the underlying energy, or separately from it. When the GO and the underlying energy are traded in a contract together, it is described as "bundled." When the GO and underlying energy are traded in separate contracts, it is described as "unbundled." In either case, the basic principles of buying renewable electricity through the GO system apply.

Source: Guarantees of Origin and Corporate Procurement Options[25]. RE-Source Platform, October 2021

A **residual electricity mix** is defined as a mix which is not documented via an Energy Attribute Certificate (EAC) tracking system.

The Association of Issuing Bodies (AIB - Home | AIB (aib-net.org)[26]) develops, uses and promotes a European, harmonised and standardised system of energy certification for all energy carriers: the European Energy Certificate System - "EECS".

The AIB is issuing residual mixes for most European countries (cf. figure below).

[23] https://recs.org/public-information/#Claiming the use of renewable energy
[24] https://recs.org/public-information/
[25] https://resource-platform.eu/wp-content/uploads/Guarantees-of-Origin-and-Corporate-Procurement-Options.pdf
[26] https://www.aib-net.org/

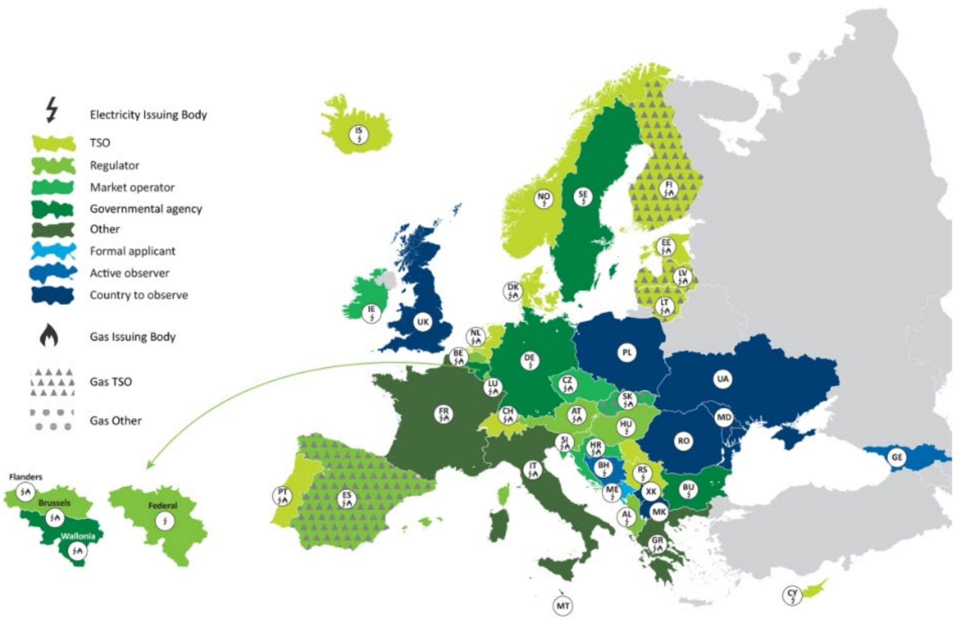


Figure 4-7 : Association of Issuing Bodies member countries

However, it is not uncommon when more than one EAC systems exist in same geographical region no residual electricity mixture is defined. In order to facilitate feasibility of all modelling approaches a residual mix modelling approach is proposed (cf. question on residual mixes modelling for the product LCA production phase).

A **Power Purchase Agreement (PPA)**, or electricity power agreement, is a long-term contract between an electricity generator and a customer, usually a utility, government, or company. PPAs may last anywhere between 5 and 20 years, during which time the power purchaser buys energy at a pre-negotiated price.

Whether the electricity producing plant is located on the site of the customer (on-site PPA model) or connected to the customer site via a purpose-built direct or 'private' wire (private-wire PPA model), the electricity generated by the renewable energy installation is sold and consumed by the customer, and power surplus is fed to the grid. GOs are not generated for the power that is consumed by the customer behind the meter. Surplus power that is exported to the grid, and metered, would receive a GO certificate to prove that the power comes from a renewable energy source.

The off-site PPA models, whether Physical (i.e. with a physical transmission of electricity via the electricity grid) or Financial (i.e. with no physical transmission of power between the producer and the customer which allows the PPA to be signed across national borders), involves the signature of a contract or a series of contracts between a producer and a consumer. GOs are bundled (linked) with the power sold and transmitted from the installation owner to the consumer as part of the contract(s).

Source: Introduction to Corporate Sourcing of Renewable Electricity in Europe. RE-Source. January 2020.RE-Source-introduction-to-corporate-sourcing.pdf (windeurope.org)[27]

To be noted: GOs bundled with physical PPAs are typical of virtuous additivity: customer is responsible, by a long-term contractual commitment, of the building of a new low carbon facility. Although electricity is delivered through the grid, contract is a specific arrangement between producer and customer, optimizing production on consumption needs, and is very similar to a private line PPA.

Main findings and learnings from WP1

The debate about the choice of a market based or location-based modelling is still an open debate. In practice, D1.1 notes that in general, the most popular choices are the national or regional (i.e., Europe) average electricity mixes based on secondary data from a LCI database. It also mentions that the GHG protocol Scope 2 guidance requires for corporations to report their scope 2 GHG emissions for both location-based approach and market-based one approach. Making it a so-called dual reporting and that guidance such as the Catena-X, PEFCR-Batteries, and CFB-EV suggest using emission factors appropriate for renewable energy consumed based on their source, by describing the EAC-type contractual instruments that can be invoked, such as RECs and GOs.

D1.1 mentions the difference which is made between bundled and unbundled RECs. Bundled RECs allow economic operators to claim “additionality” as a means of showcasing direct investment into new renewable energy generation plants and its added decarbonization contribution to the overall grid.

This bundled property is also identified in D1.2, as a key differentiating factor. It also warns against the risk of greenwashing associated with GOs and mentions that some advocate stricter requirements to strengthen the credibility of renewable energy claims based on Guarantees of Origin (GOs), including stricter time consistency criteria between energy generation and use and a stricter geographic link consistency criterion between energy generation and use.

D1.2 also reminds some pros and cons of both the market-based and the location-based approaches:

[27] https://proceedings.windeurope.org/

Location based pros / market-based cons	Location based cons / market-based pros
"real-life" approach and pushes towards lower carbon electricity contents at country/regional levels.	Location based does not account for the capacity of some suppliers that are located in contexts of "bad" electricity mixes to afford purchasing renewable energy.
When choosing a market-based approach, there is the need to carefully address the risk of double counting…	… and this is why residual mixes must be evaluated and systematically used when no specific contracts can be invoked.
Not all countries outside the EU and the US have such contractual instruments as RECs or GOs…	… but this is currently being pursued in China, UK and South Korea
There is a need to overcome potential "greenwashing" accusations when using a market-based approach. For instance: unbundled RECs can lead to a simple re-shuffling of the pre-existing GHG emission quotas.	

Proposed approach/possible options description and justification

Electricity basics

At every moment, electricity consumption and production should be at an equilibrium through the grid, otherwise the grid would collapse. Electricity supply from the grid is the result of a complex collaboration of various actors to ensure the balance between production and consumption, subject to strong physical constraints.

The electricity Transmission and Distribution systems act in a way that the physical consumption cannot be traced back to a production: the physical reality of the electric grid means that electrons cannot be traced. It is not possible to trace the electricity consumed by an entity back to any particular grid-connected power plant. Therefore, the physical tracing of electrons is not performed in existing grids.

The electricity travels on average short distances (several hundreds of km).

Main pros and cons related to the location-based approach (more details are given in the Annex)

The market-based approach amounts to determining rules to allocate energy production from a specific site to a specific consumer. Because electrons are not traceable in the network, and therefore, for every process, electricity consumption cannot be differentiated, the allocation of electrons is necessarily arbitrary. LCA reports should reflect the environmental impacts caused by a product as accurately as possible, and in this respect stay as close as possible to real GHG emissions, when considering its impacts on climate change. The market-based approach presents the risk of decoupling GHG inventory emissions from real GHG emissions to the atmosphere (because a product carbon footprint can be based on somebody else's emissions). The most accurate way to assess the environmental footprint of consumed electricity is to calculate it through a geographical average.

Associated concerns from OEMs with location-based approach are the following:

- Definition of location boundary: There are strong regional differences irrespective of the criteria for defining location. For example, if a country or continent is defined as geographic boundary there are cases where energy mix varies vastly within some geographic boundaries. An ideal solution would be to define dynamic location boundary based on the congestion zones. However, this is not possible in the current energy market.
- It is not possible to reduce electricity-related emissions via the active acquisition of electricity from specific energy sources, such as fossil-free energy.
- Potential time disconnection: electricity datasets refer to past electricity production that is used for present electricity consumption.
- Secondary datasets used in the modelling of LCAs are compiled using location-based consumption mixes, but depending on the source of data these mixes can be referenced to different years or regions. E.g. datasets from associations such as Worldsteel or PlasticsEurope are mostly not updated yearly and not available for every region. If emission factors with different temporal and spatial resolutions are permitted, an accounting system among the different electricity mix resolutions is necessary, in order to avoid double counting. [Holzapfel et.al., 2023]

Associated concerns from utilities with location-based approaches are the following:

- The location-based approach has been criticized for its lack of precision and for its lack of incentive for companies. These two limits can be mitigated first by using emission factors at a finer temporal grid, which will be practically easier to implement for the location-based approach than for the residual mix of the market-based approach, and second by acknowledging that it is not the role of GHG inventories to incentivize, but to give an accurate picture of the physical emissions of a company.

For the time being, the Supplementing Regulation (EU) 2023/1542 of the European Parliament and of the Council by establishing the methodology for the calculation and verification of the carbon footprint of electric vehicle batteries advocates for the use of the location-based approach (the text is not finalized yet):

“The PEF method contains rules for accounting for electricity from the grid, including the use of contractual instruments to demonstrate that a particular electricity product was used. It stipulates that such contractual instruments may only be used if it is ensured, inter alia, that they are the only instrument that carries the environmental attribute claim associated with the quantity of electricity generated. However, in many jurisdictions outside the Union currently this cannot be ensured, entailing a risk of not well-substantiated environmental claims. Therefore, it is appropriate not to allow for the use of contractual instruments in the carbon footprint methodology for batteries."

Main pros and cons related to the market-based approach (more details are given in the Annex)

The market-based approach is designed to allow an energy consumer to declare it has made the choice of supporting the production of a renewable or low-carbon source by creating a direct link to a producer. This is explicit in the Renewable Energy Directive (RED II): « Guarantees of origin issued for the purposes of this Directive have the sole function of showing to a final customer that a given share or quantity of energy was produced from renewable sources. »

Associated concerns from OEMs with market-based approaches are the following:

- There is a large number of EAC tracking systems (e.g. RECs (US, Canada), GoOs (Europe), GECCs (China), iRECs (Global)) with different methodological requirements, e.g. regarding different criterion for allocation of EAC to location or time expiry.
- Most life cycle inventory (LCI) datasets in common LCA databases include location-based electricity mixes. Using these LCI datasets in combination with market-based electricity accounting, for production sites within the same electricity market, leads to double counting of electricity from specific sources, such as renewable energy, in LCAs. [Holzapfel et.al., 2024]
- Potential disconnection between sourcing of EACs in location and time: geographical disconnection can be solved by defining safeguards for the use of EACs; Time disconnection can be solved by a more precise tracking of renewable electricity production.

Associated concerns from academics with market-based approaches are cited in a bibliographical section.

Associated concerns from utilities with market-based approaches are the following:

- In its current form, the market-based approach for scope 2 has not proved efficient in driving real-world decarbonization.
- Contractual instruments used in the context of the Scope 2 market-based method have proved inefficient in that they are very unlikely to lead to additional renewable electricity generation, because their price is currently too low to provide additionality.
- Contractual instruments do not reflect the real cost of technology. This low price doesn't incentivize lowering energy consumption and creates a competitive bias which can point towards the wrong decarbonization solution: if a company A invests in a heat pump to

decarbonize its scope 2 while an identical company B decides to uses natural gas combined with a GO, that company B will pay less (because the GOs currently do not reflect the real price of biogas) and will be perceived greener via the GHG inventory prism, although the first solution makes more sense from an economic and a climate point of view.

- Companies have many levers to act on all three scopes, including scope 2 with permanent measures that do not depend on market laws (such as energy efficiency, change of technology / process, etc.) and drive the transition, without having to rely on contractual instruments.
- Regarding electricity GOs, although the energy price crisis and the low hydraulic production has led to an increase in price, it is expected that prices will decrease by 2025-2026 due to the expected development of the renewable electricity park necessary for States to meet their goals.
- Furthermore, the generalization of contractual instruments will fragment the electricity market, which could lead to deoptimization of the system.

<u>To decarbonize or not to decarbonize, that is the question.</u>

Both the location-based and the market-based approach are facing accusations of not decarbonizing, either the electricity from the grid or the product itself:

Location based approach	**Market-based approach**
By using national or regional electricity mixes, the location-based approach is accused of not helping to decarbonize the national or regional electricity grid mixes because it does not incentivize investments in renewables.	By using GOs with no safeguards, the market-based approach is accused of not decarbonizing the national / regional electricity grid mixes because the overall emissions of a country / region would be the same with and without the use of GOs.
	The market-based approach is accused of not decarbonizing products, but of showing decarbonization for given products while attributing all the "bad" emissions to other products for which there is little or no reporting that is done.

There is no clear evidence of a tangible impact of mainstream market-based approaches as a driver of decarbonization of the electric grid. Multiple studies have shown that in current state contractual instruments used in the context of the Scope 2 market-based method have proved inefficient in that they are very unlikely to lead to additional renewable electricity generation, whose price is currently too low to provide additionality. The lack of impact stems from the low prices due in part to the flexibility of current spatial, temporal and additionality criteria: GOs from old renewable installations such as Norwegian dams can be used to decarbonate an installation in southern Europe during a winter night. Furthermore, [Bjørn et al., 2022] have shown that GOs represent a major part of mitigation efforts made by companies validated by SBTi (Science Based Target initiative). Because of their embedded additionality, PPAs can have a positive impact on the grid decarbonization. Nevertheless, the main contribution to additional generation has always been State subsidies. The need for privately funded renewable generation, when they exist, can be challenged, considering that the States are responsible for reaching decarbonization targets and would therefore most likely have funded the additional generation had they had to.

Double counting

There is no risk of double counting with a systematic and consistent approach, using either a location-based electricity modelling or a 100% market-based electricity modelling.

Double counting arises when within a given value chain, some electricity consumptions are modelled using EAC while others are modelled using a national or regional electricity mix, as shown in figure 3 of the article from [Holzapfel et al., 2023].

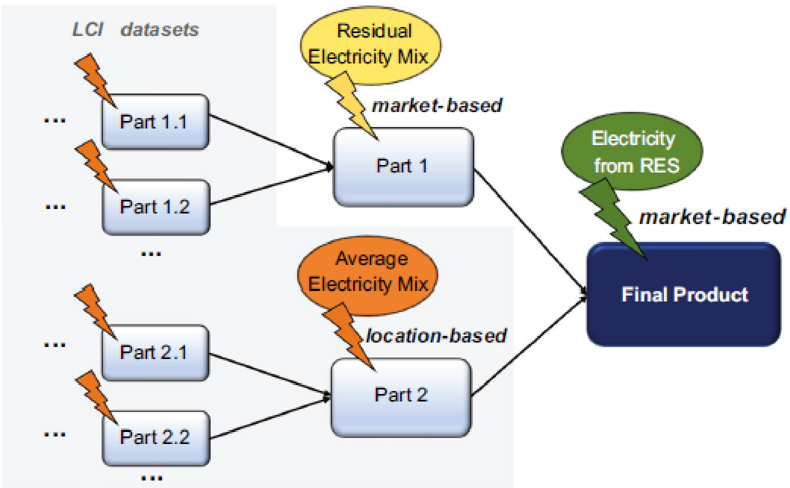


Fig. 3 Overview of simplified example illustrating the parallel use of location- and market-based electricity mixes in one LCA and GHG accounting, when including both market-based electricity and average LCI datasets with location-based electricity inputs

With the choice of the market-based method, the risk of double counting can be limited to zero if residual mixes are systematically used when no information is available about the origin of the electricity consumed.

Let’s illustrate the issue of double counting through the example of a country, with a total production of 125 MWh and with only 2 electricity consumers, one using EAC while the other one is using the national grid mix, which is 20% renewable and 80% fossil:

	Consumer A	Consumer B
National production	125 MWh	
National mix composition	25 MWh from renewables + 100 MWh from fossil = 20% renewable + 80% fossil	

Energy consumed	25 MWh from EAC	100 MWh from the grid • 20 MWh from renewables • 80 MWh from fossil
Total accounted energy mix	45 MWh from renewables + 80 MWh from fossil 36% renewable + 64% fossil	
Double counted energy	25 MWh from renewables is "consumed" by A and B!	

To avoid double counting Consumer B should use its national residual mix (100 MWh fossil) and not its national average mix (20 MWh from renewables + 80 MWh from fossil).

To be noted: the same mechanism will occur when within a given LCA a process uses an EAC while another process, occurring in the same country, uses the national grid mix (just replace consumer A by process A and consumer B by process B in the above example).

This mechanism is illustrated by Peter Holzapfel, Vanessa Bach and Matthias Finkbeiner in the figure 2 of their article (situation highlighted with a red dotted line):

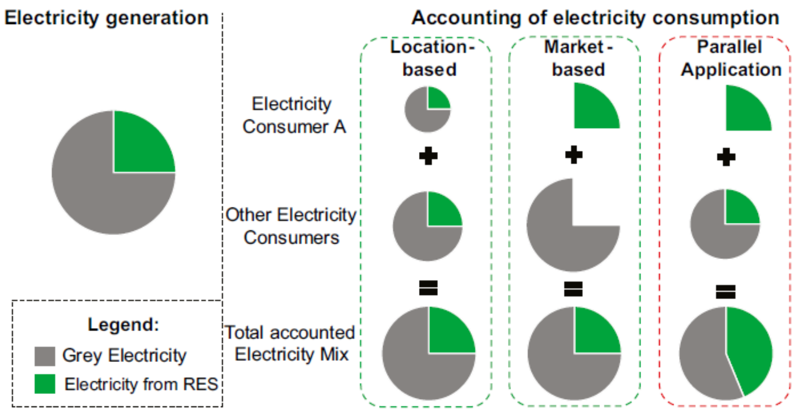


Fig. 2 Illustration of challenges of double counting electricity from specific energy sources due to a parallel application of location-based and market-based electricity accounting method, based on a hypothetical region

<u>Resource shuffling</u>

A definition of resource shuffling is proposed by the European Roundtable on Climate Change and Sustainable Transition (ERCST - [2021120914_P2R4-v11.pdf (ercst.org)](2021120914_P2R4-v11.pdf)): Resource shuffling occurs when clean foreign production is re-routed toward export to the EU, and dirty foreign production is sold elsewhere, leaving foreign production patterns ultimately unchanged.

Why it is a risk for now:

- There is a large difference between the carbon intensity of high carbon and low carbon electricity (factor 10),

- It is very easy to switch from high carbon to low carbon (just purchase the right certificates or PPA without any physical change in the factory nor in the supply chain),
- Only a small fraction of any country electricity production will be dedicated to products subject to EU regulation, therefore it is very easy to direct the clean electricity towards this product production and dirty electricity to other consumers not subject to similar regulation, without any effect on the total country emissions.
- The price of these certificates is around 5€/MWh, this indirectly shows that their effect is limited. Indeed, if these certificates were inducing real efforts towards more low-carbon electricity production instead of only inducing resource shuffling, they would be more expensive.

The components that are mostly at risk are the electricity and electricity-intensive materials such as aluminium and steel.

As resource shuffling is a way to circumvent carbon regulations that is inherently linked to the use of specific emission values, one solution may be to enforce the use of generic national or regional consumption mixes.

Impacts of the generalization of contractual instruments on the electricity grid

The generalization of contractual instruments will fragment the electricity market, which could lead to deoptimization of the system. Nonsensical situations could arise, typically, if the consumer has no need for the electricity for any given reason (for example breakdown of a factory), does this mean the renewable production should stop, or be stored for the specific consumer site? The production asset could be forced to accommodate the needs of the client and not those of the system in its production schedule, which may endanger the equilibrium of the grid.

Contractual instruments evolution

In the longer term, other instruments may allow a higher degree of confidence, such as PPA contracts, however, under the following conditions:

- Seller and buyer identities are disclosed,
- The quantity of electricity and the contract duration are disclosed,
- Any type of electricity generator is allowed, as long as it is identified together with the associated carbon content,
- A mechanism ensures that the electricity is consumed by the factory during the same 1h timestep as it is produced by the generator (temporal consistency),
- The factory and the generator are located in the same bidding zone (geographical consistency)

However, such contracts do not cancel the risk of resource shuffling.

Extract from bibliography

- From: [Brander et.al., 2018]

"It is worth emphasizing that these contractual arrangements do not entail any changes to how electricity from a renewable facility is physically delivered or consumed. The only thing transacted is a claimed right to use the emission factor associated with a certain amount of generation from a particular renewable energy facility."

"The market-based accounting method fails to provide accurate or relevant information in GHG reports."

- From: [Bjørn et.al., 2022]

"We also distinguish here between RECs and power purchase agreements (PPAs), which represent a long-term commitment by a company to purchase power from a particular renewable energy project. Although empirical evidence is still needed, we have adopted here the common assumption that PPAs do lead to additional renewable energy production and real emission reductions, as the long-term power price de-risks new projects and allows access to project finance (references 14,15,17,18)."

"When removing the emission reductions claimed through RECs, companies' combined 2015–2019 scope 2 emission trajectories are no longer aligned with the 1.5 °C goal, and only barely with the well below 2 °C goal of the Paris Agreement. If this trend continues, 42% of committed scope 2 emission reductions will not result in real-world mitigation."

- From: [Brander et.al., 2023]

"The use of market-based accounting undermines the accuracy of GHG inventories (Brander et al. 2018b; Monyei and Jenkins 2018)."

"Market-based accounting allows companies to report that they have fulfilled reduction targets without reducing emissions (Bjørn et al. 2022)."

- From: [Holzapfel et.al., 2023]

"A benefit of the exclusive application of the location-based method is that it representatively evaluates the environmental impacts of the physically consumed electricity."

"The contribution of the market-based method and accompanying EAC systems to emission reductions and the expansion of RES is critically discussed in the literature. Central discussion points are missing incentives for the expansion of electricity from RES, due to low EAC prices and reduced necessity for energy efficiency measures (Bjorn et al. 2022; Brander et al. 2018; Hulshof et al. 2019)."

"However, a price elevation, sufficient to incentivize the construction and operation of additional RES-based power plants, is by no means certain. Thus, an agreement on stricter quality criteria for accountable electricity from RES might be necessary, to ensure the contribution of the market-based method to the energy transition."

Supplementary material

1. Overview on criticism on market-based energy accounting and EACs

"The effect of Energy Attribute Certificates (EAC), such as Guarantees of Origin (GOs), and market-based (renewable) energy accounting on corporate emission reduction targets and the energy transition is critically discussed (Bjørn et al. 2022). In a performance analysis of the European GO system Hulshof et al. (2019) conclude that the GO market has a low market liquidity, as well as a high and in transparent price volatility. Additionally, they state that the GO market has been in a constant state of oversupply, leading to low GO prices.

Bogensperger and Zeiselmair (2020) state that market-based energy accounting does not provide incentives for the expansion of renewable energy sources (RES), due to the low GO prices and the low share of newly build RES among all GOs. Despite a slight price increase in recent years, GO prices still account for a very small part of the total revenues renewable power plant operators (Hauser et al. 2019). The GO related income therefore currently has more the status of a "take-home effect", which does not represent a decisive investment incentive. Additionally, the GO system is accompanied by technical challenges. The expansion of decentralized photovoltaics will lead to an increasing number of small RES based power plants with an annual power output below 1 MWh, which is the size of one GO (EU 2018; Weckmann et al. 2017). The inclusion of these small scale RES based power plants would require a general revision of the GO system design. Furthermore, the system does not generate a significant control effect for customer behavior, due to the low temporal resolution, and there is currently no integration of smart meters. Currently GOs can be issued and cancelled within an annual time period (Kuronen et al. 2020). However, recently the introduction of GOs with a higher temporal granularity of one hour is discussed (Kuronen 2021).

Furthermore, the possibility to account for 100% renewable energy might undermine the recognition of energy efficiency measures. This is due to the fact that money spend to purchase GOs from RES can lower scope 2 GHG emissions much more effectively than the same money spend in energy efficiency. Brander et al. (2018) question whether the market-based scope 2 accounting methodology is useful as a GHG emission reductions tool. They illustrate this statement using the following example.

Following the market-based GHG Protocol Scope 2 Guidance (WRI & WBCSD 2015), Company A purchases RES based GOs for all of its grid electricity consumption and reports electricity related scope 2 emissions of 0 t CO_2 eq, resulting to a 30 % reduction in its total corporate emissions (Brander et al. 2018). In contrast, the otherwise identical Company B does not purchase contractual agreements for its grid electricity consumption, but invests the equivalent money in an energy efficiency program. These measures reduce its electricity consumption and scope 2 emissions by 10 %.

Consumers and investors use the GHG reports of the two companies to make their purchasing and investment decisions (Brander et al. 2018). They prefer Company A, since it seems to have a better environmental performance. However, Company A's consumption of grid electricity remains unchanged. Assuming that the purchase of RES based GOs does not sufficiently incentivise the construction of new RES based power plants, no physical emission reduction takes place. In contrast, Company B has reduced its demand for grid electricity, some of which is supplied by fossil fuel power plants. As a result, emissions are actually reduced.

In addition, to prevent that the exclusive claiming of grid electricity from specific energy sources leads to double counting, the market-based methodology requires the application of residual electricity mixes, in case no valid contractual agreements are acquired (WRI & WBCSD 2015). As this residual mix emission factor is higher than the average grid emission factor, Company B's performance is again represented worse (Brander et al. 2018)."

Annex – PROs and CONs of the 3 electricity modelling approaches

The PROs of the 3 approaches are summarized in the table below:

Table 4-3 : Pros of the 3 electricity consumption modelling methods for the production phase

Location-based approach	100% Market-based approach	Mixed modelling approach
• Easy to use method because national and regional location-based mixes are available from most LCA databases. Location-based mixes are incorporated in many background processes such as the production of steel, copper, aluminium, plastics... • Relies on a physical approach of electricity production and consumption. Close to real-world representativeness (geographically speaking) and reflects real impacts linked to global electricity production and consumption. The average national or regional electricity mixes of the location-based approach are a way to have a simple and consistent accounting of electricity environmental impacts in a given country or region. There is no "leakage" of electricity environmental impacts towards entities that do not report their environmental impacts (like residential households for instance). • Very few accusations of greenwashing.	• Electricity consumers from anywhere in the upstream ZEV value chain can actively choose to buy RECs and take credit for the electricity they sign up for. • By increasing the demand for contractual instruments that can prove the additionality of their production, electricity consumers would give additional incentives for building new renewable power plants. • Contractual instruments (Guarantee of Origin in Europe or other EAC such as REC in other parts of the world) are accessible to large and small companies alike. • There exists some open access Python script (by Holzapfel) that replaces all background processes using European location-based mixes by processes using the corresponding residual mixes. • Encourages energy efficiency and/or energy savings measures throughout the ZEV upstream value chain within companies that want to do more than buying EACs (going neutral for instance), although the impact of energy consumption on the ZEV upstream footprint is already decreased because of the use of EACs.	• Electricity consumers from anywhere in the upstream ZEV value chain can actively choose to buy RECs and take credit for the electricity they sign up for. • By increasing the demand for contractual instruments that can prove the additionality of their production, electricity consumers would give additional incentives for building new renewable power plants. • Contractual instruments (Guarantee of Origin in Europe or other EAC such as REC in other parts of the world) are accessible to large and small companies alike. • There exists some open access Python script (by Holzapfel) that replaces all background processes using European location-based mixes by processes using the corresponding residual mixes. • Currently, simple and pragmatic approach to implement a Market-based approach. • Makes it possible for OEMs to track their decarbonisation process while being transparent about the insufficient data availability and risk of double counting • Encourages energy efficiency and/or energy savings measures throughout the ZEV upstream value chain within companies that want to do more than buying EACs (going neutral for instance), although the impact of energy consumption on the ZEV upstream footprint is already decreased because of the use of EACs.

The CONs of the 3 approaches are summarized in the table below:

Table 4-4 : Cons of the 3 electricity consumption modelling methods for the production phase

Location-based approach	Market-based approach	mixed modelling approach
• Not considering the reality of the electricity market that is already using EAC and is anticipated to do even more so in the future. • As location-based modelling results are, in average, attributed uniformly to all actors in the same geographical area, actors engaged in a voluntary individual approach to purchasing electricity from renewable energy producers, and who seek to promote their development, do not derive any credit from it. • No impact on the grid electricity decarbonization. • No incentive for companies to support renewable electricity projects. • Electricity datasets most of the time refer to electricity production periods that do not match the time period related to the Product production phase.	• Many accusations related to greenwashing in the scientific literature (see bibliography section). • Lower credibility to the LCA results if not done with safeguards (see following questions). Potential accusations of greenwashing will be motivated by: potential accusations of resource shuffling (see definition above) and potential accusations of double counting if not done properly (by using in the same LCA location grid mixes and EAC mixes). • There is a large number of EAC tracking systems (e.g. RECs (US, Canada), GoOs (Europe), GECCs (China), iRECs (Global)) with different methodological requirements, e.g. regarding different criterion for allocation of EAC to location or time expiry. • Additional workload for modeling the specific mixes and potentially the residual mixes and including these residual mixes in the background processes when needed. • Relies on financial instruments related to electricity production and consumption that open the way to decoupling reported GHG emissions from real GHG emissions associated with the product under study. For instance, in the case of unbundled EAC, reported GHG emissions using EAC not linked to the electricity consumed during the production phase will be different from the real GHG emissions related to the production phase of the product, since the electricity that has been produced for the used EAC is not consumed during the production phase of the product. • Market based instruments break physical constraints: with EAC, electricity can be transmitted over distances longer that a few hundreds of kilometres (which cannot be physically the case), and can even be consumed when no physical connexion exist between	• Robust accusations of greenwashing (double counting is scientifically acknowledged - see "Proposed approach/possible options description and justification" paragraph above). • Lower credibility to the LCA results if not done with safeguards (see following questions). • There is a large number of EAC tracking systems (e.g. RECs (US, Canada), GoOs (Europe), GECCs (China), iRECs (Global)) with different methodological requirements, e.g. regarding different criterion for allocation of EAC to location or time expiry. • Additional workload for modeling the specific mixes and potentially the residual mixes and including these residual mixes in the background processes when needed. • Relies on financial instruments related to electricity production and consumption that open the way to decoupling reported GHG emissions from real GHG emissions associated with the product under study. For instance, in the case of unbundled EAC, reported GHG emissions using EAC not linked to the electricity consumed during the production phase will be different from the real GHG emissions related to the production phase of the product, since the electricity that has been produced for the used EAC is not consumed during the production phase of the product. • Market based instruments break physical constraints: with EAC, electricity can be transmitted over distances longer that a few hundreds of kilometres (which cannot be physically the case), and can even be consumed when no physical connexion exist between the producer and the consumer (i.e. GO from Iceland can be used in continental Europe).

	the producer and the consumer (i.e. GO from Iceland can be used in continental Europe). • Impacts on the grid electricity decarbonization is not proven. • The RECs system is not meant as a lever for the development of RES, at least in Europe. The development of RES is carried out through other mechanisms: voluntarism of governments who organize calls for tenders to achieve international production mix objectives, taxes on carbon energies, etc. • Nowadays, in Europe, the price of GOs is too low to reflect the real cost of building power plants and producing the electricity. Prices may increase according to the balance between the number of companies that will want to use GOs and the GOs available. • As not all players are obliged to buy AECs, it is important that the consumers in the same bidding zone where the EACs are used, and who do not buy those EACs use the residual grid mix in their LCAs as prescribed by the market-based approach. This is especially crucial in countries with a big difference between the location-based and the market-based electricity emission factor: • Country residual mixes, since they depend on market mechanisms and not on technical issues, can have large variations from one year to another. • In practice, it may be difficult to know every amount of contracted electricity all along the ZEV upstream value chain. • Potential accusations of favouring the existence of “free riders”, who either do not report their emissions (like residential households for instance), or report them using a location-based method, therefore allowing others to take credit for the renewable electricity they physically consume (e.g. Iceland electricity consumers whereas others can take credit for GOs related to Iceland el. prod.).	• Impacts on the grid electricity decarbonization is not proven. • The RECs system is not meant as a lever for the development of RES, at least in Europe. The development of RES is carried out through other mechanisms: voluntarism of governments who organize calls for tenders to achieve international production mix objectives, taxes on carbon energies, etc. • Nowadays, in Europe, the price of GOs is too low to reflect the real cost of building power plants and producing the electricity. Prices may increase according to the balance between the number of companies that will want to use GOs and the GOs available. • As not all players are obliged to buy AECs, it is important that the consumers in the same bidding zone where the EACs are bought, and who do not buy those EACs use the residual grid mix in their LCAs as prescribed by the market-based approach. This is especially crucial in countries with a big difference between the location-based and the market-based electricity emission factor. • Country residual mixes, since they depend on market mechanisms and not on technical issues, can have large variations from one year to another. • In practice, it may be difficult to know every amount of contracted electricity all along the ZEV upstream value chain. • Potential accusations of favouring the existence of “free riders”, who either do not report their emissions (like residential households for instance), or report them using a location-based method, therefore allowing others to take credit for the renewable electricity they physically consume (e.g. Iceland electricity consumers whereas others can take credit for GOs related to Iceland el. prod).

Production phase electricity consumption modelling - Additional specifications for market-based electricity modelling approaches

Products GHG emissions are under scrutiny, by consumers, NGOs, national government, national Energy Agencies… Without clear rules, the EU decided to ban carbon neutrality claims so as not to give any misguidance to consumers. The market-based electricity modelling approach has been criticized for its ability to underestimate the GHG emissions of a product, as compared to a location-based approach. The same reasoning can apply to other LCA environmental impact categories and indicators.

Because most market-based methods rely on classic EACs, which remain unrestrictive in terms of activation time (one year) or compatibility with the physical transmission and distribution of electricity associated with these contracts, they could open the way to all the "generic arguments against the unbundled contractual instruments" (potential accusations of greenwashing).

To respond to the main criticisms related to the market-based approach (i.e. accusations of greenwashing), additional guidelines and safeguards can be used, for instance to guarantee additivity, bundling with production, synchronicity, …

Q11 – Safeguards for the use of Energy Attribute Certificate (EAC) related to additionality for the product LCA production phase

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following criteria related to additionality be used for all considered Energy Attribute Certificates (EAC):

"If no additivity constraint is imposed, a large part of Energy Attribute Certificate (EAC) can be generated by power plants that have already made a profit. They are only a windfall effect, contribute to low prices, and do not encourage the development of new renewable power plants.

Additionality definition: the installation would not have existed without the financial intervention.

Therefore, when performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following criteria related to additionality be used for all considered Energy Attribute Certificates (EAC)"

Possible answers:

	Option 1	Option 2
Description	recent installations < 15 years	recent installations < 15 years or important retrofit / repowering < 5 years
Pros	-	- Allows more power plants to be considered
Cons	-	-

Whatever the criteria related to additionality used to legitimate the use of an Energy Attribute Certificate (EAC), it shall be clearly justified and documented so that the LCA electricity modelling hypotheses are transparent to the recipients of the LCA reports."

Background

Some Energy Attribute Certificate (EAC) rely on electricity producing assets that were built some time ago. Some, like in France, can be rather old. Using such old assets, has no influence on the decarbonization of electricity mixes nor on the production phase real emissions.

Proposed approach/possible options description and justification

The whole purpose of Energy Attribute Certificate (EAC) is to promote decarbonization through the construction of new low carbon electricity production plants. If the EAC that are used for TranSensus LCAs are coming from old power plants, then their decarbonization effect can be questioned (the GHG emissions of the consumed electricity will be the same, whether or not the product under study uses such EAC, since the plants are already there since a long time).

Recent (below 5 years) important retrofit / repowering should also be considered because these actions can be cost effective and therefore could benefit from additional revenues.

This safeguard will help avoiding accusations of resource shuffling.

Resource shuffling

A definition of resource shuffling is proposed by the European Roundtable on Climate Change and Sustainable Transition (ERCST - 2021120914_P2R4-v11.pdf (ercst.org)): Resource shuffling occurs when clean foreign production is re-routed toward export to the EU, and dirty foreign production is sold elsewhere, leaving foreign production patterns ultimately unchanged.

Why it is a risk for now:

- There is a large difference between the carbon intensity of high carbon and low carbon electricity (factor 10),
- It is very easy to switch from high carbon to low carbon (just purchase the right certificates or PPA without any physical change in the factory nor in the supply chain),
- Only a small fraction of any country electricity production will be dedicated to products subject to EU regulation, therefore it is very easy to direct the clean electricity towards this product production and dirty electricity to other consumers not subject to similar regulation, without any effect on the total country emissions.
- The price of these certificates is around 5€/MWh, this indirectly shows that their effect is limited. Indeed, if these certificates were inducing real efforts towards more low-carbon electricity production instead of only inducing resource shuffling, they would be more expensive.

The components that are mostly at risk are the electricity and electricity-intensive materials such as aluminium and steel.

As resource shuffling is a way to circumvent carbon regulations that is inherently linked to the use of specific emission values, one solution may be to enforce the use of generic national or regional consumption mixes.

Q12 – Safeguards for the use of Energy Attribute Certificate (EAC) related to a production/consumption physical link for the product LCA production phase

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following criteria related to a production/consumption physical link be used for all considered Energy Attribute Certificates (EAC):

"Some Energy Attribute Certificate (EAC) rely on electricity producing assets that may not belong to the same biding zone as where the sold electricity is consumed. Some may not even be connected physically to the processes that consume electricity within the product upstream value chain. This is for instance the case of Iceland electricity that cannot be physically consumed anywhere else than in Iceland. Taking advantage of Iceland electricity production emissions for production phase processes that occur in Europe is therefore highly questionable.

When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following criteria related to a production/consumption physical link be used for all considered Energy Attribute Certificates (EAC):"

Possible answers:

	Option 1	Option 2
Description	The attribute tracking instrument shall refer to an electricity production asset located in the same regional market (within which a physical synchronous interconnection can be proven) in which the product production phase electricity-consuming operations are located.	The attribute tracking instrument shall refer to an electricity production asset located within 500 km of the location of the product production phase electricity-consuming operations (with which a physical synchronous interconnection can be proven).

Whatever the criteria related to the existence of a production/consumption physical link used to legitimate the use of an Energy Attribute Certificate (EAC), it should be clearly justified and documented so that the LCA electricity modelling hypotheses are transparent to the recipients of the LCA reports."

Proposed approach/possible options description and justification

The existence of a physical synchronous interconnection will help justify the fact that the produced electricity is consumed by some of the production phase processes.
This safeguard will help avoiding accusations of greenwashing.

Q13 – Safeguards for the use of Energy Attribute Certificate (EAC) related to production/consumption time synchronization for the product LCA production phase

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following hierarchy related to a production/consumption time synchronization be used for all considered Energy Attribute Certificates (EAC):

"Some Energy Attribute Certificate (EAC) rely on electricity producing assets that may produce electricity that is not consumed during the production phase under study. This may be the case for renewable energy plants (like wind and solar) which times of production are determined by natural conditions and not by manufacturing schedules.

The best way to show that the electricity produced is in reality consumed during the production phase would be to have an hourly synchronisation between the two. Nevertheless, at the moment, most Energy Attribute Certificate (EAC) have either monthly or yearly timesteps, therefore we propose the following hierarchy.

When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following hierarchy related to a production/consumption time synchronization be used for all considered Energy Attribute Certificates (EAC):

- Hourly production/consumption time synchronization,
- Monthly production/consumption time synchronization,
- Yearly production/consumption time synchronization.

The current OEM practice is a monthly or yearly time synchronization meaning that it is made sure that the overall amount of electricity used during that period is covered with e.g. EACs.

Whatever the production/consumption time synchronization criteria used to justify the use of an Energy Attribute Certificate (EAC), it shall be clearly reported and documented so that the LCA electricity modelling hypotheses are transparent to the recipients of the LCA reports."

Possible answers: Agree/ Disagree/ No preference

Background

At every moment, electricity consumption and production should be at an equilibrium through the grid, otherwise the grid would collapse.

As power produced by renewables depends on the weather, and not on manufacturing schedules, it is possible that there is not a perfect match between electricity production and consumption, as illustrated by the following figure, which is Figure 4-8: "Typical daily solar generation curve and load curve" from the GBA GHG Rulebook:

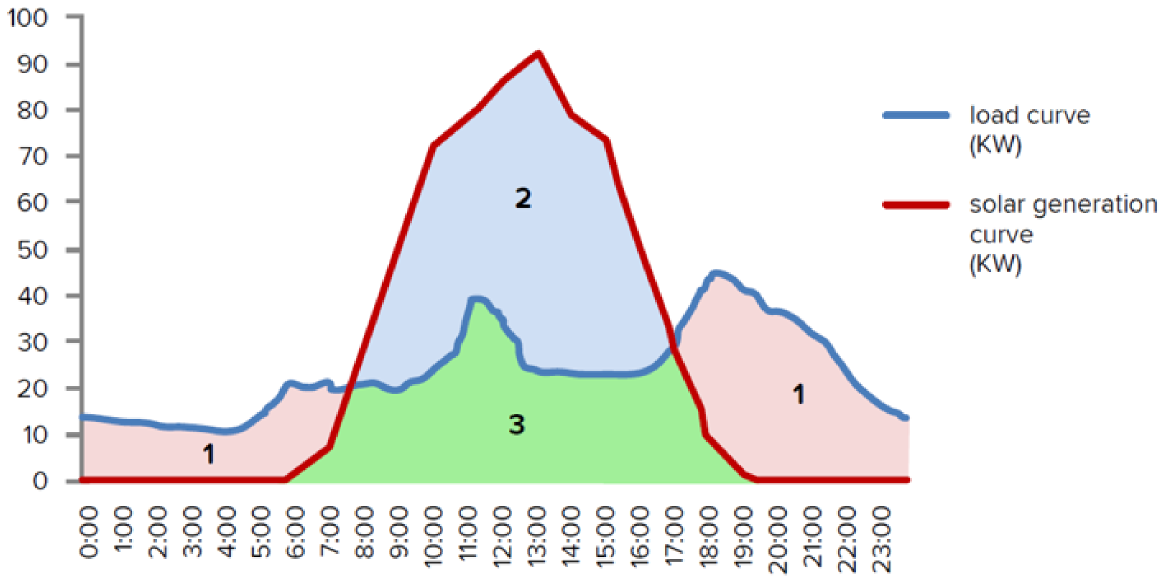


Figure 4-8 : Typical daily solar generation curve and load curve from the GBA GHG Rulebook

In this chart, only the electricity from area #3 (in green) can be counted as consumed during the production phase. The energy of area #2 cannot physically be consumed during the production phase.

Proposed approach/possible options description and justification

It is not physically correct to attribute the electricity production of both areas 2 and 3 of the above figure to the product production phase.

The best possible option would be an hourly production/consumption time synchronization. Some projects are being developed for that purpose (see https://energytag.org/ for hourly disclosure projects and see Trader (certigy.net) for a software solution for Granular Certificates, up to the hour).

Nevertheless, such an option may not be always possible, therefore the need to have less granular certificates. Monthly production/consumption time synchronization are possible in some countries such as France and Sweden.

When neither hourly nor monthly production/consumption time synchronization are available, then the last resort solution will be an annual production/consumption time synchronization, which is already available.

Q14 – Other safeguards for the use of Energy Attribute Certificate (EAC) for the product LCA production phase

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following minimum criteria be used for all considered Energy Attribute Certificates (EAC):

"When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, the following minimum criteria be used for all considered Energy Attribute Certificates (EAC):

• they shall convey the information associated with the unit of electricity delivered together with the characteristics of the generator.

• they shall be assured with a unique claim and therefore be the only instruments that carry the environmental attribute claim associated with that quantity of electricity generated.

• they shall be tracked and redeemed, retired or cancelled by or on behalf of the company (e.g., by an audit of contracts, third-party certification, or may be handled automatically through other disclosure registries, systems, or mechanisms).

It shall be clearly justified and documented, for each Energy Attribute Certificate (EAC) that is used, if it complies with the 3 criteria above so that the LCA electricity modelling hypotheses are transparent to the recipients of the LCA reports."

Possible answers: Agree/ Disagree/ No preference

Proposed approach/possible options description and justification

These requirements are classical requirements for Energy Attribute Certificate (EAC) that appear in several guidances (GHG Protocol, Catena-X (5.2.4. Accounting for GHG emissions from electricity), ISO 14068).

Q15 – Safeguards for the use of Energy Attribute Certificate (EAC) related to the excess of production that is not consumed during the product LCA production phase

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, every excess of electricity production related to an EAC that is used for the LCA and that is not consumed during the production phase of the vehicle should not be counted as negative emissions nor impacts. This is in line with the current OEM practice.

"Some Energy Attribute Certificate (EAC) rely on electricity producing assets that may produce more electricity than what is consumed during the production phase under study. This may be the case for renewable energy plants (like wind and solar) which times and quantities of production are determined by natural conditions and not by manufacturing schedules.

Counting the excess of electricity production related to the EAC that is not consumed during the production phase of the vehicle as negative emissions/impacts is questionable. Therefore, there is a need, in TranSensus, to exclude the use of negative emissions/impacts related to the excess of electricity production that is not consumed during the production phase of the vehicle.

When performing a **Product LCA**, TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, every excess of electricity production related to an EAC that is used for the LCA and that is not consumed during the production phase of the vehicle should not be counted as negative emissions nor impacts. This is in line with the current OEM practice."

Possible answers: Agree/ Disagree/ No preference

Background

At every moment, electricity consumption and production should be at an equilibrium through the grid, otherwise the grid would collapse.

As power produced by renewables energies depends on the weather, and not on manufacturing schedules, it is possible that there is not a perfect match between the electricity production and consumption, as illustrated by the following figure, which is Figure 4-8: "Typical daily solar generation curve and load curve" from the GBA GHG Rulebook:

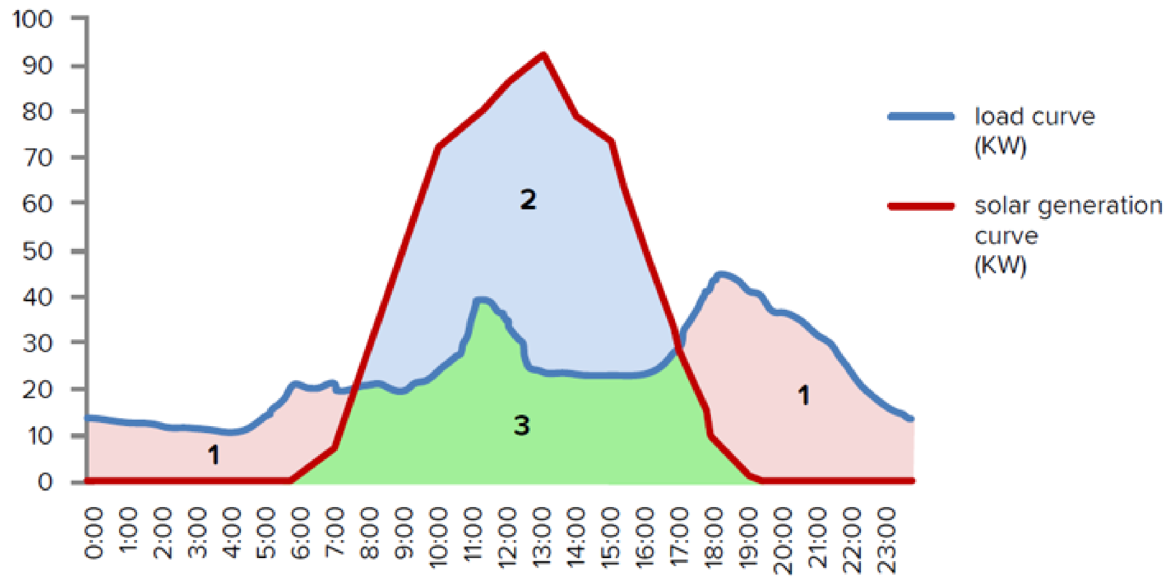


Figure 4-8: Typical daily solar generation curve and load curve from the GBA GHG Rulebook

In this chart, only the electricity from area #3 (in green) can be counted as consumed during the production phase. The energy of area #2 cannot physically be consumed during the production phase. It can either be wasted or injected to the grid. In the latter case, the question would be: should this amount of energy generate or not negative emissions/impacts?

Proposed approach/possible options description and justification

Negative emissions/impacts is a very controversial topic.

TranSensus methodology, to be as robust as possible, should not allow to consider negative emissions/impacts to avoid raising doubts and criticism.

Q16 – Guidance for residual mixes modelling for the product LCA production phase

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

When performing a **Product LCA,** TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, to ensure a sound and robust market-based approach, and depending on resources available to the LCA practitioner,

> the residual mixes that are used within the chosen market-based approach be modelled according to the following hierarchy:

"When performing a **Product LCA,** TranSensus LCA proposes that, in case a **market-based** electricity modelling option is chosen for the **production phase**, to ensure a sound and robust market-based approach, and depending on resources available to the LCA practitioner, the residual mixes that are used within the chosen market-based approach be modelled according to the following hierarchy:

- Use the residual mixes characteristics prescribed by coordinating entities that disclose annually all the residual mixes related to their bidding zone, each coordinating entity covering all Energy Attribute Certificate (EAC) issued in the corresponding bidding zone,
- Use national mixes from which all the renewable production (hydroelectricity, wind power, photovoltaic and biomass energy) as well as nuclear electricity production has been taken out (conservative approach that reflects the future development of Energy Attribute Certificate (EAC)).

Since the modelling of residual mixes can, for some locations, be time consuming, TranSensus LCA proposes that, in case a market-based electricity modelling option is chosen for the production phase, the modelling of residual mixes be carried in the best possible manner according to available resources (available time, data and software).

TranSensus LCA also proposes that, in case a market-based electricity modelling option is chosen for the production phase, the modelling of residual mixes, if any be used, be clearly justified and documented, and if no residual mixes are modelled, this shall also be clearly justified and documented so that the LCA electricity modelling hypotheses are transparent to the recipients of the LCA reports."

Possible answers: Agree/ Disagree/ No preference

Background

Some countries residual electricity consumption mixes are already available: in Europe for instance the Association of Issuing Bodies (AIB - Home | AIB (aib-net.org)) develops, uses and promotes a European, harmonised and standardised system of energy certification for all energy carriers: the European Energy Certificate System - "EECS". The AIB is issuing residual mixes for most European countries (cf. figure below).

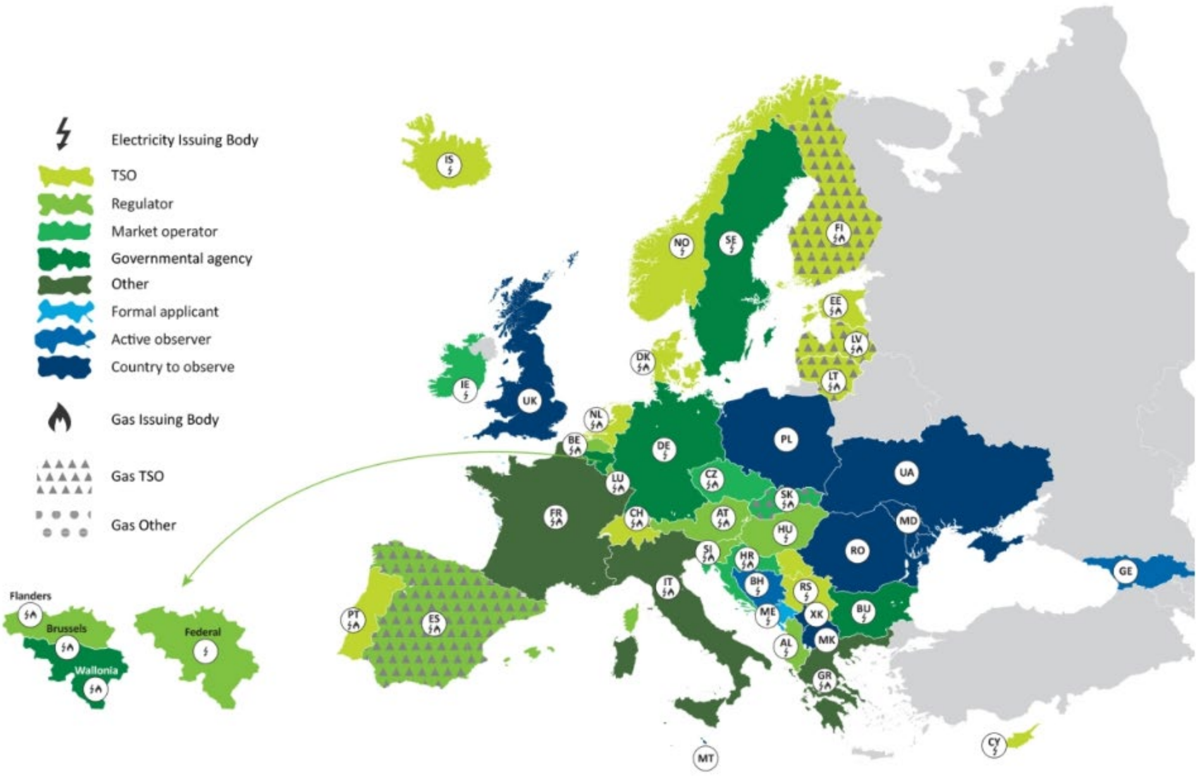


Figure 4-7: Association of Issuing Bodies member countries

Such a system is not available for all countries, therefore the need to have another approach for those countries without official residual mixes.

Proposed approach/possible options description and justification

The proposed hierarchy is applicable for all locations, therefore offering the possibility to carry a 100% market-based approach.

The second possibility for modelling countries electricity consumption residual mixes in the above hierarchy have been proposed by Matthias Finkbeiner, from the Technische Universität Berlin, Institute of Environmental Technology, Chair of Sustainable Engineering, in an oral discussion.

Use Phase electricity consumption modelling for Product LCA – details for using a "dynamic" modelling approach

Electric vehicle use-phase is a particularly energy- / electricity-intensive phase, accounting for ~90% total electricity consumed over an average electric vehicle's life cycle (Ecoinvent, 2000). Having established the significance of this life cycle phase, it is of utmost importance that modelling approaches that reflect the most representative assumptions and input data be recommended for adoption by the TranSensus LCA methodology. Two modelling approaches have been identified:

(i) 'static current mix' and

(ii) 'conservative future dynamic mix'.

In light of the expected evolution of the grid mix composition in the real world, the use of a 'static' mix for the entire use phase is methodologically questionable and would inevitably lead to an overestimation of emissions. Also, such practice would hinder the TranSensus LCA methodology's alignment with key existing and evolving policies and their assessment strategies, including REDIII and Car and Van CO_2 regulations. Therefore, the recommendation is to use a 'dynamic' mix for the TranSensus product use-phase. Nevertheless, because OEMs are legally responsible for all published values and claims regarding their vehicles, TranSensus will allow the use of a "static" mix for OEMs: the market- and year-specific electricity mix at date of production can be used to model the electricity input throughout the entire use phase of BEVs and PHEVs.

Q17 – General guidance for the Use Phase electricity consumption "dynamic" modelling approach

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, Macro fleet level LCA**

Complete question submitted to voting

When performing a **Product LCA**, and modelling the use-phase of ZEVs using a dynamic future electricity grid mix (as the default case or in scenario analysis), the following methodological approach is proposed. This includes the approach that shall be followed in prioritising data sources/the basis for the default conservative future electricity mix projection to be used

“The following hierarchy has been agreed upon during the 2nd voting phase of the project:

1. TranSensus LCA **SHALL use a “dynamic” modelling approach, informed by a reputable energy futures scenario (to be determined - e.g., IEA WEO STEPS) in order to model the electricity input to the use phase of BEVs and PHEVs**. This modelling approach is deemed to be the most realistic and most likely to approximate the actual environmental emissions and impacts accruing over the full service life of the vehicle.
2. However, TranSensus LCA acknowledges that OEMs are legally responsible for all published values and claims regarding their vehicles, and that therefore **OEMs MAY opt to use a more conservative “static” modelling approach instead**, whereby the market- and year-specific electricity mix at date of production is used to model the electricity input throughout the entire use phase of BEVs and PHEVs. (Further recommendations and/or requirements on the adoption of alternative modelling approaches by way of Sensitivity Analysis will be decided upon at a later date, within WP2.5).
3. Regardless of the chosen modelling approach (points 1. and 2. above), in TranSensus LCA **the same approach SHALL be used in all instances of explicitly comparative LCAs**, which are aimed at making “comparative assertions”, as defined by ISO 14044. (This latter principle is not limited to electricity modelling, but applies to TranSensus LCA as a whole).

This question relates only to the “dynamic” modelling approach, i.e. case 1.

When performing a **Product LCA**, and modelling the use-phase of ZEVs using a dynamic future electricity grid mix (as the default case or in scenario analysis), the following methodological approach is proposed. This includes the approach that shall be followed in prioritising data sources/the basis for the default conservative future electricity mix projection to be used.

To be noted: Due to legal concerns, OEMs are allowed to use the static electricity mix by default when modelling the use phase.”

<u>Possible answers:</u> Agree/ Disagree/ No preference

Background

The environmental impacts arising from the use phase of BEVs (and also other plug-in electric powertrains, and vehicles operating on electric road systems - ERS) represent a significant share of the total life cycle impacts of such vehicles. The impact related to the use phase is strongly dependent on how the electricity used to charge the on-board batteries and power the vehicles is generated. In general terms, such electricity is sourced from a grid mix that comprises a number of different electricity generation technologies, the relative shares of which are subject to change over time (and, critically, over the service life of the vehicle being assessed).

More specifically, in many regions of the world, due to political and legislative pressure to meet climate targets, the electricity grid mixes have so far been evolving towards lower shares of fossil energies and higher shares of low-carbon technologies such as variable renewable energies (primarily wind and solar PV) and nuclear, and similar trends are expected to continue into the next decades.

Therefore, in order to provide an accurate estimate of the real-world environmental impacts of xEVs over their full life cycle, it is important to account for this dynamic evolution of the grid mix in the LCI modelling stage. This is of even more importance in comparative LCAs, where the environmental impacts of xEVs are compared to those of ICEVs, since failure to account for the progressive decarbonization of the electricity grid mix over the service life of xEVs would result in an overestimation of the GHG emissions of the xEVs during their use phase.

In view of the above, in TranSensus LCA, a decision has already been reached that a conservative dynamic electricity mix projection approach shall be used to model the electricity modelling input to the use phase of BEVs (with special provision for deviating from this and instead adopting a "static" electricity mix projection approach, only in those instances where legal responsibilities may prevent OEMs from doing so by default). Sensitivities on alternative future projections for the electricity mix have also been identified as important (also to assess the uncertainty in this area), though a definitive decision on whether these should be mandatory or only recommended has yet to be established.

This document then aims to provide clear guidance on how to implement such dynamic electricity mix modelling as part of the LCA of an xEV within TranSensus LCA, be it as the default scenario (in compliance with TranSensus LCA general recommendation), or as part of a Sensitivity Analysis (in those cases where a "static" grid mix projection is permissible to be adopted as default, instead).

A similar approach may also be appropriate for the consideration of use-phase hydrogen supply mix, for ZEV powertrains using hydrogen (i.e. FCEVs, FC-REEVs and H2 ICEVs). However, the approach for use-phase hydrogen supply mix will be developed separately and voted for in another question.

Proposed approach/possible options description and justification

The following step-by-step methodological approach is proposed for the modelling of electricity grid mixes feeding into the use phase of xEVs.

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

a. The official published scenario specifically for electricity supply mix for the country or geographical region of interest. For TranSensus LCA, it should be for the EU by default. (Additional alternative official scenarios may also be used in the sensitivity analysis, where available).

b. 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)[1]. For TranSensus LCA this should be for the EU by default. (Additional alternative official scenarios may also be used in the sensitivity analysis, where available).

c. Stated Policies Scenario (STEPS) from the most recent International Energy Agency's World Energy Outlook (IEA WEO) report, for the geographical region of interest[2]. For TranSensus LCA it should be for the EU by default. (The Sustainable Development Scenario (SDS) or other alternative official IEA scenarios may also be used in the sensitivity analysis, where available).

d. If none of the previous options (a to c) are available for the geographical region of interest, then the most recent "static" grid mix composition shall be used instead (as is already allowed for OEMs in the default case, where legal responsibilities may prevent OEMs from adopting a dynamic electricity mix modelling). In this case, it is proposed to also provide an alternative assessment using a 100% renewable electricity mix for comparison. **The latter is intended as a hypothetical scenario corresponding to an optimistic assumption (to provide counterpoint to the otherwise likely pessimistic assumption of the current static grid mix); it is acknowledged that in some countries, the 100% RE scenario may be unrealistic.** Please see example in Figure 4-9. For further guidance and worked examples, please follow this link.

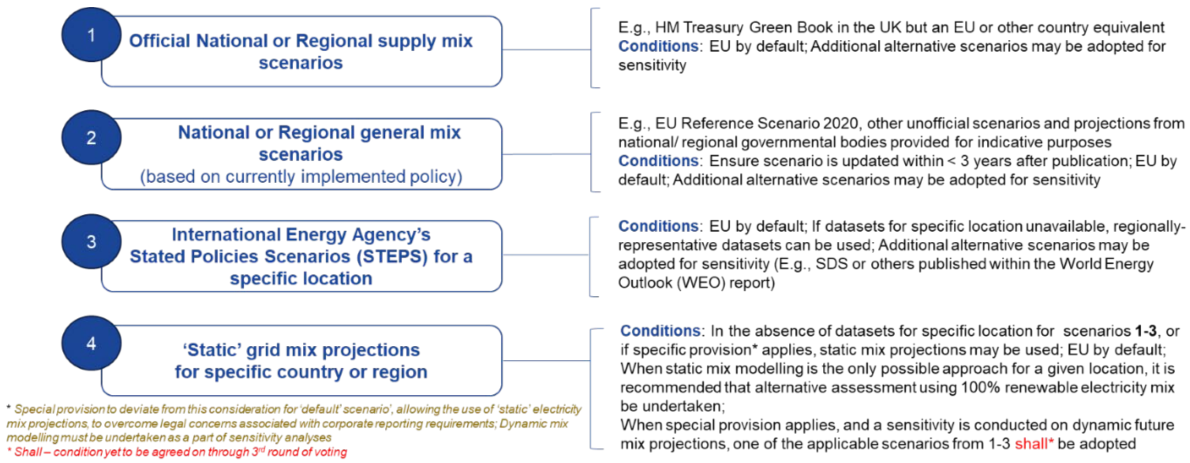


Figure 4-9 : Recommended hierarchy for the selection of appropriate datasets for use-phase dynamic mix electricity modelling

2. The grid mix composition for each year of vehicle operation shall be estimated (i.e., the shares $S_{i,N}$ 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:
   a. **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).
   b. 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 $S_{i,N}$ of electricity supplied by each technology i in the year N, i.e.:

$$\sum_{N} W_N S_{i,N}$$

   Where $W_N = A_N/L$ (A_N = vehicle activity in year N, L = total lifetime activity).
4. A bespoke grid mix model shall finally be built in the LCA software package of choice (e.g., "LCA for Experts", or "SimaPro"), 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[28,29].

[28] For Variable Renewable Energy (VRE) generators like solar photovoltaics (PV) and Wind, increased accuracy may be attained by using the database processes per unit of installed power [kW_p], and then multiplying the associated LCIs by the appropriate region-specific Capacity Factors (CF), which are defined as the ratio of the electricity delivered in a year [kWh] to the product of the nameplate installed power [kW_p] times the number of hours in a year. CFs for Wind and PV for all World locations are freely available at, respectively: https://globalwindatlas.info/ and https://globalsolaratlas.info/

[29] An additional element of complexity is represented by the fact that some technologies (among which primarily PV and Wind) may also be expected to continue evolving and improving over time, leading to reduced average impact per unit of electricity generated as newer generations of these technologies come on-line and start contributing to the grid mix. However, addressing this aspect in the modelling may be deemed outside of scope for conventional product LCAs, and may instead form part of a dedicated Sensitivity Analysis, especially in prospective and fleet-level LCAs.

On-site electricity production modelling

There may be some electricity production systems (e.g., solar panels, wind turbines) within the boundaries of the LCA. This would be the case for instance for an electricity production system that is located within the premises of any manufacturing or operating site that is part of the vehicle value chain and/or directly connected to such sites but not connected to the grid.

To be characterised as an on-site electricity production system, it should be owned by the company manufacturing or operating the vehicles. In such a case the produced electricity is part of the system, there is no need to buy it, it can be considered as a "co-product" that is meant to be consumed within the system.

To be noted: this case is different from the case where the consumed electricity is bought from an external entity (with or without an Energy Attribute Certificate) to fulfil the needs of the vehicle life cycle. For instance, if an external company owns and operates a photovoltaic system installed on a company manufacturing premises, and sells the generated electricity to the manufacturing company, the photovoltaic system shall be considered as an external system (outside of the boundaries of the LCA). Whereas the same photovoltaic system, being owned by the manufacturing company, and operated by an external entity (which is paid for that), in the name of the manufacturing company, shall be considered an on-site production system.

For all on-site electricity production systems, part of the produced electricity can be consumed by the product system under study and part of it can be fed into the grid (excess of production).

The way this on-site electricity production is considered for TranSensus LCAs needs to be clarified and harmonized.

Q18 – Guidance for on-site electricity production modelling for Product LCA production phase

There may be some electricity production systems within the boundaries of the study. These will be called on-site electricity production systems if they are owned by the entity that owns and operates the premises. Such systems may exist on manufacturing sites.

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

When performing a **Product LCA**, in the case of **on-site produced electricity**, with no contractual instruments sold to a third party, that is partly or entirely consumed during the **production phase**, TranSensus LCA proposes that:

"There may be some electricity production systems (e.g., solar panels, wind turbines) within the boundaries of the LCA. This would be the case for instance for an electricity production system that is located within the premises of the manufacturing plant considered and/or directly connected to the plant but not connected to the grid. When such electricity production systems are owned by the entity owning and operating the facilities, it is called an on-site electricity production system. For such systems, part of the produced electricity can be consumed by the facility it is related to and part of it can be fed into the grid (excess of electricity production).

When performing a **Product LCA**, in the case of **on-site produced electricity**, with no contractual instruments sold to a third party, that is partly or entirely consumed during the **production phase**, TranSensus LCA proposes that:

- The energy producing system be within the boundaries of the studied system,
- Its inventory be included in the LCA inventory,
- Its inventory be prorated to the time and quantity of the electricity production that is really consumed during the production phase,
- For the electricity produced that IS consumed during the production phase the following hierarchy applies:
    - Proof must be given that the electricity produced is used during the production phase on an hourly basis (taking into account electricity storage devices),
    - Proof must be given that the electricity produced is used during the production phase on a yearly basis.

- The electricity produced that is NOT consumed during the production phase is either wasted or fed to the grid as grey electricity (no EACs associated with it) and no negative emissions nor impacts can be associated with the excess of electricity produced on site.

In the case of on-site produced electricity, with related contractual instruments sold to a third party, TranSensus LCA proposes that the on-site electricity production system be out of the boundaries of the studied system and not considered for the LCA (no negative emissions nor impacts can be associated with such on-site electricity production system). This is in line with the current OEM practice.

The use and characteristics of on-site electricity production for Product LCA production phase shall be clearly justified and documented so that the LCA electricity modelling hypotheses are transparent to the recipients of the LCA reports."

Possible answers: Agree/ Disagree/ No preference

Background

There is a need to clarify whether the on-site electricity production system is included in the boundaries of the system or not, and if it is, how the part of the produced electricity that is consumed during the production phase should be accounted for, and, similarly, how the part of the produced electricity that is NOT consumed during the production phase should be accounted for.

There is also a need to verify that the produced electricity is really consumed during the production phase, since most of the on-site electricity production systems are based on renewable energies, for which production depends on the weather, and not on manufacturing schedules. It is possible that there is not a perfect match between on-site electricity production and the production phase electricity consumption.

Proposed approach/possible options description and justification

Since, in most cases, part of the on-site electricity production will be consumed during the production phase and part will be fed to the grid, part of the on-site electricity production system inventory should be allocated to the production phase (the inventory should be prorated according to the amount of electricity consumed by the manufacturing sites and produced by the considered on-site electricity production system). This recommendation is derived from usual boundaries and allocation rules.

The way on-site electricity production is handled for the production phase does not depend on whether the location-based or the market-based approach is chosen for the production phase electricity consumption modelling.

Negative emissions/impacts is a very controversial topic. TranSensus methodology, to be as robust as possible, should not allow to consider negative emissions/impacts to avoid raising doubts and criticism. This requirement is in line with the one related to the safeguards for the use of Energy Attribute Certificate (EAC) related to the excess of production that is not consumed during the product LCA production phase.

Q19 – Guidance for on-site electricity production modelling for the use and EoL phases

There may be some electricity production systems within the boundaries of the study. These will be called on-site electricity production systems if they are owned by the entity that owns and operates the premises. Such systems may exist on charging stations.

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> When performing a **Product LCA**, TranSensus LCA proposes that **on-site electricity production** (e.g. charging station on-site electricity production) will not be considered for the **use phase**.
>
> When performing a **Product LCA**, TranSensus LCA proposes that **on-site electricity production** will not be considered for the **EoL phase**

"There may be some electricity production systems (e.g., solar panels) within the boundaries of the LCA. This would be the case for instance for an electricity production system that is located within the premises of the charging stations considered within the LCA and/or directly connected to the charging stations but not connected to the grid. When such electricity production systems are owned by the entity owning and operating the charging stations, it is called an on-site electricity production system. For such systems, part of the produced electricity can be consumed to charge the vehicle and part of it can be fed into the grid (excess of electricity production). Similar situations can apply to the End of Life (EoL) phase.

When performing a **Product LCA**, TranSensus LCA proposes that **on-site electricity production** (e.g. charging station on-site electricity production) will not be considered for the **use phase**.

When performing a **Product LCA**, TranSensus LCA proposes that **on-site electricity production** will not be considered for the **EoL phase**."

Possible answers: Agree/ Disagree/ No preference

Background

There is a need to clarify whether or not the on-site electricity production system is included in the boundaries of the system or not.

Proposed approach/possible options description and justification

For harmony and comparability in this very impactful aspect (electricity in use phase), we decided to refer to a default way of modelling electricity consumption with a location-based approach (dynamic future electricity grid mix or static current mix) and to neglect exceptions (e.g. home chargers fed by solar panels) … This way, the modelling for on-site electricity production for the use phase does not depend on whether the dynamic future electricity grid mix approach or static current mix approach is chosen for the use phase electricity consumption modelling.

For simplicity and robustness (very difficult to make robust assumptions for on-site electricity production during the EoL phase), we decided not to consider / model on-site electricity production systems for the EoL phase.

Fleet level LCA

Fleet level LCAs are different from single vehicle LCA in the sense that many vehicles are considered, which can be manufactured in different countries, and therefore with different grid mixes. As for the use phase, the electricity that will be consumed by the studied fleet can either be related to one country, in the case of a national fleet, or to several countries, in the case of an OEM's fleet.

Whatever the situation, either one or several grid mixes need to be considered, depending on the national shares of produced and used vehicles.

Q20 – General guidance for electricity modelling for Fleet level LCA

Executive summary

Type of LCA concerned by the question: **OEM's and Macro Fleet level LCA**

Complete question submitted to voting

TranSensus LCA proposes using the same electricity consumption modelling approach for the **Fleet level LCA** as for Product LCA regarding:

- The production phase, including on-site electricity production,

- The use phase, except for on-site electricity production (see following question)
- The EoL phase

Possible answers: Agree/ Disagree/ No preference

Proposed approach/possible options description and justification

There is no need to have a different electricity modelling approach for the Fleet level LCA and for the product level LCA.

To be noted: for the Fleet level LCA market shares should be taken into account, both at the production, use and EoL phases, to consider adequate electricity mixes (usual LCA practice).

The only difference between the two types of LCA concerning the electricity modelling approach is related to on-site electricity production for the use phase (see following question).

Q21 – Guidance for on-site electricity production modelling for Fleet level LCA for the use phase

Executive summary

Type of LCA concerned by the question: **OEM's and Macro Fleet level LCA**

Complete question submitted to voting

When performing a **Fleet level LCA**, in the case of **on-site produced electricity**, with no contractual instruments sold to a third party, that is partly or entirely consumed during the **use phase**, TranSensus LCA proposes that

- The energy producing system be within the boundaries of the studied system,
- Its inventory be included in the LCA inventory,
- Its inventory be prorated to the time and quantity of the electricity production that is really consumed during the use phase,
- For the electricity produced that IS consumed during the use phase the following hierarchy applies:
    - Proof must be given that the electricity produced is used during the use phase on an hourly basis (taking into account electricity storage devices),
    - Proof must be given that the electricity produced is used during the use phase on a yearly basis.

- The electricity produced that is NOT consumed during the use phase is either wasted or fed to the grid as grey electricity (no EACs associated with it) and no negative emissions nor impacts can be associated with the excess of electricity produced on site.

In the case of on-site produced electricity, with related contractual instruments sold to a third party, TranSensus LCA proposes that the on-site electricity production system be out of the boundaries of the studied system and not considered for the LCA (no negative emissions nor impacts can be associated with such on-site electricity production system).

The use and characteristics of on-site electricity production for Fleet level LCA use phase shall be clearly justified and documented so that the LCA electricity modelling hypotheses are transparent to the recipients of the LCA reports."

Possible answers: Agree/ Disagree/ No preference

Background

Some charging stations can be equipped with electricity production systems, like photovoltaic panels. Electricity generated by these on-site electricity production systems should be included in Fleet level LCA under the same conditions as the electricity production systems that are installed on ZEV manufacturing sites for product LCA.

Proposed approach/possible options description and justification

It can be possible, at fleet level, to assume where the vehicles will be charged (public or company charging stations for instance). Therefore, there can be a need to consider the electricity produced on-site in charging stations.

Prospective LCA

Prospective LCA will have production, use and Eol phases that will occur in the future. The exact time frame of these three phases should be specified within the goal and scope of the study.

Many hypotheses should also be specified within the goal and scope of the study. The use of PPAs is one of them.

Since the production, use and EoL phases of Prospective LCA occur in the future, it is impossible to use usual Energy Attribute Certificate (EAC), since such contractual instruments are dedicated to past electricity production.

Nevertheless, it is possible to assume that some PPA can be secured. It is not in the scope of TranSensus LCA to verify how PPAs can be secured for Prospective LCA.

A PPA is a combination of electricity and EACs. It is often a long-term agreement between a seller of renewable electricity and a buyer of that renewable electricity. Within that PPA both electricity and EACs are purchased.

Q22 – Guidance for electricity modelling for the production, use and EoL phases in Prospective LCA

Executive summary

Type of LCA concerned by the question: **Prospective LCA**

Complete question submitted to voting

> When performing a **Prospective LCA**, TranSensus LCA proposes using the following decision tree for the **production, use and EoL phases** electricity modelling approach:

- Is there a hypothesis concerning the use of PPAs for a Prospective LCA electricity production modelling?
  - If No, then use the specific average grid mix of the country or region where the vehicle is expected to be produced, used and decommissioned, estimated for the considered time frame, as defined in the goal and scope of the study, on the basis of the use phase electricity modelling approach for Product LCA (dynamic future electricity grid mix or static current mix).
  - If Yes, then use the following hierarchy:
    - if specific contracts (like PPA) are expected to be used for the same time representativeness as the study, use these specific contracts mixes,
    - For whatever electricity that is not expected to be covered by a PPA contract, use a prospective residual grid mix with the same time representativeness as the study,
    - For whatever electricity that is not expected to be covered by a PPA contract, use a current residual grid mix.

TranSensus LCA proposes that the residual mixes that should be used for Prospective LCA be modelled as national mixes (whether dynamic future electricity national grid mixes or static current national mixes) from which all the renewable production (hydroelectricity, wind power, photovoltaic and biomass energy) as well as nuclear electricity production has been taken out (conservative approach that reflects the future development of Energy Attribute Certificate (EAC)).

To model future electricity mixes, LCA practitioners may use the results of the PREMISE (PRospective EnvironMental Impact asSEment) project, which offers a streamlined approach to producing databases for prospective Life Cycle Assessment using Integrated Assessment Models.

[PRospective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models - ScienceDirect]
[Premise | Technology Assessment | PSI]"

Possible answers: Agree/ Disagree/ No preference

Proposed approach/possible options description and justification

These recommendations are aligned with those related to Product and Fleet level LCA and nevertheless take into account the fact that all Prospective LCA phases (production, use and EoL phases) occur in the future.

Q23 – General guidance for on-site electricity production modelling for Prospective LCA

Executive summary

Type of LCA concerned by the question: **Prospective LCA**

Complete question submitted to voting

When performing a **Prospective LCA**, in the case of a hypothesis that there is some **on-site produced electricity**, with no contractual instruments sold to a third party, TranSensus LCA proposes the following approach for production and use phases:

"Prospective LCA can use many different hypotheses. Among them would be the presence of on-site electricity production systems. If electricity production systems that are located on the life cycle processes premises and/or directly connected to them and not connected to the grid are owned by the entity owning and operating the related facilities, then these electricity production systems can be considered as on-site electricity production systems. For such systems, it can be assumed that part of the produced electricity is consumed by the facility it is related to and part of it is fed into the grid (excess of electricity production).

When performing a **Prospective LCA**, in the case of a hypothesis that there is some **on-site produced electricity**, with no contractual instruments sold to a third party, TranSensus LCA proposes that, for the **production and use phases**:

- The energy producing system be within the boundaries of the studied system,
- Its inventory be included in the LCA inventory,
- Its inventory be prorated to the time and quantity of the electricity production that is really consumed during the production and use phases,

- The electricity produced that is NOT consumed during the production and use phases is either wasted or fed to the grid as grey electricity (no EACs associated with it) and no negative emissions nor impacts be associated with the excess of electricity produced on site.

In the case of a hypothesis that there is some on-site produced electricity, with related contractual instruments sold to a third party, TranSensus LCA proposes that the on-site electricity production system be out of the boundaries of the studied system and not considered for the LCA (no negative emissions nor impacts be associated with such on-site electricity production system.

These proposals apply to Prospective LCA production and use phases.

TranSensus LCA proposes that on-site electricity production will not be considered for Prospective LCA EoL phase."

Possible answers: Agree/ Disagree/ No preference

Proposed approach/possible options description and justification

These recommendations are aligned with those related to Fleet level LCA and nevertheless will allow to take into account the fact that production and use Prospective LCA phases occur in the future.

4.2.3 Multifunctionality

A complete guidance to deal with Multifunctionality is reported in the Annex.

Q24 – Do you agree with the refined version of the general hierarchy?

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TransensusLCA proposes confirming the current refined version of the general hierarchy. The changes from the last voting are mainly: introduction of the functional flows concept, distinction between "good" and "waste" flows, and the procedure to determine a multifunctional process. This procedure consists of three steps: (1) determining the types of exchanges (good or waste) per unit process, (2) identifying functional flows and, (3) determining multifunctional processes based on how many functional flows were identified. Another change from the last hierarchy is the addition of restrictions to physical allocation when applied in certain situations to enhance harmonization as recommended in the comments received in the last voting. The full detailed guidance can be found in section 1 in annex 1

Possible answers: Agree/ Disagree/ No preference

Background

This is a refined version of the hierarchy that was approved in the last voting session. Comments from voters were considered to produce this improved version.

Proposed approach/possible options description and justification

1. *The identification of each flow between two processes as either a product (good) or a waste.*
   A product (good) is a flow between two processes with an economic value higher than or equal to zero, whereas a waste is a flow between two processes with an economic value smaller than zero. Note that any other criterion to distinguish between products (goods) and wastes could be applied as long as it can be consistently applied over different product systems.
2. *The identification of a process' functional flow(s).*
   Having identified product and waste flows, the functional flow(s) of each process can now be identified, which are either products (goods) that are produced by a process or wastes that are treated by a process. Note that every process needs at least one functional flow.
3. *The identification of multi-functional processes.*

Having identified the functional flows of all processes, multi-functional processes can now be identified: they are unit processes yielding more than one functional flow.

4. *Solving the problem*
   Summary of the hierarchy:
   1. Subdivision
   2. System expansion
   3. Substitution
   4. Allocation

Q25 – Do you agree with the following approach to handle multifunctionality in the EoL stage?

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TransensusLCA proposes the following: Multifunctionality in the end of life (EoL) of a vehicle or battery shall be dealt with using the cut-off approach which is also referred to as "recycled content" or "100:0" approach. Future updates of the TranSensusLCA method can consider shifting to the Circular Footprint Formula (CFF) if its applicability is improved in the future. The cut-off point shall come at least after sufficient separation and sorting including all transportation until this point. After this, the exact position shall be based on the market value of each individual waste stream resulting from previous processes. In case the market value of a waste or product flow cannot easily be determined, and as a last resort, we provide a general vehicle EoL management scheme with preset cut-off points for typical waste streams.

Possible answers: Agree/ Disagree/ No preference

Background

It was voted in the last session that we need an exception for EoL multifunctionality situations. In another question from the last voting, consensus was reached on cut-off as the method to deal with this. Consequently, we provide this detailed guidance on the application and the context of the cut-off method.

Proposed approach/possible options description and justification

1. Model EoL until sufficient sorting leads to distinct waste streams (incl. all transportation). Namely, collection, pretreatment, dismantling and shredding
2. After having clear waste streams, follow the market value of each waste stream until it turns positive. This is where the point of cut-off should be placed. Market values should be based on market investigation of each waste stream (knowing who pays to whom).
3. If the point of cut-off cannot be determined via this procedure, e.g. because it proves difficult to determine the market value, use the general reference model provided in Figure 4-15 in annex 1 to determine the cut-off point for typical streams.
4. If a recycled content exists in the production/manufacturing phase, the LCA practitioner must account for any additionally needed upgrading/processing of the burden-free input until the intended component of the new vehicle is obtained. Carefully reading datasets documentation is recommended to reduce omission or double counting risks.

Q26 – Multifunctionality in prospective LCA

Executive summary

Type of LCA concerned by the question: **Prospective LCA (pLCA)**

Complete question submitted to voting

TransensusLCA proposes that the general hierarchy above shall be used in case of conducting prospective LCA, however we provide additional considerations that LCA practitioners should heed to. These considerations can be translated into parameters and combined into scenarios to be explored within a prospective LCA. Furthermore, in the EoL, the Cut-off method shall be used as indicated in the previous question, however, as for the hierarchy, further considerations are pointed out which can be considered in pLCA scenarios such as the second life of batteries.

These considerations can be found in section 3 in annex 1

Possible answers: Agree/ Disagree/ No preference

Background

Here we provide a brief additional part in case TranSensusLCA method is used in prospective LCA. It was agreed that TranSensusLCA will only provide high level guidance for best practice when it comes to prospective LCA.

Q27 – Multifunctionality in Fleet Level LCA

Executive summary

Type of LCA concerned by the question: **OEM fleet-level LCA, Macro fleet-level LCA**

Complete question submitted to voting

> TransensusLCA proposes the following: Given the overall attributional approach of TranSensus LCA, the rules of dealing with multifunctionality should not change from what is stated in questions 1 and 2. However, in Macro fleet-level LCA, overlooking the strict first substitution condition (i.e. "There is a real, measurable substitution effect ") can be accepted if justified and clearly stated.

Transensus LCA proposes the following: Given the overall attributional approach of TranSensus LCA, the rules of dealing with multifunctionality should not change from what is stated in questions 1 and 2. However, in Macro fleet-level LCA, overlooking the strict first substitution condition (i.e. "There is a real, measurable substitution effect ") can be accepted if justified and clearly stated.

A possible novel multifunctional situation in fleet-level LCAs is vehicle to grid services (V2G) or more generally to (V2X) where "X" can be home, office, etc. This is expected to be a widespread technology in the future hence can be tested in scenarios in future fleet-level studies. The hierarchy as in question 1 should be sufficient to deal with the situation.

The rules to deal with end of life in question 2 still apply to fleet-level LCA. If the second life of batteries are part of the main system or tested in a scenario, it should be handled the same way as mentioned in pLCA section."

Possible answers: Agree/ Disagree/ No preference

Background

Here we provide a brief additional part in case TranSensus LCA method is used in fleet-level LCA. It was agreed that TranSensus LCA will only provide high level guidance for best practice when it comes to fleet-level LCA.

4.2.4 Data collection and type

Energy consumption – accounting for RW effects and degradation

Executive summary

Type of LCA concerned by the question: **Product LCA (also relevant for Prospective and Fleet LCA, but where other options may also be available/suitable depending on the study objectives).**

Complete question submitted to voting

This question consists of two sub questions. TranSensus LCA proposes providing guidance on the preferred methodological approaches to be used when including accounting for use phase vehicle energy consumption impacts that are not captured by regulatory (i.e. WLTP) – i.e. covering (i) real-world (RW) uplift factors, and (ii) degradation in efficiency over the service life of the vehicle. After agreeing on including them in the last voting. Each of these elements is represented by a separate question below for more targeted voting.

Background

There is a gap between regulatory testing results (i.e. WLTP) and real-world energy consumption performance of light duty vehicles, which is well documented and significant. There are also efficiency degradation effects anticipated over the vehicle lifetime in some cases for all vehicle categories. These differences can be defined through two separate effects (i) differences due to energy demands not captured during regulatory testing and due to user behaviour and real-world environmental/operational conditions, (ii) degradation in vehicle efficiency over the life of the vehicle (mainly affecting fuel cell electric vehicles).

For light-duty vehicles, it has been previously agreed within TranSensus LCA's previous voting rounds to include accounting for impacts on the gap to real-world energy consumption either by default, or as a mandatory sensitivity (depending on the requirements set out at the UNECE-level, or the methodology to be developed by the EC for voluntary LCA reporting under the LDV CO2 regulations). There is now a need to define the specific methodological basis and data prioritisation recommended for this, so that such calculations can be performed in a consistent and harmonised way.

In addition to differences in performance in real-world conditions compared to regulatory testing for new vehicles, there is a need to account for loss in vehicle efficiency over its lifetime in some cases (for light-duty, heavy-duty and other vehicle categories). For batteries used in electric vehicles, the reduction in round-trip charge/discharge efficiency is reportedly very low (unlike energy storage capacity loss, is significant). However, for fuel cells there is a more significant loss in overall efficiency due to a reduction in the peak power/voltage over the life of the fuel cell (with fuel cell durability defined as the number of operational hours until 10% peak power degradation). This loss in efficiency over the lifetime of the use of the vehicle also needs to be taken into account in the calculations, where it is anticipated to be significant. Like this such calculations can be performed in a consistent / harmonised way.

Proposed approach/possible options description and justification

The following overall methodological approach is proposed when accounting for adjustments for LDV type-approval (i.e. WLTP) energy consumption data, which is consistent with the one being developed in the UNECE Informal Working Group on Automotive LCA:

Lifetime energy consumption = WLTP energy consumption
x RW Adjustment Factor[(i)]
x Degradation Factor[(ii)]

Notes: (i) Where this is to be applied, either as a default or sensitivity scenario; (ii) where applicable for defined powertrains/vehicle types.

The following two sections provide a summary of the proposed methodological approach to be recommended by TranSensus LCA for the Real-World (RW) Adjustment Factor and the Degradation factor.

Q28 – Energy consumption - subquestion 1: Realword emission factor"

Complete question submitted to voting

Where an adjustment factor is applied to account for 'real-world' (RW) operational energy consumption of light duty vehicles (either in the default assessment, or in sensitivity analyses), the following prioritisation methodology should be applied to determine the appropriate RW Adjustment Factor(s) to apply, depending on the available data.

Executive summary

The following TranSensus LCA prioritisation is proposed for the real-world adjustment factor to apply to WLTP-based energy consumption. The different options are listed in order of accuracy and preference, with the choice of which option is most appropriate or feasible left to the practitioner (i.e. depending on the availability of data / objective of the study). The first option is the preferred one. The second option can be considered as the minimum default approach to follow. Option 3 is a mitigation approach to option 2 in case values are not yet available at the time of the study.

Proposed prioritisation in order of accuracy and specificity (highest to lowest)	UNECE Level
1. 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, FCEVs, etc), matched to the region of operation (i.e. European region for TranSensus LCA)*	Level 4 (Optional, depending on availability)
2. Default values provided for European application as part of (i) the LCA methodology for the LDV CO_2 regulations, or (ii) the UNECE A-LCA methodology (priority in this order, depending on availability).	Level 3 and below.
3. If the previous options are not available, use default values based on EC JRC's 2018 analysis, as used in impact assessments of the car and van CO_2 regulations before 2024 (see Table V-8 below).	Level 3 and below.

Notes: * For example based on OBFCM or similar data provided by operators with a suitably wide/significant sample size across the European region, or alternatively data based on RDE testing for the specific model.

Table 4-5: Summary of the default WLTP-RW conversion factors proposed to be used for prioritisation option 3, in the absence of other datasets

Mode	Segment	Powertrain	WLTP-RW
Cars	Small (A, B)	BEV	115%
Cars	Medium (C, D)	BEV	113%
Cars	Large (Other segments)	BEV	112%
Cars	Small (A, B)	FCEV	115%
Cars	Medium (C, D)	FCEV	113%
Cars	Large (Other segments)	FCEV	112%
LCVs	All	BEV	120%
LCVs	All	FCEV	120%

Source: (Ricardo et al., 2018), Assessing the impacts of selected options for regulating CO_2 emissions from new passenger cars and vans after 2020 (europa.eu)

Possible answers: Agree/ Disagree/ No preference

Q29 – Energy consumption - subquestion 2: Fuel cell degradation

To account for degradation in the efficiency of fuel cells over the operational life of the vehicle (for all vehicle categories), the following methodology should be applied for FCEVs/FC-REEVs to determine the Degradation Factor, depending on the available data.

Executive summary

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. 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 rproposed 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)[30]. 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 FCEV 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 FCEV – 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:

EnCon [AvLife] = EnCon [Start]

/ (1- (10% * *FCEV[lifetime energy] / FC[max energy] /2)*)

Where:

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

EnCon [Start] = 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).

FCEV[lifetime energy] = 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] = 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).

[30] FCH 2 JU - MAWP Key Performance Indicators (KPIs) - European Commission (europa.eu)

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 (***FCEV[lifetime energy])*** are calculated as follows:

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

FC[max energy] (kWh) = Fuel cell durability (hrs)
* Fuel cell average running power (kW)

Where:

Fuel cell average running power (kW) = 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) (= ***FCEV[lifetime energy]****):*

FCEV[lifetime energy] (kWh) = EnCons [Start] (MJ/km) * fuel cell average efficiency (%)
* EnConConversion (kWh/MJ) * Lifetime activity (km)

Where:

EnCons [Start] = MJ/km hydrogen energy input to the vehicle, i.e. hydrogen energy consumption, based on the initial certified value at the start of the vehicle's lifetime.

EnConConversion = 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.

Proposed prioritisation in order of accuracy and specificity (highest to lowest)	UNECE Level
1. 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)
2. 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)
3. 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	Level 3 and below.

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.	

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.

Possible answers: Agree/ Disagree/ No preference

Q30 – Non-exhaust emissions: Proposed methodology for estimating hydrogen leakage

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA.**

Complete question submitted to voting

When utilising hydrogen supply mix in modelling the use-phase of ZEVs, the following methodological approach is proposed to estimate hydrogen leakage across the lifecycle.

Possible answers: Agree/ Disagree/ No preference

Background

Hydrogen is used in several ZEV powertrains. It has a significant impact on their overall lifecycle emissions even with actual practices to consider only hydrogen production and supply without the impact of hydrogen itself. Hydrogen has been previously characterised as an indirect greenhouse gas, and recent scientific evidence suggests that these impacts are more than double that previously estimated. As part of the Impact Assessment, it has been recommended that until an official GWP value is agreed upon for hydrogen, a hydrogen emission flow indicator should be provided (see separate voting question under Task 2.4). Hydrogen emissions are not commonly captured in LCI datasets, and there is a need to define an approach to estimate the hydrogen leakage rate for consistency in modelling this.

Emissions of hydrogen can occur mainly during the hydrogen production and distribution stage (predominantly due to fugitive leakage) – see Table 4-10. Emissions are also anticipated to a lesser extent directly from hydrogen fuelled vehicles though no standardised test methods currently exist for this. H_2 can slip from combustion vehicles and potentially fugitive emissions from H_2 storage systems (particularly for liquefied hydrogen). Recent research has found emission rates of hydrogen from the supply chain are likely to be similar to those of methane from the natural gas supply chain, with net leakage rates estimated to be 2.6%-6.9% for green hydrogen supply chains by (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022)[31].

Table 4-6 : Estimated H2 supply chain emission rates from (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022)*

	Production and processing	Compression	Storage and transport	Liquefaction	Haber-Bosch	Shipping	Regasification	N: H3 cracking	Transmission and storage	Distribution
USA biomass gasification for local use	0.55% (0.10–1.00%)									0.08% (0.05–0.12%)
Australian blue H_2 from coal for export to Japan	0.55% (0.10–1.00%)	0.18% (0.15–0.27%)	0.31% (0.06–0.53%)	0.34% (0.15–2.21%)		0.03% (0.00–0.10%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
Qatar blue H_2 from natural gas for export to Japan	0.55% (0.10–1.00%)			0.33% (0.14–0.98%)		0.06% (0.01–0.17%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
North Sea green H_2 for local use	2.05% (0.10–4.00%)								0.05% (0.04–0.06%)	0.02% (0.0003–0.03%)
Australian green H_2 for export to Japan	2.05% (0.10–4.00%)			0.32% (0.14–0.95%)		0.03% (0.003–0.10%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
Saudi Arabian green H_2 for export to Japan-as LH2	2.05% (0.10–4.00%)	0.17% (0.14–0.26%)	0.31% (0.05–0.54%)	0.33% (0.01–2.04%)		0.06% (0.01–0.17%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
Saudi Arabian green H2 for	2.05% (0.10–4.00%)				0%	0%		0%	0.03% (0.02–0.05%)	0.08% (0.05–0.16%)

[31] Hydrogen emissions from the hydrogen value chain-emissions profile and impact to global warming - ScienceDirect - https://doi.org/10.1016/j.scitotenv.2022.154624

export to Japan- as NH3a										

Notes: Engine slip of H_2 is reported to range from 0 to 12%, and a value of 0.5% was assumed in (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022).

Proposed approach/possible options description and justification

The following approach is proposed for the modelling of hydrogen emissions resulting from the supply, distribution and use of hydrogen as a fuel, as also outlined under the Task 2.4 question. Emissions from other parts of the lifecycle within the study system boundary are not anticipated to be significant in comparison, and are not generally reported in LCI datasets, however these could also ideally be included where readily available (or in case significant other sources are identified).

The following hierarchy shall be applied to account for typical fugitive hydrogen emissions from the supply chain and from vehicle use:

1. Where available, use official governmental estimates on typical fugitive hydrogen emissions for different hydrogen production options, local production vs imported hydrogen, and for different hydrogen vehicle types.
2. In the absence of official governmental estimates (or supplier-specific information) on fugitive hydrogen emissions, include estimated H_2 supply chain emission rates based on Table 4-11, derived and simplified from (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022).

Table 4-7 : Proposed default H2 supply chain emission rates for hydrogen produced from (i) steam reforming of natural gas, (ii) electrolysis of water

	Production and processing	Compression	Storage and transport	Liquefaction	Shipping	Regasification	Transmission and storage	Distribution	Use in H2 ICEV, FCEV and FC-REEV*	Total
H_2 from natural gas (production in same region as use)	0.55%	0.17%	0.31%				0.05%	0.02%	0.50%	**1.61%**
H_2 from natural gas (imported to region of use - as LH2)	0.55%	0.17%	0.31%	0.33%	0.06%	0.00%	0.03%	0.08%	0.50%	**2.05%**
H_2 from electrolysis (production in same region as use)	2.05%	0.17%	0.31%				0.05%	0.02%	0.50%	**3.13%**
H_2 from electrolysis (imported to region of use - as LH2)	2.05%	0.17%	0.31%	0.33%	0.06%	0.00%	0.03%	0.08%	0.50%	**3.57%**

Notes: Hydrogen has a high tendency to leak, which makes it difficult to be contained; primarily due to safety concerns, many studies have assessed the potential for hydrogen leakage from fuel cell electric vehicles, both in stationary conditions and from operation. However, such studies generally do not contextualise hydrogen leakage rates in terms of the overall supply of hydrogen to the vehicle. Engine slip of H_2 in ICEVs fuelled by hydrogen is reported to range from 0 to 12%, and a value of 0.5% is assumed by (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022).
In the absence of other information, a similar rate is assumed also for hydrogen vehicles using fuel cells.

Q31 – Proposed approach for modelling hydrogen supply mix during the vehicle use phase

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro fleet-level LCA.**

Complete question submitted to voting

When utilising hydrogen supply mix in modelling the use-phase of ZEVs, the following methodological approach is proposed. This includes the approach that shall be followed in prioritising data sources and the basis for the default conservative future hydrogen mix projection to be used.

Possible answers: Agree/ Disagree/ No preference

Background

Similarly as for BEVs and their use of electricity, the environmental impacts arising from the use phase of ZEV powertrains using hydrogen (i.e. FCEVs, FC-REEVs and H2 ICEVs) represent a significant share of the total life cycle impacts of such vehicles. They are strongly dependent on the hydrogen fuel production and supply chain. Hydrogen can be supplied from a limited number of different sources and processes (currently steam reforming natural gas, or electrolysis of water, e.g. using grid electricity or renewable electricity). And compared to electricity, there is relatively much greater uncertainty on what the actual supply mix will be for future hydrogen fuelled vehicles, and how this is likely to change over time. This is important particularly for comparative LCAs, where the environmental impacts of different ZEV powertrains are likely to be compared to each other, and to those of ICEVs, and different assumptions can make a significant impact on comparisons.

In TranSensus LCA, a decision has already been reached that a conservative dynamic electricity mix projection approach shall be used by default to model the electricity modelling input to the use phase of BEVs (with some exceptions, e.g. for OEMs where a static grid mix may be allowed). A similar approach is also proposed for hydrogen, however this is currently limited by the comparative lack of availability of robust future projections, compared to the availability of projections for future electricity supply mixes produced by the IEA. However, should official projections become available in the future, it is desirable to already have a proposed methodology that can account for this (similarly as for electricity).

This document then aims to provide a proposed hierarchy for the assumptions used for use-phase hydrogen supply mix, and clear guidance on how to implement a dynamic hydrogen mix modelling within TranSensus LCA (i.e. similarly to electricity), be it as a default scenario, or as part of a Sensitivity Analysis.

Proposed approach/possible options description and justification

The following step-by-step methodological approach is proposed for the modelling of hydrogen supply mixes feeding into the use phase of xEVs, which is analogous to that used for electricity. Since there are currently no official projections for future hydrogen supply mix, in practice it is anticipated that 1(c) or 1(d) will be the *de facto* default approach in near term:

1) **A scenario for the expected default conservative future evolution of the hydrogen supply mix in the geographical region of interest shall be selected**, according to the following order of preference – i.e. also limited by whether this is explicitly available for hydrogen:

   a) The official published scenario specifically for hydrogen supply mix for the country or geographical region of interest. For TranSensus LCA, it should be for the EU by default. (Additional alternative official scenarios may also be used in the sensitivity analysis, where available).

   b) The official general scenario based on currently implemented policy for the country or geographical region of interest (providing this has been updated within less than 3 years). For TranSensus LCA, this should be for the EU by default. (Additional alternative official scenarios may also be used in the sensitivity analysis, where available).

   c) Hydrogen produced by electrolysis using a conservative future grid electricity mix scenario (which should be consistent also with the scenario being used for ZEVs using electricity in comparative studies also including these):

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

      ii)The official general scenario based on currently implemented policy for the country or geographical region of interest (providing this has been updated within less than 3 years)[32].

      iii)Stated Policies Scenario (STEPS) from the most recent International Energy Agency's World Energy Outlook (IEA WEO) report, for the geographical region of interest[33]. For TranSensus LCA, it should be for the EU by default. The Sustainable

[32] For the EU, the most recent official reference scenario for current policy is EU Reference Scenario 2020. However, this scenario is now out of date compared to recent policies implemented as part of the Green Deal. The European Commission is currently working on an updated reference scenario, which will be available later in 2024. Ideally an official electricity mix projection would be provided and updated at a higher frequency than this, which may be the case in the future.

[33] IEA WEO region-specific datasets for STEPS are available for purchase for the following regions: North America, USA, Central&South America, Brazil, Europe, EU-27, Africa, Middle East, Eurasia, Russia, Asia Pacific, China, India, Japan, Southeast Asia, OECD, non-OECD, Emerging and developing economies.

Development Scenario (SDS) or other alternative official IEA scenarios may also be used in the sensitivity analysis, where available.

d) If none of the previous options (a to c) are available for the geographical region of interest, or legal responsibilities may prevent OEMs from adopting a dynamic electricity mix modelling, then it is recommended that hydrogen produced by electrolysis using the most recent "static" grid mix composition shall be used instead.

In the case either option 1(c) or 1(d) is applied, it is proposed to also provide an alternative assessment using (i) production from steam reforming of natural gas, (ii) a 100% renewable electricity (RE) mix for comparison. The latter is intended as a hypothetical scenario corresponding to an optimistic assumption (to provide counterpoint to the otherwise likely pessimistic assumption of the current static grid mix or production from natural gas). It is acknowledged that in some countries, the 100% RE scenario may be unrealistic.

2) **The electricity grid mix composition for each year of vehicle operation shall be estimated** based on the methodology outlined for this (see separate question on Vehicle Use Phase Electricity Supply Mix). The hydrogen supply mix composition for each year of vehicle operation shall then be estimated (i.e., the shares $S_{i,N}$ of hydrogen supplied by each technology i in the year N), in a similar way to the electricity mix, by applying linear interpolation between the respective hydrogen supply shares reported for the nearest predefined time horizons in the scenario selected at point 1 above. To clarify, for each year of operation N, BOTH the share $S_{i,N}$ of hydrogen supplied by each technology i (where i = steam reforming, or electrolysis) AND the specific electricity grid mix used to power the electrolysis process in the same year must be calculated. However, if option 1(c) or 1(d) is applied, then i = electrolysis only, and only the grid mix calculations apply.

3) **The average representative hydrogen supply mix composition over the full service life of the vehicle shall be calculated** as follows (i.e. similarly as for electricity use):

   By default, as the arithmetic average of the individual hydrogen 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 modelling approach may be adopted, employing a weighted average (as opposed to a simple arithmetic average) of the individual shares $S_{i,N}$ of hydrogen supplied by each technology i in the year N, i.e.:

Where $W_N = A_N/L$ (A_N = vehicle activity in year N, L = total lifetime activity).

4) **A bespoke hydrogen mix model shall finally be built** in the LCA software package of choice (e.g., “LCA for Experts”, or “SimaPro”), using the hydrogen mix composition calculated at point 3 above, and leveraging the most up-to-date database processes available for the individual hydrogen production and electricity generation technologies[34,35].

Q32 – Proposed approach for calculating impacts from maintenance, wear and consumables

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-fleet LCA**

Complete question submitted to voting

“Do you agree with this proposed way of accounting for maintenance, wear and consumables during the use phase?”

Possible answers: Agree/ Disagree/ No preference

Background

Maintenance is most often excluded in the scientific literature and also by some OEM vehicle LCAs, generally justified by the low impacts relative to the vehicle life cycle, and lack of available data. Nonetheless, it is good practice in the industry to include maintenance in the use-phase, and it has been agreed within TranSensus LCA’s previous voting to include accounting for maintenance impacts. Currently, where accounting for maintenance and wear parts is included in OEM product LCA, there is not a good level of consistency in the overall approach and items covered. There is now a need to define the specific methodological basis for this.

Proposed approach/possible options description and justification

The maintenance parts may be very different regarding an LDV or HDV, or even different models inside one category. Therefore, the lists of parts and consumables to consider will need to take into account differences in vehicle types and powertrains. At present, most of the automotive OEMs already recommend a list of consumables/maintenance parts in owner’s manual

[34] For Variable Renewable Energy (VRE) generators like solar photovoltaics (PV) and Wind, increased accuracy may be attained by using the database processes per unit of installed power [kW_p], and then multiplying the associated LCIs by the appropriate region-specific Capacity Factors (CF), which are defined as the ratio of the electricity delivered in a year [kWh] to the product of the nameplate installed power [kW_p] times the number of hours in a year. CFs for Wind and PV for all World locations are freely available at, respectively: https://globalwindatlas.info/ and https://globalsolaratlas.info/

[35] An additional element of complexity is represented by the fact that some technologies (among which primarily PV and Wind) may also be expected to continue evolving and improving over time, leading to reduced average impact per unit of electricity generated as newer generations of these technologies come on-line and start contributing to the grid mix. However, addressing this aspect in the modelling may be deemed outside of scope for conventional product LCAs, and may instead form part of a dedicated Sensitivity Analysis, especially in prospective and fleet-level LCAs.

(including frequency) – e.g. Figure 4-17 . The development of a fully exhaustive list seems unrealistic, but nevertheless it is feasible to provide a non-exhaustive list as starting point and guidance for the practitioner. Building on the non-exhaustive list from TranSensus LCA, the manufacturer would be obliged to provide a complete list with frequency of maintenance (OEM and model specific). However, due to the low impact of some maintenance items, emission factors and processes may be taken from secondary data sources in some cases.

Based on this information, it is proposed that as a minimum the maintenance, wear and consumable items listed in Table 4-12 be considered in all studies, with a smaller list of items responsible for the most significant potential impacts marked as being mandatory for inclusion in the assessment. For consumables and maintenance items, the assessment of requirements should be based on the vehicle/model's maintenance schedule, with the number of replacements required based on the relevant replacement/maintenance interval in mileage or time – whichever comes first – and the corresponding lifetime activity (in km) and operational lifetime (in years) defined in the study's Goal & Scope (i.e. according to TranSensus LCA guidance on these).

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

	M1	Tracks	moto
Oilfilter	○	○	○
air cleaner element	○	○	○
fuel filter	○	○	○
timing belt	○	○	○
spark plug	○	-	○
Disk Pad (Front Wheel)	○	○	○
Brake shoe (rear wheel)	○	○	○
MT Clutch Plate	-	○	-
Regulator	-	○	-
Chain for driving vehicle body side	-	-	○
engine oil	○	○	○
brake fluid	○	○	○
Long Life Coolant	○	○	○
Tires	○	○	○
Auxiliary Battery (Lead Battery)	○	○	○
MT Mission Oil	-	○	-
AT Oil	-	○	-
differential oil	-	○	-

Passenger car example

Maintenance Request	BEVs Mileage	BEVs Time	Gasoline ICEVs Mileage	Gasoline ICEVs Time	Diesel ICEVs Mileage	Diesel ICEVs Time
Passenger Air Filter	36,000 km	2 years	36,000 km	2 years	72,000 km	2 years
Electric Drive Unit Fluid	72,000 km	-	-	-	-	-
Hood Lift Support Gas Struts	161,000 km	10 years	161,000 km	10 years	-	-
Body Lift Support Gas Struts	161,000 km	10 years	161,000 km	10 years	-	-
Coolant Circuits	240,000 km	5 years	-	-	-	-
Brake Fluids	-	5 years	-	5 years	156,000 km	5 years
Air Conidtioning Desicant	-	7 years	-	7 years	-	7 years
Engine Filter	-	-	12,000 km	12 months	12,000 km	12 months
Engine Oil	-	-	12,000 km	12 months	12,000 km	12 months
Engine Air Filter	-	-	12,000 km to 24,000 km	-	72,000 km	4 years
Automatic Transmission Fluid	-	-	72,000 km	-	-	-
Automatic Transmission Filter	-	-	72,000 km	-	-	-
Spark Plugs	-	-	96,000 km to 156,000 km	-	-	-
Transfer Case Fluid (if 4WD)	-	-	161,000 km	-	72,000 km	24 months
Rear Axle Fluid (if AWD)	-	-	240,000 km	-	-	-
Engine Cooling System	-	-	240,000 km	6 years	240,000 km	6 years
Fuel Filter	-	-	-	-	36,000 km	2 years
Front Axle Oil	-	-	-	-	96,000 km to 156,000 km	12 months
Front Axle Bearing Grease	-	-	-	-	156,000 km	12 months
Power Steering Fluid	-	-	-	-	144,000 km	-
Power Steering Filter	-	-	-	-	144,000 km	-
Windshield Wiper Blades	-	-	-	-	12,000 km	6 months

Figure 4-10 : Example of maintenance and servicing requirements for a passenger car (see Annex for a higher resolution version)

Source: UNECE A-LCA IWG: SG4 - 7th meeting - Transport - Vehicle Regulations - UNECE Wiki

Table 4-8 : Proposed list of maintenance and wear parts and consumables to consider in LCA studies – items marked as mandatory should be included in all studies (values can be zero if no replacements are required). Inspired by UNECE A-LCA IWG: SG4 - 7th meeting - Transport - Vehicle Regulations - UNECE Wiki

Type	Item	Mandatory, if replacement is needed*	H2 ICEV	BEV	BEV-ERS	FCEV	FC-REEV
Consumables	Engine lubricant		ü	N/A	N/A	N/A	N/A
	Engine/oil filters		ü	N/A	N/A	N/A	N/A
	AdBlue/Urea	**Yes**	(ü)	N/A	N/A	N/A	N/A
	Coolants		ü	ü	ü	ü	ü
	Screen wash		ü	ü	ü	ü	ü
	Electric drive unit /transmission fluid		ü	ü	ü	ü	ü
	Brake fluids		ü	ü	ü	ü	ü
	Refrigerants for Heating, Ventilation and Air conditioning (HVAC)	**Yes**	ü	ü	ü	ü	ü
	Other fluids or filters		ü	ü	ü	ü	ü
Maintenance and wear parts	Passenger air filter		ü	ü	ü	ü	ü
	Windscreen wiper blades		ü	ü	ü	ü	ü
	Tires	**Yes**	ü	ü	ü	ü	ü
	Starter battery (i.e. 12V)	**Yes**	ü	ü	ü	ü	ü
	Brake pads	**Yes**	ü	ü	ü	ü	ü
	Brake discs		ü	ü	ü	ü	ü
	Steering joint		ü	ü	ü	ü	ü
	Link arm		ü	ü	ü	ü	ü
	Traction/storage battery	**Yes**	N/A	ü	ü	ü	ü
	Fuel cell stack	**Yes**	N/A	N/A	N/A	ü	ü
	Other auxiliary batteries	**Yes**	(ü)	(ü)	(ü)	(ü)	(ü)

Notes: Items marked (ü) may only be relevant for certain vehicle types or configurations. N/A means not applicable

*For more information. Please see the explanation in text right before the table.

Traction batteries and fuel cells systems are generally designed so that no replacement should be needed during the vehicle lifetime in most vehicle types (except for some heavy duty vehicles with higher lifetime activity). However, due to the major impact of battery and fuel cell on the vehicle LCA, the need for replacement or not of these systems in the context of the LCA study should be checked and justified. The specific proposed methodologies recommended for determining the number of battery or fuel cell replacements, are still under discussion pending finalization, and will be voted on/reviewed at a later date.

Q33 – Do you agree with this proposed approach for data quality rating (DQR)?

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes that a data quality assessment must take place to be ISO compliant especially when the study is communicated to a third party for verification. Nevertheless, we do not mandate a specific way of doing this. For consistency however, we recommend adopting the same DQR method through the entire product system, which might mean using the same method in the background systems (LCA database or data from external suppliers) to evaluate the data of the foreground system.

Possible answers: Agree/ Disagree/ No preference

Background

According to ISO 14044, a data quality assessment must be performed. This assessment relates differently to each LCA phase. An overview is provided in Table 4-13. Data quality assessment is emphasized further in case of third-party reporting.

Table 4-9 : Data quality assessment in ISO 14044

Goal and Scope Definition	Life Cycle Inventory	Life Cycle impact assessment	Interpretation
In the scope definition, minimum data quality requirements that fulfill the goal of the study shall be defined. These include time, geography and technology coverage, precision , completeness , consistency, reproducibility, source, and uncertainty	When collecting data, further information about data quality indicators shall be referenced. If such data do not meet the data quality requirements, this shall be stated. This shall be validated whether it fulfills data quality requirements in scope definition	Data quality analysis is mentioned as an optional step after weighting. To be done via gravity, uncertainty, or sensitivity analysis	Has an impact on mandatory interpretation components which are completeness check, sensitivity checks, and consistency checks.

ISO however doesn't provide a specific way to execute such data quality assessment. In order to tackle this issue, what is called Data Quality Rating (DQR) became a staple part of many guidelines including PEF. Nevertheless, there is no consensus on a single method to calculate it. Although all methods depart from the same concept of defining criteria for quality (mostly inspired from ISO data quality requirements in table #) and giving each criterion a qualitative or more commonly quantitative score, they differ in the criteria suggested and the scoring system. The criteria are usually related to technological, geographical, time representativeness, in addition to completeness, and reliability of each exchange (inflow/outflow of a unit process). Then each exchange within an activity is assigned a single DQR depending on the average of the scores in each of these criteria. See example from Catena X below:

Data quality rating	1 – Good	2 – Fair	3 – Poor
Technology (TeR)	Same technology	Similar technology (based on secondary data)	Different or unknown technology
Time (TiR)	Data from reporting year	Data less than 5 years old (creation date of dataset)	Data more than 5 years old (creation date of dataset)
Geography (GeR)	Same country or country subdivision	Same region or subregion	Global or unknown
Completeness (C)	All relevant sites for specified period	<50% of sites for specified period or >50% of sites for shorter period	Less than 50% of sites for shorter time period or unknown
Reliability (R)	Measured activity data	Activity data partly based on assumptions	Non-qualified estimate

The data quality rating for activity data or an emission factor shall then be calculated from the five data quality indicators as an arithmetic mean.

$$DQR = \frac{TeR + GeR + TiR + C + R}{5}$$

Figure 4-11 : Catena-x proposed sample scoring criteria for performing a qualitative data quality assessment (Please note this is taken from Catena X V2, Catena X V3 has a slightly different DQR method)

Catena-x proposes five criteria (which they call indicators) and only 3 scores Good, Fair, Poor which are translated into numbers 1, 2, 3 respectively, with 1 indicating the best quality.

Another variation of the same concept is found in ecoinvent which is the pedigree matrix. ecoinvent applies a method for estimation of default standard deviations for flow data. Characteristics of these flows and the respective processes are turned into uncertainty factors in a pedigree matrix, starting from qualitative assessments. The uncertainty factors are aggregated to the standard deviation. This approach allows calculating uncertainties for all flows in the ecoinvent database. For more information See (Ciroth et al., 2016; Muller et al., 2016; Weidema et al., 2013)

Proposed approach/possible options description and justification

SO is clear in its recommendation on carrying out a data quality assessment, and compare it with data quality requirements decided in the scope definition. However, since moving from qualitative evaluation of data to numbers is not entirely objective in these methods, we do not mandate a specific way to assess the data quality or to calculate DQRs, especially given that some of these methods are time and resource demanding.

However, we recommend [not mandate] that the LCA practitioners apply the same method used in the background database (e.g, ecoinvent, MLC Sphera). This will probably save resources, boost the consistency, and will facilitate calculating global DQR of the study if needed (i.e. the aggregations of the DQRs per exchange from all unit processes (background and foreground)).

Note: Besides the data rating that comes with databases, the foreground system data should be evaluated by the LCA practitioner. Normally, this data is expected to score high in quality. For example, if an OEM models the manufacturing stage of an in-house product with directly collected data from its own facilities, the OEM might end up with a score “1” for all or most flows.

An example of data quality assessment activity done by Volvo in a vehicle LCA can be found in Appendix 6 in https://www.volvocars.com/images/v/-/media/Project/ContentPlatform/data/media/sustainability/volvo_ex30_carbonfootprintreport_A4.pdf

4.3 Task 2.4: Impact assessment

4.3.1 List of questions submitted to the 3rd voting by Task 2.4

Summary of TranSensus LCA propositions & voting options:

Table 4-10 : List of questions submitted by task 2.4 to 3rd voting of September 2024

TranSensus LCA proposes for task T2.4	Status
Mandatory set of LCA-Impact Category	
• TranSensus LCA proposes the inclusion of Cumulative Energy Demand (CED) as mandatory impact category and Renewable/Non-Renewable indicators	*(1)*
• TranSensus LCA proposes the use of EF3.1 method and associated indicators for all TranSensus LCA mandatory impact categories.	*(1)*
• TranSensus LCA proposes inclusion of depletion of abiotic resources in the mandatory list and dissipation in optional list of TranSensus LCA impact categories	*(1)*
• TranSensus LCA proposes to include a mandatory hydrogen (H2) emission flow indicator, and to include a sensitivity including H2 emission impacts as a greenhouse gas, until a formalised GWP is available according to IPCC/within the EF LCIA method	*(1)*
Recommended social impact indicators	
• Transensus LCA proposes to include the Rate of fatal accidents at workplace in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Rate of non-fatal accidents at workplace in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Right of Association in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Right of Collective bargaining in the recommended list of TranSensus LCA social indicators (Workers)	*(1)*
• Transensus LCA proposes to include the Right to strike in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Children in employment, total in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Minimum wage, per month in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Living wage, per month (AV) in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Weekly hours of work per employee in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the social security expenditures in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Overall country sector risk forced labour in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*

• Transensus LCA proposes to include the Forced labour risk (Global Savery Index) in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Workers)	*(1)*
• Transensus LCA proposes to include the Presence of indigenous population in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Local community)	*(1)*
• Transensus LCA proposes to include the Corruption Perception Index (CPI) in the recommended list of TranSensus LCA social indicators (Stakeholder Category: Society)	*(1)*

(1): agree/disagree

Mandatory set of LCA-Impact Category

TranSensus LCA first 2023 building blocks (deliverable D2.2) provides guidance for the impact assessment on indicators to be considered in an optional set advised by the methodology, the question of the integration of a mandatory set and S-LCA. Optional set building blocks recommend the inclusion of the EF method, CED-total, CED_non-renewable, criticality and resource dissipation as well as the exclusion of biodiversity impact and circularity indicators and aspects. Nevertheless, biodiversity and circularity indicators will be important to include in TranSensus methodology when a robust indicator will be available.

In 2024, T2.4 partners have analysed a list of existing LCA impact categories and evaluated the relevance of each impact for zero emission vehicles (ZEVs) life cycle assessment. This evaluation has been performed by scoring each impact regarding a set of 5 criteria (see D2.3 and previous voting documents):

- Science based criteria: 1) robustness of the impact, and 2) relation to planetary boundaries.
- Other criteria: 3) importance for ZEVs, 4) data availability, and 5) easy-to-use.

Based on this analysis, we have proposed a list of mandatory impacts categories meaning that this set of impacts has to be calculated.

Impacts not included in this list are either optional with TranSensus LCA recommendation of calculation or not recommended for calculation (see details below).

The scoring system used for the evaluation is designed with a range of "A" to "E", where "A" represents the highest possible score, indicating the most favorable assessment or the highest level of compliance with the criteria evaluated. Conversely, "E" denotes the lowest score, reflecting significant deficiencies or areas in need of improvement. This hierarchical system of letter grades is intuitive, as it is based on rating systems known from educational contexts and allows for quick and clear comparisons and decision-making processes.

In the context of a quantitative analysis or further statistical evaluation, these letter grades are converted into numerical values. Specifically, "A" equals a score of 5, reflecting the highest compliance or the most favorable conditions, while "E", with a score of 1, signals the lowest level of compliance. When the scores for several criteria are added together to calculate an average, the resulting figure does not always perfectly match the integer numbers. To address this problem and maintain the integrity of the assessment, a more granular rating scale was used for averages that fall between the standard letter grades. This refined rating scale introduces "+" and "-" modifiers to the basic letter grades, creating subdivisions that more accurately represent nuanced differences in performance or compliance levels.

The Joint Research Center has worked for several years to establish a link between LCA and Planetary Boundaries (PBs) through different methods, mapping most of the EF impact categories to the planetary boundaries[36,37]. Their papers show on two scales (global and European) the results for each impact category, some of them exceed the limit no matter the scale and the method and find themselves in the high-risk zone. In this workgroup, we considered that such impact categories are of the utmost importance to integrate in the TranSensus methodology. Thus, we provided a rating for the impact categories considering how many times they were found in the safe operating space (“E”), the zone of uncertainty (“D”, “C”) or the high-risk zone (“C”, “B”, “A”).

The particulate matters (PM), climate change (CC) and land use (LU) impact categories exceed the limit by a factor 8 for PM and CC and a factor 60 for LU. That’s why they were given the highest rating as they are considered urgent to address in LCA.

Table 4-11 : Mandatory impact categories evaluation by TranSensus LCA

	Science based criteria		Other criteria			
Impact category	**Robustness**	**Relation to planetary boundaries**	**Importance for ZEVs**	**Easy to use**	**Data availability**	**Score**
Climate change	A+	A+	A+	A+	A+	A+
Photochemical ozone formation	B-	D+	A-	A	A+	B+
Acidification	B	D	A	A	A	B
Freshwater eutrophication	B	B-	B-	A	A+	B+
Particulate matter	A	A+	A	A+	A	A

[36] Esther Sanyé-Mengual, Serenella Sala; Life Cycle Assessment support to environmental ambitions of EU policies and the Sustainable Development Goals; Integrated Environmental Assessment and Management — Volume 18, 2022, Number 5— pp. 1221–1232; DOI: 10.1002/ieam.4586

[37] Serenella Sala, Eleonora Crenna, Michela Secchi, Esther Sanyé-Mengual; Environmental sustainability of European production and consumption assessed against planetary boundaries; Journal of Environmental Management, Volume 269, 2020, 110686, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2020.110686

T2.4 has decided to propose as mandatory impact categories, those reaching a total score of A+, A, A- or B+. Below this threshold limit, it is understood that impact considered is non-mature enough, methodology or data are not available yet. The concerned impact may be a priority for R&D activities in order to include it as mandatory within a future revised TranSensus LCA methodology for ZEV.

The results of 2nd voting session led to a list of 5 impact categories to be mandatory in TranSensus LCA methodology:

- Climate change
- Photochemical ozone formation
- Acidification
- Particulate matter
- Freshwater eutrophication

This 3rd voting session will focus on recommended LCIA methods and associated indicators for those 5 impacts.

Furthermore, a another mandatory indicator for primary energy demand (or cumulative energy demand, CED) and a new mandatory indicator coupling natural resources depletion and dissipation are proposed in this voting round.

Table 4-12 : Proposal of new mandatory impact categories evaluation by TranSensus LCA

	Science based criteria		Other criteria			
Impact category	**Robustness**	**Relation to planetary boundaries**	**Importance for ZEVs**	**Easy to use**	**Data availability**	**Score**
Depletion of abiotic resources	C-	B	A+	A+	A-	B+
CED	A-	C+	A	A-	A	A-

Q34 – Inclusion of Cumulative Energy Demand (CED) as mandatory impact category

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes CED to be part of the mandatory list of TranSensus LCA impact categories including the split of renewable and non-renewable CED. TranSensus LCA proposes using CED with the method based on the energy-harvested approach[38,39]

Definition of CED:

Cumulative Energy Demand (CED) is the amount of primary energy consumed during the life cycle of a product or a service. It can be differentiated between renewable and non-renewable energy demand. Renewable and non-renewable energy demand are then divided into eight impact subcategories: non-renewable—primary forest, nuclear, and fossil fuels; renewable resources—biomass, wind, solar, geothermal, and water based on the Ecoinvent database (Table 4-17), and no aggregated value is presented due to the existence of divergent concepts and the unclear basis for the characterization of the various primary energy carriers.

Table 4-13 : List of CED indicators

	subcategory	includes
non-renewable resources	fossil	hard coal, lignite, crude oil, natural gas, coal mining off-gas, peat
	nuclear	uranium
	primary forest	wood and biomass from primary forests
renewable resources	biomass	wood, food products, biomass from agriculture, e.g. straw
	wind,	wind energy
	solar	solar energy (used for heat & electricity),
	geothermal	geothermal energy (shallow: 100-300m)
	water	run-of-river hydro power, reservoir hydro power

It can also be called Primary Energy Consumption or Primary Energy Demand, these three names are, to the best of TranSensus LCA knowledge, equivalent and refer to the same indicator. CED being the most known and used in the LCA community, it will be the name used hereafter.

[38] Hischier R., Weidema B., Althaus H.-J., Bauer C., Doka G., Dones R., Frischknecht R., Hellweg S., Humbert S., Jungbluth N., Köllner T., Loerincik Y., Margni M. and Nemecek T. (2010) Implementation of Life Cycle Impact Assessment Methods. Ecoinvent report No. 3, v2.2. Swiss Centre for Life Cycle Inventories, Dübendorf

[39] Frischknecht R., Wyss F., Knöpfel B. S., Lützkendorf T. and Balouktsi M. (2015) Cumulative energy demand in LCA: the energy harvested approach. *Int J Life Cycle Assess* 20:957–969

There is still a debate on whether CED is a life cycle inventory indicator (driver indicator) or a life cycle impact assessment indicator. However, TranSensus LCA recommends using CED by following the energy harvested approach defended by Frischknecht et al.[39], in their paper they refer to CED as an LCA impact category with Renewable and Non-Renewable indicators. To be consistent, CED will be considered as an LCA impact category in the TranSensus LCA methodology.

Frischknecht et al. define the energy-harvested approach as a quantification of "*the amount of energy resources made available for human use. Following this approach, the intrinsic value and the depletion aspect of resource protection are combined and the following definition of the indicator proposed:*

- *Energy deposits, stocks of funds and flows do have an intrinsic value.*
- *The harvested amount of energy resources qualifies for accounting the cumulative energy demand based on the intrinsic value of the energy resources.*
- *The intrinsic value is determined by the amount of energy extractable from the harvested energy resources*
- *All other aspects like abundance, societal demand, possibilities for substitution etc. add nothing to the value of energy resources*"[39].

Possible answers: Agree/ Disagree/ No preference

Background

Justification of the recommendation:

In the policy framework and decarbonation targets, energy efficiency is one of the key drivers to reduce environmental impacts. That is why, including the CED as a mandatory indicator (both renewable and non-renewable) is essential in LCAs. It is already mandatory to calculate for some product declaration programs (The International EPD System[40], Green NCAP[41], 'and included in most LCAs performed reflecting the global scientific consensus of its relevance. Including CED as a mandatory indicator is even more important in the case of ZEVs as their production and overall life cycle is energy intensive. Especially, when studying the effects of using renewables for the use phase of ZEV, and how it affects the energy demand according to different vehicle types.

[40] https://environdec.com/resources/indicators
[41] https://www.greenncap.com/lca-explained/

Table 4-14 : Proposal of new mandatory impact categories evaluation by TranSensus LCA – Results for CED

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
CED	A-	C+	A	A-	A	A-

The analysis performed in the project and provided in the table above shows that, according to the partners, this indicator is robust, easy to use, and data is easily available. However, the grade regarding the relation to the planetary boundaries is low. This is due to the fact that this relation has not been assessed in scientific papers yet. Moreover, CED is an indicator that is quite transversal and would have an influence on most of the planetary boundaries, as such, it is still relevant to consider as a mandatory indicator in TranSensus LCA.

TranSensus LCA acknowledges that there could be a bias while using the CED indicator that does, under some circumstances, under-estimate the impact on natural ecosystems due to human-induced degradation of high-quality forms of renewable energy resources (e.g., visible sunlight) into lower-quality heat[7]. However, all LCA impact indicators only estimate a "potential" impact and only provide an estimation, there will always be uncertainties while calculating environmental impacts, and the uncertainties for CED seem no greater than for many other impact categories. Thus, TranSensus LCA recommends using CED indicator with care and taking into account the uncertainties that come with.

Q35 – Use EF3.1 as LCIA method for mandatory impact category

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the use of the last version of EF method (EF3.1) and associated indicators for all TranSensus LCA mandatory impact categories

Five LCA impact categories are already defined as mandatory within TranSensus LCA methodology: Climate change, Photochemical ozone formation, Acidification, Particulate matter, Freshwater eutrophication. In order to calculate and compare indicators associated to each LCA impact categories, TranSensus LCA recommends applying the same homogenised LCIA method. TranSensus-LCA also recommend applying the latest/most recent version available of the EF method at the LCA calculation time. When a new version is released, it should be adopted.

Possible answers: Agree/ Disagree/ No preference

Background

Five LCA impact categories are already defined as mandatory within TranSensus LCA methodology. Our recommendation is to apply the latest version of Environmental Footprint (EF) method[8] for each mandatory LCA impact category.

- Climate Change: the indicator is Global Warming Potential (GWP), the reference substance is CO_2 and the reference unit is kg CO_2-equivalents
- Pollution impact categories:
  - Photochemical ozone formation: the reference substance is NMVOC (Non-Methane Volatile Organic Compounds) and the reference unit is kg NMVOC-equivalents→.
  - Acidification: the reference substance is hydrogen ion and the reference unit is mol H^+ equivalent
  - Particulate matter: the reference indicator is the disease incident (probability of new cases of diseases in a population over a given time period). TranSensus-LCA recommends to apply a second indicator, particulate matter including the amount of primary (directly emitted) and secondary (formation due to emissions of precursors) particulates – i.e. particulate matter formation (PMF), to better estimate particulate matter impact. The reference unit of this indicator is kg $PM_{2.5}$ equivalents according to (de Leeuw, 2002)[42].
  - Freshwater eutrophication: The reference substance is phosphorus and the reference unit is kg P equivalent.

The European Commission has published a recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations in the Official Journal of the European Union.

[42] Where characterisation factors in kgPM equivalent are: PM = 1, NO_x = 0.88, SO_2 = 0.54, NH_3 = 0.64. https://doi.org/10.1016/S1462-9011(01)00042-9

Q36 – TranSensus LCA proposes including depletion of abiotic resources in the mandatory list and dissipation in the optional list of TranSensus LCA impact categories

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including depletion of abiotic resources in the mandatory list and dissipation in the optional list of TranSensus LCA impact categories

Depletion of abiotic resource addresses the use of non-renewable abiotic natural resources (minerals and metals: copper, potash, rare earths, sand, etc.). It focuses on the contribution of product systems to the exhaust of primary stocks of a non-renewable resource.

Efforts for a better understanding of the impacts associated to non-renewable resources highlight barriers other than depletion; notably criticality and dissipation. Criticality is already part of the optional list of impact categories in TranSensus LCA. The method testing conducted since the last voting session reveals the relevance to include "dissipation of abiotic resources" as an optional impact category that also serves as a complement to depletion.

Possible answers: Agree/ Disagree/ No preference

Background

Table 4-15 : Proposal of new mandatory impact categories evaluation by TranSensus LCA – Results for depletion of abiotic resources

	Science based criteria		Other criteria			
Impact category	Robustness	Relation to planetary boundaries	Importance for ZEVs	Easy to use	Data availability	Score
Depletion of abiotic resources	C-	B	A+	A+	A-	B+

The depletion of abiotic resources impact received a B+ score reflecting its importance in the broader context of environmental science and policy. Its ease to use is highlighted by a A+ score. It should be noted that data are relatively available, which led to a A- grade.

A previous review on this impact presented in deliverable D1.1 "Review of current practices on life cycle approaches along the electromobility value chain" lead to the conclusion that an interesting alternative for this indicator is the dissipation of abiotic resources. A dissipation model also might better address circularity issues, since it could help identify hotspots in which resources are not recovered.

Two methods for the assessment of dissipation were short-listed for further testing: Average Dissipation Rate (ADR) and Environmental Dissipation Potential (EDP). These methods were applied to a case study (one electric vehicle) in parallel to abiotic depletion potential (ADP). Highlights of the method testing are described in the Table 4-20, based partially on (1) the SUPRIM framework (Schulze et al. 2020) for impact assessment methods for resource use and (2) insights from the method testing conducted as part of TranSensus LCA.

Table 4-16 : Qualitative comparison of the depletion (ADP) and dissipation (EDP, ADR) methods

Method	Abiotic Depletion Potential (ADP)	Environmental Dissipation Potential (EDP)	Average Dissipation Rate (ADR)
Reference	van Oers et al. 2019b	van Oers et al. 2020	Charpentier Poncelet et al. 2019, 2021, 2022
Role of resources	Abiotic resources are valued by humans for their functions used (by humans) in the technosphere, taking into account primary production only.	Abiotic resources are valued by humans for their functions used (by humans) in the technosphere, taking into account both primary and secondary production.	
Problem definition	Decrease of accessibility to primary resources (from environment)	Decrease of accessibility to primary (from environment) and secondary resources (from technosphere)	
Time perspective	Long term (exhaust of primary stocks)	Very long term (focus on emissions of elements to the environment)	Short to long term (focus on current rates of resource dissipation)
Elementary flow to be assessed	Extraction (resources from ground)	Emission (emissions to the environment)	Extraction (resources from ground)
Availability of characterization factors	Available	Version used for the method testing is not yet available; previous version is available	Available
Integration of method in LCA databases	Fully integrated and operational	Files available for import to LCA databases.	Operational in Ecoinvent, files available for import to other LCA databases.

The dissipation methods take the concept of dissipation of resources as a problem definition. These are developed as complementary methods for the currently used impact category Abiotic Depletion (AD). The rationale behind this shift in problem definition, from depletion to dissipation, is the notion that elements after extraction from the environment are actually not depleted for future use, since they end up in stocks in the technosphere, which are accessible again to a certain extent.

The application of the dissipation methods to the proposed case study reveals hotspots that are not highlighted by the ADP method. These hotspots are mainly explained by the efficiency in the recovery of elements from primary and secondary sources, highlighting a different concern than the physical availability of elements in the earth's crust.

Proposed approach/possible options description and justification

According to the on-going schedule, the subtask will later provide a recommendation for dissipation impact category method to be applied within TranSensus-LCA methodology. This later recommendation will be based on further discussion of BRGM results on both dissipation methods evaluation.

Q37 – Inclusion of a mandatory H_2 emissions flow indicator and a sensitivity on GWP impacts of H_2 emissions

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, Manufacturer fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes to include a mandatory hydrogen (H2) emission flow indicator, and to include a sensitivity including hydrogen emission greenhouse gas impacts for LCAs of hydrogen fuelled ZEVs, until a formalised GWP is available according to IPCC/within the EF method

The lifecycle impacts of hydrogen fuelled ZEVs (i.e. FCEV, FC-REEV and H2 ICEV) are particularly influenced by the impacts from production, supply and use of hydrogen fuel. Whilst most LCA studies address impacts resulting from hydrogen production, impacts from fugitive hydrogen emissions are not generally included. There is some uncertainty on the GWP100 value of hydrogen itself, and it was not included in IPPC AR6 (and consequently also not in relevant LCI and impact methodologies). However, recent scientific evidence from (Sand, et al., 2023)[43] suggests these impacts are double those previously estimated, making lifecycle GWP impacts of hydrogen emissions potentially significant for vehicles using it as a fuel.

Without formalisation of the GWP of hydrogen (e.g. in the next IPCC Assessment Report, or UNECE IWG A-LCA methodology) it is difficult to recommend mandating its inclusion by default in the TranSensus LCA's methodology. Until this is the case, because of the potential

[43] Sand *et al. 2023* - https://doi.org/10.1038/s43247-023-00857-8

significance of hydrogen emissions, and to future-proof analyses using the TranSensus LCA recommended method, it is proposed for LCA of vehicles using hydrogen as a fuel:

1. To include a mandatory hydrogen emission flow indicator (corresponding to the mass of hydrogen emitted into the atmospheric environment (in kgH2).
2. To include a mandatory sensitivity analysis

Further, it is proposed by default to recommend:

i. In the absence of supplier-specific information on fugitive hydrogen emissions from the supply chain, to include estimated H2 supply chain emission rates based on (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022)[44].

ii. The use of GWP100 of 11.6 for characterising the impacts of hydrogen emissions for the sensitivity analysis (unless this is superseded by a formally agreed figure).

Possible answers: Agree/ Disagree/ No preference

Background

Hydrogen is used in a number of ZEV powertrains, and has a significant impact on their overall lifecycle emissions though previous analysis has been limited to impacts from hydrogen production and supply only and not from emissions of hydrogen itself. Hydrogen has been previously characterised as an indirect greenhouse gas, and has previously been included in the IPPC AR5 (2007) with a GWP100 value of 5.8[45], but an updated value was not provided in AR6 (2021). However, recent scientific research has found hydrogen's climate impact to be significantly higher – around double the previous figure – with the most recent authoritative research estimating a value of a hydrogen of GWP100 of 11.6 ± 2.8 (one standard deviation)[46].

Emissions of hydrogen can occur mainly during the hydrogen production and distribution stage (mainly due to fugitive leakage) – see Table VI-8, but also emissions are anticipated to a lesser extent directly from hydrogen fuelled vehicles (though no standardised test methods currently exist for this) through H_2 slip from combustion vehicles and potentially fugitive emissions from H_2 storage systems (particularly for liquefied hydrogen). Recent research has found emission rates of hydrogen from the supply chain are likely to be similar to those of methane from the natural gas supply chain, with net leakage rates estimated to be 2.6%-6.9% for green hydrogen supply chains[47]. Together with the higher estimated values for GWP100, accounting for these

[44] Cooper, Jasmin; Dubey, Luke; Bakkaloglu, Semra; Hawkes, Adam, Hydrogen emissions from the hydrogen value chain-emissions profile and impact to global warming, Science of The Total Environment, 2022
[45] WGI_AR5.Chap_.8_SM.pdf (ipcc.ch), page 8SM-23.
[46] A multi-model assessment of the Global Warming Potential of hydrogen | Communications Earth & Environment (nature.com); The science of hydrogen's warming effects (edf.org)
[47] Hydrogen emissions from the hydrogen value chain-emissions profile and impact to global warming - ScienceDirect - https://doi.org/10.1016/j.scitotenv.2022.154624

emissions would likely to result in a significant impact on the full LCA for hydrogen fuelled ZEVs (i.e. FCEV, FC-REEV and H_2 ICEV).

Hydrogen emissions are not commonly captured in LCI datasets, and a characterisation factor for hydrogen is currently not included (e.g. in the EF method) due to its exclusion from the explicit list of greenhouse gases in AR6. There is currently mixed support for including hydrogen as a greenhouse gas (with GWP based on the best current scientific evidence) at the UNECE Informal Working Group on Automotive LCA. Therefore, it is recommended that accounting for hydrogen as a greenhouse gas should be included by default in the future only once consensus has been reached formally on the GWP value, and/or its inclusion within the EF method.

However, in order to future-proof the TranSensus LCA methodology, it is recommended for now (until hydrogen's GWP is formalised/agreed) to assess the total lifecycle emissions of hydrogen as a mandatory flow indicator, and additionally conduct a sensitivity on the potential GWP impacts of these.

Further information on the potential significance of emissions from different hydrogen production and supply chains has been recently assessed by (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022)[47], with further information in Table 4-21.

Table 4-17 : Estimated H2 supply chain emission rates from (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022)*

	Production and processing	Compression	Storage and transport	Liquefaction	Haber-Bosch	Shipping	Regasification	NH_3 cracking	Transmission and storage	Distribution
USA biomass gasification for local use	0.55% (0.10–1.00%)									0.08% (0.05–0.12%)
Australian blue H_2 from coal for export to Japan	0.55% (0.10–1.00%)	0.18% (0.15–0.27%)	0.31% (0.06–0.53%)	0.34% (0.15–2.21%)		0.03% (0.00–0.10%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
Qatar blue H_2 from natural gas for export to Japan	0.55% (0.10–1.00%)			0.33% (0.14–0.98%)		0.06% (0.01–0.17%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
North Sea green H_2 for local use	2.05% (0.10–4.00%)								0.05% (0.04–0.06%)	0.02% (0.0003–0.03%)
Australian green H_2 for export to Japan	2.05% (0.10–4.00%)			0.32% (0.14–0.95%)		0.03% (0.003–0.10%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
Saudi Arabian green H_2 for export to Japan- as LH2	2.05% (0.10–4.00%)	0.17% (0.14–0.26%)	0.31% (0.05–0.54%)	0.33% (0.01–2.04%)		0.06% (0.01–0.17%)	0.00%		0.03% (0.02–0.05%)	0.08% (0.05–0.16%)
Saudi Arabian green H2 for export to Japan- as NH3a	2.05% (0.10–4.00%)				0%	0%		0%	0.03% (0.02–0.05%)	0.08% (0.05–0.16%)

Notes: Engine slip of H2 is reported to range from 0 to 12%, and a value of 0.5% was assumed in (Cooper, Dubey, Bakkaloglu, & Hawkes, 2022).

Proposed approach/possible options description and justification

You can detail here, if necessary, precise information regarding your recommendation or explain further two options selected and secondary terms definitions.

Please justify briefly but soundly why the recommendation or each option can serve the objectives of the methodology.

Recommended set of social impact indicators

During the first voting, a set of mandatory and optional social impact sub-categories and stakeholder categories in the context of Battery Electric Vehicles (BEVs) reached consensus with a qualified majority. To achieve this, the analysis employed a three-step filtration process. The first step involved a materiality assessment based on methodologies proposed by the European Financial Reporting Advisory Group (EFRAG) and the Sustainability Assessment Questionnaire (SAQ) from Drive Sustainability. This step identified the primary impact sub-categories by examining their frequency of reporting in relevant policies and frameworks related to BEVs. The next step categorized stakeholders into groups such as workers, local communities, value chain actors, consumers, and society, and associated each stakeholder category with specific impact sub-categories to cover a wide range of social aspects based on UNEP Guideline. The final step prioritized these impact sub-categories across the lifecycle stages of BEVs, including extraction, manufacturing, distribution, use, and end-of-life (EoL), based on the frequency of their reporting.

The key findings of the analysis were significant in shaping the S-LCIA framework. Firstly, the analysis successfully identified mandatory and optional impact sub-categories, with mandatory ones having well-defined key performance indicators (KPIs) sourced from databases such as PSILCA (Product Social Impact Life Cycle Assessment) and SHDB (Social Hotspot Database). The mandatory impact sub-categories included (shortlisted) such as: freedom of association and collective bargaining, child labor, fair salary, working hours, worker health and safety, social benefits/social security, and corruption.

Additionally, the analysis ensured comprehensive coverage of social and socio-economic aspects related to BEVs, facilitating a detailed evaluation of potential impacts on different stakeholder groups. By engaging stakeholders in the prioritization process, the analysis promoted transparency and accountability, building trust and credibility in the assessment results. This stakeholder engagement was instrumental in capturing diverse perspectives and insights, leading to a more robust and meaningful S-LCIA framework.

In preparation for the third voting phase, a meticulous selection of social indicators for all mandatory Social Impact subcategories was undertaken to refine the Social Life Cycle Impact Assessment (S-LCIA) framework for BEVs. The primary goal was to evaluate an extensive list of social indicators and recommend a concise shortlist based on specific criteria. These proposed social indicators are directly linked to the final list of impact sub-categories identified during the first voting phase. The focus was on stakeholders and social impact sub-categories designated as mandatory during the initial analysis.

The process began with the identification of social indicators from the most widely used social LCA databases, PSILCA and SHDB (Table 4-22). The table below illustrates the number of social indicators identified for each impact sub-category. Some impact sub-categories included more than 10 social indicators (e.g., health and safety), necessitating a preliminary materiality analysis to determine their “relevance” in the context of BEVs. Partners involved in the social LCA subtask evaluated each social indicator, categorizing them as "relevant," "not relevant," or "maybe relevant."

Table 4-18 : List of social indicators extracted from the PSILCA[48] and SHDB[49] databases by impact sub-categories and stakeholders.

Stakeholder	Impact Sub-categories	Number of social indicators (from PSILCA and SHDB)
Worker	Health and safety	20
Worker	Freedom of association and collective bargaining	7
Worker	Child labour	9
Worker	Fair salary	9
Worker	Working hours	4
Worker	Social benefits / social security	10
Worker	Forced labour	5
Local community	Respect of Indigenous rights	7
Society	Corruption	5

Following this initial analysis, a shortlist of 19 social indicators was identified as relevant in the context of BEVs. To finalize this selection and propose the social indicators for the TranSensus LCA project, the methodology proposed by Haslinger et al. (2024)[50] was utilized. This methodology involved a Multi-Criteria Decision Analysis (MCDA) that evaluated each indicator based on four criteria: i) achievability; ii) feasibility; iii) ease of interpretation, and; iv) relevance. Each criterion was scored on a scale from 0 to 3, with specific reference points used to

[48] https://psilca.net/wp-content/uploads/2020/06/PSILCA_documentation_v3.pdf
[49] http://www.socialhotspot.org/for-more-information.html.
[50] Haslinger, A.S., Huysveld, S., Cadena, E. and Dewulf, J., 2024. Guidelines on the selection and inventory of social life cycle assessment indicators: a case study on flexible plastic packaging in the European circular economy. *The International Journal of Life Cycle Assessment*, pp.1-18.

justify the reduction of the extensive list from a scientific perspective (Table 4-23). For instance, in the achievability criterion, an indicator receives the highest score (i.e., 3) when it involves access to specific supplier data obtained by the company, such as those available in Corporate Social Responsibility (CSR) reports or internal health and safety management systems. Conversely, an indicator receives a score of 0 if there is no access to the necessary data or if the data collection phase is too time-consuming.

Table 4-19 : List of criteria and scale used to evaluate the social indicators (Haslinger et al. (2024)[50]

Criteria	Scale	Reference Point (RF)
Relevance	3	High relevance of the assessed impact.
	2	Medium relevance of the assessed impact.
	1	Low relevance of the assessed impact.
	0	No relevance of the assessed impact.
Feasibility	3	Information to be found at company.
	2	Information to be found in database i.e. PSILCA, SHDB, ecovadis, datamaran, RepRisk, Sedex, Supplyshift (country level and specific company data) or in relevant open data sources i.e. from NGOs.
	1	Information to be found in reliable online sources (e.g., local and global news).
	0	No information available.
Easiness to interpret	3	High clarity and awareness of the assessed impact.
	2	Medium clarity and awareness of the assessed impact.
	1	Low clarity and awareness of the assessed impact.
	0	No clarity and awareness of the assessed impact.
Achievability	3	Access to supplier specific data from company, already available in CRS reports or via internal reporting (health and safety management systems).
	2	Access to company specific data (e.g., ecovadis, datamaran, RepRisk, Sedex, Supplyshift), medium term availability.
	1	Access to regional /country level data from databases (e.g., PSILCA, SHDB, Verisk Maplecroft, NGO sources), long term collection phase.
	0	No access and/or too time extensive collection phase.

Table 4-24 summarizes the final scores obtained for each social indicator, representing the mean values scored for each criterion.

Table 4-20 : Evaluation results of the social indicators proposed by impact sub-categories and stakeholders.

Stake-holder	Impact Sub-cate-gories	Social indi-cators	Rele-vance	Feasibil-ity	Easiness to inter-pret	Achievabil-ity	Total (mean)
Worker	Health and safety	Rate of fatal accidents at workplace	3.00	2.67	3	2.67	2.83
Worker	Health and safety	Rate of non-fatal accidents at workplace	3.00	2.52	3.00	2.67	2.79
Worker	Freedom of association and collec-tive bar-gaining	Right of As-sociation	3.00	2.00	2.83	2.00	2.41
Worker	Freedom of association and collec-tive bar-gaining	Right of Col-lective bar-gaining	3.00	2.00	2.83	2.00	2.41
Worker	Freedom of association and collec-tive bar-gaining	Right to strike	3.00	2.00	2.83	2.00	2.41
Worker	Freedom of association and collec-tive bar-gaining	Trade union density	2.21	2.00	2.62	2.00	2.19
Worker	Child la-bour	Children in employment, total	3.00	2.03	2.56	2.28	2.44
Worker	Fair salary	Minimum wage, per month	2.83	2.67	3.00	2.00	2.60
Worker	Fair salary	Living wage, per month (AV)	2.52	2.00	3.00	1.81	2.29
Worker	Working hours	Weekly hours of work per employee	3.00	2.67	3.00	2.67	2.83
Worker	Working hours	Risk of work-ing >48 hrs per week (ILO)	2.38	2.52	2.00	2.12	2.25

Stake-holder	Impact Sub-cate-gories	Social indi-cators	Rele-vance	Feasibil-ity	Easiness to inter-pret	Achievabil-ity	Total (mean)
Worker	Social ben-efits / so-cial secu-rity	Social secu-rity expendi-tures	2.38	2.00	1.49	1.22	1.71
Worker	Forced la-bour	Frequency of forced labour	2.28	1.19	1.73	1.19	1.54
Worker	Forced la-bour	Goods pro-duced by forced labour	2.28	1.68	3.00	1.19	1.92
Worker	Forced la-bour	Trafficking in persons	2.06	1.19	2.71	1.19	1.68
Worker	Forced la-bour	Overall Country Sec-tor Risk Forced La-bour	1.68	3.00	2.21	1.68	2.08
Worker	Forced la-bour	Forced La-bour Risk (Global Sav-ery Index)	1.41	3.00	2.45	1.68	2.04
Local com-munity	Respect of Indigenous rights	Presence of indigenous population	2.42	2.25	2.28	1.64	2.12
Society	Corruption	Corruption Perception In-dex (CPI) (Transpar-ency Int.)	2.38	2.00	1.77	1.10	1.75

WP2.4 proposed selecting social indicators that scored more than 2.0 (between 2.0 and 3.0). However, the social indicators that are only linked with one impact sub-category (e.g., Social benefits / social security) were considered as recommended even if the score was below 2.0; this approach was decided in order to cover all the impact sub-categories. In some cases, multiple social indicators were selected for one impact sub-category, while in others, only one indicator was available, such as "Respect of Indigenous rights" for the Local community stakeholder or "Corruption" for the Society stakeholder. Additionally, the selected social indicators were cross-referenced with those included in the UNEP guidelines, ensuring that the majority of selected indicators were directly connected with that recognized guideline.

This comprehensive approach ensures that the final selection of social indicators for the TranSensus LCA project is scientifically robust and contextually relevant, providing a solid foundation for evaluating and improving the social performance of BEVs.

Q38 – Integration of Rate of fatal accidents as recommended social impact indicator for the Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the “Rate of fatal accidents” in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category

The "Rate of fatal accidents" measures the number of fatal accidents occurring in the workplace per 100,000 employees annually. This indicator provides a clear understanding of workplace safety by quantifying the frequency of fatal incidents relative to the size of the workforce. It is a critical measure for assessing occupational health and safety performance within an organization or industry.

Reference Method/Model:

The risk levels associated with the rate of fatal accidents are categorized as follows:

- **0 - <7.5**: Very low risk.
- **7.5 - <15**: Low risk.
- **15 - <25**: Medium risk.
- **25 - <40**: High risk.
- **>40**: Very high risk.
- **No data**: Indicates the absence of available data.

This reference method helps in classifying the safety performance and identifying areas needing improvement. Organizations can use this categorization to benchmark their performance, set safety targets, and implement necessary measures to enhance workplace safety. The classification aids in making informed decisions and prioritizing safety interventions to mitigate the risk of fatal accidents in the workplace.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-cate-gories	Social indi-cators	Rele-vance	Feasibil-ity	Easiness to inter-pret	Achievabil-ity	Total (mean)
Worker	Health and safety	Rate of fatal accidents at workplace	3.00	2.67	3.00	2.67	2.83

The total score for the "Rate of fatal accidents" is 2.83, which is well above the threshold of 2.0. The high scores across all criteria—relevance (3.00), feasibility (2.67), ease of interpretation (3.00), and achievability (2.67)—demonstrate that this indicator is not only critical for assessing workplace safety but also practical and understandable. Because of its comprehensive impact on assessing and improving workplace safety, this social indicator has been recommended as a key social indicator for TranSensus LCA.

Why is this indicator important?

Relevance: it is highly relevant because it directly reflects the safety conditions and risks faced by employees in their work environment. Ensuring employee safety is a fundamental aspect of social responsibility and sustainability. A high rate of fatal accidents indicates significant safety issues that need to be addressed to protect workers' lives.

Feasibility: it is feasible to measure as it relies on data that can typically be obtained from company records, safety reports, and regulatory bodies. Many organizations already track and report workplace accidents as part of their health and safety management systems, making this data relatively accessible.

Ease of interpretation: it is straightforward to understand and interpret, expressed as the number of fatalities per 100,000 employees per year. The reference model categorizes the risk levels (very low, low, medium, high, and very high), making it easy for stakeholders to gauge the severity of safety issues.

Achievability: achieving and reporting on this indicator is realistic. Companies can leverage existing health and safety data collection processes, such as incident reporting systems and CSR (Corporate Social Responsibility) reports, to gather the necessary information. This makes it practical for organizations to monitor and improve their safety performance.

Q39 – Integration of Rate of non-fatal accidents at workplace as recommended social impact indicator for the Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the “Rate of non-fatal accidents at workplace” in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Rate of non-fatal accidents at workplace" measures the number of non-fatal accidents occurring in the workplace per 100,000 employees annually. This indicator provides a clear understanding of workplace safety by quantifying the frequency of non-fatal incidents relative to the size of the workforce. It is a critical measure for assessing occupational health and safety performance within an organization or industry.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **0 - <750**: Very low risk.
- **750 - <1500**: Low risk.
- **1500 - <2250**: Medium risk.
- **2250 - <3000**: High risk.
- **>3000**: Very high risk.
- **No data**: Indicates the absence of available data.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-cate-gories	Social indi-cators	Rele-vance	Feasibil-ity	Easiness to inter-pret	Achievabil-ity	Total (mean)
Worker	Health and safety	Rate of non-fatal accidents at workplace	3.00	2.52	3.00	2.67	2.79

The total score for the "Rate of non-fatal accidents at workplace" is 2.79. The high scores across all criteria—relevance (3.00), feasibility (2.52), ease of interpretation (3.00), and achievability (2.67)—demonstrate that this indicator is not only critical for assessing workplace safety but also practical and understandable. Because of its comprehensive impact on assessing and improving workplace safety, this social indicator has been recommended as a key social indicator for TranSensus LCA.

Why is this indicator important?

Relevance: scored a perfect 3.00 for relevance. It is highly relevant because it directly reflects the safety conditions and risks faced by employees in their work environment. Non-fatal accidents can significantly impact worker health and productivity, highlighting areas where safety measures need improvement to prevent injuries and ensure a safe working environment.

Feasibility: this indicator received a score of 2.52 for feasibility. It is feasible to measure as it relies on data that can typically be obtained from company records, safety reports, and regulatory bodies. Many organizations already track and report workplace accidents as part of their health and safety management systems, making this data relatively accessible.

Ease of interpretation: the rate of non-fatal accidents scored a perfect 3.00 for ease of interpretation. It is straightforward to understand and interpret, expressed as the number of non-fatal accidents per 100,000 employees per year. The reference model categorizes the risk levels (very low, low, medium, high, and very high), making it easy for stakeholders to gauge the severity of safety issues.

Achievability: for achievability, the indicator scored 2.67. Achieving and reporting on this indicator is realistic. Companies can leverage existing health and safety data collection processes, such as incident reporting systems and CSR (Corporate Social Responsibility) reports, to gather the necessary information. This makes it practical for organizations to monitor and improve their safety performance.

Q40 – Integration of Right of association at workplace as recommended social impact indicator for Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Rate of non-fatal accidents at workplace" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Right of association" measures the degree to which workers are able to freely form and join associations or unions. This indicator uses an ordinal 4-point scale (0-3) to assess the risk level associated with the violation or respect of this right. It is a critical measure for evaluating the state of labor rights within an organization or industry.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **3**: No risk.
- **2**: Low risk.
- **1**: High risk.
- **0**: Very high risk.
- **No data**: Indicates the absence of available data.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Freedom of association and collective bargaining	Right of Association	3.00	2.00	2.83	2.00	2.41

The total score for the "Right of association" is 2.41. The high scores across all criteria—relevance (3.00), feasibility (2.00), ease of interpretation (2.83), and achievability (2.00)—demonstrate that this indicator is not only crucial for assessing labor rights but also practical and understandable.

Because of its comprehensive impact on assessing and improving labor rights, the "Right of association" has been recommended as a key social indicator for TranSensus LCA.

Why is this indicator important?

Relevance: this social indicator scored a perfect 3.00 for relevance. It is highly relevant because it directly reflects the ability of workers to exercise their fundamental rights to join and form associations or unions. Ensuring this right is respected is crucial for protecting workers' rights, promoting fair labor practices, and fostering a collaborative and supportive work environment.

Feasibility: the indicator received a score of 2.00 for feasibility. It is feasible to measure through existing labor rights assessments, company policies, and reports on compliance with international labor standards. Organizations often have mechanisms in place to monitor and report on the state of labor rights, making this data relatively accessible.

Ease of interpretation: it scored 2.83 for ease of interpretation. It uses an ordinal 4-point scale (0-3), which makes it straightforward to understand and interpret. The scale categorizes the risk levels (no risk, low risk, high risk, and very high risk), providing a clear metric for evaluating the respect and protection of this fundamental labor right.

Achievability: for achievability, the indicator scored 2.00. Achieving and reporting on this indicator is realistic as companies can utilize existing labor relations frameworks, audits, and compliance reports. This makes it practical for organizations to monitor and improve their performance in protecting the right of association.

Q41 – Integration of Right of collective bargaining as recommended social impact indicator for Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Right of collective bargaining" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Right of collective bargaining" measures the degree to which workers are able to engage in collective negotiations with their employers. This indicator uses an ordinal 4-point scale (0-3) to assess the risk level associated with the violation or respect of this right. It is a critical measure for evaluating the state of labor rights within an organization or industry.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **3**: No risk.
- **2**: Low risk.
- **1**: High risk.
- **0**: Very high risk.
- **No data**: Indicates the absence of available data.

Possible answers: Agree/ Disagree/ No preference

Background

Stakeholder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Freedom of association and collective bargaining	Right of Collective bargaining	3.00	2.00	2.83	2.00	2.41

The total score for the "Right of collective bargaining" is 2.41, which is above the threshold of 2.0. The high scores across all criteria—relevance (3.00), feasibility (2.00), ease of interpretation (2.83), and achievability (2.00)—demonstrate that this indicator is not only crucial for assessing labor rights but also practical and understandable.

Why is this indicator important?

Relevance: it is highly relevant because it directly reflects the ability of workers to engage in collective negotiations with their employers. Ensuring this right is respected is crucial for protecting workers' rights, promoting fair labor practices, and fostering a collaborative and supportive work environment.

Feasibility: it is feasible to measure through existing labor rights assessments, company policies, and reports on compliance with international labor standards. Organizations often have mechanisms in place to monitor and report on the state of labor rights, making this data relatively accessible.

Ease of interpretation: it uses an ordinal 4-point scale (0-3), which makes it straightforward to understand and interpret. The scale categorizes the risk levels (no risk, low risk, high risk, and very high risk), providing a clear metric for evaluating the respect and protection of this fundamental labor right.

Achievability: achieving and reporting on this indicator is realistic as companies can utilize existing labor relations frameworks, audits, and compliance reports. This makes it practical for organizations to monitor and improve their performance in protecting the right of collective bargaining.

Q42 – Integration of Right to strike as recommended social impact indicator for Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes to include the “Right to strike” in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Right to strike" measures the degree to which workers are able to engage in strike actions. This indicator uses an ordinal 4-point scale (0-3) to assess the risk level associated with the violation or respect of this right. It is a critical measure for evaluating the state of labor rights within an organization or industry.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **3**: No risk
- **2**: Low risk

- **1**: High risk
- **0**: Very high risk
- **No data**: Indicates the absence of available data

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Freedom of association and collective bargaining	Right to strike	3.00	2.00	2.83	2.00	2.41

The total score for the "Right to strike" is 2.41, which is above the threshold of 2.0. The high scores across all criteria—relevance (3.00), feasibility (2.00), ease of interpretation (2.83), and achievability (2.00)—demonstrate that this indicator is not only crucial for assessing labor rights but also practical and understandable.

Why is this indicator important?

Relevance: it is highly relevant because it directly reflects the ability of workers to take strike action as a form of protest or to demand better working conditions. Ensuring this right is respected is crucial for protecting workers' rights, promoting fair labor practices, and empowering workers to advocate for their interests.

Feasibility: it is feasible to measure through existing labor rights assessments, company policies, and reports on compliance with international labor standards. Organizations often have mechanisms in place to monitor and report on the state of labor rights, making this data relatively accessible.

Ease of interpretation: the "Right to strike" scored 2.83 for ease of interpretation. It uses an ordinal 4-point scale (0-3), which makes it straightforward to understand and interpret. The scale categorizes the risk levels (no risk, low risk, high risk, and very high risk), providing a clear metric for evaluating the respect and protection of this fundamental labor right.

Achievability: for achievability, the indicator scored 2.00. Achieving and reporting on this indicator is realistic as companies can utilize existing labor relations frameworks, audits, and compliance reports. This makes it practical for organizations to monitor and improve their performance in protecting the right to strike.

Q43 – Integration of Children in employment, total as recommended social impact indicator for the Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Children in employment, total" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Children in employment, total" measures the percentage of children aged 7-14 who are employed. This indicator provides a clear understanding of the prevalence of child labor within an organization or industry. It is a critical measure for evaluating the state of labor rights and the effectiveness of policies aimed at reducing child labor.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **0%**: No risk.
- **0% - <2.5%**: Very low risk.
- **2.5% - <5%**: Low risk.
- **5% - <10%**: Medium risk.
- **10% - <20%**: High risk.
- **>=20%**: Very high risk.
- **n.a.**: No data.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Child labour	Children in employment, total	3.00	2.03	2.56	2.28	2.44

The total score for "Children in employment, total" is 2.44, which is above the threshold of 2.0. The high scores across all criteria—relevance (3.00), feasibility (2.03), ease of interpretation (2.56), and achievability (2.28)—demonstrate that this indicator is not only crucial for assessing child labor but also practical and understandable. Because of its comprehensive impact on assessing and reducing child labor, "Children in Employment, Total" has been recommended as a key social indicator for TranSensus LCA.

Why is this indicator important?

Relevance: it is highly relevant because it directly reflects the prevalence of child labor within a given population/company. Child labor is a critical issue that impacts children's health, education, and overall well-being. Addressing this issue is essential for promoting ethical labor practices and ensuring the protection of children's rights.

Feasibility: this indicator received a score of 2.03 for feasibility. It is feasible to measure through existing labor force surveys, national statistics, and reports from international organizations. Many organizations and governmental bodies track child labor statistics, making this data relatively accessible.

Ease of interpretation: the indicator scored 2.56 for ease of interpretation. It is expressed as the percentage of all children aged 7-14 who are employed, providing a straightforward metric for understanding the extent of child labor. The reference model categorizes the risk levels (no risk, very low, low, medium, high, and very high), making it easy for stakeholders to gauge the severity of the issue.

Achievability: for achievability, the indicator scored 2.28. Achieving and reporting on this indicator is realistic, as companies can use existing labor data, national statistics and reports from international agencies. This makes it practical for organizations to monitor and reduce child labor in their operations and supply chains.

Q44 – Integration of Minimum wage, per month as recommended social impact indicator for Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes to include the "Minimum wage, per month" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The " Minimum wage, per month " measures the lowest remuneration that employers can legally pay their workers. This indicator provides a clear understanding of the wage levels within an organization or industry. It is used to evaluate the sector average or the actually paid wage in a company. Together with the living wage, it is an important indicator to assess if the salary is fair and allows the worker to lead a dignified life.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **LW-MW-ratio >= 1.2 OR ratio >= 1 and MW < 300 USD**: Very high risk.
- **Ratio = 1 - <1.2 and MW >= 300 USD OR ratio = 0.8 - <1 and MW < 300 USD**: High risk.
- **Ratio = 0.8 - <1**: Medium risk and MW > 300 USD.
- **Ratio = 0.5 - <0.8**: Low risk.
- **Ratio < 0.5**: Very low risk.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Fair salary	Minimum wage, per month	2.83	2.67	3.00	2.00	2.60

The total score for " Minimum wage, per month" is 2.60, which is above the threshold of 2.0. The high scores across all criteria—relevance (2.83), feasibility (2.67), ease of interpretation (3.00), and achievability (2.00)—demonstrate that this indicator is not only crucial for assessing wage fairness but also practical and understandable.

Why is this indicator important?

Relevance: it is highly relevant because it directly reflects the fairness of compensation provided to workers. Ensuring that wages are fair and sufficient to meet the cost of living is crucial for promoting social equity and improving the quality of life for employees. This indicator, along with the living wage, helps assess if the salary provided allows workers to lead a dignified life.

Feasibility: it is feasible to measure as it relies on data that can typically be obtained from company records, payroll reports and national labor statistics. Many organizations and governmental bodies track minimum wage statistics, making this data relatively accessible.

Ease of interpretation: it is expressed in USD, providing a straightforward metric for understanding the wage levels in an organization or industry. The reference model categorizes the risk levels (very high, high, medium, low, and very low), making it easy for stakeholders to gauge the fairness of wages.

Achievability: achieving and reporting on this indicator is realistic as companies can utilize existing payroll data, national wage statistics, and industry benchmarks. This makes it practical for organizations to monitor and improve their wage policies.

Q45 – Integration of Living wage, per month (AV) as recommended social impact indicator for Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Living wage, per month (AV)" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Living wage, per month (AV)" measures the average wage required for workers to meet their basic needs and maintain a decent standard of living. This indicator provides a clear understanding of whether the wages paid are sufficient to ensure the financial stability and well-being of employees. It is used to evaluate the subcategory of fair salary and other indicators, such as minimum and sector average wages. The values are presented in local currencies and converted to USD for consistency.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **<100 USD**: Very low risk.
- **100 - <200 USD**: Low risk.
- **200 - <500 USD**: Medium risk.
- **500 - <1000 USD**: High risk.
- **>1000 USD**: Very high risk.
- **n.a.**: No data.

Possible answers: Agree/ Disagree/ No preference

Background

Stakeholder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Fair salary	Living wage, per month (AV)	2.52	2.00	3.00	1.81	2.29

The total score for "Living wage, per month (AV)" is 2.29, which is above the threshold of 2.0. The high scores across all criteria—relevance (2.52), feasibility (2.00), ease of interpretation (3.00), and achievability (1.81)—demonstrate that this indicator is not only crucial for assessing wage adequacy but also practical and understandable.

Why is this indicator important?

Relevance: it is highly relevant because it serves as a proxy to evaluate the subcategory of fair salary and other indicators such as minimum and sector average wages. Ensuring that wages are fair and sufficient to meet the cost of living is crucial for promoting social equity and improving the quality of life for employees.

Feasibility: it is feasible to measure as it relies on data that can be obtained from company records, payroll reports, and national labor statistics. Many organizations and governmental bodies track living wage statistics, making this data relatively accessible.

Ease of interpretation: it is expressed in USD, providing a straightforward metric for understanding the wage levels in an organization or industry. The reference model categorizes the risk levels (very low, low, medium, high, and very high), making it easy for stakeholders to gauge the adequacy of wages.

Achievability: achieving and reporting on this indicator is realistic as companies can utilize existing payroll data, national wage statistics, and industry benchmarks. This makes it practical for organizations to monitor and improve their wage policies. However, gathering this data may involve comprehensive surveys and collaboration with local stakeholders, making the process more time-consuming and resource-intensive.

Q46 – Integration of Weekly hours of work per employee as recommended social impact indicator for the Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes to include the “Weekly hours of work per employee” in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Weekly hours of work per employee" measures the number of hours worked by each employee per week. This indicator provides a clear understanding of the workload and time commitment required from employees. It is used to evaluate whether the working hours are conducive to maintaining a healthy work-life balance and overall employee well-being.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **40 - <48 hr**: Low risk.
- **30 - <40 and 48 - <55 hr**: Medium risk.

- **20 - <30 and 55 - <60 hr**: High risk.
- **<20 and >60 hr**: Very high risk.
- **n.a.**: No data.

Although the social indicator "Risk of working >48 hrs per week (ILO)" also obtained a score higher than 2.0 for the impact sub-category "Working hours," it was not considered as recommended. This decision was made because this indicator evaluates the same aspect as the "Weekly hours of work per employee" indicator. To avoid redundancy and ensure a streamlined assessment process, the indicator that received the highest total score, "Weekly hours of work per employee," was selected. This choice ensures that the most effective and comprehensive indicator is used to evaluate and manage working hours within the context of BEVs production and related industries.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Working hours	Weekly hours of work per employee	3.00	2.67	3.00	2.67	2.83

The total score for "Weekly hours of work per employee" is 2.83, which is well above the threshold of 2.0. The high scores across all criteria—relevance (3.00), feasibility (2.67), ease of interpretation (3.00), and achievability (2.67)—demonstrate that this indicator is not only crucial for assessing workload but also practical and understandable.

Why is this indicator important?

Relevance: it is highly relevant because it directly reflects the workload and potential stress levels experienced by employees. Ensuring that working hours are within a reasonable range is crucial for promoting employee well-being, productivity, and work-life balance. Excessive working hours can lead to health issues and reduced efficiency, making this indicator vital for sustainable labor practices.

Feasibility: it is feasible to measure as it relies on data that can typically be obtained from company records, payroll systems, and employee timesheets. Many organizations already track working hours as part of their labor management systems, making this data relatively accessible.

Ease of interpretation: it is expressed in hours (hr) per week, providing a straightforward metric for understanding the workload of employees. The reference model categorizes the risk levels (very low, low, medium, high, and very high), making it easy for stakeholders to gauge the appropriateness of working hours.

Achievability: achieving and reporting on this indicator is realistic as companies can utilize existing time tracking and payroll systems to gather the necessary information. This makes it practical for organizations to monitor and adjust working hours to ensure they are within acceptable limits.

Q47 – Integration of Social security expenditures as recommended social impact indicator for Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Social security expenditures" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Social security expenditures" measures the percentage of a country's Gross Domestic Product (GDP) allocated to social security programs. This indicator provides a clear understanding of the financial commitment of a country or organization to social security. It reflects the level of support provided to workers through benefits such as unemployment insurance, pensions, and healthcare.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **0-2.5%**: Very high risk.
- **>2.5-7.5%**: High risk.
- **>7.5-15%**: Medium risk.
- **>15-20%**: Low risk.
- **>20%**: Very low risk.
- **n.a.**: No data.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-cate-gories	Social indi-cators	Rele-vance	Feasibil-ity	Easiness to inter-pret	Achievabil-ity	Total (mean)
Worker	Social ben-efits / so-cial secu-rity	Social secu-rity expendi-tures	2.38	2.00	1.49	1.22	1.71

The total score for "Social security expenditures" is 1.71, which is below the threshold of 2.0. The scores across all criteria—relevance (2.38), feasibility (2.00), ease of interpretation (1.49), and achievability (1.22)—indicate that while this indicator is important, it is less practical and straightforward compared to other indicators. However, despite scoring lower than 2.0, this social indicator was selected as it was the only available indicator for the impact sub-category "Social benefits / social security." In order to ensure comprehensive coverage of all impact sub-categories, it was exceptionally selected. This decision underscores the importance of including all relevant aspects of social performance in the TranSensus LCA methodology, even when certain indicators pose measurement challenges.

Why is this indicator important?

Relevance: it is important because it reflects the level of financial support provided to workers through social security systems. Adequate social security is crucial for protecting workers against economic risks and ensuring their well-being during periods of unemployment, illness, or retirement.

Feasibility: it is feasible to measure as it relies on data that can typically be obtained from national economic reports, government publications, and international databases. Many organizations track social security expenditures as part of their economic assessments, making this data relatively accessible.

Ease of interpretation: it is expressed as a percentage of Gross Domestic Product (GDP), which may require more economic understanding to interpret correctly. The reference model categorizes the risk levels (very high, high, medium, low, and very low), providing a framework for evaluating the adequacy of social security expenditures.

Achievability: while reporting on this indicator is realistic, it can be complicated due to the need for comprehensive economic data and analysis. Gathering this data may involve collaboration with national statistical offices and understanding the intricacies of GDP and social security funding mechanisms.

Q48 – Integration of Overall country sector risk forced labour as recommended social impact indicator for the Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Overall country sector risk forced labour" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Overall country sector risk forced labour" measures the risk of forced labor within specific sectors of a country. This indicator relies on qualitative assessments provided by sources such as ILO reports on the advancement of conventions 29 and 105, and the U.S. Department of Labor's list of goods produced by child labor or forced labor. It provides a comprehensive understanding of the forced labor risk within a country and its sectors.

Reference Method/Model:

To provide context for evaluating this indicator, data is sourced from:

- **ILO reports** on the advancement of conventions 29 and 105.
- **U.S. Department of Labor's list** of goods produced by child labor or forced labor.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Worker	Forced labour	Overall Country Sector Risk Forced Labour	1.68	3.00	2.21	1.68	2.08

The total score for "Overall country sector risk forced labour" is 2.08, which is above the threshold of 2.0. The scores across all criteria—relevance (1.68), feasibility (3.00), ease of interpretation (2.21), and achievability (1.68)—indicate that while this indicator is somewhat complex, it is practical and provides critical insights into labor risks.

Why is this indicator important?

Relevance: it is significant because it reflects the risk of forced labor within specific sectors of a country. Understanding and addressing this risk is crucial for protecting workers' rights and ensuring ethical labor practices within the supply chain.

Feasibility: it is feasible to measure using data from reputable sources such as ILO reports on the advancement of conventions 29 and 105, and the U.S. Department of Labor's list of goods produced by child labor or forced labor. These sources provide comprehensive data on the prevalence of forced labor, making it accessible for assessment.

Ease of Interpretation: while it provides valuable information, interpreting the risk levels may require an understanding of international labor standards and the context of forced labor in different sectors. The use of established reports and lists helps provide a framework for evaluating the risk.

Achievability: while realistic, measuring and addressing forced labor risk can be complex due to the need for detailed and specific data from various sources. It may require collaboration with international organizations and thorough analysis to ensure accurate assessment.

Q49 – Integration of Forced labour risk (Global Savery Index) as recommended social impact indicator for Workers stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Forced labour risk (Global Slavery Index)" in the recommended list of TranSensus LCA social indicators for the Workers stakeholder category.

The "Forced Labour Risk (Global Slavery Index)" measures the risk of forced labor within specific countries and sectors. This indicator relies on qualitative assessments provided by sources such as ILO reports on the advancement of conventions 29 and 105, the U.S. Department of Labor's list of goods produced by child labor or forced labor, and Walk Free's flagship report, the Global Slavery Index (GSI), which provides national estimates of modern slavery for 160 countries. It provides a comprehensive understanding of the forced labor risk within a country and its sectors.

Reference Method/Model:

To provide context for evaluating this indicator, data is sourced from:

- **ILO reports** on the advancement of conventions 29 and 105.
- **U.S. Department of Labor's list** of goods produced by child labor or forced labor.
- **Global Slavery Index (GSI)** from Walk Free's flagship report, providing national estimates of modern slavery for 160 countries.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-cate-gories	Social indi-cators	Rele-vance	Feasibil-ity	Easiness to inter-pret	Achievabil-ity	Total (mean)
Worker	Forced labour	Forced Labour Risk (Global Savery Index)	1.41	3.00	2.45	1.68	2.04

The total score for "Forced labour risk (Global Slavery Index)" is 2.04, which is above the threshold of 2.0. The scores across all criteria—relevance (1.41), feasibility (3.00), ease of interpretation (2.45), and achievability (1.68)—indicate that while this indicator is somewhat complex, it is practical and provides critical insights into labor risks.

Why is this indicator important?

Relevance: it is significant because it provides a comprehensive assessment of the risk of forced labor within specific countries and sectors. Understanding and addressing this risk is crucial for protecting workers' rights and ensuring ethical labor practices within the supply chain.

Feasibility: it is feasible to measure using data from reputable sources such as ILO reports on the advancement of conventions 29 and 105, the U.S. Department of Labor's list of goods produced by child labor or forced labor, and Walk Free's Global Slavery Index (GSI). The GSI provides national estimates of modern slavery for 160 countries, making comprehensive data accessible for assessment.

Ease of Interpretation: while it provides valuable information, interpreting the risk levels may require an understanding of international labor standards and the context of forced labor in different countries and sectors. The use of established reports and lists helps provide a framework for evaluating the risk.

Achievability: while realistic, measuring and addressing forced labor risk can be complex due to the need for detailed and specific data from various sources. It may require collaboration with international organizations and thorough analysis to ensure accurate assessment.

Q50 – Integration of Presence of indigenous population as recommended social impact indicator for the Local community stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes to include the "Presence of indigenous population" in the recommended list of TranSensus LCA social indicators for the Local community stakeholder category.

The "Presence of indigenous population" measures whether there are indigenous communities in the area of operation. This indicator provides a clear understanding of the potential impact of industrial activities on these communities. It is a critical measure for evaluating the respect and protection of indigenous rights within an organization or industry.

Reference Method/Model:

To provide context for evaluating this indicator, the risk levels are categorized as follows:

- **0 (No)**: No risk.
- **1 (Yes)**: Medium risk.

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-categories	Social indicators	Relevance	Feasibility	Easiness to interpret	Achievability	Total (mean)
Local community	Respect of Indigenous rights	Presence of indigenous population	2.42	2.25	2.28	1.64	2.12

The total score for "Presence of indigenous population" is 2.12, which is above the threshold of 2.0. The scores across all criteria—relevance (2.42), feasibility (2.25), ease of interpretation (2.28), and achievability (1.64)—demonstrate that this indicator is crucial for assessing the impact on indigenous rights, despite some complexities in data gathering. Because of its comprehensive impact on assessing and respecting indigenous rights, this social indicator has been recommended as a key social indicator for TranSensus LCA.

Why is this indicator important?

Relevance: it is significant because it directly reflects the presence of indigenous communities in the area of operation. Recognizing and respecting indigenous rights is crucial for promoting social equity and ensuring that the activities of companies do not negatively impact these communities.

Feasibility: it is feasible to measure as it relies on straightforward data that can typically be obtained from national censuses, local government reports, and community records. The presence or absence of indigenous populations is generally well-documented, making this data accessible.

Ease of Interpretation: it uses a binary metric (Yes/No), providing a clear and straightforward assessment of whether indigenous populations are present. The reference model categorizes the risk levels as no risk (0 = No) and medium risk (1 = Yes), making it easy for stakeholders to understand the potential impact.

Achievability: while realistic, gathering and verifying data on indigenous populations can be complicated due to the need for engagement with local communities and accurate record-keeping. This process may require collaboration with local authorities and indigenous representatives to ensure accuracy and respect.

Q51 – Integration of Corruption Perception Index (CPI) as recommended social impact indicator for the Society stakeholder category

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes to include the "Corruption Perception Index (CPI)" in the recommended list of TranSensus LCA social indicators for the Society stakeholder category.

The "Corruption Perception Index (CPI)" measures the perceived levels of public sector corruption in different countries. This semi-quantitative indicator is published annually by Transparency International and provides a score that reflects the degree of corruption as seen by businesspeople and country experts. The CPI is a critical measure for evaluating the risk of corruption within an organization or industry.

Reference Method/Model:

To provide context for evaluating this indicator, data is sourced from:

- **Transparency International**'s Corruption Perception Index (CPI).

Possible answers: Agree/ Disagree/ No preference

Background

Stake-holder	Impact Sub-cate-gories	Social indi-cators	Rele-vance	Feasibil-ity	Easiness to inter-pret	Achievabil-ity	Total (mean)
Society	Corruption	Corruption Perception Index (CPI) (Transparency International)	2.38	2.00	1.77	1.10	1.75

The total score for "Corruption Perception Index (CPI) (Transparency International)" is 1.75, which is below the threshold of 2.0. The scores across all criteria—relevance (2.38), feasibility (2.00), ease of interpretation (1.77), and achievability (1.10)—indicate that while this indicator is important, it is less practical and straightforward compared to other indicators. However, despite scoring lower than the defined threshold, this social indicator was selected because it was the only available indicator for the impact sub-category "Corruption" of the stakeholder "Society." In order to ensure comprehensive coverage of all impact sub-categories, it was exceptionally selected. This decision underscores the importance of including all relevant aspects of social performance in TranSensus LCA methodology, even when certain indicators pose measurement challenges.

Why is this indicator important?

Relevance: it is significant because it provides a comprehensive assessment of perceived corruption levels in different countries. Understanding and addressing corruption is crucial for ensuring ethical business practices and promoting transparency within the supply chain.

Feasibility: it is feasible to measure using data from Transparency International, which publishes the CPI annually. This semi-quantitative indicator is well-documented and widely used, making the data accessible for assessment.

Ease of Interpretation: while it provides valuable information, interpreting the CPI scores may require an understanding of how perceptions of corruption are measured and reported. The use of established indices helps provide a framework for evaluating corruption risk.

Achievability: while realistic, addressing and mitigating corruption risk can be complex due to the need for comprehensive anti-corruption measures and the variability of corruption across different regions. Implementing effective policies and practices requires a thorough understanding of local contexts and continuous monitoring.

4.4 Task 2.5: Interpretation, decision making and frontloading concept

4.4.1 List of questions submitted to the 3rd voting by Task 2.5

Summary of TranSensus LCA propositions & voting options:

Table 4-21 : List of questions submitted by task 2.5 to 3rd voting of September 2024

TranSensus LCA proposes for task T2.5 Interpretation, decision making and frontloading concept:	Status
Mandatory analysis of parameters	
• Mandatory analysis on the future electricity/H2 mix for the use phase.	*(1)*
• Mandatory scenario analysis on the future electricity/H2 mix for the use phase.	*(1)*
• Guidelines for the mandatory scenario analysis on the future electricity/H2 mix for the use phase.	*(1)*
• Mandatory sensitivity analysis on the usage: consumption	*(1)*
• Guidelines for the mandatory sensitivity analysis on the usage: consumption	*(1)*
• Mandatory sensitivity analysis on the usage: vehicle lifetime activity	*(1)*
• Guidelines for the mandatory sensitivity analysis on the usage: vehicle lifetime activity	*(1)*
• Mandatory scenario analysis on the usage: variation of energy mix consumption	*(1)*
• Guidelines for the mandatory scenario analysis on the usage: variation of energy mix consumption	*(1)*
• Mandatory sensitivity analysis on the quantity value for hotspots	*(1)*
• Guidelines for the mandatory sensitivity analysis on the quantity value for hotspots	*(1)*
Recommended analysis of parameters	
• Recommended sensitivity analysis on the choice of secondary data for the components/materials/flows that are deemed relevant, e.g., leading to hotspots (to be defined).	*(1)*
• Guidelines for the recommended sensitivity analysis on the choice of secondary data for the components/materials/flows that are deemed relevant, e.g., leading to hotspots (to be defined).	*(1)*
• Recommended scenario analysis on the location of the value chain and how it affects the electricity mix.	*(1)*
• Guidelines for the recommended scenario analysis on the location of the value chain and how it affects the electricity mix.	*(1)*
• Recommended scenario analysis on process improvements with respect to the use of recycled vs. primary materials.	*(1)*
• Guidelines for the recommended scenario analysis on process improvements with respect to the use of recycled vs. primary materials.	*(1)*
• Recommended scenario analysis on maintenance & wearing during usage.	*(1)*
• Guidelines for the recommended scenario analysis on maintenance & wearing during usage.	*(1)*
• Recommended scenario analysis on the payload/number of passengers during usage.	*(1)*
• Guidelines for the recommended scenario analysis on the payload/number of passengers during usage.	*(1)*

• Recommended scenario analysis on the ambient temperature during usage.	*(1)*
• Guidelines for the recommended scenario analysis on the ambient temperature during usage.	*(1)*
• Recommended scenario analysis on the EoL electricity/fuel mix modelled with a future mix (whether static or dynamic).	*(1)*
• Guidelines for the recommended scenario analysis on the EoL electricity/fuel mix modelled with a future mix (whether static or dynamic).	*(1)*
• Recommended scenario analysis on the second use.	*(1)*
• Guidelines for the recommended scenario analysis on the second use.	*(1)*
Recommended S-LCA interpretation parameters	
• TranSensus LCA proposes including the quantity value for certain components/materials/flows leading to hotspots in the recommended list of TranSensus LCA social interpretation parameters.	*(1)*
• TranSensus LCA proposes including the geographical variation of the value chain in the recommended list of TranSensus LCA social interpretation parameters.	*(1)*
• TranSensus LCA proposes including the choice of the activity variable (e.g. working hour vs. value added) in the recommended list of TranSensus LCA social interpretation param.	*(1)*
• TranSensus LCA proposes including assumptions on data in the recommended list of TranSensus LCA social interpretation parameters.	*(1)*
• TranSensus LCA proposes including the price related to processes or materials in the recommended list of TranSensus LCA social interpretation parameters.	*(1)*
• TranSensus LCA proposes including the geographical variation of the energy consumed (electricity mix or H2 mix) during usage in the recommended list of TranSensus LCA social interpretation parameters.	*(1)*
• TranSensus LCA proposes including the quantity of energy consumed during the use phase in the recommended list of TranSensus LCA social interpretation parameters.	*(1)*
Integration in product development process	
• TranSensus LCA proposes to follow the frontloading LCA approach for product development as described in the following scheme.	*(1)*
Reporting	
• TSLCA adherence levels for product LCA	*(1)*
• TSLCA additional partial adherence level for product LCA	*(1)*
• 3rd party verification for level 3 (UNECE) Product LCA	*(1)*
• Public reporting content for Product LCA: Minimum info (Goal and scope)	*(1)*
• Public reporting content for Product LCA: Minimum info (LCI)	*(1)*
• Public reporting content for Product LCA: Minimum info (LCIA)	*(1)*
• Public reporting content for Product LCA: Minimum info for reporting (Interpretation)	*(1)*
• TSLCA adherence for other types of LCAs than product LCA	*(1)*
• S-LCA reporting	*(1)*

Within this task, the approach for the interpretation step for LCA and S-LCA will be defined. Recommendations for conducting sensitivity analysis, scenario analysis and uncertainty analysis will be proposed, considering user behaviour, electricity mix, value chain scenarios, and other identified parameters from Tasks 2.1-2.4 and findings from Task 1.2. In view of the overall objective to pave the path towards an LCA-driven product development, this task will also conceptualise how decision-making and frontloading processes can be easily implemented into industrial product development processes along the supply chain. The goal is to enable engineers and managers according to their profile (industry, RTO, academia, policy, regulation, etc.) to select solutions and technologies (both existing and emerging) based on their environmental and social impacts, while balancing all other requirements. Furthermore, to enable informed decisions to be made within the constraints of the LCA and S-LCA results following the proposed approach, recommendations on how to report the results to the decision-maker in a clear, consistent and transparent way will be proposed.

Description of the subtasks and priority

The task was divided into three subtasks to divide the work and prioritise it:

- Subtask 1: Uncertainty, sensitivity and scenario analysis

This subtask has the goal to elaborate a definition fort the terms uncertainty analysis, sensitivity analysis and scenario analysis. As a main result of this subtask, recommendations for conducting an uncertainty, sensitivity and scenario analysis are available. This subtask also aims to identify the parameters that will be considered in the uncertainty analysis, sensitivity analysis and scenario analysis. This subtask was divided into two subtasks “Uncertainty, sensitivity and scenario analysis” and “Considered parameters” but was later merged into just one subtask.

- Subtask 2: Integration in product development process

The second subtask has the goal to conceptualise how decision-making and frontloading processes can be easily implemented into industrial product development processes along the supply chain.

- Subtask 3: Reporting

The third subtask dealt with defining mandatory requirements in order to claim that a study was “carried out following the TSLCA methodology” or “carried out partially following the TSLCA methodology”. The latter meaning that the TSLCA methodological buildings blocks were adhered to but that mandatory reporting information is missing.

General information for parameter analysis

To issue recommendations on how to conduct an uncertainty, sensitivity and scenario analysis, certain requirements must be met. A particularly important point here is the development of a common understanding of the various terms of analysis. To this end, various sources from science, standards and legislation were consulted. The following short and long descriptions of the terms uncertainty, sensitivity and scenario analysis were created within the subtask and were agreed upon with the partners in Task 2.5 and represent a finding. Within the first voting these terms were confirmed with a qualified majority.

Sensitivity analysis

Short version	The sensitivity analysis focuses on the influence each parameter has on the result (e.g., OAT on location of the electricity mix).
Long version	Most guidelines refer to sensitivity as a 2-step-process. First step ("check", "analysis") is changing parameters like inventory data, used methods, impact categories or assumptions to be able to evaluate the influence these changes have on the final results of the LCA. According to the ISO 14040 this can be done in absolute numbers or a variation in %. The aim of the second step ("evaluation") is to assess the results concerning their relevance for final conclusions and suggestions. This step is an iterative process along all steps of the LCA and should also incorporate expert knowledge and prior experiences. The most commonly used approach is the local sensitivity analysis (LSA) which evaluates the variation caused by one input around its reference point as opposed to global sensitivity analysis (GSA) which evaluates the variation of outputs caused by all input parameters.

Uncertainty analysis

Short version	The uncertainty analysis focuses on how well we know the absolute value of the result (e.g., Monte Carlo).
Long version	Uncertainty analysis, in general, is carried out to investigate the accuracy and reliability of the LCA model of a product or a process, which has been developed with various underlying variables and assumptions as the basis of LCA. Particularly applied to comparative LCA, uncertainty analysis must be applied to estimate and report any statistical differences in the results reported for the different variables. Where not possible, a thorough evidence-based justification of the preference of one system over the other should be provided.

Scenario analysis

Short version	A scenario represents a storyline that determines a variation of key parameters/assumptions (applies well where parameters are correlated) of the model.
Long version	A scenario in LCA as described in the ILCD and PEF guidelines is a choice of model. Those choices encompass the inventory data, parameters, flow properties, functional unit, but also method assumptions such as allocation. Thus, a scenario analysis evaluates how varying the choices made can have an influence on the results. In scenario analysis there is more than one parameter that can vary in each scenario (but not necessarily all the parameters at the same time). This variation is determined by a storyline that must be relevant to the situation. The likelihood of these storylines should appear in the scenario analysis. Scenario analysis is a part of sensitivity analysis and is distinct from local or global sensitivity analysis. With this definition, scenario analysis can be seen as a means to compensate for lack of knowledge of a present system, uncertainties about the methodology/functional unit and variability of the products.

Mandatory parameters

- Usage: consumption
- Quantity value
- Usage: vehicle lifetime
- Usage: geographical variation of energy mix consumption
- Future mix: use phase electricity/H2 mix

Recommended parameters

- Choice of secondary data
- Location of the value chain: electricity mix
- Supply chain improvements: recycled vs. primary materials
- Usage: maintenance & wearing
- Usage: payload/nb of passengers
- Usage: temperature
- Future mix: EoL electricity/H2 mix
- Second use

Optional parameters

- Supply chain improvements: supplier choice
- Location of the value chain: fuel mix, transport distance & means
- Process improvements (waste management, upstream recycling processes, packaging...)
- Process improvements: energy consumption

Figure 4-12 : Voting results for parameter analysis in TSLCA

In the second vote, the parameters shown in Figure 4-19 had a qualified majority in favour of these parameters being analysed (mandatory, recommended, and optional). In order to focus on the most important parameters, only the mandatory and recommended parameters are considered in the 3rd vote. All but one of the questions received a qualified majority. The question about the "mandatory analysis on the future electricity/H2 mix for the use phase" has narrowly missed the qualified majority and is asked again with more background information.

Due to the growing importance of circular economy to reduce the environmental and social impact over the life cycle, TranSensus LCA recommends performing an optional sensitivity analysis. Circularity scenarios can include factors such as car sharing, vehicle-to-grid, reuse, recycling, and second-life applications.

The following definitions apply in the implementation of the proposals:

- Mandatory – required for compliance with the methodology
- Recommended – advisable to implement rather than required
- Optional – not required for compliance with methodology
- Informative – included for information purposes only, no action required

The part of the document that deals with the mandatory and recommended analysis of parameters is divided into two parts. Firstly, a question is posed as to what type of analysis should be used to analyse a parameter. Secondly it is asked whether the corresponding guidelines proposed by TranSensus LCA are accepted. It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval. The following guidelines to carry out the [sensitivity/scenario] analysis on the […] parameter are a proposal on which we ask for your feedback/opinion. The final guidelines will be established after the third voting considering your inputs.

Mandatory analysis of parameters

Q52 – Mandatory analysis on the future electricity/H2 mix for the use phase

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes performing a mandatory analysis on the future electricity/H2 mix for the use phase..

NOTE: Applicable to special provisions for deviating from this and instead adopting a "static" electricity mix projection approach, only in those instances where legal responsibilities may prevent OEMs from doing so by default.

Context addressing Electricity Mix

The environmental impacts arising from the use phase of BEVs (and also other plug-in electric powertrains, and vehicles operating on electric road systems - ERS) represents a significant share of the total life cycle impacts of such vehicles. These impacts are strongly dependent on how the electricity used to charge the on-board batteries and power the vehicles is generated. In general terms, such electricity is sourced from a grid mix that comprises a number of different electricity generation technologies, the relative shares of which are subject to change over time (and, critically, over the service life of the vehicle being assessed). More specifically, in many regions of the world, due to political and legislative pressure to meet climate targets, the electricity grid mixes have so far been evolving towards lower shares of fossil energies and higher shares of low-carbon technologies such as variable renewable energies (primarily wind and solar PV) and nuclear, and similar trends are expected to continue into the next decades.

Therefore, in order to provide an accurate estimate of the real-world environmental impacts of xEVs over their full life cycle, it is important to account for this dynamic evolution of the grid mix in the LCI modelling stage. This is of even more importance in comparative LCAs, where the environmental impacts of xEVs are compared to those of ICEVs, since failure to account for the progressive decarbonization of the electricity grid mix over the service life of xEVs would result in an overestimation of the GHG emissions of the xEVs during their use phase, putting them at an artificial competitive disadvantage vs. ICEVs.

In view of the above, in TranSensus LCA, a decision has already been reached that a conservative dynamic electricity mix projection approach shall be used to model the electricity modelling input to the use phase of BEVs (with special provision for deviating from this and instead adopting a "static" electricity mix projection approach, only in those instances where legal responsibilities may prevent OEMs from doing so by default). While sensitivities on alternative future projections for the electricity mix have also been identified as important (also to assess the uncertainty in this area), a definitive decision on whether these should be mandatory or only recommended is yet to be established.

Context addressing H2 mix

Similarly, as for BEVs and their use of electricity, the environmental impacts arising from the use phase of ZEV powertrains using hydrogen (i.e. FCEVs, FC-REEVs and H2 ICEVs) represent a significant share of the total life cycle impacts of such vehicles. They are strongly dependent on the hydrogen fuel production and supply chain. Hydrogen can be supplied from a limited number of different sources and processes (currently steam reforming natural gas, or electrolysis of water, e.g. using grid electricity or renewable electricity). And compared to electricity, there is relatively much greater uncertainty on what the actual supply mix will be for future hydrogen fuelled vehicles, and how this is likely to change over time. This is important particularly for comparative LCAs, where the environmental impacts of different ZEV powertrains are likely to be compared to each other, and to those of ICEVs, and different assumptions can make a significant impact on comparisons.

In TranSensus LCA, a decision has already been reached that a conservative dynamic electricity mix projection approach shall be used by default to model the electricity modelling input to the use phase of BEVs (with some exceptions, e.g. for OEMs where a static grid mix may be permissible). A similar approach is also proposed for hydrogen; however, this is currently limited by the comparative lack of availability of robust future projections, compared to the availability of projections for future electricity supply mixes produced by the IEA. However, should official projections become available in the future, it is desirable to already have a proposed methodology that can account for this (similarly as for electricity).

"Mandatory" means that TranSensus LCA mandates these parameters to be analysed.

Possible answers: Agree/ Disagree/ No preference

Background

In the 2nd voting this proposed approach did not reach a qualified majority. Due to its importance for the LCA, this question will be asked again, and more information is provided.

Q53 – Mandatory scenario analysis on the future electricity/H2 mix for the use phase

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes performing a mandatory scenario analysis on the future electricity/H2 mix for the use phase.

Possible answers: Agree/ Disagree/ No preference

Background

Electricity/H_2 consumed during the use stage has large influence on the total life cycle impacts of vehicles. Since the supply mixes for both electricity and H_2 supply mixes can evolve over time, this introduces uncertainty into LCA results. To address this, it's essential to consider alternative scenarios that capture a range of future mix projections, ranging from conservative to more ambitious net-zero projections. The methodology for modelling these future mixes is identical to that outlined under question on "Vehicle Use Phase Electricity Supply Mix" and "Proposed approach for modelling hydrogen supply mix during the vehicle use phase". For a comprehensive description of electricity modelling, please refer to Q17 of Task 2.3.

Q54 – Guidelines for the mandatory scenario analysis on the future electricity/H2 mix for the use phase

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the mandatory scenario analysis on the future electricity/H2 mix for the use phase.

Scenario analysis should be conducted using alternative future projections for the electricity/H_2 supply mix in the geographical region of interest. If TranSensus LCA uses a static electricity/H_2 supply mix by default, the analysis should include both a conservative mix projection (e.g., the Stated Policies Scenario (STEPS) from the IEA) as well as more ambitious climate scenarios such as the Sustainable Development Scenario (SDS) from the IEA). However, if a dynamic electricity/H_2 supply mix based on a conservative scenario is the default approach, only the more ambitious scenarios need to be tested, thus generating a ranged estimate. The electricity grid mix composition under these alternative scenarios shall be estimated according to the methodology outlined for this (see separate question on Vehicle Use Phase Electricity Supply Mix). Similarly, the H_2 supply mix composition under the alternative scenarios shall be estimated based on the methodology outlined for this (see separate question on Proposed approach for modelling hydrogen supply mix during the vehicle use phase).

For a comprehensive description of electricity modelling, please refer to Q17 of Task 2.3.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q55 – Mandatory sensitivity analysis on the usage: consumption

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes performing a mandatory sensitivity analysis on the usage: consumption.

Possible answers: Agree/ Disagree/ No preference

Background

It was decided in the Task 2.2 that a sensitivity analysis on vehicle energy consumption using real world factors was to be performed.

Q56 – Guidelines for mandatory sensitivity analysis on the usage: consumption

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes the following guidelines for the mandatory sensitivity analysis on the usage: consumption.

LDV: Depending on definition of default (WLTP or Real-World basis), sensitivity analysis is conducted on the alternative at least (e.g. if default is WLTP, RW as sensitivity, or vice-versa).

HDV: sensitivity analysis for different relevant drive cycles for the vehicle type (e.g. those used to form the certification weighted average, such as urban delivery, long haul, etc.).

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q57 – Mandatory sensitivity analysis on the usage: vehicle lifetime activity

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes performing a mandatory sensitivity analysis on the usage: vehicle lifetime activity.

Possible answers: Agree/ Disagree/ No preference

Background

Sensitivity on the lifetime activity (km driven), depending on how/by whom the vehicle is driven (e.g., taxi car or family car).

This is one of the key assumed parameters and it has a great impact on the overall results which is why it should be mandatory to study. It covers a life cycle phase that lies in the future at the time when the LCA is performed so it is unknown, as such it is uncertain and should be subject to a sensitivity analysis.

In the internal vote in Task 2.5 there was an equal number of votes in favour for a scenario analysis and a sensitivity analysis. Due to the lower complexity, it was decided that a sensitivity analysis will be carried out.

Q58 – Guidelines for the mandatory sensitivity analysis on the usage: vehicle lifetime activity

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the mandatory sensitivity analysis on the usage: vehicle lifetime activity.

The values used for the sensitivity analysis will be considering the typical lifetime activity [in driving distance] for vehicle type (low-high lifetime km).

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q59 – Mandatory scenario analysis on the usage: variation of energy mix consumption

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> “TranSensus LCA proposes performing a mandatory scenario analysis on the usage: variation of energy mix consumption”.

Definition for the analysis of variation of energy consumed: This parameter aims to study the influence of the energy mix consumed depending on where the vehicle is driven.

This analysis should be performed regardless of whether a static or dynamic mix is used in the initial model.

Example: If an electric car is driven and charged in Norway it has a different electricity mix, than a car driven and charged in Poland, which has an enormous impact on the life cycle impacts. The mix can also be varied e.g., renewables vs fossil mix.

Possible answers: Agree/ Disagree/ No preference

Background

Analysis of the use phase variation of the electricity mix (regardless of whether static or dynamic) or H2 mix depending on where the vehicle is driven or what kind of mix is used.

This is one of the key assumed parameters and it has a great impact on the overall results which is why it should be mandatory to study. It covers a life cycle phase that lies in the future at the time when the LCA is performed so it is unknown, as such it is uncertain and should be subject to a scenario analysis.

In the last voting the geographical variation instead of the variation at all was agreed on. To make the question appliable to more contexts, the *geographical* was left out.

Q60 – Guidelines for the mandatory scenario analysis on the usage: variation of energy mix consumption

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes the following guidelines for the mandatory scenario analysis on the usage: variation of energy mix consumption.

If the default assumption is that the vehicle is driven in Europe powered by the European electricity mix, at least an alternative scenario where the vehicle operates in a global context, using the global electricity mix, should be assessed. Scenarios considering vehicle usage in specific countries, using the corresponding national electricity mixes, can be included provided that the choice of these mixes is carefully justified. For example, that they reflect the range of renewable energy penetration, such as Norway for a highly renewable mix and Poland for a highly fossil-fuel mix.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q61 – Mandatory sensitivity analysis on the quantity value for hotspots

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes performing a mandatory sensitivity analysis on the quantity value for hotspots.

Definition for the analysis of quantity values leading to hotspots: This is the amount of component/material/energy that is put in the LCI and that results in a notable contribution to overall impacts. For supplier-specific data, the quantity is known and measured and thus comes with statistical information on measurement. For secondary data, the quantity is either provided by literature or databases and thus can come with uncertainties (e.g., ecoinvent datasets) or the quantity is not known (e.g., battery/vehicle lifetime) and an assumption is made, a sensitivity is then needed on that value. Certain flows can be excluded from the sensitivity analysis if it is possible to justify that they are fixed (e.g., the BOM for a representative vehicle).

Definition of hotspot: It is a specific process or unit process or product / environmental flow within a process or value chain where the environmental impacts are notably significant.

Possible answers: Agree/ Disagree/ No preference

Q62 – Guidelines for the mandatory sensitivity analysis on the quantity value for hotspots

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the mandatory sensitivity analysis on the quantity value for hotspots.

The recommendation is to perform mandatory sensitivity analysis for those LCI flows identified as hotspots. Certain flows can be excluded from the sensitivity analysis if it is possible to justify that they are fixed (e.g., the BOM for a representative vehicle). Sensitivity analysis can be conducted using worst/best cases for the remaining flows based on measurements or data from literature.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Recommended analysis of parameters

Q63 – Recommended sensitivity analysis on the choice of secondary data

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes performing a recommended sensitivity analysis on the choice of secondary data for the components/materials/flows that are deemed relevant, e.g., leading to hotspots.

Definition: This choice arises when several datasets are available to represent one component/material/flow and the LCA practitioner does not know which one suits their model best. Thus, the decision to use one dataset rather than another one is often arbitrary and leads to uncertainty in the results.

Possible answers: Agree/ Disagree/ No preference

Background

If the LCA practitioner has the choice between two datasets to model one component and no knowledge on which one to use, e.g., 2 alloys possible.

This wouldn't have to be done for all secondary datasets, maybe only for those leading to hotspots (e.g., steel / aluminium).

Q64 – Guidelines for the recommended sensitivity analysis on the choice of secondary data

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the recommended sensitivity analysis on the choice of secondary data for the components/materials/flows that are deemed relevant, e.g., leading to hotspots (to be defined).

Conduct an OAT-type analysis by changing one dataset at a time and evaluating the influence on the final results (e.g., changing the dataset for the cobalt sulphate used in battery manufacturing, and evaluate the influence on the carbon footprint of the EV). The datasets selected for this analysis should be justified based on a hotspot analysis and depending on data availability.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q65 – Recommended scenario analysis on the location of the value chain

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the partners to perform a recommended scenario analysis on the location of the value chain and how it affects the electricity mix.

Definition: The location of some of the suppliers along the value chain might not be known to the LCA practitioner (i.e., no supplier-specific data available) and thus the electricity mix used (whether location or market-based) for some process/components/materials is also unknown.

This analysis does not have to be performed for all suppliers along the value chain, only for relevant process/suppliers e.g., leading to hotspots or energy intensive processes.

Possible answers: Agree/ Disagree/ No preference

Q66 – Guidelines for the recommended scenario analysis on the location of the value chain

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the recommended scenario analysis on the location of the value chain and how it affects the electricity mix.

The scenarios could involve assessing alternative supply chains based on potential production locations for the same product (e.g., synthetic graphite supply from China vs. USA). The alternative supply chains are modelled by varying the electricity mix (country-specific) used in key manufacturing processes. No specific guidelines are provided in this regard, so the practitioner must select the most appropriate choice and justify it accordingly.

Due to potential data availability constraints (requiring access to disaggregated unit process datasets), it is recommended to conduct this analysis, at a minimum, for the most critical tier-1 processes. The justification for selecting these key processes can be based on the hotspot analysis.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q67 – Recommended scenario analysis on process improvements with respect to the use of recycled vs. primary materials.

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the partners to perform a recommended scenario analysis on process improvements with respect to the use of recycled vs. primary materials.

Definition: This parameter is linked to the decision of the OEM or supplier to use recycled materials instead of primary.

This analysis doesn't have to be performed on all materials but only those deemed relevant by the LCA practitioner.

Possible answers: Agree/ Disagree/ No preference

Background

This parameter comes from the decision of the OEM/supplier to choose to use recycled material X instead of primary material X.

Q68 – Guidelines for the recommended scenario analysis on process improvements

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the recommended scenario analysis on process improvements with respect to the use of recycled vs. primary materials.

Scenarios with varying rates of recycled materials incorporation should be considered. The low scenario could involve 0% incorporation of recycled material, while the high scenario could reflect the maximum share of recycled material that is achievable within the industry at a specific time.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q69 – Recommended scenario analysis on maintenance & wearing during usage

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the partners to perform a recommended scenario analysis on maintenance & wearing during usage.

Definition: This is another parameter linked to the way the vehicle will be driven and by whom. A more intensive use might lead to more maintenance and wearing of some parts/components.

Maintenance includes tasks such as tire rotations, fluid checks, and other routine inspections. Wear include wear on tires, brake pads, and other mechanical components. Wear is a natural part of a car's lifespan and may require maintenance or replacement.

Possible answers: Agree/ Disagree/ No preference

Q70 – Guidelines for the recommended scenario analysis on maintenance & wearing during usage

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes the following guidelines for the recommended scenario analysis on maintenance & wearing during usage.

If available: Different scenarios depicting low and high wearing and maintenance requirements are recommended to be analysed.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q71 – Recommended scenario analysis on the payload/number of passengers during usage

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes the partners to perform a recommended scenario analysis on the payload/number of passengers during usage.

Definition: This is another parameter linked to the way the vehicle will be driven and by whom (e.g., family of 6 or single person).

Possible answers: Agree/ Disagree/ No preference

Background

Sensitivity on the payload/number of passengers depending on how/by whom the vehicle is driven (e.g., taxi car or family car).

This is one of the key assumed parameters that will have an important influence on the results if the functional unit is expressed in p*km/t*km. The agreed functional unit in TranSensus LCA is km-based, it was agreed in the previous voting in task 2.2 that the functional unit is ton*km for freight vehicles and passenger*km for buses and passenger cars.

Q72 – Guidelines for the recommended scenario analysis on the payload/number of passengers during usage

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the recommended scenario analysis on the payload/number of passengers during usage.

LDV: Consider low-high scenarios for the number of passengers, where low is 1 passenger and high corresponds to the maximum capacity of the vehicle (e.g., 5 passengers). If the default assumption corresponds to the low scenario, only the high scenario needs to be assessed. When conducting this analysis, it is important to note that increasing the number of passengers affects energy consumption during usage and potentially other inventory flows. Therefore, the scenario analysis should capture these effects and transparently document the assumptions made.

HDV: Consider low-high scenarios for the payload. The used range could be based on typically payload range (e.g., 25-100%).

Important information: Changing the payload could also influence other parameters such as the consumption/ maintenance & wear.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q73 – Recommended scenario analysis on the ambient temperature during usage

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the partners to perform a recommended scenario analysis on the ambient temperature during usage.

Definition: This is another parameter linked to the way the vehicle will be driven and where (e.g., in Spain or in Norway). The ambient temperature will affect the ageing, the range, and the performance of some parts/components like the battery for example.

Example: A car driven in Norway experiences cold temperatures especially in winter. This may cause a reduced efficiency and a decrease in its overall range. While a car driven in Spain in summer needs cooling for the passengers and the battery which results in a higher energy consumption.

Possible answers: Agree/ Disagree/ No preference

Q74 – Guidelines for the recommended scenario analysis on the ambient temperature during usage

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes the following guidelines for the recommended scenario analysis on the ambient temperature during usage.

"TranSensus LCA recommends the following guidelines for the recommended scenario analysis on the ambient temperature during usage.".

Considering locations with different annual average temperatures for comparison (e.g., Norway vs southern Italy). When conducting this analysis, it is important to note that varying the temperature affects the EV range, with direct implications for energy consumption during usage and potential on several other inventory flows. The scenario analysis should capture these effects and transparently document the assumptions made.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Q75 – Recommended scenario analysis on the EoL electricity/fuel mix modelled with a future mix

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes the partners to perform a recommended scenario analysis on the EoL electricity/fuel mix modelled with a future mix.

Possible answers: Agree/ Disagree/ No preference

Background

Similar to the electricity modelling for the electricity that is consumed during use phase, at the end of a vehicle's service life, the vehicle is assumed to be scrapped thus reaching its end-of-life. From a temporal perspective, it must be acknowledged that the time the vehicle is scrapped lies in the future, and therefore, electricity consumed for scrapping the vehicle is sourced from the national grid during that particular timeframe. This presents the requirement to account for future projected electricity mix, in that specific location, at the end of the vehicle's service life. Therefore, it is recommended that only one set of electricity mix projections from the year the vehicle scrapped is used for, for that specific location (if available).

Q76 – Guidelines for the recommended scenario analysis on the EoL electricity/fuel mix modelled with a future mix

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

TranSensus LCA proposes the following guidelines for the recommended scenario analysis on the EoL electricity/fuel mix modelled with a future mix (whether static or dynamic).

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

Background

Similar to the electricity modelling for the electricity that is consumed during use phase, at the end of a vehicle's service life, the vehicle is assumed to be scrapped thus reaching its end-of-life. From a temporal perspective, it must be acknowledged that the time the vehicle is scrapped lies in the future, and therefore, electricity consumed for scrapping the vehicle is sourced from the national grid during that particular timeframe. This present the requirement to account for future projected electricity mix, in that specific location, at the end of the vehicle's service life. Therefore, it is recommended that only one set of electricity mix projections from the year the vehicle scrapped is used for, for that specific location (if available)

Proposed approach/possible options description and justification

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, according to the following order of preference:
   a. Official scenario for the country or geographical region of interest (e.g., EU Reference Scenario 2020)
   b. Stated Policies Scenario (STEPS) from the most recent International Energy Agency's World Energy Outlook (IEA WEO) report, for the geographical region of interest[51]
   c. IF NEITHER a. NOR b. IS AVAILABLE for the geographical region of interest, then the most recent "static" grid mix composition shall be used instead
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 $S_{i,N}$ 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 in the LCA software package of choice (e.g., "LCA for Experts", or "SimaPro"), 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[52]

[51] IEA WEO region-specific datasets for STEPS are available for purchase for the following regions: North America, USA, Central&South America, Brazil, Europe, EU-27, Africa, Middle East, Eurasia, Russia, Asia Pacific, China, India, Japan, Southeast Asia, OECD, non-OECD, Emerging and developing economies.

[52] For Variable Renewable Energy (VRE) generators like solar photovoltaics (PV) and Wind, improved accuracy may be attained by adjusting the database processes to account for more accurate region-specific Capacity Factors (CF are defined as the ratio of the electricity actually delivered in a year [kWh] to the product of the nameplate installed power [kW_p] times the number of hours in a year).

Q77 – Recommended scenario analysis on the second use

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the partners to perform a recommended scenario analysis on the second use.

Definition: This parameter evaluates the impacts of adding a second use to the initial system. The task 2.5 encourages to perform such analysis if a business case exists.

Study the effects on the results to have a second use. TranSensusLCA encourages the LCA practitioner to evaluate the effects of a second use on the overall results. Due to the increasing importance of second use in the context of zero-emission road transport, a more in-depth analysis is highly recommended and encouraged by the advisory board.

Possible answers: Agree/ Disagree/ No preference

Q78 – Guidelines for the recommended scenario analysis on the second use

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> TranSensus LCA proposes the following guidelines for the recommended scenario analysis on the second use.

Potential alternative scenarios consider that the battery at its end-of-life is suitable for second use in stationary applications. This second use requires several processes, including battery collection, battery dismantling to module/cell level, SoH testing, and battery refurbishment. The percentage of battery cells suitable for second use is a critical parameter and should be assessed through a worst-case and best-case scenario, assuming that only certain percentage of battery cells are suitable for being reused in stationary application. Cells not suitable for reuse will need to be replaced during the refurbishment.

It is important here that the proposals do not yet correspond to the final wording, but that the question is asked whether the general concept of the guidelines meets with approval.

Possible answers: Agree/ Disagree/ No preference

4.4.2 Recommended set of S-LCA interpretation parameters

The process began with the review of the 2nd voting results on (environmental) LCA interpretation parameters. In a first step, the list of LCA interpretation parameters that was voted on and reached consensus was evaluated by the partners involved in the social LCA subtask. In the meetings it was jointly decided which of the (environmental) LCA interpretation parameters might also be relevant for S-LCA, based on the following categorisation: 'relevant', 'maybe relevant' and 'not relevant'. In a second step, the resulting list of S-LCA interpretation parameters containing the categories 'relevant' and 'maybe relevant' was supplemented by missing S-LCA interpretation parameters that are exclusively relevant for S-LCA interpretation, as for example the choice of activity variable. This step was also conducted jointly in the social LCA subtask meetings. In a third step, the resulting comprehensive list of S-LCA interpretation parameters, including 14 different parameters, was circulated among the social LCA subtask members in order to select the most relevant S-LCA interpretation parameters that can be recommended for the 3rd voting. This selection process was conducted by following a simplified approach similar to the methodology proposed by Haslinger et al. (2024)[53].

Each interpretation parameter was evaluated based on three criteria: i) relevance, ii) data availability and iii) ease of interpretation. Each criterion was scored on a scale from 0 to 3, with specific reference points used to justify the reduction of the extensive list from a scientific perspective. For example, an interpretation parameter can be of high relevance for the assessed impact, however, data is very limited and there might be no information available and/or would be too time extensive to collect the necessary data. In the following, the applied criteria including scale and reference points can be found:

Criteria	Scale	Reference Point (RF)
Relevance	3	high relevance of the assessed impact
	2	medium relevance of the assessed impact
	1	low relevance of the assessed impact
	0	no relevance of the assessed impact
Data availability	3	access to supplier specific data from company (Drive Sustainability Questionnaire), already available in CSR reports or via internal reporting (health and safety management systems) and/or access to company specific data i.e. ecovadis, datamaran, RepRisk, Sedex, Supplyshift
	2	access to regional / country level data from databases i.e. PSILCA, SHDB, Verisk Maplecroft (fee based), NGO sources (open access), long term collection phase

[53] Haslinger, A.S., Huysveld, S., Cadena, E. and Dewulf, J., 2024. Guidelines on the selection and inventory of social life cycle assessment indicators: a case study on flexible plastic packaging in the European circular economy. The International Journal of Life Cycle Assessment, pp.1-18.

	1	access to reliable online sources i.e. News (local and global)
	0	no information available and/or too time extensive collection phase
Easiness to interpret	3	high clarity and awareness of the assessed impact i.e %
	2	medium clarity and awareness of the assessed impact
	1	low clarity and awareness of the assessed impact
	0	no clarity and awareness of the assessed impact

It was decided to only recommend the interpretation parameters for the 3rd voting that reach a mean value combining all three criteria of above 2.0 (between 2.0 and 3.0). In that way, the threshold is consistent with the threshold for S-LCA indicator selection. This leads to the following final set, consisting of 7 remaining interpretation parameters that are recommended for the 3rd voting.

Recommended Interpretation Parameters	Relevance	Data availability		Easiness to interpret	Total (mean)
Quantity value for certain components/materials/flows leading to hotspots	3.0	2.8	3.0	2.9	
Geographical variation of the value chain	3.0	2.0	2.8	2.6	
Choice of the activity variable (e.g. working hour vs. value added)	3.0	2.2	2.2	2.4	
Assumptions on data	3.0	2.6	3.0	2.8	
Price related to processes or materials	2.7	3.0	2.4	2.7	
Geographical variation of the energy consumed (electricity mix or H2 mix) during usage	3.0	2.6	3.0	2.8	
Quantity of energy consumed during the use phase	2.4	2.6	2.6	2.5	

Q79 – Integration of the quantity value for certain components/materials/flows leading to hotspots as recommended S-LCA interpretation parameter

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including the quantity value for certain components/materials/flows leading to hotspots in the recommended list of TranSensus LCA social interpretation parameters.

Varying quantities of components, materials, or flows from a particular region/country in a S-LCA can significantly impact the identification of hotspots. This is because changes in quantity can alter the relative importance of different stages in the life cycle, as well as the corresponding social impacts related to those processes and locations. For instance, increasing the volume of a particular material might intensify social impacts in its extraction phase, while decreasing it could shift the hotspot to another stage, such as manufacturing or transportation. Therefore, considering quantity is crucial for accurate hotspot identification and effective mitigation strategies. A social hotspot is a location and/or activity in the life cycle where a social issue (as impact) and/or social risk is likely to occur. It is usually linked to life cycle stages or processes. In other words, social hotspots are unit processes located in a region where a problem, a risk, or an opportunity may occur in relation to a social issue that is threatening social well-being or that may contribute to its further development.

Possible answers: Agree/ Disagree/ No preference

Background

<table>
<tr><th>Recommended Interpretation Parameters</th><th colspan="3">Relevance</th><th>Data availability</th><th>Easiness to interpret</th><th>Total (mean)</th></tr>
<tr><td>Quantity value for certain components/materials/flows leading to hotspots</td><td>3.0</td><td>2.8</td><td>3.0</td><td colspan="3">2.9</td></tr>
</table>

The total score for the "quantity value for certain components/materials/flows leading to hotspots" is 2.9, which is not only well above the threshold but also the highest score among the proposed interpretation parameters, making this S-LCA interpretation parameter the most important one among the recommended interpretation parameters. This score reflects the fact that changes in the quantity value for certain components/materials/flows leading to hotspots can significantly change the social impact and is crucial for accurate hotspot identification.

Q80 – Integration of geographical variation of the value chain as recommended S-LCA interpretation parameter

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including the geographical variation of the value chain in the recommended list of TranSensus LCA social interpretation parameters.

Geographical variation significantly influences social impacts within a value chain. Factors like labor standards, human rights conditions, and other social regulations differ widely between regions. Interpretation helps identify how these geographical shifts impact social performance. By altering the location of specific value chain stages, analysts can assess the resulting changes in social hotspots and social impacts, informing decisions about sourcing, production, and supply chain management for improved social sustainability.

Possible answers: Agree/ Disagree/ No preference

Background

Recommended Interpretation Parameters	Relevance	Data availability	Easiness to interpret	Total (mean)
Geographical variation of the value chain	3.0	2.0	2.8	2.6

The total score for the "geographical variation of the value chain" is 2.6, well above the threshold. This also reflects the importance of varying the location of the value chain as social standards can vary a lot in different geographical regions.

Q81 – Integration of the choice of the activity variable as recommended S-LCA interpretation parameter

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including the choice of the activity variable (e.g. working hour vs. value added) in the recommended list of TranSensus LCA social interpretation parameters.

The choice of activity variable (working hours vs. value added) significantly influences the allocation of social impacts in a life cycle. Using working hours may overemphasize labour-intensive processes, while value added might prioritize processes with higher economic output. Conducting a sensitivity analysis on these variables helps to understand the potential impact of this choice on the overall results and identify potential biases.

Possible answers: Agree/ Disagree/ No preference

Background

Recommended Interpretation Parameters	Relevance	Data availability	Easiness to interpret	Total (mean)
Choice of the activity variable (e.g. working hour vs. value added)	3.0	2.2	2.2	2.4

The total score for the "choice of activity variable" is 2.4. Especially regarding data availability (2.2) and easiness to interpret (2.2), the S-LCA subtask members were hesitant to give the highest scores, as S-LCA case studies applying a sensitivity analysis on the choice of activity variable are still limited. Nevertheless, WP2 recommends including the choice of the activity variable as a recommended interpretation parameter as it not only passed the threshold of 2.0 but is also considered to be an important interpretation parameter that significantly influences the allocation of social impacts.

Q82 – Integration of assumptions on data as recommended S-LCA interpretation parameter

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including assumptions on data in the recommended list of TranSensus LCA social interpretation parameters.

Given the inherent uncertainties associated with primary and secondary social data, exploring how variations in data assumptions impact the final outcomes is essential. By varying the assumptions on social data, practitioners can identify critical data points influencing hotspot identification and understand the potential range of impacts. This enhances the reliability and credibility of the S-LCA findings, ultimately leading to more informed decision-making.

Possible answers: Agree/ Disagree/ No preference

Background

Recommended Interpretation Parameters	Relevance	Data availability	Easiness to interpret	Total (mean)
Assumptions on data	3.0	2.6	3.0	2.8

The total score for the "assumptions on data" interpretation parameter is 2.8, highlighting the significance to include this parameter. Especially regarding the criteria "Relevance" and "Easiness to interpret", where this interpretation parameter was ranked highest (3.0). Applied assumptions on data may crucially influence S-LCA results, which is why WP2 recommends including this interpretation parameter in the recommended list of S-LCA interpretation parameters.

Q83 – Integration of the price related to process or materials as recommended S-LCA interpretation parameter

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including the price related to process or materials in the recommended list of TranSensus LCA social interpretation parameters.

By varying prices of processes or materials, analysts can identify which cost factors significantly influence social performance indicators. This helps to pinpoint areas where economic incentives could be leveraged to improve social conditions, such as fair wages, safe working conditions, or community well-being.

Possible answers: Agree/ Disagree/ No preference

Background

Recommended Interpretation Parameters	Relevance	Data availability	Easiness to interpret	Total (mean)
Price related to process or materials	2.7	3.0	2.4	2.7

The total score of the "price related to process or materials" is 2.7, also ranking clearly above the threshold. Data availability was ranked highest (3.0), however, it might not always be easy to interpret the results (2.4). Nevertheless, as varying prices of processes or materials can significantly impact the social performance, WP2 recommends this interpretation parameter to be included in the recommended list of S-LCA interpretation parameters.

Q84 – Integration of the geographical variation of the energy consumed during usage as recommended S-LCA interpretation parameter

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including the geographical variation of the energy consumed (electricity mix or H2 mix) during usage in the recommended list of TranSensus LCA social interpretation parameters.

Geographical variation in energy consumption during product usage significantly influences the overall social impact of a product. Conducting intepretation on this factor allows for a more accurate and comprehensive assessment of social hotspots and social impacts. By analyzing how changes in energy sources, production methods, and regional social conditions impact the product's social performance, LCA practitioners can identify potential risks, evaluate mitigation strategies, and inform decision-making based on geographically specific contexts.

Possible answers: Agree/ Disagree/ No preference

Background

Recommended Interpretation Parameters	Relevance	Data availability	Easiness to interpret	Total (mean)
Geographical variation of the energy consumed (electricity mix or H2 mix) during usage	3.0	2.6	3.0	2.8

The total score of the "geographical variation of the energy consumed (electricity mix or H2 mix) during usage" is 2.8, clearly above the threshold. The score for data availability (2.6) reflects the fact that data for this S-LCA interpretation parameter might not always be available. Nevertheless, geographical variation of the energy consumed during usage indirectly also varies the labour conditions in the energy production and distribution sector. This is why WP2 recommends including this S-LCA interpretation parameter in the recommended list of S-LCA interpretation parameters.

Q85 – Integration of the quantity of energy consumed during the use phase as recommended S-LCA interpretation parameter

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> TranSensus LCA proposes including the quantity of energy consumed during the use phase in the recommended list of TranSensus LCA social interpretation parameters.

Interpretation analysis of energy consumption during the use phase is crucial in S-LCA interpretation as it can significantly influence social impacts. Variations in energy consumption can directly affect labour conditions, human rights, and community well-being in energy production and distribution sectors.

Possible answers: Agree/ Disagree/ No preference

Background

Recommended Interpretation Parameters	Relevance			Data availabil-ity	Easiness to interpret	Total (mean)
Quantity of energy consumed during the use phase	2.4	2.6	2.6	2.5		

The total score for the "quantity of energy consumed during the use phase" is 2.5, with scores for "relevance" of 2.4, and for "data availability" and "easiness to interpret" of 2.6. This interpretation parameter, just as the previous recommended interpretation parameter regarding the geographical variation of the energy consumed during usage is of high importance due to the varying labour conditions in the energy production and distribution sector as well as all related labour-intensive work regarding the energy infrastructure and energy supply chain.

<u>Integration in product development process</u>

Q86 – TranSensus LCA approach for product development

Executive summary

<u>Type of LCA concerned by the question:</u> **Prospective LCA**

<u>Complete question submitted to voting</u>

> TranSensus LCA proposes following the frontloading LCA approach for product development as described in the following scheme.

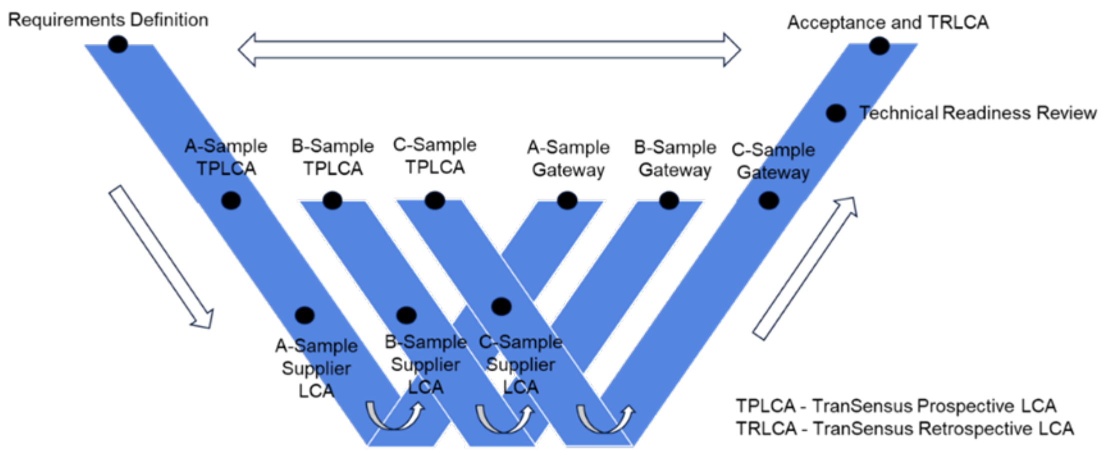


Figure 4-13 : TranSensus LCA Calculations within Product Development Process

TranSensus LCA proposes performing prospective LCA to frontload support to the engineering development process of new vehicles and automotive components (adaptation from V-Model).

The LCA effort should be performed as early as practicably possible within the development process to support decision-making on technology, design and manufacturing choices from an environmental perspective. The LCA process should follow the recommended TranSensus framework for prospective LCA. Models with a subset of key indicators can be used to provide early direction to the design and manufacturing teams within the OEM or Tier 1. These models can be updated and iterated as the design matures and more accurate input data is provided by suppliers and design teams. Best practice is to iterate the LCA calculation at every major gateway. The results are used to assess suitability of the designs against the requirements at a product level.

Possible answers: Agree/ Disagree/ No preference

Background

Decision Making and Frontloading in the Product Development Processes using TranSensus LCA

Introduction

In view of the overall objective of TranSensus LCA to pave the path towards an LCA-driven product development, a study has been performed to conceptualise how decision-making and frontloading processes can be implemented into the automotive product development processes. The goal is to enable engineers and managers according to their profile (industry, research and technology organisations, academia, policy, regulation, etc.) to select solutions and technologies (both existing and emerging) based on their environmental and social impacts, while balancing all other requirements.

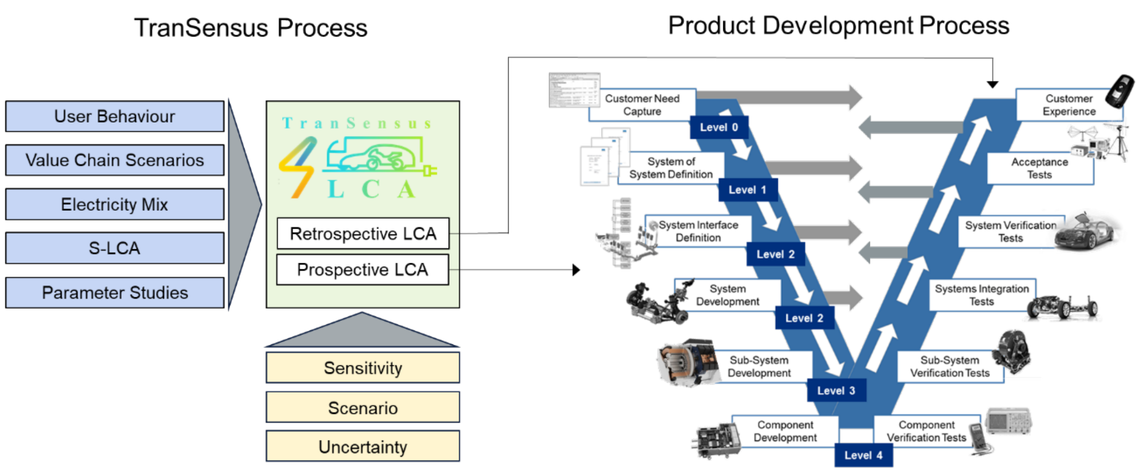


Figure 4-14 : Implementation of TranSensus LCA Process in the Product Development Process

TranSensus LCA aims to develop a baseline for a European-wide harmonised, commonly accepted and applied single life cycle assessment approach for a zero-emission road transport system. The framework for the TranSensus LCA process, including the assumptions, process steps, studies and reporting as shown on the left side of Figure 4-20 have been developed and agreed by the project partners. One objective for TranSensus project is to assess how the LCA processes defined by the TranSensus LCA framework can be effectively applied for frontloading and decision making within the product development process.

The product development process is shown on the right-hand side of Figure 4-20. The product development process is represented by a V-diagram which is a widely used representation used within systems engineering. The V-diagram is used in a simplistic form within ISO15288[4] where a generic lifecycle development model is used to describe the various engineering technical processes involved in a system engineering approach. The lifecycle model describes the product development process, including capturing the customer needs and requirements, the systems design process, and the validation. It is important to note that the product development process, as represented in Figure 4-20, is included in the systems engineering lifecycle but is not included within the boundaries of the TranSensus Life Cycle Analysis framework. Product development is specifically excluded from the boundary for vehicle LCA as impacts are likely to be very low versus other aspects of the lifecycle and harder to objectively quantify. For example, there are no agreed methods of how to spread development impacts consistently and objectively over the number of vehicles eventually manufactured.

The V-model is further developed and detailed within The International Council on Systems Engineering (INCOSE) Handbook[5]. The representation shown within Figure 4-21 is a Ricardo automotive representation of the product development stages within this process.

Within the V-model, time travels on a left to right axis. The project therefore begins with collating the customer needs and project requirements before system and interface definition. On the left-hand side of the V there is an evolving baseline of approved status and consideration of new designs under progressive management. At any point in time, which would be represented by a vertical line along the left to right axis, the development team can shift their focus from the highest available viewpoint (the requirements) to the lowest level of detail available which progresses from systems, to sub-systems and components. Risk management is performed by addressing development options along this timeline. These decisions direct the selection of the technology, supplier, manufacturing options or designs to ensure the requirements can be achieved. It is important, therefore, for LCA to interface with the systems engineering process to include life cycle considerations and manage environmental risk. On the right-hand side of the V, verification can identify problems and causes and also approval that the performance is acceptable. Information flows between the left-hand side and right-hand sides of the V, for example to show the requirements at each level and the validation status.

Why frontloading?

A retrospective LCA aims to evaluate environmental impacts slightly before or after the start of production. A nearly finalised bill of materials of all parts is available to the OEM at this stage. Figure 4-22 shows how the retrospective LCA results can feed into the end of the product development timeline at the final validation steps of the process. At this stage all the decisions on design, suppliers and materials have been made. Figure 4-21 shows the relationship between cost and ability to change decisions within the product development process. Early in the product development process, there is freedom in design and choice of suppliers or materials. Later in the process, designs are "frozen", and changes become increasingly difficult. Retrospective LCA is therefore unlikely to have a large positive impact on the environmental performance of the vehicle due to cost and timing implications of making late changes to address hotspots. Additionally, late changes will also be resisted as these can generate quality problems as it may not be possible to validate all the systems sufficiently.

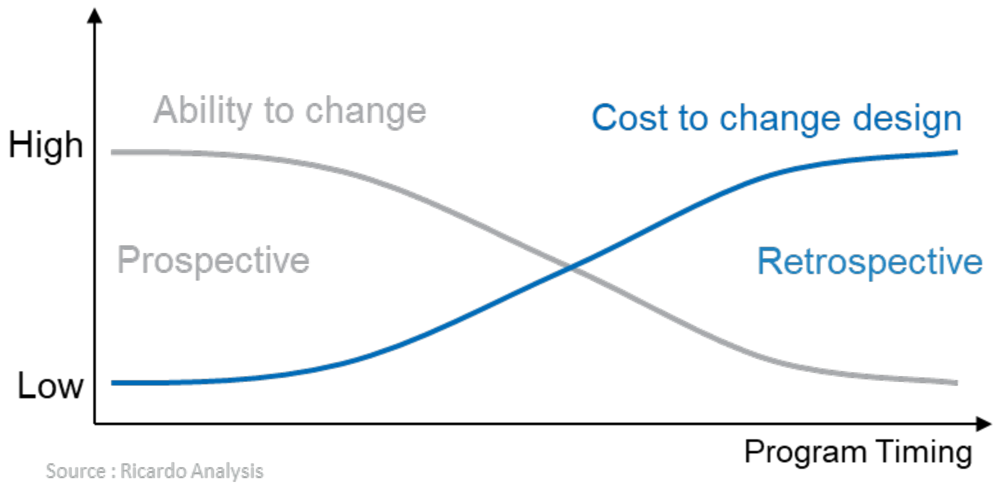


Figure 4-15 : Project Timeline Cost and Changeability

A prospective LCA is conducted during the earlier development stages and aims to estimate environmental impacts before the start of production. The bill of materials is not completely defined. Using prospective LCA to feed into the left-hand side of the product development process (Figure 4-20) to review calculated LCA impacts versus requirements and identify hotspots will frontload the consideration of the environmental performance. In contrast to the application of a retrospective LCA only, it is far more likely a balanced set of attributes can be achieved, life cycle emissions can meet requirements, costs are reduced, and quality is improved.

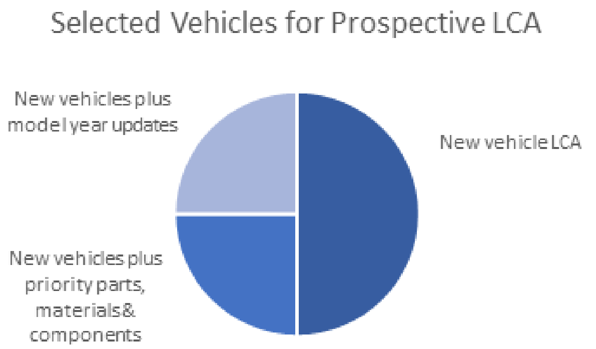
Prospective LCA within TranSensus

The review and development of a harmonized process for Prospective LCA is included within the TranSensus LCA project scope. This harmonized process will be developed and reported in other TranSensus LCA deliverables (for example WP1 Review of Current Practices and WP2 Conceptualising LCA approach) and will not be duplicated in detail in this frontloading study. It is expected that characteristics recommended by TranSensus LCA for a retrospective LCA such as impact categories, impact assessments and indicators will carry over and apply to the Prospective LCA. Goal and scope can be simplified within TranSensus LCA for prospective LCA, which will make it a more streamline process suitable for early application and iteration as the product design matures.

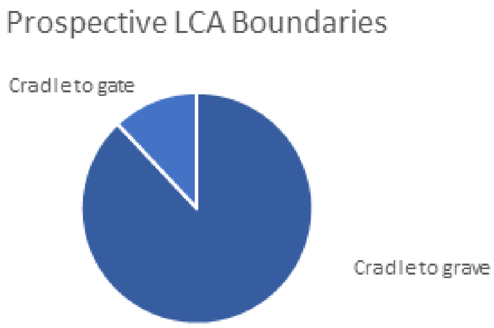
Survey on Application of Prospective LCA

A survey of partners within TranSensus LCA was performed to assess the state-of-the-art use of prospective LCA for frontloading the product development process. A questionnaire was sent to and completed by eight OEM partners with questions focussing on the application of prospective LCA. It was decided to focus on vehicle OEMs as the TranSensus LCA process considers the full vehicle lifecycle, whereas it is not possible to allocate emissions for the use phase for a single component or system. Alternatively, cradle to gate analysis is typically performed by the tier 1s to provide input data for the OEM full life cycle assessments. A tier 1 was included in the frontloading study team to provide supplier input of this methodology.

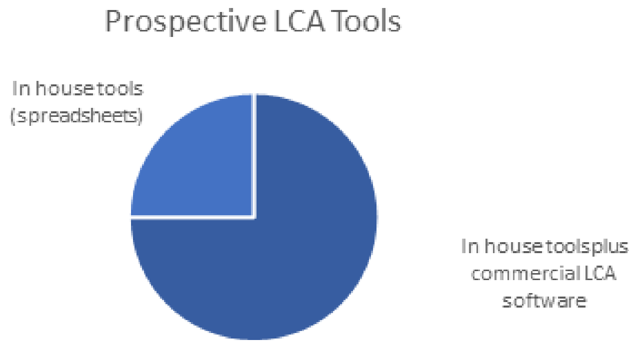
All the respondents used prospective LCA to support and direct the product development process. All of the OEMs performed this analysis on new vehicle designs. In addition, 25% of the OEM's performed Prospective LCA calculations on priority parts, materials, and components and 25% performed LCA on model year upgrades.



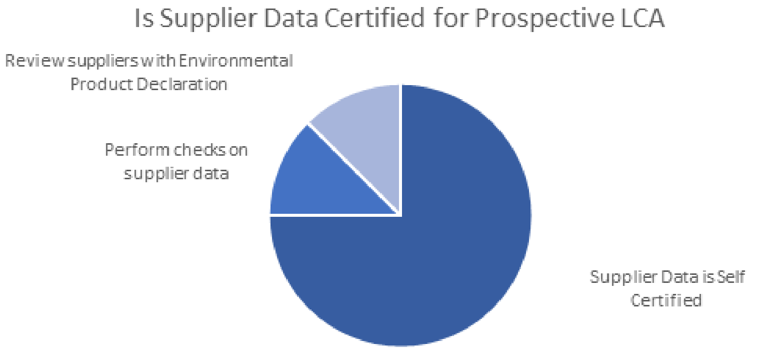
88% of the OEM's performed the Prospective LCA over the full life cycle and 12% considered the cradle to gate stages only.



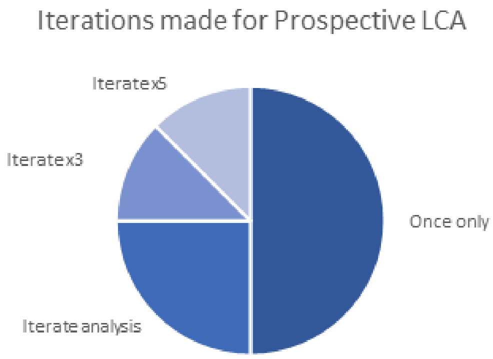
75% of the OEM's use in-house spreadsheet tools plus commercial LCA software. All of the respondents use a mixture of primary data and commercial databases when the primary data is not available.



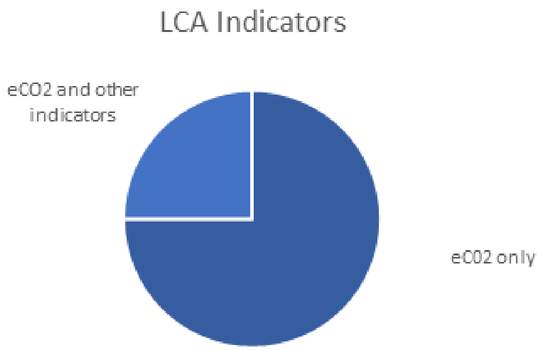
5% of OEM's use supplier input data which is self-certified. 12.5% perform checks and reviews on all data supplied and 12.5% review suppliers with Environmental Product Declarations.



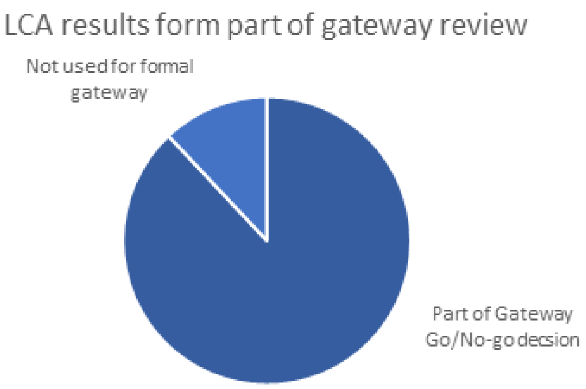
When applying prospective LCA, 50% of the OEM's perform the calculations once only. 25% iterate their analysis without specifying how many times. 12.5% iterate three times, and 12.5% iterate five times.



Within the calculations, 50% include trajectories within the calculation and 50% use current data (e.g., current energy mix) for calculating future emissions. All of the OEMs calculate GWP eCO2 in the results, with 25% also using other indicators.



To support the ranking of GWP eCO2 with other attributes 63% of the OEMs use internal emissions pricing (e.g., €150/tonne eC02). All of the OEMs use the data for supporting objective corporate targets (e.g., fleet targets) and vehicle model comparisons. 88% of the OEMs use the Prospective LCA results to form part of a project gateway (go/no-go) decision.



All of the OEM's use prospective LCA for internal purposes only.

Additional summaries and comments were provided by the OEM's as follows:

- It is recommended to ask all environmental questions early in the process.
- It is recommended to harmonise methods for efficient and accurate supplier data collection.
- Full life cycle analysis is essential.
- Scenario analysis, for example around electricity supply assumptions, is important.

Discussion of Survey Results

All OEMs in the survey use prospective LCA to frontload the product development process. The tools and methodology used in the analysis is reported as being quite similar amongst all the respondents. In-house spreadsheet tools are used by all of the OEMs. This is potentially to reduce investment in licence cost and software skills development and also to tailor the inputs and outputs to the OEM requirements to simplify and reduce complexity. Most of the OEMs supplemented the in-house tools with commercial software and external life cycle inventory databases.

Differences in approach were identified were in the vehicles/components chosen for prospective LCA by the OEMs and the number of iterations of the LCA models performed as the design matures during the product development process. State of the art would be the most comprehensive i.e., modelling all vehicles and model year upgrades for the full life cycle, cascading the environmental requirements and cradle to gate analysis to key systems and components. The LCA analysis should be performed as early as possible, using early concepts and iterating the model regularly as the design matures.

The tier 1 included on the sub-task team also completed the questionnaire. The approach taken was very similar to the most comprehensive methods by the OEMs, with eCO2 plus additional indicators used, iteration of results and similar toolsets. The main difference, as expected, was the limit of component cradle-to-gate analysis only, rather than a full vehicle calculation with a use phase for automotive LCA.

Recommendations

Based on the analysis of best practice, Figure 4-23 shows a representation of how TranSensus LCA can be implemented effectively within the V-model product development process. In this representation, multiple staggered Vs are shown to represent the different development phases and design freeze gateways typical in automotive development. These are nominally shown as A-Sample, B-Sample and C-Sample although the naming convention and number of phases will vary dependant on the OEM. Good practice would be to iterate Prospective LCA for each of the development phases to support design decisions with environmental status against the requirements and hotspot analysis to identify areas for improvement. Supplier LCAs are performed at a sub-system or component level to support this analysis. TranSensus LCA recommends that all impact categories used in product (retrospective) LCA are also applicable for prospective LCA. This requires extension of the analysis to comprise GWP eCO2 and in addition photochemical ozone formation, acidification, freshwater eutrophication and particulate manager (see T2.4 Impact Category of WP2 reporting). LCA results are then used to support gateway reviews to enable “go or no-go" decisions based on status versus requirements.

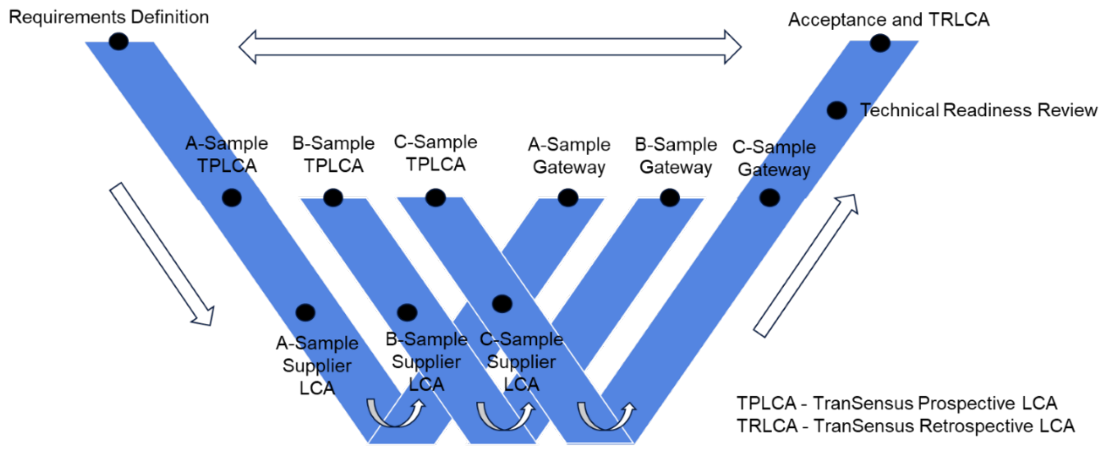


Figure 4-16 : TranSensus LCA Calculations within Product Development Process

Conclusions

TranSensus LCA proposes performing prospective LCA to frontload support to the engineering development process of new vehicles and automotive components (adaptation from the V-Model). The LCA effort should be performed as early as practicably possible within the development process to support decision making on technology, design and manufacturing choices from an environmental perspective. The LCA process should follow the recommended TranSensus framework for prospective LCA. Models with a subset of key indicators can be used to provide early direction to the design and manufacturing teams within the OEM or Tier 1. These models can be updated and iterated as the design matures and more accurate input data is provided by suppliers and design teams. Best practice is to iterate the LCA calculation at every major gateway. The results are used to assess suitability of the designs against the requirements at a product level.

Reporting

This subtask dealt with:

- Minimum information expectancies for public reporting of studies claiming TSLCA adherence
- 3rd party verification recommendation
- Differences between product LCA and other type of LCAs
- S-LCA reporting

Regarding LCA public reporting, we defined mandatory requirements to claim that a study was “carried out following the TSLCA methodology” or “carried out partially following the TSLCA methodology”. This additional subtask and the resulting voting question was deemed necessary because some OEMs voiced their concern of not being able or not wanting to disclose all results of the vehicle LCA studies conducted following the TSLCA methodology. The agreed upon mandatory reporting requirements therefore encompass the minimum information necessary for a recipient of the LCA study to evaluate or judge the results and to enable drawing meaningful insights when comparing across different LCAs of ZEVs.

Recommendations on the minimum content of public reporting have been built on:

- A consultation sheet collecting information individuals would like to read from a study claiming adherence to TSLCA, circulated among project's beneficiaries -> called the "wish list"
- A 2nd consultation sheet collecting acceptable level of transparency for respondant organization for every requirement in the "wish list" between mandatory, recommended, optional, no preference or no communication – circulated among project's beneficiaries
- A collection of T2.2, T2.3, T2.4 and T2.5 requests regarding the level of transparency in reporting they expect for the methodological requests they have built.
- T2.5 reporting meetings to confront and enable the convergence of these three points of view.
- Bilateral discussions with T2.2, T2.3, T2.4 and T2.5 task leaders to adjust remaining disagreements
- T2.2 and T2.4 requests were collectively assessed and refined by T2.5 reporting contributors
- T2.3 and T2.5 requests were not collectively refined but we collectively agreed in our last meeting to submit them as they were in a decisive voting anyway.

At least 5 industrials among beneficiaries actively participated to consultations and/or T2.5/reporting meetings with valuable and valued contributions to enable following questions.

Q87 – TranSensus LCA adherence statement

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

TranSensus LCA proposes that a study can claim two levels of adherence with TSLCA methodology, in the following circumstances:

- Study can be stated as carried out "**following the full TranSensus LCA methodology**" if:
  - All mandatory requirements from TSLCA (including those on public reporting) are followed, i.e., respectively:

    - Requirements with no choices possibilities -> requirements strictly followed
    - Requirements with choices -> choice needs to be transparent, justified and documented when asked
  - Recommended or optional requirements (including those on public reporting) may or may not be followed.
- Study can be stated as carried out **"following the TranSensus LCA methodology, reporting excluded"** if:
  - All mandatory requirements from TSLCA (excluding those on public reporting) are followed, i.e., respectively:
    - Requirements with no choices possibilities -> requirements strictly followed
    - Requirements with choices -> choice needs to be transparent and justified and documented when asked
  - One (or more) mandatory requirements from TSLCA on public reporting are NOT followed.
  - Recommended or optional requirements (including those on public reporting) may or may not be followed. Review comments on recommendations followed or not by the practitioner can be part of the verification report.

Any other exception to mandatory requirements implies that the study cannot be claimed to follow previous level of adherence.

Table 4-22 : Description of two levels of adherence to TSLCA that can be claimed.

	A: Carried out **following** the **full** TSLCA methodology		**B**: Carried out **following** the TSLCA methodology, **reporting excluded**	
TSLCA methodology requirements	% of requirements satisfied		% of requirements satisfied	
	Mandatory requirements	Recommended or optional	**Mandatory** requirements	Recommended or optional
Goal and Scope	**100%**	0% to 100%	**100%**	0% to 100%
Life Cycle Inventory	**100%**	0% to 100%	**100%**	0% to 100%

Life Cycle Impact Assessment	**100%**	0% to 100%	**100%**	0% to 100%
Interpretation	**100%**	0% to 100%	**100%**	0% to 100%
Reporting	**100%**	0% to 100%	**< 100%**	0% to 100%

("%" refers to % of TSLCA requirements that are strictly followed, and for which any methodological choices (where allowed) are made transparently and with justification)

Possible answers: Agree/ Disagree/ No preference

Background

The main objective of TranSensus LCA is to enable drawing meaningful insights when comparing across different LCAs of ZEVs. In order to achieve this objective fully, two key steps are required:

1) the LCAs must be carried out in adherence to the exact same methodological rules (i.e., following all TSLCA mandatory requirements across all steps of the calculations, thereby ensuring consistency), and

2) the exact same set of results must be reported (i.e., following all TSLCA mandatory requirements on reporting, thereby ensuring transparent comparability).

For the sake of illustrating the importance of point 2) above, we can consider a hypothetical case where two LCAs are carried out in full adherence to TranSensus LCA methodological guidelines, but where then an extreme difference arises at the reporting stage: the first study reports all results as required by TranSensus LCA, whereas the second study does not report any quantitative results at all.

Clearly, in this rather extreme case, no meaningful insights could be drawn at all from the comparison of the two reports, thereby completely negating the main *raison d'etre* of TranSensus LCA.

In less extreme (and more realistic) cases, where only one, or a few, quantitative results are not fully reported, there still ensues a partial failure to enable drawing meaningful insights from the comparison; however, such issue is then only limited to those specific results which are withheld from reporting.

WP2 therefore deemed it important to differentiate between two levels of adherence, as defined at point V.1.1, i.e., respectively: "**following the full TranSensus LCA methodology**" (fully, with no exceptions), and **"following the TranSensus LCA methodology, reporting excluded".**

Q88 – TranSensus LCA partial adherence statement

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

> To allow rapid but progressive adoption and appropriation of the methodology, TranSensus LCA would like to propose an intermediate adherence statement.

In addition to the two levels of adherence described at point V1.1 above, WP2 proposes that a study can claim **partial adherence** with TSLCA methodology, in the following circumstances:

Study can be stated as carried out **"partially following the TranSensus LCA methodology"** if

- One (or more, up to a threshold "T" of the total to be defined by the end of 2024) mandatory requirements from TSLCA (excluding those on public reporting) are NOT followed, i.e., either:
  - Requirements with no choices possibilities -> requirement NOT strictly followed
  - Requirements with choices -> choice NOT transparent and/or NOT justified
- Recommended or optional requirements (including public reporting) may or may not be followed.

Any further exception to mandatory requirements, beyond the threshold specified above, implies that the study cannot be claimed to have been carried out "**partially following TSLCA methodology**".

Table 4-23 : Additional third level of partial adherence to TSLCA that can be claimed, profil C

	A: Carried out **following** the **full** TSLCA methodology		**B**: Carried out **following** the TSLCA methodology, **reporting excluded**.		**C**: Carried out **partially following** the TSLCA methodology.
TSLCA methodology requirements	% of requirements satisfied		% of requirements satisfied		% of requirements satisfied
	Mandatory requirements	Recommended or optional	**Mandatory** requirements	Recommended or optional	**Mandatory** requirements

Goal and Scope	**100%**	0% to 100%	**100%**	0% to 100%	**≥T%**
Life Cycle Inventory	**100%**	0% to 100%	**100%**	0% to 100%	**≥ T%**
Life Cycle Impact Assessment	**100%**	0% to 100%	**100%**	0% to 100%	**≥ T%**
Interpretation	**100%**	0% to 100%	**100%**	0% to 100%	**≥ T%**
Public Reporting	**100%**	0% to 100%	**<100%**	0% to 100%	**≥ T%**

("%" refers to % of TSLCA requirements that are strictly followed, and for which any methodological choices (where allowed) are made transparently and with justification
"T%" refers to a threshold to be defined later in 2024, in accordance with formatting of the requirements by WP5 and their relative importance among each LCA stage)

Possible answers: Agree/ Disagree/ No preference

Background

In addition to the differentiation introduced at point V.1.1, and discussed at V.1.2, it is also important to be able to differentiate between studies where the all TSLCA mandatory requirements (excluding those on reporting) are strictly followed, with exceptions only introduced in reporting, and studies where instead one (or only a limited number) of TSLCA mandatory requirements are not followed during the LCA calculations (prior to reporting).

WP2 suggests that, while the latter studies cannot be claimed to have been carried out "**following the TranSensus LCA methodology**", they may still be claimed to be "**partially following the TranSensus LCA methodology"**, provided that the number of exceptions does not exceed a pre-set threshold. It has been suggested that such be set at 20% of the total TSLCA mandatory requirements (excluding reporting) but its calculation and its value still need to be consolidated at the time of this voting.

Q89 – 3rd party verification

Executive summary

Type of LCA concerned by the question: **Product LCA (only level 3 (UNECE) ones)**

Complete question submitted to voting

> Regarding 3rd party verification, TranSensus LCA proposes as mandatory requirement, a 3rd party verification in the case of a publication of a level 3 (UNECE) product LCA. TSLCA proposes to follow ISO 14040/44 type and format for the extensive reporting needed by the verification.

A checklist will be included in WP5 final guidance document for 3rd party verification according to previous principles of TSLCA adherence.

Possible answers: Agree/ Disagree/ No preference

Background

For this question, following definitions are taken:

- Level 3 (UNECE) Product LCA: It is a product LCA satisfying level 3 underneath created by UNECE working group.

Table 4-24 : Level concept as proposed by the UNECE working group and as adopted by TranSensus LCA (see SG4 - 3nd meeting - Transport - Vehicle Regulations - UNECE Wiki)

SUPPLY CHAIN & PRODUCTION	Possible Comparison[1)]	Vehicle modelling	Representativeness[2)]	Supply chain modelling	OEM manufacturing Processes	Supplier manufacturing process	Individual decarbonisation measures
Level 1	General concept of drivetrains (e.g. BEV vs. ICEV)	Generic material composition & average vehicle curb weight	Global average / regional	generic footprint per kg of vehicle curb weight			none
Level 2	General concept of drivetrains (e.g. BEV vs. ICEV) based on exemplary „real" car vehicle model	BOM & Material information system (CMDS / IMDS[3)])	Global average / regional	global secondary data material footprints (incl. generic information for production processes)			none
Level 3	A representative vehicle of OEM A VS A representative vehicle of OEM B	BOM & Material information system (CMDS / IMDS) & „part-by-part" for hotspots	Regional & individual SC for hotspots	primary information for the vehicle hotspot parts	Optional: primary data for OEM's inhouse hot spot processes	primary information for the manufacturing of vehicle hotspot parts	included
				secondary information for the rest	Secondary information for the rest or average values per vehicle from OEM's Scope 1 & 2 emissions	secondary information for the rest	
Level 4	e.g. OEM A's BEV model vs. OEM B's BEV model	BOM („part-by-part")	individual SC	regional or primary data based part (& material) footprints	included	included	included

- Party: Person, personnel or organization/company. (definition from Catena-X, adapted from ISO 17029)
- 3rd party: Personnel from an organization/company that is neither supplier, customer nor competitor. (definition from Catena-X, adapted from ISO 17029)

Q90 – Public reporting content for Product LCA: Minimum information for Goal and scope

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

Transensus proposes TSLCA users to mandatory publish following information (at least) as applicable when publicly reporting Goal and Scope part of their study:

LCA typology	Confirmation of LCI modelling approach (attributional)
	Precise whether it is product/fleet/prospective LCA
	Standards/methodologies adhered to (i.e. ISO, TranSensus LCA, UNECE Level (3) if applicable, etc.)
TSLCA deviations	Statement of any goal & scope deviations from TSLCA with justification
Vehicle descriptions and specifications	Vehicle's name
	Vehicle's segment (according to internal practices)
	Vehicle's manufacturer
	Vehicle's make/model, year of production
	Vehicle's specific configuration(s)/options studied,
	Vehicle's size
	Vehicle's mass: GVW/TPMLM and unladen total vehicle mass (kg), DIN Curb weight.
	Vehicle's maximum number of passengers (nb of seats), commercial vehicles' maximum payload
	Vehicle's powertrain
	Peak power rating
	Official certified energy consumption (according to WLTP for light vehicles and to VECTO for HDV)
	Electric or hydrogen range (according to WLTP for light vehicles and to VECTO for HDV) for dual-fuel / REEV (Range-extended electric vehicle) powertrains
	Battery capacity (gross)
	Battery mass (pack kg) OR Battery energy density (kWh/kg)
	Battery chemistry (at least 'NMC', 'LFP', etc, but ideally more specific).
	Number of batteries in the vehicle and during lifetime
	Fuel cell power rating (kW)
	H_2 storage capacity (kg H_2)
	H_2 storage type (e.g. 700 bar compressed)

	HDV: number of axles and wheels
	Material Breakdown in % according to VDA material classes
Functional unit (FU)	Clear statement of functional unit
	Precision of service life period (years)
	Precision of lifetime km,
	Precision of passenger or freight loading assumption (ideally both in absolute units - i.e. #passengers or kg payload - and % capacity).
System boundaries	Confirmation of Cradle-to-grave
	High-level description of inclusions and exclusions
	Simple system diagram/flowchart to illustrate, overview or a figure of the system boundary which also shows when e.g. second use or V2G are integrated (especially relevant for prospective LCA)
Geographical considerations	Material extraction regions: geographical scope of supply chain modelling approach for most impacting materials (e.g. global average model or EU-sourcing mainly with some exceptions or specific sourcing)
	Key Components origin: geographical scope of supply chain modelling approach for most impacting key components (e.g. global average model or EU-sourcing mainly with some exceptions or specific sourcing)
	Battery production: electrode manufacturing, cell assembly and pack assembly continent (Europe, Asia, North/south America, Africa, Oceania...) at least
	Location (country at least) of the vehicle production factory(ies)
	Use phase regions considered (impacting energy mix, meteorological conditions of use...)
	Geographical considerations for end-of-life
	Noting any particularity in European region: in-/ex-clusion of UK, CH…
Third party verification	Third party verification: yes or no + verification statement made available
	Organisation/individual verifier

<u>Possible answers:</u> Agree/ Disagree/ No preference

In addition to these mandatory information requirements, TSLCA users are advised to publish the following information when publicly reporting the Goal and Scope part of their study:

Topic	Additional information encouraged to be reported	Level of advice
Vehicle descriptions and specifications	Electric or hydrogen range (according to WLTP for light vehicles and to VECTO for HDV) for mono-fuel powertrains	Recommended
Geographical considerations	Noting any differences between different phases	Optional
Third party verification	Validity period: date until when the LCA is valid	Recommended

Regarding the 3rd voting process, recommended and optional elements listed in above table are informational. They are not submitted to voting since users can choose to follow them or not without any consequences on their level of adherence to TSLCA.

But we think it is important though to mention them in the 3rd voting:

- since we elaborated a recommendation on whether to include them in the mandatory reporting or not.
- also because some of mandatory requirements can be related to them.

Even if we are not asking your preference, your comments are welcome in a dedicated free text box underneath.

Possible answers: Free text box to enable dedicated comments

Q91 – Public reporting content for Product LCA: Minimum information for Life Cycle Inventory

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

Transensus LCA proposes TSLCA users to mandatory publish following information when publicly reporting LCI part of their study:

Topic	Mandatory information to be reported
TSLCA deviations	Statement of any LCI modelling deviations from TSLCA with justification
General info on data	Database(s) used: name & version
	Clear statement of important limitations
	Short summary of where primary data (OEM's in-house production), supplier specific data (and which level tier 1 etc.) and generic data has been used
	Summary of data quality assessment results according to TSLCA recommendations
Electricity modelling	Energy mix for production phase
	Approach used for use phase: dynamic vs conservative vs other + justifications/sources
	Energy mix for use phase (including period used for average for dynamic mix, where used). Can be high-level (e.g. 'Renewable'/'Nuclear'/'Fossil' share) if need to protect detail from paid sources (e.g. IEA or EU-27 electricity grid mix with X kg CO_2/kWh
	Energy mix for End-of-life phase

Multifunctionality	Description of the multifunctionality processes (i.e. naming the MF processes encountered in the foreground system, no need to describe the solutions in background databases)
	The MF choices based on the hierarchy (substitution/system expansion/economic/ physical allocation) for each MF reported above in the foreground system (perhaps in a form of table?). (No need of details like allocation factor or economic value or justification of choice can be silenced)
Data specific to production phase	How Level 3 minimum criteria are met (which components used to meet the 20% of supply chain GWP with tier-1 specific data besides the battery system)
	The name of the datasets used to model each product flow used in the model (i.e. feeding the foreground unit processes)
Data specific to use phase	Hydrogen mix/origin
	Real world (RW) and/or efficiency degradation ~~correction~~ adjustment factor(s) where applied
	Summary of non-exhaust emissions included
	Consumable and maintenance parts assumptions: justification if deviation from minimum required by TSLCA
Data specific to EoL and circularity	Brief description of EoL modelling approach
	Brief description of modelled EoL processes

Possible answers: Agree/ Disagree/ No preference

In addition to these mandatory information requirements, TSLCA users are advised to publish the following information when publicly reporting the LCI part of their study:

Topic	Advised information to be reported	Level of advice
General info on data	Short summary of where primary data (OEM's in-house production), supplier specific data (and which level tier 1 etc.) and generic data has been used	Optional
	Statement of third-party review of data received (and according to which standard/guideline)	Recommended
	Software used: name & version	Recommended
Multifunctionality	For the EoL, a sentence confirming that verification of complete system in case of recycling was done (see step 4 in the EoL document hierarchy)... No need to report details on cut-off point location in a summary report.	Optional
Data specific to production phase	Non-exhaustive list of components modelled with supplier-specific data (regarding recycled content and/or process inventory...)	Recommended
	Description OR diagram of main/simplified steps of the vehicle production	Recommended
	Summarised information on production locations and sites where specific data has been utilised	Recommended
	Recycled content of the vehicle	Recommended

	More detailed list of components with main materials, weights, sources, geographical locations, production processes	Optional
Data specific to use phase	More detailed list of Consumable and maintenance parts assumptions (e.g. consumables/part replacement frequency/# per lifetime)	Optional
	How the lifetime of the battery is calculated? (e.g. additional charging losses, use of heating/cooling during use…)	Recommended
	How the lifetime of the fuelcell is calculated (e.g. degradation factor?)	Recommended
	Thermal management of the vehicle: use of external heater, refrigerated truck?,…	Optional
Data specific to EoL and circularity	Statement of respect of TSLCA for EoL modeling and cut-off point	Recommended
	Overall recycling efficiency of EoL modeled	Recommended
	Yield of each process modeled in EoL value chain	Recommended

Regarding the 3rd voting process, these elements are for additional information~~al~~. They are not submitted to voting since users can choose to follow them or not without any consequences on their level of adherence to TSLCA.

But we think it is important though to mention them in the 3rd voting:

- since we elaborated a recommendation on whether to include them in the mandatory reporting or not.
- also because some of mandatory requirements can be related to them.

Even if we are not asking your preference, your comments are welcome in a dedicated free text box underneath.

Possible answers: Free text box to enable dedicated comments

Q92 – Public reporting content for Product LCA: Minimum information for Life Cycle Impact Assessment

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

Transensus LCA proposes TSLCA users to mandatory publish following information (at least) as applicable when publicly reporting Goal and Scope part of their study

Topic	Mandatory information to be reported
TSLCA deviations	Statement of any LCIA deviations from TSLCA with justification
General information	Impact assessment method name, version and year
	List of impact categories reported, name and source
Absolute value of impacts scaled to FU	Absolute value of results for all TSLCA mandatory impacts
Normalization	Approach for normalization if normalization results are shown (confirmation of planetary boundaries NF used)

Possible answers: Agree/ Disagree/ No preference

In addition to these mandatory information requirements, TSLCA users are advised to publish the following information when publicly reporting the LCIA part of their study:

Topic	Additional information encouraged to be reported	Level of advice
Absolute value scaled to FU	Absolute value of results for TSLCA optional impacts that only shows significance in normalisation (if conducted)	Recommended
	Absolute value of results for all TSLCA optional impacts	Optional
	Absolute value of results for optional EF impacts (not mandatory ones)	Recommended
Normalization	Normalization results	Optional

Regarding the 3rd voting process, recommended and optional elements listed in above table are informational. They are not submitted to voting since users can choose to follow them or not without any consequences on their level of adherence to TSLCA.

But we think it is important though to mention them in the 3rd voting:

- since we elaborated a recommendation on whether to include them in the mandatory reporting or not.
- also because some of mandatory requirements can be related to them.

Even if we are not asking your preference, your comments are welcome in a dedicated free text box underneath.

Possible answers: Free text box to enable dedicated comments

Q93 – Public reporting content for Product LCA: Minimum information for Interpretation

Executive summary

Type of LCA concerned by the question: **Product LCA**

Complete question submitted to voting

Transensus LCA proposes TSLCA users to mandatory publish following information when publicly reporting interpretation part of their study:

Topic	Mandatory information to be reported
TSLCA deviations	Statement of any Interpretation deviations from TSLCA with justification
Contribution analysis	Life cycle stages contribution to mandatory impacts results (4 main stages like in the battery regulation, absolute value or in % or shown graphically)
	Table and/or diagram presenting results per life cycle phase. Results must give the contribution of parts/processes/materials with sufficient details so that the reader can understand the results (but how to define that?)
	Main hotspots by life cycle stage (like battery+electricity for production, electricity/H2 for use, air emissions for EoL)
	Breakdown of impacts by LC stage and by main types of contributors like "raw materials", "electricity", "heat", "H2", "emissions", "wastes", "others"
Sensitivity, scenario and uncertainty analysis	Brief description of type and parameters studied through sensitivity, scenario and uncertainty analysis.
	More detailed table of analysis conducted with type of the analysis (sensitivity, scenario,...), parameters studied, brief description of variation occurred.
	Qualitative summary of influence of all mandatory parameters on mandatory impact results
	Variability (quantification expected) induced by all mandatory parameters on all mandatory impact results

Possible answers: Agree/ Disagree/ No preference

In addition to these mandatory information requirements, TSLCA users are advised to publish the following information when publicly reporting the LCIA part of their study:

Topic	Advised information to be reported	Level of advice
Other expression of absolute values	Absolute values of a selection of impacts scaled to lifetime	Recommended
	Absolute values of a selection of impacts on the Cradle-to-gate perimeter for 1 vehicle	Recommended
Comparisons	With previous models	Optional
	With other powertrains (owned studies)	Optional

	With other vehicles (not owned studies)	Optional
Sensitivity, scenario and uncertainty analysis	Qualitative summary of influence of all mandatory parameters on relevant optional impact results	Recommended
	Variability (quantification expected) induced by all mandatory parameters on relevant optional impact results	Recommended
Methodology checks	Summary about completeness and consistency checks	Recommended
	% of mandatory TSLCA requirement satisfied (100% if TLSA adherence profile A)	Optional
	% of recommended topics followed (0%= LCA results are following TLSA with or without minimum reporting, 100% = extremely complete study/report)	Optional

Regarding the 3rd voting process, recommended and optional elements listed in above table are informational. They are not submitted to voting since users can choose to follow them or not without any consequences on their level of adherence to TSLCA.

But we think it is important though to mention them in the 3rd voting:

- since we elaborated a recommendation on whether to include them in the mandatory reporting or not.
- also because some of mandatory requirements can be related to them.

Even if we are not asking your preference, your comments are welcome in a dedicated free text box underneath.

Possible answers: Free text box to enable dedicated comments

Q94 – TSLCA adherence for other types of LCA than product LCA

Executive summary

Type of LCA concerned by the question: **Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

Transensus LCA proposes to allow TSLCA users when conducting other type of LCA than product LCA to claim “using best practices from TranSensus LCA methodology” as long as they cite the methodology and provide the list of best practices followed and/or deviations made at least in a public annex.

Possible answers: Agree/ Disagree/ No preference

Background

Along the project, following priorities regarding the 4 types of LCA have been set to enable the project's objective, resulting in providing requirements at different level of constraint

Type of LCA	Priority	Degree of guidance	Level of constraint on requirements
Product vehicle LCA	1	Full guidance	Mandatory by default, unless it is expressively qualified as recommended or optional
OEM's fleet LCA	2	Detailed guidance (baseline = product LCA + specific guidance when manufacturer's fleet LCA needs it)	Recommended by default unless it was explicitly built upon product LCA (LCIA, Interpretation)
Prospective LCA	3	Best practices (baseline = product LCA + best practices to deviate from product LCA when prospective LCA needs it)	Recommended by default unless it was explicitly built upon product LCA (LCIA, Interpretation)
Macro-Fleet level LCA	4	Best practices (baseline = product LCA + best practices to deviate from the baseline when fleet level LCA needs it)	Recommended by default unless it was explicitly built upon product LCA (LCIA, Interpretation)

Adherence statement proposed for product LCA is based on the satisfaction of mandatory requirements which are not present enough in other type of LCA to differentiate the quality of studies. We propose users for OEM's fleet LCA, prospective LCA and Macro-fleet LCA to list the practices adopted from TSLCA or the deviations from so that they can still refer to the methodology.

Q95 – S-LCA reporting

Executive summary

Type of LCA concerned by the question: **Product LCA, Prospective LCA, OEM fleet-level LCA, Macro-level fleet LCA**

Complete question submitted to voting

> Regarding S-LCA reporting (for 3rd party review & public reporting), TranSensus LCA proposes that:
>
> 1) S-LCA reporting shall (mandatory) be aligned with LCA reporting regarding common aspects (e.g FU or MF)
>
> 2) S-LCA reporting shall (mandatory) follow underneath recommendations for the rest

Draft ISO 14075

The type and format of the report shall be determined during the scope phase of the study.

The S-LCA results and findings must be completely and accurately conveyed without bias to the intended audience.

The conclusions, data, techniques, assumptions, and limitations must be transparent and provided with sufficient detail for the reader to understand the intricacies and trade-offs inherent in the S-LCA.

The report shall also allow the results and interpretation to be used in a manner consistent with the goals of the study. It can be helpful to include a graphical representation of the S-LCI and S-LCIA data in the report, but keep in mind that doing so encourages inferred inferences and comparisons.

Study documentation that includes confidential data that isn't always included in the third-party report may serve as the basis for the third-party report. Therefore, the third-party report is referred to a document and shall be made available to any third party to whom the communication is made.

The following elements shall be included in the third-party report:

1. General aspects:
   a. Any modifications to the Goal and scope aspects, proposed in TranSensus together with their justification;
   b. S-LCA commissioner and practitioner of S-LCA
   c. date of report;
   d. statement that the study has been conducted in accordance with the requirements of TranSensus LCA approach.
2. Goal of the study:
   a. reasons for carrying out the study;
   b. its intended applications;
   c. the target audiences;
   d. statement as to whether the study intends to support social comparative assertions intended to be disclosed to the public.
3. Scope of the study:
   a. function, including:
      i. statement of performance characteristics;
      ii. any omission of additional functions in comparisons;
   b. functional unit, including:

i. consistency with other goal and scope aspects;
ii. Functional unit definition;

c. system boundary, including:

i. omissions of life cycle stages, processes or data needs;
ii. quantification of energy and material inputs and outputs;
iii. assumptions about electricity production;

- type of inputs and outputs of the system as elementary flows;
- decision criteria;

d. cut-off criteria for initial inclusion of inputs and output, including:

i. description of cut-off criteria and assumptions;
ii. effect of selection on results;
iii. inclusion of mass, energy and environmental cut-off criteria.

4. Social life cycle inventory analysis:

a. data collection procedures;

b. qualitative and quantitative description of unit processes;

c. sources of published literature;

d. calculation procedures;

e. validation of data, including:

i. data quality assessment;
ii. treatment of missing data;

f. sensitivity analysis for refining the system boundary;

g. allocation principles and procedures, including:

i. documentation and justification of allocation procedures;
ii. uniform application of allocation procedures.

5. Reference scale assessment, where applicable:

a. the reference scale assessment procedures, calculations and results of the study;

b. limitations and relationship of the reference scale assessment results relative to the defined goal and scope of the S-LCA;

c. the relationship of the reference scale assessment results to the S-LCI results,

d. impact categories/impact subcategories and category indicators considered, based on TranSensus , justify for any deviations

e. descriptions and reference to all value-choices used in relation to impact categories, weighting and, elsewhere in the, a justification for their use and their influence on the results, conclusions and recommendations;

f. a statement that the reference scale assessment results are relative expressions and do not predict impacts on category end points, the exceeding of thresholds, safety margins or risks; and, when included as a part of the S-LCA, also:

   i. a description and justification of the definition and description of any new impact categories, category indicators used for the reference scale assessment;
   ii. a statement and justification of any grouping of the impact categories;
   iii. any further procedures that transform the category indicator results and a justification of the selected references, weighting factors, normalisation factors etc.;
   iv. any analysis of the category indicator results, for example sensitivity and uncertainty analysis or the use of social data, including any implication for the results;
   v. data and category indicator results reached prior to any normalization, grouping or weighting shall be made available together with the normalized, grouped or weighted results.

6. Social Life cycle impact assessment (Impact pathway Approach), where applicable:

a. the S-LCIA procedures, calculations and results of the study;

b. limitations and relationships of the S-LCIA results relative to the defined goal and scope of the S-LCA and S-LCI results;

c. impact categories/impact subcategories and category indicators considered, based on TranSensus , justify for any deviations

d. descriptions and reference to all characterization models, characterization factors and methods used, including all assumptions and limitations;

e. a statement that the S-LCIA results are relative expressions and do not predict impacts on category end points, the exceeding of thresholds, safety margins or risks; and, when included as a part of the S-LCA, also:

   i. a description and justification of the definition and description of any new impact categories, category indicators or characterization models used for the S-LCIA;
   ii. a statement and justification of any grouping of the impact categories;
   iii. any further procedures that transform the category indicator results and a justification of the selected references, weighting factors, normalisation factors etc.;
   iv. any analysis of the category indicator results, for example sensitivity and uncertainty analysis or the use of environmental data, including any implication for the results;

v. data and category indicator results reached prior to any normalization, grouping or weighting shall be made available together with the normalized, grouped or weighted results.

7. Life cycle interpretation:
   a. the results;
   b. assumptions and limitations associated with the interpretation of results, both methodology and data related;
   c. full transparency in terms of value-choices, rationales and expert judgements.
8. Critical review, where applicable:
   a. name and affiliation of reviewers;
   b. critical review reports;
   c. responses to recommendations.

Possible answers: Agree/ Disagree/ No preference

5. References

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6. Annexes

6.1 Annex to Chapter 2.2

Goal definition Annex

Partner Input on retrospective vehicle LCA **(InPart = Transensus consortium industry partner, RPart = Transensus consortium research partner)**

Partner	When is it performed?	For what is it performed?	Who is the user of the methodology?
InPart2	• Starting **4 months before SOP**, when (most of) **IMDS data** is available.	• **reporting** vehicle information to **customer** • calculation basis for Scope 3 **reporting** (--> [COMPANY] sustainability report)	• LCA department within **R&D**
InPart4	• When most of the **material composition data** (via **IMDS** and **primary supplier data from key components) is available**. • We get **MDS** linked to **PPAP close to start of sales** - late compared to many OEMs within passenger cars.	• for **customers** and wider audience (broadly internal, Academia and policy makers)	• LCA team within Technical **Product Planning** at **R&D.**
InPart1	• **at SOP and after SOP** • when a **significant change in the BOM** is • observed after SOP • **few months** before SOP • **95% of the BOM is set**	• **Reporting...** • … public **report** to **customer** • … to identify main **hotpsot** & levers of decarbonization • … to compare vehicle env. performances • … to check if we are in line with our **CO2 roadmap** • … to **set targets** (internal and to suppliers)	• **LCA product department**
InPart13	• When product is **on the market** • Access to **final BOM**	• Internal use to make **baseline** for that model • To identify **hot spot** for next model development	• R&D • Purchasing • ESG
InPart3	• When **BOM is complete**	• see [InPart2] (--> **reporting**) • **hot spot analyses**	• see [InPart2] (on Group level and in each brand)--> **R&D department**
RPart1	• Once the product is on an **industrial scale**, when the **final BOM** is available.	• External **reporting**; **eco-labeling**; for **benchmarking** with similar products (internal and external).	• Sustainability department; **R&D department**

RPart2	• Given the name, it is after the product system is on **industrial scale** with established market (**High TRL**). • It is ok to have some stages of the life cycle like EoL not yet fully consolidated for the product, this can be tackled by tools in LCA like sensitivity analysis, but definition-wise, this does not mean that it is a prospective LCA.	• **Reporting** to **consumer**/marketing • Environmental **Labelling** • (Accounting) --> Check decision making scheme of ILCD • detecting **environmental hotspots** of current products to support/guide future development of these products.	• I think this changes depending on the organization but it does not change the definition.
InPart8	• Can begin at any time once a product is being finalised, shortly before SOP, where the vast majority of specifications/details is set.	Can be multiple reasons: • internal **reporting**/improvement (and roadmaps for corporate decarbonisation targets) • public disclosure/product **declarations** for **customers** • potentially **regulatory reporting** in future (e.g. battery regulation).	• LCA department (wherever this sits)/sustainability function (e.g. if out-sourced LCA development to 3rd party).
RPart4	• Typical case 1: when the product is well designed (**TRL 6-7**) • Typical case 2: when the product is manufactured (**TRL 8-9**) • In both cases the inventory of this product and its manufacturing is relatively well known, but use phase and EoL can be mostly unknown.	• To **comply** with regulations (at TRL 9) • For **consumers** (at TRL 9) • Forbottom internal uses and stake holders (communication) • To **compare** with another product • For **eco-design** : to assess the **hotspots and improve design** in future versions.	• LCA expert in the firm (preferably one working with the researchers/developers) • External consulting firm

Partner Input on prospective vehicle LCA (InPart = Transensus consortium industry partner, RPart = Transensus consortium research partner)

	When is it performed?	For what is it performed? (Audience and reason)	Who is the user?
InPart2	With **start of development phase** for a vehicle.	• **R&D** • vehicle project management • to **set targets**	LCA department within **R&D**
InPart4	• **Prior to project target setting** in development projects (likely BOM, use case, market and decarbonisation actions on material and/or supply chain level). • LCA needs to be done **iteratively** during project to follow up **target fulfillment.**	**Internal improvement** work (**decarbonization**) and target setting/follow up.	LCA team within technical product planning at **R&D** in collaboration with purchasing department (to know upcoming decarb actions for supply chain).
InPart1	• **in R&D phase** : 1/ in R&D when working on a new technology with low maturity **- SOP 8 years** (e.g. new chemistry, new H2 tank material, new process of extraction ...) • BOM are not defined at all, inventory very difficult to collect • RL low 2/ in dev. phase of a car / battery • with mid maturity of the technology - SOP **<5 year,** BOM are not completely defined	• to make **decision**: **eco-design** • to **compare different technologies** • to identify main hotspot & **lever** of **decarbonization** • to make sure we are in line with our target • to **determine target for suppliers** • in order to build CO2 roadmap and **internal** target	• **Research department** • **Development department** • Project department
InPart13	At start of the development of the product project (**decision making timing**).	• Vehicle project management • **Target setting** for CO2 reduction & suppliers engagement	• **R&D** • **Purchasing** • ESG
InPart3	• see [InPart2] (--> **start of development phase**) • when **preliminary BOM** is available	See [InPart2] (--> **R&D**)	• See [InPart2](--> LCA department within **R&D**) • **procurement** for potential targeting of components/materials
RPart1	• When the product is still in the **design phase**. • When the product is at **a low TRL and the BOM is still under construction**	• **Internal** communication • for **eco-design** and product **design** optimization purposes.	• **R&D** department • sustainability department

RPart2	• This should be the opposite of retrospective. • A study should be considered prospective when the main product of the system (representing the function) **is at very low TRL.** Which means it is not yet in the market or on industrial scale. • Prospective LCA has its own tools of **upscaling technique** from lab or pilot/scenario development/...etc to tackle the high uncertainty. • So it should be done when the product is not yet on the market (industrial scale) or a completely new technology is being tested out. for me this is the most two obvious situation when we can call it prospective (**TRL and market data availability** can be used as a reference for deciding in which box we are).	Most obvious to me: • **Internal** communication • **Eco design** • **Sustainability goals**	Again this is a formality however, I would say more of **R&D** job given the application.
InPart8	At the start of the development of a **new product**, or even conceptual research into new products.	• Internal: to inform product development and/or strategy • Optimisation of designs, exploration of environmental performance of new concepts	• **R&D** department • potentially also for strategic departments
RPart4	• During **product design** (TRL<6). • BOM and manufacturing process are still under construction. • **Inventory canot be measured** and needs to be extrapolated. • It can be a generic inventory, not specific to a given product reference from a given factory, e.g. when a research center is testing a new battery chemistry.	• For eco-design: to assess the hotspots and improve design of this product • To inform policy makers (should they promote this or that technology)	• LCA expert in the firm (preferably one working with the **researchers/developers**) • State agency (to inform policy) • Research lab

Partner Input on fleet level LCA (InPart = Transensus consortium industry partner, RPart = Transensus consortium research partner)

	When is it performed?	For what is it performed? (Audience and reason)	Who is the user?
InPart2	• as needed (relevant changes) • **min. yearly**	• internally: **sustainability head**, for **decision** making	LCA department within **R&D**
RPart1	• as needed by the industry • on an **annual** basis	Industry and **policy** maker	Industry and **policy** maker
InPart4	• We don´t conduct fleet level LCAs at the moment. • This could however change when offering autonomous transport solutions, which can be a **mix of vehicles** (ICE, BEV etc.) **offered to a customer** (a harbour or mining site etc.), when more equipment and services (control tower etc.) are part of the customer offer. • It is very hard to see cases where we as OEMs conduct LCAs of **technology transition in such a scale** that it **affects demand and prices**, indirectly affecting the background system of an LCA. • This is **more Academia** with some input from us as OEMs.	n/a	n/a
InPart3	For the past reporting year **once a year** in the **beginning of the following year** (January 2023 for 2022), and **twice a year** for our **whole planning round** several year in the future.	• See [InPart2]	• see [InPart2] • [COMPANY] **managers** for **target tracking** + general **public** (infos in Annual and Sustainability report) • CDP, sustainability ratings, financial ratings
InPart13	On request.	High level calculation of **product mix** for **strategy making**	**R&D** currently

RPart2	• To **support economy-scale strategies** with no focus on specific product (with big changes are expected as consequences from the outcomes). • Specification can be done on a high level (e.g. Passenger cars & SUVs). • Put in mind this is not related to the terms 'Retrospective & Prospective. • This is a completely different categorization. **Fleet level can be both**. • We are only talking about **scale** here. Fleet level can be seen simply as the **opposite of "product-level**“.	General **policy making** whether for government or for high **strategic planning** of companies --> (Situation B in ILCD)	• **Government** environmental departments/ urban **planning** ..etc • companies LCA departments or **R&Ds**
InPart1	**Both** on **retrospective and prospective** products.	[COMPANY] does not perform fleet level LCA ... So I can't answer.	[COMPANY] does not perform fleet level LCA ... So I can't answer.
InPart8	• For industry: **annually** (if informing corporate reporting - Scope 3), or less frequently to **inform future strategy** for reducing emissions. • **Policy analysis**: no fixed frequency, **depends on needs**.	• Industry: **corporate reporting** (Scope 3) or to inform future **decarbonisation strategy** for this. • Policy: to **inform policy decision making** - could be for individual policy or wider policy strategy.	• Industry: **R&D**, corporate **strategy/sustainability departments**, etc. • Policy: **policymakers** primarily
RPart4	• Technology exists, but is **not** necessarily **widespread**. • **Inventory is typically generic**, i.e. representative of a **variety of manufacturers**.	• To **inform policy makers** (should they promote this or that technology) • To evaluate **consequences of large scale deployment** (including on infrastructure…)	• **State agency** • **Research** lab • External consulting firm

System boundaries Annex

InPart = Transensus consortium industry partner, RPart = Transensus consortium research partner

	Which system boundary (cradle-to-gate, cradle-to-grave, gate-to-gate) do you model?	**How do you model the energy supply in the use phase (WTW, TTW,…)?**	**Consider second life of batteries in system boundary in case of BEVs (End Of Life stage)?**
InPart3	cradle-to-grave	WTW	no (EoL cut off)
RPart4	For vehicles: cradle to grave For batteries: it depends - when evaluating a **new chemistry** or other prospective aspect (cycle and calendar life mostly unknown, as well as recycling): first cradle to gate, then evaluation of additional impacts during use phase due to added mass and roundtrip losses using a lump-sum durability. - when designing a **new pack** (this describes ongoing research): cradle-to-grave including the impacts during use phase due to added mass, roundtrip losses, thermal management, and durability. This is done by coupling LCA with a performance model, a thermal model, and an aging model. Evaluation of use phase (including calculation of aging) requires assumptions on the vehicle and the usage pattern. For batteries, the system includes everything inside the pack but excludes power electronics (charger and inverter), and the part of thermal management (pipes, pumps, heat pumps...) which is outside the pack and often shared with the cabin. For fleet level: cradle to grave including the infrastructure	For BEV vehicles: Electricity supplied from the grid, modelled with national average consumption grid mix. For FCEV vehicles: Model H2 used including its production. For batteries: Only the additional electricity due to the fact that the battery is not perfect (not 0 losses, not 0 mass, and not 0 thermal management). This requires assumptions on the vehicle and the usage pattern.	
InPart6	"cradle to grave" studies, whether for the evaluation of our electricity production activity, or for (internal) studies of downstream services, which may concern (generic) versions of electric vehicles.	For BEV vehicles: electricity supplied from the grid, modelled with national average consumption grid mix, + sensitivity with other mixes, which might include a scenario of mix evolution by the TSO. For FCEV vehicles: same for production of H2	not considered

RPart1	In our experience, it depends on the type of technology and project, but for this case it is more advisable cradle-to-grave, if possible.	Electricity supplied from grid, considering country-wide average.	Not considered.
RPart2	I think we should always seek to provide a method for cradle to grave. then from this holistic framework, selection of certain stages can happen depending on the case (goal, technology, vehicle or battery)	I am not sure if this should be a part of the discussion in this subtask. at least with the current format of quesiton. I believe it is more of Task 2.3 work. From system boundary point of view,we cetainly should include WTT system building on what I said that we will consider a full LCA with the USE phase.	
InPart1			
InPart8			
RPart6			
InPart4	Cradle-to-Grave	WTW	no
RPart5			
InPart2	for vehicles: cradle-to-grave (including logistics, excluding employee commuting, research and development or administration) for components (during development phase, for concept decision...): cradle-to-gate	WTW (WTT based on secondary data for average mixes; TTW based on type approval WLTP consumption)	no
RPart7	Most of our work is focused on batteries (including new materials, production and recycling processes). System boundary depends on project and technology that is assessed. If new technology (e.g. CAM), typically cradle to gate due to lack of info on use and EOL phase. But all depends on TRL and porject objective.	Electricity from grid, based on national average (i.e. GABI or Ecoinvent)	Second life typically not considered in our battery LCA work
RPart9			
InPart10			

InPart12	cradle-to-grave analysis at semiconductor component level	WTW with ecoinvent global energy mix	Not implicated in battery business and focus on component level only
InPart13			

Cut-off rules Annex

	What cut-off rules do you apply? (InPart = Transensus consortium industry partner, RPart = Transensus consortium research partner)
InPart3	no intentional cut offs for parts and manufacturing processes, documentation of data gaps
RPart4	
InPart6	Allocation, cut-off by classification
RPart1	No specific cut-off rule defined.
RPart2	We do not really recommend percentage-based cutoff rules because if we say 2%, 2% of what and how do you know that these excluded flows represent 2% of the total.You need proper data to know that, but if you have this data then there is actually no need for cut off. In general data estimation and adequate reporting of these estimations are the way to go. Please see section 1.1.1 in the LCA handbook by Guinee et al 2002 where some guidance is provided for two types of LCA (simplified and detailed). In a nutshell, cuttoff should be avoided by more data collection (practically not feasible) then data estimation (preferred but usually also not feasible) then the easiest thing is to put the unknown flows to zero explicitly (clear reporting of that is crucial though) Generally, We also have to distinguish between cut off of unit processes (omitting some unit processes) and cut off of exchanges (flows).
InPart1	
InPart8	
RPart6	
InPart4	No intentional cut-off concerning parts list and bill of materials. No intentional cut-off for manufacturing processes and emissions in the foreground system. Manufacturing of capital goods are partly included in the background system of LCI datasets but are not included in the foreground system.
RPart5	
InPart2	no cut-off for parts (100% weight and material) and inhouse manufacturing, documentation of data gaps
RPart7	None defined as default. Differs per project.
RPart9	
InPart10	
InPart12	no intentional cut off rule
InPart13	

Functional Unit Annex

Input from survey

For vehicle-focused LCAs, which mileage are you considering for the lifetime of a vehicle, and what is the source/basis of this? (Please indicate the vehicle type and state separately for all different vehicle types covered)

ResponseID	Response
28	for all passenger vehicles and vans: 200,000 v-km Source: https://www.springerprofessional.de/statistical-analysis-of-empirical-lifetime-mileage-data-for-auto/7072472
29	200 000 v-km for all considered vehicle types
37	since this year we assume 200.000km for all types, acc. to the VDA LCA guide. for better comparability
41	150 000 km generic vehicle life assumption for all vehicle types.
48	Real customer operational data from vehicle fleet is basis for mileage figures. e.g. 1.300.000 km for long haulage operating in Europe.
67	segment A& B : 150 kkm segment C &D : 225kkm segment E&F : 270 kkm CDV/ VAN1-2 : 270/300 kkm all 15 years (lifetime based on PFA consensus 2022)
70	15 years from 150 000 km to 300 000 km depending of veh types
78	Passenger vehicles: 200 000 km. Based on common practice by other OEMs
80	150,000- 200,000 km
81	NA
82	mileage according to vehicle segment
85	passenger car - 200.000 km

For vehicle-focused LCAs, what average occupancy (passenger vehicle) or load factor (freight) do you assume for the vehicle, and what is the source/basis of this? (Please indicate the vehicle type and state separately for all different vehicle types covered)

ResponseID	Response
28	we do not need this info for our vehicle LCAs as we refer to v-km only in the FU
29	only vehicle-km are considered not occupancy or load
37	we evaluate empty vehicles, with the DIN "Leergewicht"
41	We do not consider occupancy. Typical weight average for a vehicle is 1475 kg
48	Real customer operational data from vehicle fleet is basis for load factor (average payload).
67	I do not know, the consumption Wh/km are based on WLTP cycle --> to be checked inside the WLTP regulation
70	not taken into account for the moment
78	We do not use occupancy in the assessment
80	no average occupancy considered
81	NA
82	passenger and freight are not included in the functional unit

Partner inputs

From RPart4:

When eco-designing an EV battery pack, taking into account performance and ageing, we use the following FU :**"Perform a given mission profile for one year".**

This FU is simple and very generic, however it encompasses all the effects we need to see (e.g. on consumption and ageing).

For that, the mission profile has to be well defined and consistent with forecasted usage. It would typically include daily short trips and some longer trips for holidays. External temperature and occupancy rate must also be specified in the profile.

The lifetime is defined exactly the same way : the vehicle reaches end-of-life when it is not able any more to perform the mission profile (not enough energy or not enough power).

In one specific example, we use the following (complicated) mission profile.

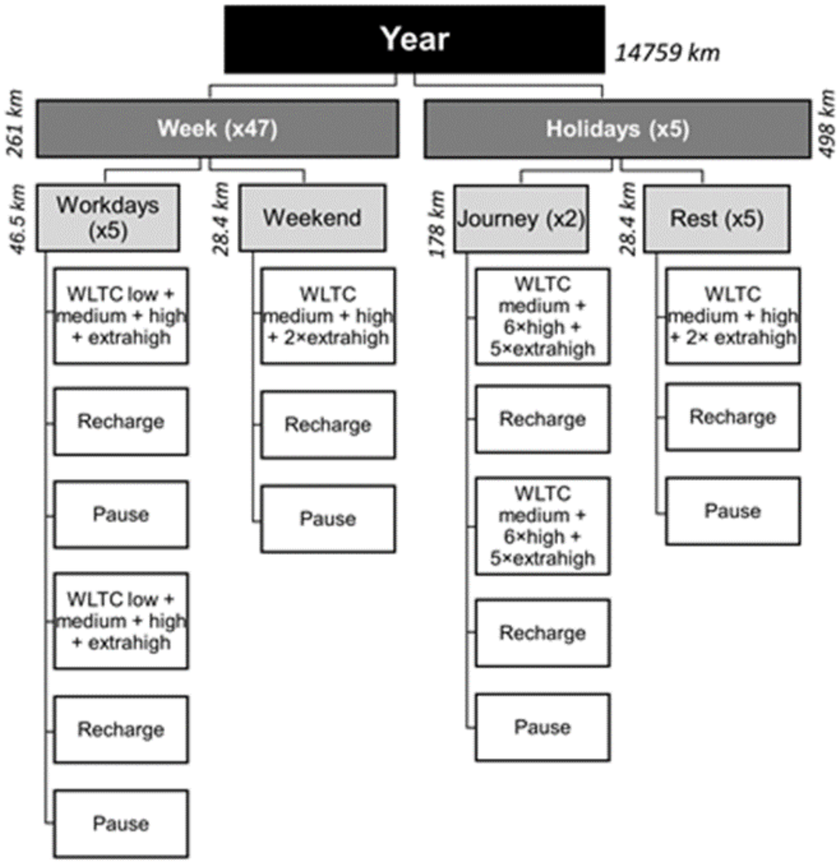


Figure 2-1 : Example of mission profile for one year

It could be a focus of TranSensus to define such a mission profile for various vehicle types.

	What functional unit do you assume for vehicle LCAs?	What lifetime (mileage) of the vehicle do you assume? [If available, give details for different vehicle types]	What are the assumption based on?
InPart3	one vehicle over lifetime at its SOP (start of prod.)	we assume 200.000 km for all types (acc. to VDA LCA guideline)	VDA LCA guidelines, Internal research
RPart4	Perform a given mission profile for one year. But we could easily convert it to Ricardo's very good suggestion of 1 passenger.km or 1 t.km. In any case **specifying the mission profile is of utmost importance** : which trips, of which length, how often, where, at which temperature... It has tremendous implications on use phase consumption and on lifetime. By comparison nobody would imagine declaring vehicle consumption without specifying the mission profile. Still to be tackled : * Multifunctionality of vehicle or battery : second life, V2G... -> we do not recommand to include them in FU of the vehicle LCA. These aspects can be tackled in dedicated studies with extension of the perimeter and FU. * Batteries that do not stay their whole life in the same vehicle : swappable modules, EP Tender, etc. : In these cases the allocation of ageing of each battery module due to the usage of this vehicle is very difficult to estimate and would require a specific work. Maybe this question is similar to the one concerning the inclusion of the charging infrastructure (fleet-level LCA).	cf batteries	
InPart6	1 km traveled for passenger vehicle 1 t.km transported and traveled for truck	225,000 km for Segment C passenger vehicle (Mégane, 308, golf) 700,000 km for truck	Mean values found in the literature
RPart1	It depends on the G&S of the study, but the following most common FU can be applied: per passenger-kilometer traveled; per ton-kilometer traveled; per vehicle lifetime; per year of use; per kilogram of vehicle mass.	It depends on the characteristics and performance of the vehicle, for example for small segment vehicles (A + B), 160,000 km.	

RPart2	First of all, we have always to keep in mind the connection between the choice of the system boundary and the functional unit. Since we agreed that for vehicles we should recommend a cradle to grave in TranSensus, then I agree with Ricardo on using the "pkm" for LDV and "tkm" for HDV including buses and couches althought theoritically these are inteded for transporting people. for simplification regarding the light duty vehicles, we can directly use the km regardless the occupancy (not really significant for passenger cars and it's hard to assume). for fright vehicles on the other hand (in addition to busses and couches), the mass fraction has to be considered (expected/hypothetical payload). This concept is also in line with Units used by Ecoinvent database both for passenger cars and bigger vehicles. I won't consider any other choices in system boundary since it is not part of TranSensus	This is the tricky part. To avoid complexity of defining individual mission profile per vehicle. I say we stick to averages per vehicle segments (like in VDA) and complement that with senstivity analysis of plus or minus 20% or whatever percentage we agree on. An important aspect here is the battery, battery lifetime should be defined independentally from the vehicle. it is just a component to the vehicle in this case, and a vehicle can consume more than one battery in its lifetime which is to be taken into account. How to define the lifetime for batteries is discussed below	Best Practice (method and concept) and some guidelines like VDA
InPart1	[COMPANY] uses vkm functional unit	[COMPANY] applies PFA methodology, 15 years and different mileage depending on French segment cars : '- segment A & B cars : 150 kkm '- segment C & D cars : 225 kkm '- segment E & F cars : 270 kkm '- CDV / Van 1-Van 2 : 270 / 300 kkm	Data collected from EoL vehicules companies and Ademe PFA rules June 2022
InPart8	Best functional units for vehicles is "passenger*km" (for passenger vehicles) and "tonne*km" (for freight vehicles), since they more clearly specifies the intended functions (i.e., to transport passengers or goods), and facilitate comparisons across different vehicle types/classes. A second acceptable choice may be "vehicle*km", especially for passenger vehicles, for which it is sometimes difficult to make assumptions on avg. vehicle occupancy.	150,000-300,000 km for passenger vehicles, subject to sensitivity analysis. Smaller vehicles tend towards the lower end of the range, and larger vehicles towards the higher end. 250,000-1,000,000 km for commercial vehicles. Again, in general terms, larger vehicles are expected to trend towards the higher end of the range.	Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA - Publications Office of the EU (europa.eu)
RPart6	The "Passenger-kilometer" (pkm) or "Vehicle-kilometer" (vkm) travelled functional unit is commonly used. The "Passenger-kilometer" (pkm) functional unit considers the distance traveled by the vehicle while carrying passengers. It takes into account the number of kilometers traveled by the BEV and the number of	For BEV, should we consider both the lifetime of vehicle and battery together for the FU?	

	passengers it can carry during the assessment period. The "Vehicle-kilometer" (vkm) functional unit, on the other hand, considers the distance traveled by the vehicle regardless of passenger occupancy. It only takes into account the total distance covered by the BEV during the assessment period. This unit is useful when the focus is on the overall energy consumption, emissions, and impacts associated with operating the vehicle itself, irrespective of the number of passengers it carries. This is something that need to finalised based on the intended application of TranSensus LCA.		
InPart4			
RPart5	Preferably something that reflects the function oft he vehicle in a good way. Something along the lines of tonne*km for vehicles that transport goods and passenger*km for vehicles transporting passengers. It is usually quite hard to determine average occupancy for cars and there is never specific information for specific car models which often means that the FU is per kilometer instead of pkm. However, one vehicle over its lifetime is the most commonly requested from OEMs. Probably since that is what most others are publishing		
InPart2	one vehicle over lifetime at its SOP (start of prod.)	since this year we assume 200.000km for all types (acc. to VDA LCA guideline) for better comparability between our different LCA reports	VDA LCA guidelines
InPart13	one vehicle over lifetime from production to end of life	we assume 200.000 km for all types	Alignment with Ricardo study (225,000km as baseline) https://climate.ec.europa.eu/system/files/2020-09/2020_study_main_report_en.pdf

6.2 Annex to Chapter 2.3.4

Data collection

Definitions primary and secondary data guidelines

Guideline	Primary data	Secondary data
GBA	"Data pertaining to a specific product or activity within a company's value chain. Such data may take the form of activity data, emissions or emission factors. Primary data is site-specific, company-specific (if there are multiple sites for the same product) or supply chain–specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material or product balances, stoichiometry or other methods for obtaining data from specific processes in the value chain of the company." **(WBCSD, 2021)**	"Data that is not from specific activities within a company's value chain but from databases, based on averages, scientific reports or other sources". **(WBCSD, 2021).** In this Rulebook secondary data are any data that are not primary data, i.e., all kind of data not directly measured or gathered from company owned information systems. Secondary data include e.g., life cycle inventory data from a third party, emission factors from inventory guidebooks, data from scientific papers and other kind of literature. (Note that data sourced from **information systems** or **engineering models** that **collect** or **obtain data** directly from specific processes in the value chain of the company (e.g., **the International Material Data System [IMDS] of the automotive industry**), shall be considered **primary data**)"
CATARC	No clear definition but available slides refer to "on-site data" for primary data. Examples include Weight of materials, Carbon emissions factors of materials, Material utility factor or energy consumption data of vehicle production	No clear definition but available slides refer to "default data" & "other secondary data". Default data comes from LCI databases (CALCD and CICE). Other secondary data comes from "field research or data released by competent government authorities."
Catena-X	"Data pertaining to a specific product or activity within a company's value chain. Such data may take the form of activity data, emissions, or emission factors. Primary data is site-specific, company-specific (if there are multiple sites for the same product) or supply chain–specific" **(source WBCSD Pathfinder)**	"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." **(Source: DIN EN ISO 14067, Feb. 2019, p. 28)**

PEFCR-Batteries	"This term refers to data from specific processes within the supply-chain of the company applying the PEFCR. Such data may take the form of activity data, or foreground elementary flows (life cycle inventory). **Primary data** are site-specific, company-specific (if multiple sites for a same product) or supply-chain-specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the company applying the PEFCR. In this Guidance, **primary data is synonym of ""company-specific data"" or ""supply-chain specific data"""**	"refers to data **not from specific proces**s within the supply-chain of the company applying the PEFCR. This refers to data that is **not directly collected, measured, or estimated by the company, but sourced from a third-party life-cycle-inventory database or other sources**. **Secondary data** includes industry-average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and can also be based on financial data, and contain proxy data, and other generic data. Primary data that go through a horizontal aggregation step are considered as secondary data"
CFB-EV	"**Company-specific data'** refers to directly measured or collected data from one or multiple facilities (site-specific data) that are representative for the activities of the company. It includes company-specific activity data and elementary flows. It is synonymous to '**primary data'"**	"'**Secondary datasets**' refers to any dataset that is not company-specific, e.g., from a database"
EPD passenger cars	Refers to „specific data": • data gathered from the actual manufacturing plant where product-specific processes are carried out; • actual data from other parts of the life cycle traced to the product under study, for example site-specific data on the • production of materials or generation of electricity provided by contracted suppliers, and transportation data on • distances, means of transportation, load factor, fuel consumption, etc., of contracted transportation providers; and • LCI data from databases on transportation and energyware that is combined with actual transportation and energy parameters as listed above.	Refers to "generic data": • selected generic data: data (e.g. commercial databases and free databases) that fulfil prescribed data quality requirements for precision, completeness, and representativeness (see below Section 4.7.1), • proxy data: data (e.g. commercial databases and free databases) that do not fulfil all of the data quality requirements of "selected generic data".
eLCAr	"The term 'measurement' is here intended in the wider sense of direct acquisition from the producer or operator of the process of interest. For example, with respect to electricity consumption, electricity bills from the production site can be important data sources. This type of data is typically referred to as **primary data**"	"Instead, for the background system, due to the averaging effect across suppliers, homogeneous average data sets depicting the average market situation can be assumed to appropriately represent the respective processes **(ILCD, 2010).** Data of this type can often be acquired from national and international LCI databases, consultants, and research groups; it is commonly referred to as secondary data. Hence, in the battery example mentioned in the previous section, data for the material types

		and quantities, the energy inputs, and wastes and emissions outputs related to the production process of the battery should derive from measurements at the specific production plant involved, while data for the generation of the electricity may be taken from average data sets provided, for example, by LCI data providers."
PFA	Not differentiated between primary and secondary; Data in general: "The mass and material data of parts and components are partly derived from data collected via IMDS" "Most of industrial sites are subject to detailed environmental reporting to meet regulatory or normative constraints (ISO9001, ISO14001). These reports should inform on energy consumption, emissions in the air, in water and on the quantities of waste generated. These emissions shall be reported to the system/vehicle under investigation. Thus, if different systems/vehicles are produced in the plant, an allocation rule will have to be defined depending for example on the volumes of vehicles studied produced (body-assembly plant)" "The "cradle to gate" models of the materials and associated processes can be derived from the GaBi ts database or from any other LCA database (Ecoinvent, etc.) to be specified. The precise data recommended by the PFA will be updated later"	
VDA-PC	Indirect definition: "While some OEMs use measured primary data to establish emission profiles of processes, others use average data from databases or literature."	See left

What should be included in primary data:

Guideline	cite/figure
GBA	The requirement of this rulebook is that for the **foreground system for which the company is responsible**, i.e., material inputs and product and waste outputs, energy consumption, direct CO_2 emissions, etc., **primary data is used**. Gaps in primary data, e.g., methane or GHG relevant refrigerant leakage, **may be filled with literature data** but **need to be verified by a third party and are limited to direct emissions**, which cannot be calculated based on the mass balance, auxiliary materials, and waste treatment. Foreground system is: "Those processes of the system that are specific to it … and/or directly affected by decisions analysed in the study." (JRC, 2010, p. 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system

CATARC

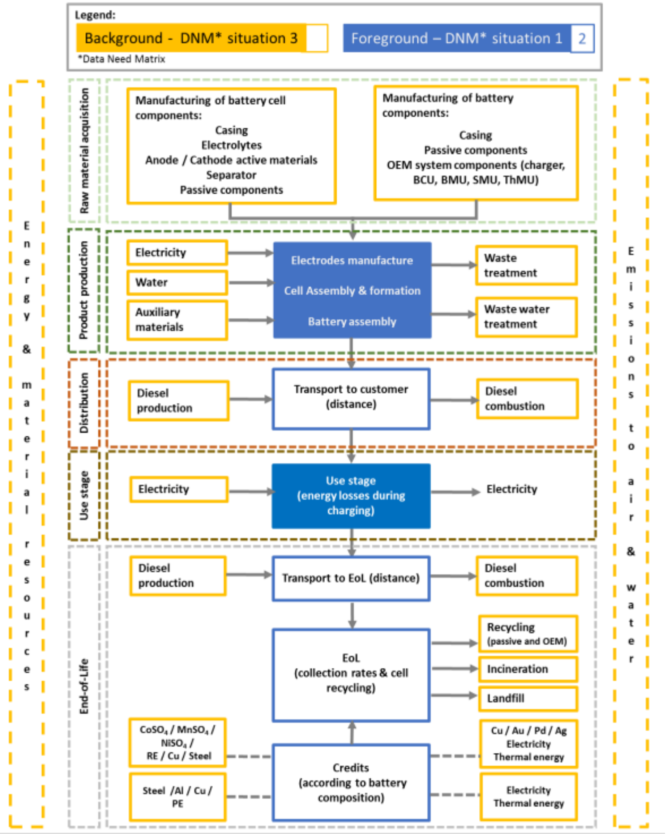
Life Cycle Stage	Data	Source
Material Production	Weight of primary materials	● (red)
	Carbon emission factors of primary materials	● (red)
	Weight of secondary materials	● (red)
	Carbon emission factors of secondary materials	● (red)
	Weight of materials (Primary and secondary)	● (red) ● (green)
	Carbon emission factors of materials (Primary and secondary)	● (red) ● (green)
	Material utility factor	● (red) ● (green)
Vehicle Production	Energy consumption data of vehicle production	● (red)
	Carbon emission factors of fuel production	● (green)
	Carbon emission factors of fuel use	● (green)
	Carbon leakage	● (red)
Vehicle Usage	Fuel consumption	● (red)
	Carbon emission factors of fuel production	● (green)
	Carbon emission factors of fuel use	● (green)
	Tire replacements times	● (green)
	Battery replacements times	● (red) ● (green)
	Liquid replacements times	● (red) ● (green)
	Refrigerant escapes times	● (green)
Life Cycle	Life Cycle Mileage	● (green)

Catena-X

Ideally, the use of secondary data warrants the following crucial requirements:
When using secondary data, a **conservative** estimate shall be applied to avoid a lower PCF compared to a PCF based on respective primary data. With this, the **motivation to replace secondary by primary data shall be strengthened**.
Three options for secondary data:

- Definition of CX-prescriptive secondary data (considered superior option **but large effort** required to research and prepare the likely large amount of data needed to cover the full supply chain and to keep such data up to date over the years to com)
- Definition of a whitelist of data sources
- Definition of hierarchy for secondary data sources

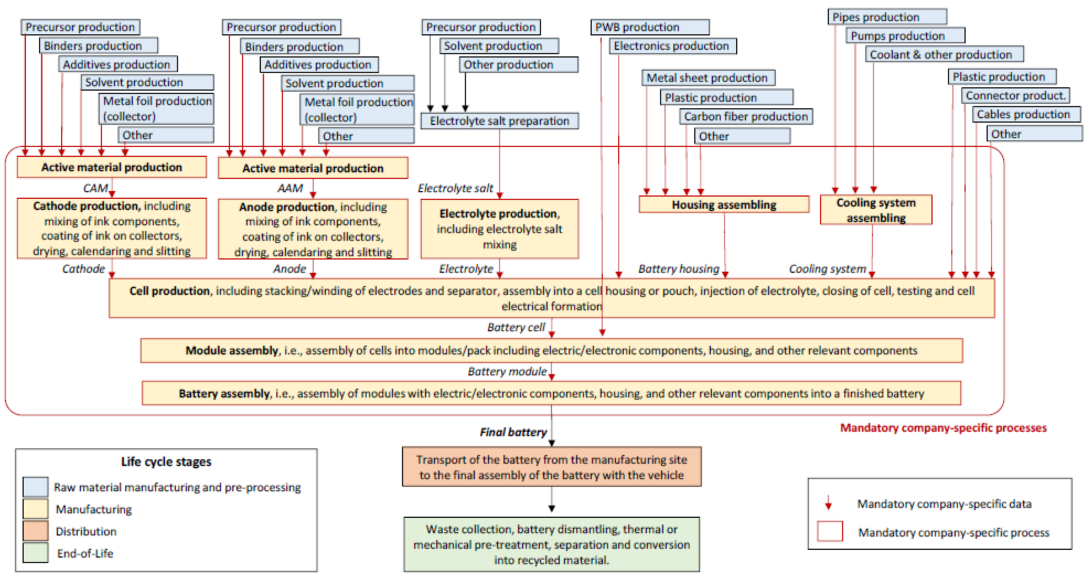
As a bottom line, providing a harmonized set of industry association data as prescriptive for CX is the superior approach. As of now, this harmonized data does not yet exist and CX will thus require hierarchical use of secondary data sources in the following sequence:

	1. Industry association data 2. General LCA data, e.g., commercial LCA databases 3. Other documented references, e.g., scientific literature If secondary data is not available within the references listed in, other sources can be used to fill data gaps. If no data is available at all, proxy data may be used. The employment of proxy data sources shall be documented and made transparent to auditors and recipients of any data (see Section 7)
PEFCR-Batteries	

	All processes required to model the product and that are not on the list of mandatory company-specific data (listed in section 5.1) shall be evaluated using the Data Needs Matrix (see Table). The user of the PEFCR shall apply the DNM to evaluate which data is needed. It shall be used within the modelling of its PEF study, depending on the level of influence the user (company) has on the specific process. The following three cases are found in the DNM: • **Situation 1**: the process is run by the company applying the PEFCR • **Situation 2**: the process is not run by the company applying the PEFCR but the company has access to (company-)specific information. • **Situation 3:** the process is not run by the company using the PEFCR and this company does not have access to (company-)specific information.
VDA	Primary data for: **Components:** • **Traction battery** • **Electric motor** • **Fuel cell stack** **Materials:** ▪ Battery materials (lithium, nickel, manganese, graphite) ▪ Fuel cell materials (platinum, palladium, nafion) ▪ Carbon fibers ▪ Aluminium ▪ Rare earth metals ▪ Secondary precious metals Secondary: Dismantling ▪ Shredder including separation of fractions

CFB-EV

Figure 1. System boundaries of the carbon footprint of a generic EV battery. Other types of batteries (e.g., anode-free batteries, cell-to-pack design) may have a different visualization of their system boundaries. Each square represents a process, while each arrow represents an activity data (e.g., kg of solvent, kg of additive). The different colours (blue, yellow, orange, and green) indicates in which life-cycle stage each process belongs, while red arrows and red borders indicates if a process/activity data shall be company-specific (section 6.1). PWB: Printed Wiring Board. CAM: cathode active material, AAM: anode active material.



Source: JRC

mandatory company-specific process is a process for which all data (i.e., activity data and elementary flows) shall be company-specific and shall refer to a specific battery model produced in a specific manufacturing plant. NOTE: If the **active material is equivalent to the active material precursor** (such as in the case of natural graphite, hard carbon, lithium metal, and silicon), the active materials production may be modelled as the active material precursors production and not as mandatory company-specific process.

Suppliers can provide "company specific data" in three options:

- Option 1: The suppliers provide to the CFB declarant al**l activity data, elementary flows,** and all the information required for the CFB supporting study and for verification

- Option 2: The suppliers provide to the CFB-declarant a **CFB-compliant company-specific dataset**. In this case, the CFB-declarant shall make sure that the notified body receives all the document when the CFB-declarant submits the carbon footprint declaration.
- Option 3: The suppliers provide all **activity data, elementary flows, and all the information required for the CFB supporting study and for verification to a third-party subjec**t (e.g., a data management company) that combines the inputs from different companies and provides the CFB-declarant with aggregated CFB-compliant datasets for different processes, thus ensuring confidentiality across the supply-chain. In this case, the CFB-declarant, the suppliers, and the third-party subject shall ensure that the notified body receives all the documentation needed for the verification of the carbon footprint declaration.

Modelling options for most relevant processes:

Case 1: At least one technologically representative secondary dataset[25] is available in the 'CFB node'[26]. In this case, there are two modelling options:

— Option a): Select the most representative secondary dataset[27]. The electricity in the '–1 level'[28] may be changed with the average consumption mix (modelled as in section 7.1.5) of the country where the process is occurring. In this case, the declarant shall duly justify this modelling in the CFB supporting study. Supplier-specific electricity mix (such as the use of a Guarantee of Origin) shall not be used in this case.

— Option b) A CFB-compliant company-specific dataset (either as LCI or LCIA dataset) referring to the intermediate product with a DQR[29] ≤ 2 may be used.

Case 2: No technologically representative secondary dataset is available in the CFB node. In this case, there are two modelling options:

— Option a): Select a secondary dataset respecting the following hierarchy:

1. Select the most representative EF-compliant dataset available in the LCDN.
2. Select the most representative EF-compliant dataset from any other source.
3. Select the most representative ILCD entry-level compliant dataset either from the LCDN or from any other source.

— Option b) A CFB-compliant company-specific dataset (either as LCI or LCIA dataset) referring to the intermediate product with a DQR ≤ 3 may be used.

The modelling approach used for each most relevant process (i.e., the use of a secondary dataset or of a CFB-compliant company-specific dataset) shall be reported in the CFB supporting study, clearly indicating the modelled process, and any relevant modelling assumption and justification (e.g., choice of a proxy).

Input	Activity data	Source of activity data	Background dataset	Considered as
Material A	3 kg	Literature	Secondary (e.g. PEF, Ecoinvent, Sphera)	Secondary
Material B	1 kg	Measured	Secondary (e.g. PEF, Ecoinvent, Sphera)	Secondary ?
Material C	1 kg	Measured	Company specific	Primary

Company specific

Input	Activity data	Source of activity data	Background dataset	Considered as
Material C.1	1 kg	Literature	Secondary (e.g. PEF, Ecoinvent, Sphera)	Secondary
Material C.2	1 kg	Measured	Secondary (e.g. PEF, Ecoinvent, Sphera)	Secondary?
Material C.2	1 kg	Measured	Company specific	Primary

Company specific sub process

Input	Activity data	Source of activity data	Background dataset	Considered as
Material C.2.1	1 kg	Literature	Secondary (e.g. PEF, Ecoinvent, Sphera)	Secondary
Material C.2.2	1 kg	Measured	Secondary (e.g. PEF, Ecoinvent, Sphera)	Secondary ?
Production of C.2	1 kg	Measured	Company specific	Primary

6.3 Annex to Chapter 2.4.5

In the realm of environmental impact assessment, this comprehensive content delves into a multitude of methodologies and approaches used to evaluate the intricate interplay between energy consumption and resource utilization in the life cycles of products. The central focus lies on the concept of Cumulative Energy Demand (CED) and the role it plays as an impact category indicator within Life Cycle Impact Assessment for vehicles. The work of Frischknecht et al. (2015) serves as a pivotal reference in this context, offering insights into the characterization of CED and the underpinning assumptions that guide its formulation. The discussion expands further, encompassing critical raw materials (CRMs) and the methodologies employed to assess their supply risk, considering the socio-economic and geopolitical dimensions beyond environmental concerns. Additionally, the annex elucidates on resource use assessment methodologies, including depletion-based methods and supply risk indicators, shedding light on their integration within the broader scope of life cycle assessment (LCA). The content culminates with an exploration of resource depletion models, specifically the Abiotic Depletion Potential (ADP) method, Environmental Dissipation Potential (EDP), and Abiotic Resources in PEF project (ARP) method, each offering distinctive perspectives on mineral resource depletion. This multifaceted narrative serves as a valuable resource for anyone seeking a comprehensive understanding of the complex interdependencies between energy, resources, and environmental impacts in the domain of life cycle assessment.

Cumulative Energy Demand Annex

Description of the paper on CED by Frischknecht et al. (2015)

The aim of this section on Cumulative Energy Demand (CED) is to assess the usefulness and feasibility to include energy[54] indicators in Life Cycle Impact Assessment for vehicles.

The most recent review of characterization methods on Cumulative Energy Demand is the paper by (Frischknecht R. W., 2015). The paper gives an overview of existing life cycle based energy indicators. It also aims to provide a consistent approach to develop characterization factors for a Cumulative Energy Demand indicator, based on structured reasoning and clear assumptions, the harvested energy approach. The description of the impact category "Cumulative Energy Demand" and the characterization model and assumptions that are used to derive the characterization factors is based on the paper of Frischknecht el al. (2015). For details on the model and its characterization factors is referred to the original paper.

[54] The CED indicator focusses on the supply of energy by energy resources. It does not refer to methods based on exergy content, surplus energy and surplus costs related to mining of abiotic resources as a total (both energy and mineral or element resources).

Frischknecht et al. (2015) starts his paper with mentioning that since long it is debated if CED is a driver-indicator belonging to the inventory (Klöpffer, 1997) or an environmental impact indicator belonging to LCIA (Frischknecht R. , 1997). However, in the paper of Frischknecht (2015), the cumulative energy demand is considered to be an impact category indicator and thus belongs to the life cycle impact assessment.

In Frischknecht et al. (2015), the problem definition of energy use is defined based on an assumed **intrinsic value of energy**. This means energy is worth saving, because it has a value on its own, independent of a defined usefulness for humans or a function for supporting ecosystems.

According to Frischknecht et al (2015) there is no harmonized approach to calculate the CED of a system. The cumulative energy demand (CED) assesses the quantity of energy content of all different energy sources, both renewable and non-renewable, used throughout the Life Cycle of a product.

Different energy sources can be distinguished, see table xx1.

Table 2-1: Different types of non-renewable and renewable energy sources (Frischknecht el al., 2015)

type	Energy source
non-renewable	fossil (oil, natural gas, hard coal, soft coal)
	nuclear from uranium
	primary forest
renewable	biomass (cultivated wood and crops)
	wind, solar, geothermal
	water power

Despite the relative simple concept of total energy consumption by a system, the different characterization methods for energy related indicators lead to rather large differences in proposed characterization factors due to choices made, see table xx2.

Table 2-2: Possible choices when calculating CED values and the option chosen by Frischknecht (2015)

Choice	options	Choice by Frischknecht
Which **type of energy resources** are included when calculating CED?	fossil fuels only, non-renewables only, non-renewables and renewables	non-renewables and renewables (table xx1)
Which **energy content** is used for *fossil fuels* and *biomass?*	Higher Heating Value (HHV), Lower Heating Values (LHV)	HHV[55]
How is the **energy content** of *uranium* calculated?	uranium extracted and multiplied by energy content, nuclear electricity produced and efficiency assumed 100%, nuclear electricity produced and efficiency assumed far less than 100% (3.5 factor difference between assumed efficiencies)[56]	nuclear electricity produced and efficiency assumed far less than 100%
Which **inflow of energy resources** is used to calculate CED of renewables?	harvested or harvestable energy[57]?	harvested energy

Large differences in calculated results for CED are mainly due to different concepts used to determine the characterization factors for *renewable* and *nuclear energy resources* (Frischknecht, 2015).

In the approach taken by Frischknecht et al. (2015) the following choices are made. The problem definition of the use of energy resources is based on the assumed intrinsic value of energy. That means that energy, as such, is considered worth to be saved. Therefore, all different types of energy resources are considered (and optionally aggregated into one score). The HHV is chosen because it better reflects the energy balance of inputs and outputs of energy producing processes and its waste heat. The energy efficiency of nuclear energy production in practice is far less than 100%. Therefore, this more realistic efficiency is assumed. The harvested energy

[55] HHV is LHV + energy for the evaporation of water. (waste heat in vapor, in case there is no recovery of energy)

[56] The problem with nuclear energy is, at which point is the (harvested) energy flow measured? Is it the energy contained/released in the atoms? Or the energy received by the water that is heated up? Or the amount of nuclear electricity supplied? The point of measurement has large implications for the estimated (harvested) energy flow. This is the reason why different literature sources report different CED values for nuclear energy.

[57] Energy harvested: The renewable energy input into the manmade environment equals the amount of energy delivered by the energy collecting facility. Energy harvestable: The renewable energy input into the
manmade environment is the amount of renewable energy needed to produce the amount of energy delivered by the energy collecting facility. Some examples of harvestable energy versus harvested energy: the kinetic energy impacting the circular surface covered by the rotor blades of a wind turbine versus the amount of rotational energy transferred to the gear box; the energy input from sun light to a photovoltaic panel versus the converted solar energy into electricity; the potential energy of the water in the reservoir of a hydroelectric power plant versus rotation energy of the turbine; the amount of energy available in an oil field versus the amount of energy extracted therefrom. Please note that the two concepts differ by the conversion efficiency of the energy collecting facility (e,g., rotation blades, photovoltaic panel). This means that the harvested amount for solar/wind, hydro, biomass and fossils will depend on technological and economic conditions and are now based on the PRESENT conditions. So the efficiency of the harvesting facility, the ratio between harvestable and harvested amount, will depend on the time horizon that is chosen for the problem definition.

approach is taken in order to be able to align the energy of renewables with those of non-renewables.

Now, when aggregating different types of energy, the question rises whether the intrinsic value of different types of energy are the same? So, is the intrinsic value of a MJ renewable energy resource the same as the intrinsic value of a MJ non-renewable energy resource? According to Frischknecht et al., 2015), for weighting of these different types of energy sources different options are possible:

- No weighting, meaning to aggregate renewable and non-renewable cumulative energy demand using equal weightings (of 1 for both).
- Distance to target, uses the ratio of the current to the targeted annual consumption of renewable energy and non-renewable energy, respectively.
- Formation/generation time, takes the time into account, which was (or is) needed to create the energy resource.

Frischknecht et al. (2015) does not mention explicitly which weighting factor is proposed. It is mentioned that aggregation without weighting it is the method which is most often used. However, the paper also mentions that it's better to report different indicators separately, or at least renewables and non-renewables separately.

Critical reflection on the paper:

Problem definition of use of energy resources and weighting of different types of energy sources

In Frischknecht (2015), the problem of energy use is based on an assumed intrinsic value[58] of energy. This means that it is believed that energy resources have a value on its own, independent of usefulness for humans or a function for driving the ecosystem etcetera. However, this problem definition has a rather weak link to environmental problems. After all, according to the intrinsic value approach, it's the energy that is worth saving. There is no need to distinguish what the origin or destination of this energy is. However, if the problem is defined as "the use of energy inflows", then what is the environmental problem that is safeguarded?

It is imaginable that you want to have an indicator for total energy consumption (driver indicator) to monitor the energy efficiency of a system. However, what is the environmental problem of capturing energy inflow from the sun (photovoltaic, biomass), or kinetic energy inflow from the wind (wind turbines) or potential energy inflow from stored water (hydro power)? This flow

[58] In ethics, intrinsic value is a property of anything that is valuable on its own. Intrinsic value is in contrast to instrumental value (also known as extrinsic value), which is a property of anything that derives its value from a relation to another intrinsically valuable thing, e.g., the economy or the ecosystem.

of energy is (nearly) endless and the energy is refreshed on a very regular, short-term basis (daily for solar and wind, or maybe weekly for hydro, or yearly for biomass). In contrast, the non-renewable resources will be depleted and can be considered lost for future generations (for a long term).

Please note, what is meant here is the problem related to the extraction of the energy flow (which might be considered an elementary flow). What is NOT meant here is that the economic activity[59] of producing renewable energy also will have environmental impacts due to other elementary flows, like emissions of substances and extractions of mineral resources. The impacts of these economic activities and their emissions should be considered in LCA.

Many people might argue that the 'intrinsic value' of energy sources is rather debatable. In the UNEP-SETAC task force on mineral resources (Berger, 2020)) and in the SUPRIM workshop, including different stakeholders from industry, policy and science (Rita Schulze, 2020), there was general consensus on the role of resources for mankind: *"Abiotic resources are valued by humans for their functions used (by humans) in the economy (Technosphere). Resources may originate from both primary and secondary production."*

For energy resources this can be translated into: *"Energy resources are valued by humans for their functions used (by humans) in the Technosphere. Energy may originate from both non-renewable resources (fossil, nuclear, primary forest) and renewable (solar, wind, hydro, biomass) resources."*

If the problem definition is defined based on the intrinsic value of energy, then (by definition) the weighting between renewable and non-renewable should be equal weighting, because the energy is believed to be worth saving, as such, irrespective of the type of energy source (origin) or the application of the energy (destination or function).

If weighting is based on formation/generation time, the weighting factors are based on the time it takes to regenerate or refresh the energy source. According to Frischknecht et al. (2015), this third approach would lead to the most discriminating weighting factors between non-renewable and renewable energy sources. Practically, then the energy problem becomes a depletion problem. Weighting for renewables should be (nearly) zero and we only should focus on non-renewable resources.

So, given the regeneration possibility of renewables, which mean that the use of solar and wind energy actually are NOT considered a problem, the problem definition of the use of energy

[59] For example, to capture the energy from sunlight and convert it into electricity one needs to produce solar cells. The production of these cells requires energy inputs which (partly) might be based on fossil fuels that will lead to depletion of fossil energy resources and carbon dioxide emissions contributing to climate change. Next to that a transition to renewable energy sources will lead to a demand for Rare Earth Elements, which are used in solar cells and magnets for wind turbines. The extraction of these REEs will contribute to the impact category "abiotic resource depletion of elements". The agricultural process of the production of energy crops will lead to emissions of nutrients and pesticides contributing respectively to impact categories eutrophication and ecotoxicity.

resources could be rephrased as: *"The decrease of accessibility on a global level of non-renewable resources over the very long term (LT: e.g., 500 years) or short term (ST: e.g., 25 years)."*

The assumed time horizon (LT or ST) might have implications whether the use of primary old forest should be considered as depletion. Also, it might have implications for which reserves to consider, in the case the reserves are part of your characterization model. (By the way, the energy harvest approach only looks at the harvested amount of energy. The characterization model (equation) does not consider the amount of reserve that is available. All energy sources are considered substitutable so only the total reserve of MJ that is available matters. I think this is correct. This is also the assumption that is made for the ADP_fossil).

Relation of CED to other impact categories

The results for the (driver) indicator on Cumulative Energy Demand CED together with results for impact categories (on the level of state indicators), like 'abiotic resource depletion of fossil fuels' or 'climate change' etcetera, should be interpreted cautiously, because of possible redundant information.

CED_total, based on renewable and non-renewable energy, partly overlaps directly with the impact category on resource use which is presently recommended in EF, namely 'abiotic resources fossil fuels' (based on ADP fossil), which can be seen as a partial indicator of CED_non-renewable energy.

When used as a driver indicator, the CED concept overlaps indirectly with the impact category on resource use which is presently recommended in EF, namely 'abiotic resources minerals' (based on ADP elements). For example, the extraction of uranium for the production of electricity in a nuclear power plant is considered in the characterization score. But also, the steel and rare earth elements that are extracted for the production of wind turbines and magnets in wind turbines are considered when calculation the impact category score for the IC 'abiotic resources minerals'.

Furthermore, when used as a driver indicator, the CED concept overlaps indirectly with other Impact Categories, like climate change (CO2 emissions), acidification and eutrophication (NOx emissions), PM, etcetera. That is, to fulfill the demand for energy, fossil fuels are combusted leading to CO2 and NOx emissions. Or, for the production of biomass to produce renewable energy, fertilizers and pesticides are used that will lead to impacts on eutrophication and ecotoxicity, and so on.

In other words, when you have indicators at different levels in the DPSIR framework, like 'CED' as a driver indicator and, for example 'climate change' as a state indicator, you have the risk that the effect of the economic activity (e.g., the production of electricity from the combustion of a fossil fuel) is measured twice.

Recommendations on CED for TranSensus

CED_total (both renewable and non-renewable)

- Use characterization factors for CED_non-renewables and CED_renewables as defined by Frischknecht (2015) which is most widely used and implemented in Ecoinvent (and other databases).

CED_total gives insight into the energy efficiency of an economic system, which is considered an important indicator for policy.

- Therefore, CED_total, based on aggregation of different energy sources by equal weighting, might be considered an interesting additional indicator on the driver level,
- However, CED_total, as such, should not be recommended as an Environmental Impact Category, because of the weak link of the renewable energy flow to an environmental problem defined in terms of safeguarding energy as such.
- Indicators on driver level and environmental impact level should be interpreted cautiously when presented and discussed together. Because the different indicators measure effects of economic activities on different levels in the DPSIR framework, there might be overlap in indicated effects.

CED_non-renewable (fossil, nuclear, primary forest)

CED_non-renewable is a state indicator for the depletion of non-renewable energy resources.

The indicator relates to the following problem on energy resource use: *The decrease of accessibility on a global level of non-renewable resources over the very long term (LT: e.g. 500 years) or short term (ST: 25 years).*

It basically follows the same problem definition as the Impact Category 'abiotic resources fossil fuels', which is presently used in EF, but includes uranium and primary forest as other depletable energy resources, next to fossil fuels.

- Therefore, CED_non-renewable, based on aggregation of different non-renewable energy sources by equal weighting, might be recommended as an alternative indicator for the impact category 'abiotic resources fossil fuels'.
- Downside is that the assumed amount of harvested energy from uranium is quite variable between different literature sources, leading to high uncertainty for this item of the CED_non-renewable.
- flag that this CED indicator for nuclear energy is less robust and more research is recommended to develop consensus on which value for harvested energy flow should be used.

Criticality

Introduction

Since the second half of the 20th century, concern about the reliability and availability of natural resources has increased, especially in the case of geographically limited resources (Council, 2008). This is due, in part, to rising demand from emerging economies such as the BRICS nations (Brazil, Russia, India, China, South Africa) (European Commission, 2020). These concerns led to the concept of Critical Raw Materials (CRMs), resources vital for sustaining modern lifestyles and economic sectors. CRMs have particular relevance in eco-efficient technologies such as e-mobility, batteries, and renewable energies (Bobba et al., 2020).

Criticality assessment (CA) methodologies predominantly focus on minerals and metals (Berger et al., 2020a), with fewer considering biotic materials or water (Bach et al., 2018; Sonderegger et al., 2020a). Elements such as indium, gallium, cobalt, and Rare Earth Elements (REEs) are often the subject of these assessments (Schrijvers et al., 2020a). However, methodologies for CA are not standardized internationally and can vary in scope from product-specific to regional levels (European Commission, 2020). However, methodologies for CA are not standardized internationally and can vary in scope from product-specific to regional levels. It is important to mention that, by definition, criticality assessments depend on the perspective from which the assessment is made.

The United States and European Union have taken lead roles in CRM identification. The U.S. National Research Council issued the first structured CA of CRMs in 2008 (Council, 2008). The European Union, through its Raw Materials Initiative (RMI), started listing CRMs in 2011, with assessments based on economic and geopolitical factors (European Commission, 2011). These lists have evolved over time, but the aspects under analysis remain the same (e.g. EU list considers only supply risk + economic importance) (European Commission, 2016).

Several other countries, including Japan, Australia, and China, have also developed task forces to identify CRMs (Andersson, 2020; Hatayama & Tahara, 2015; Mudd et al., 2019). Supply risk factors are often categorized into technical, economic, social, and political dimensions (Dewulf et al., 2016; Vogtländer et al., 2019). Given the multiplicity of CA methods, there is ongoing dialogue on harmonizing these approaches (Schrijvers et al., 2020a).

Furthermore, the identification and assessment of CRMs are closely linked to broader sustainability and policy initiatives such as the EU Circular Economy Plan (Santillán-Saldivar et al., 2021a). Life cycle assessment (LCA) techniques are used to gauge the environmental impact of products, including their dependency on CRMs. However, the scope and methodology of such assessments remain subjects of debate within the LCA community (EC-JRC, 2012; UNEP, 2019). Overall, the growing importance of CRMs in technological development underscores the need for continued evaluation, monitoring, and methodological refinement in their assessment. In LCA, the term "natural resources" broadly includes land, sea, energy sources, water, air, flora and fauna, minerals, fossil fuels, metallic ores, and nuclear ores (Dewulf et al., 2015).

Four general categories of methods are employed to assess the use of natural resources: 1) depletion methods, which measure the reduction in resource stocks; 2) future efforts methods, gauging additional societal efforts needed due to current extraction; 3) thermodynamic accounting methods, quantifying energy loss; and 4) supply risk methods, addressing resource criticality concerning supply disruption (Sonderegger et al., 2020b). The most common approach for resource use in LCA is depletion-based methods, particularly in Product Environmental Footprint (PEF) studies (Di Noi et al., 2020; Zampori & Pant, 2019). UNEP (UNEP, 2019) recommends "inside-out approaches," which consider future generational use, for environmental LCA and "outside-in approaches," which focus on resource availability, for broader life cycle sustainability analysis (LCSA).

The concept of supply risk has gained attention since the first US report on Critical Raw Materials (CRM) in 2008 (Council, 2008). The LCA community is increasingly interested in incorporating supply risk indicators to account for socio-economic and geopolitical variables, which are beyond the purview of environmental LCA alone (Berger et al., 2020b; Di Noi et al., 2020). Methods such as Economic Resource Scarcity Potential (ESP) (Schneider et al., 2014), ESSENZ (Bach et al., 2016), and GeoPolRisk (Gemechu et al., 2016) have been developed to assess supply disruption risks in the context of LCSA. These methods factor in both the probability and vulnerability aspects of supply disruption similar to CA methods utilized by the US and EU (Sonderegger et al., 2020b).

Definition

The concept of material "criticality" varies according to the context and lacks a universally accepted definition (Frenzel et al., 2017; Jin et al., 2016; Terlouw et al., 2019). In mechanics, ISO 13372 (ISO, 2012) defines it as the index reflecting the severity of an effect and its expected frequency, while in management, ISO 22300 (ISO, 2018) describes it as a process for systematically evaluating organizational assets. In the context of supply-chain analysis, criticality assigns importance to high-demand materials but lacks a standardized framework (Mancini et al., 2015).

Material criticality generally includes dimensions such as supply risks and vulnerability to supply disruptions, which are influenced by geopolitical factors, trade barriers, and environmental regulations (Dewulf et al., 2016; Knobloch et al., 2018; Sonderegger et al., 2020b). Various standards and organizations offer their definitions. For instance, the British standard CLC/TR 45550 (CEN, 2020) defines CRMs as economically important materials with high supply risk.

The European Commission (European Commission, 2017) echoes this by emphasizing the economic importance and high supply risk of CRMs.

An added dimension to criticality is the environmental implication of material processing, as suggested by Graedel et al. (2012). This approach aligns with Life Cycle Thinking (LCT) and uses a Life Cycle Impact Assessment (LCIA) approach for criticality assessment. While there is no consensus on the definition of criticality, some authors associate vulnerability with scarcity and abundance rather than economic importance (Adibi et al., 2017; Klinglmair et al., 2014). This perspective, however, often overlooks the role of recycling as a strategy to mitigate supply risk, a factor considered by the Raw Materials Initiative (RMI) in Europe.

Criticality indicators in LCA primarily focus on supply risks rather than resource depletion, yet their inclusion provides valuable complementary information for understanding material criticality (Drielsma et al., 2016; Klinglmair et al., 2014). While scientific consensus is lacking on the optimal methodology for evaluating criticality, either generally or within a product life cycle context, there is a pressing need for guidelines like those recommended by the Joint Research Centre (JRC) for Product Environmental Footprint (PEF)/Organisation Environmental Footprint (OEF) assessments (Schrijvers et al., 2020b; Zampori & Pant, 2019).

The academic community largely concurs that material criticality lies outside the scope of environmental LCA, but should be incorporated as part of a broader LCSA framework, which encompasses environmental, economic, and social dimensions (Drielsma et al., 2016; Sonnemann et al., 2015; Van Oers & Guinée, 2016; among others). Nevertheless, the integration of criticality indicators within LCSA has given rise to diverse viewpoints, particularly in how they connect to different sustainability dimensions. For example, Sonnemann et al. (2015) and Mancini et al. (2015) suggest that criticality could be framed within environmental LCA, primarily due to the utilization of biophysical elementary flows in the life cycle inventory (LCI).

Nonetheless, this technical argument should not overshadow the broader context that criticality indicators provide, including economic and social impacts such as supply disruption risks associated with geopolitical issues or labor conditions. Despite the absence of support for treating criticality as a standalone sustainability dimension, there is advocacy within the scientific community for its inclusion in LCSA. Specific methods such as ESSENZ, ESP, and GeoPolRisk have been highlighted as important frameworks for incorporating criticality into LCSA, as per UNEP's 2019 guidelines.

Considering the context of the project, it is suggested to adopt the European Commission's definition of CRM, which identifies two main parameters: economic importance (EI) and supply risk (SR) (Blengini et al., 2017; European Commission, 2017). In this sense, EI offers insights into potential economic consequences of supply inadequacy, including the feasibility of substitutes. SR gauges the risk of disruption based on governance performance, trade barriers, and the role of secondary raw materials through recycling. Therefore, in this research, criticality is assessed primarily in terms of SR, with EI considered relevant but not essential (Blengini et al., 2017).

Methodologies reviewed

A systematic review was conducted to survey the current state of criticality assessments within and beyond the context of LCSA. Literature searches were performed using Web of Science (WoS) and Google Scholar for broader criticality studies, and Scopus and ScienceDirect specifically for those related to LCSA. The search period covered publications from 2006 to mid-April 2021. For LCSA-related criticality, the search returned 65 and 68 articles from Scopus and WoS, respectively, with 44 duplicates. The literature was screened based on three conditions relevant to the project: (i) inclusion of supply risk and/or economic importance indicators, (ii) incorporation of LCA/LCSA/Life Cycle Thinking (LCT) methodologies, and (iii) a complementary interpretation between LC(S)A and Criticality Assessment (CA). Post-screening, 25 documents were selected for in-depth analysis, along with four other seminal documents, leading to a total of 29 documents.

In the case of non-LCSA related literature, 33 documents were identified between mid-February and mid-March 2021 through WoS and Google Scholar. An additional three publications were identified from a review by Schrijvers et al. (2020), culminating in 36 documents for further review. Among the 65 total documents considered, 11 review articles were excluded for lacking specific, analyzable methods. The focus was narrowed to methods that have been used or updated since 2015 and primarily evaluate criticality in terms of supply risk, in alignment with Sonderegger et al. (2020b).

The review ultimately yielded seven key methods for criticality assessment:

1. National Research Council (NRC) (Council, 2008).
2. European Commission's Criticality Assessment (EC-CA) (European Commission, 2017, 2020).
3. Yale methodology (Graedel et al., 2012), with extensions (Graedel et al., 2015; Ioannidou et al., 2017).
4. ESSENZ (Bach et al., 2016).
5. British Geological Survey (BGS, 2015).
6. Japan's Resource Strategy (NEDO) (Hatayama & Tahara, 2015).
7. GeoPolRisk (Cimprich et al., 2017; Gemechu et al., 2016).

Methodologies reviewed

1. U.S. National Research Council (NRC)

The U.S. National Research Council (NRC) introduced a framework for assessing supply risk and impacts of supply restrictions on minerals in a two-dimensional space (Council, 2008). On the x-axis, supply risk is determined by considering five distinct aspects of availability, which may differ based on the timeframe of assessment (long, medium, or short term). The y-axis evaluates the impacts of supply restrictions using a composite score, which is weighted. The resulting methodology categorizes minerals within a matrix, indicating their level of criticality. Importantly, the NRC perceives criticality as a spectrum rather than a binary determination, emphasizing its context-dependency. This approach has been employed to assess the significance of non-fuel minerals in the U.S., both for understanding their relevance and determining their short and long-term availability. The primary target audience for this framework includes federal agencies, industry stakeholders, research institutions, and policymakers. A case study conducted under this framework evaluated 11 mineral candidates, emphasizing the U.S. context, although the method is adaptable to other regions. Notably, while the NRC has not directly updated the approach, its foundational matrix concept has been adopted and modified by other entities, e.g., the EU. Additionally, the NRC's initial work paved the way for subsequent studies in criticality, such as the research by Graedel et al. (2012).

2. European Commission Criticality Assessment - EU CRM list

The European Commission has established a systematic ranking for Critical Raw Materials (CRMs), initially published in 2011 and updated triennially (European Commission, 2017, 2020). This ranking evaluates materials based on two key dimensions: Supply Risk (SR) and Economic Importance (EI). Developed in consultation with stakeholders, the 2017 revised method employs specific equations to quantify these dimensions. The EI equation incorporates variables such as the sectoral share of end use for a raw material and the sector's value added, along with a SI. The Supply Risk (SR) equation involves a variety of metrics including the Herfindahl Hirschman Index for country concentration, the World Governance Index for governance quality, import reliance, global supply, and end-of-life recycling input rate, among others.

These assessments rely on a five-year reference period for data collection. Materials that exceed established thresholds in both SR and EI are designated as "critical" and are consequently listed as CRMs by the European Commission. It is important to note that the methodology is "non-forward looking," serving as a temporal snapshot based on the most recent data and is specifically tailored to the European context.

3. Methodology of Metal Criticality Determination (also known as Yale methodology)

The Yale methodology for Determining Metals Criticality was developed in 2012 as an extension of work done by the U.S. National Research Council (NRC) on minerals and their importance to the U.S. economy (Graedel et al., 2012). This comprehensive framework evaluates the criticality of metals in the periodic table primarily from a utilization standpoint. It considers three organizational levels (i.e., corporate, national, and global) and operates under two time frames: medium and long-term. The methodology employs indicators for three distinct dimensions: supply risk, environmental implications, and vulnerability to supply restrictions. These indicators are then aggregated to yield either a quantitative score for each dimension, which ranges from 0 to 100 points and is sometimes based on semi-quantitative or qualitative metrics, or a unified single-score indicator known as "criticality vector magnitude."

Results are presented in a three-dimensional space, capturing all three aspects of criticality, and are designed to serve as a temporal snapshot. Since its inception, the Yale methodology has been expanded to evaluate a broader spectrum of 62 metals and metalloids at both national and global levels (Graedel et al., 2015). Additionally, the framework has been adapted by other researchers to assess water criticality at a global scale (Sonderegger et al., 2015) and construction aggregates at local or regional levels (Ioannidou et al., 2017).

4. ESSENZ

The ESSENZ methodology, developed at TU Berlin, is an extension of the ESP method and aims to provide a comprehensive evaluation of resource criticality by integrating environmental, economic, and social factors (Bach et al., 2016). The method considers five environmental impact categories, such as climate change and acidification, which are assessed through standard Life Cycle Impact Assessment methods. Additionally, it evaluates abiotic resource depletion as an economic dimension. ESSENZ also incorporates two social indicators related to environmental compliance and quantifies eleven geopolitical and socioeconomic factors that influence material accessibility.

The indicators for these categories are calculated and divided by a target value to produce a distance-to-target (DtT) ratio. This ratio is normalized by global production volume, assuming that resources produced in smaller quantities may face greater accessibility constraints. The normalized DtT factors are then scaled within a pre-defined range to balance the influence of life cycle inventory and characterization factors (CFs) on the LCIA results.

ESSENZ achieves results in 19 categories. Although a single-score metric is possible, it is not recommended. Out of these categories, 11 indicators focus on socio-economic availability relevant for criticality, while eight are grounded in Life Cycle Assessment (LCA) and two concentrate on social implications. The method is primarily intended for small to medium-sized enterprises and large corporations that aim to evaluate their product portfolios' resource efficiency. However, the method advises selective external communication: while results pertaining to "environmental impact" can be shared with customers, findings related to "physical and socio-economic availability" and "social acceptance" should not be disclosed.

CS-ESSENZ (Company-Specific ESSENZ) is a 2021 adaptation of the ESSENZ method designed to assess resource efficiency, criticality and social impact within company-specific abiotic resource supply chains (Yavor et al., 2021). It integrates elements of the ESSENZ and SCARCE methodologies, with 20 categories and indicators based on their combined frameworks. Eleven indicators were modified, four new ones were developed (e.g., economic importance), and five from ESSENZ and SCARCE were retained. Through a smartphone case study, CS-ESSENZ demonstrated its applicability for assessing company-specific criticality and social impact, pointing out areas for improvement such as purchasing strategies for materials like cobalt. It complements the ESSENZ results by adding a business perspective to criticality assessment, enhances product-level assessment, and contributes to the field of enterprise-level supply risk methods by enabling accurate assessment of supply chain dynamics and priorities.

Developed with strong industrial collaboration, ESSENZ has been recommended as an interim approach for evaluating resource criticality by the Global Life Assessment on Metals (GLAM) Phase 2 (UNEP, 2019).

5. British Geological Survey - Supply Risk Index

The British Geological Survey's Supply Risk Index (SRI), updated in 2015, serves as a diagnostic tool for assessing the relative risk of supply for 41 chemical elements or element groups (BGS, 2015). The SRI is formulated using seven criteria: Production Concentration, Reserve Distribution, Recycling Rate, Substitutability, Governance of the top-producing nation, Governance of the top reserve-hosting nation, and Companion Metal Fraction. Each criterion is scored on a scale from one (low contribution to supply risk) to three (high contribution to supply risk). These scores are then aggregated, and the resulting sum is normalized to produce a supply risk index ranging from one (very low risk) to ten (very high risk). Notably, the 2015 update eliminated the criterion of "Scarcity," previously based on crustal abundance.

The index predominantly focuses on supply-side risks and largely omits demand-side considerations, except for the criterion of "Substitutability." The SRI aims to inform policy-makers, industries, and consumers about potential vulnerabilities to supply disruptions, which are most likely attributable to non-geological factors such as geopolitical tensions, labor strikes, and infrastructure availability. The overarching objective is to promote resource diversification, encourage recycling, and mitigate resource use intensity.

However, the SRI should be seen as an initial exploratory analysis and requires further refinement to account for the unique circumstances associated with each metal and each country

(BGS, 2015). Moreover, the methodology does not incorporate future changes in mineral markets, acknowledging that the risk landscape may evolve over time, thus altering the results.

6. NEDO (Japan's criticality assessment)

The New Energy and Industrial Technology Development Organization (NEDO) of Japan has formulated a methodology for evaluating the risk associated with "strategic minerals" crucial to the nation (Hatayama & Tahara, 2015). Although the terms 'criticality' or 'critical metals/materials' are not explicitly used in the assessment report, the framework serves to evaluate the critical metals for Japan. The methodology employs a multi-criteria approach, comprising five risk categories with a total of 12 indicators. These categories include Supply Risk, Price Risk, Demand Risk, Recycling Restriction, and Potential Risk. Each indicator is normalized and assigned a value ranging from 0 to 3 points.

To arrive at an integrated criticality score, these normalized indicators are aggregated using specific weighting factors: 25% each for Supply, Price, and Demand Risks, 20% for Recycling Restriction, and 5% for Potential Risk. Within each risk category, indicators are given equal weight. The maximum attainable criticality score is 32 points, with minerals scoring 18 points or higher being classified as "strategic." Hatayama & Tahara (2015) suggest an additional indicator (sufficiency of mineral interest) within the Supply Risk category, which would contribute an extra 3 points to the maximum score.

The methodology emphasizes minerals and incorporates recycled materials through the Recyclability index. It aims to serve industry sectors with high import dependencies for materials, as well as policymakers. The final output comprises both the individual indicators presented in absolute values and a single, integrated criticality index.

7. GeoPolRisk

The Geopolitical Supply Risk (GeoPolRisk) methodology, developed by Gemechu et al. (2017), aims to assess supply risks associated with raw materials at the component/product production level. Targeting various industry sectors, policymakers, and LCA practitioners, the approach encompasses both mining/extraction and processing/refining stages and incorporates recycled or secondary raw materials through a recyclability index.

Initially, the method built upon existing criticality assessment frameworks such as Council (2008), Graedel et al. (2012), and European Commission (2014), among others. It employs the Herfindahl-Hirschman Index (HHI) and the World Bank's Worldwide Governance Indicators (WGI) to evaluate supply risks. Specifically, the method considers the global share of a supplying country in commodity production, geopolitical stability of that country, and the import share from the supplying country to the demand-side nation. The initial focus was purely on resource identification, irrespective of the volume of flows.

Subsequent enhancements were introduced to extend the method's complexity and applicability. Helbig et al. (2016) incorporated supply chain intricacies, noting that mining and processing stages might not occur in the same nation, and that relationships between such nations are relevant. Cimprich et al. (2017) proposed the inclusion of vulnerability parameters at both the economy and product-levels, considering the mass flows analogous to LCI and in the next iteration Cimprich et al. (2019) introduced substitutability indicator as one of the vulnerability factor. Further, Santillán-Saldivar et al. (2021b) introduced recycling rates as supply risk mitigating parameter. To associate the method with the mass flows, Santillán-Saldivar et al. (2022) introduced yearly average market price of the commodity to the methodology. The resulting GeoPolRisk indicator involves multiple factors, such as geopolitical supply disruption probabilities, recycling rate of the commodity, yearly average market price of the commodity, and is formulated for specific raw materials needed to produce particular products in a given country.

The methodology has been recognized as an interim recommendation in Phase 2 of the Global LCA Metrics for Natural Resource Use and Eco-Innovation (GLAM) criticality project by UNEP (UNEP, 2019).

Evaluation of methodologies in the context of the ORIENTING project

The ORIENTING project employed a structured approach to evaluate the 7 selected methodologies, drawing from existing frameworks such as the RACER methodology (Robust, Accepted, Credible, Easy, and Relevant) and a range of literature sources (EC-JRC, 2012; Eisenmenger et al., 2016; European Commission, 2009). The initial set of criteria focused on stakeholder acceptance, credibility, applicability, complexity, transparency, scientific robustness, completeness, and compatibility with life cycle approaches.

The finalized set of criteria included six main building blocks:

1	Stakeholder acceptance, credibility and suitability	4	Scientific robustness
2	Applicability / Complexity	**5**	Completeness
3	Transparency	**6**	Compatibility with life-cycle approach

Each sub-criterion was scored on a scale from A (best) to E (worst). Pre-established understandings of each sub-criterion were adapted to the specific requirements in the material criticality topic. The scoring system was numerical (5 for "A", 4 for "B", etc.), with "N/A" (Not Applicable) scores being excluded. The simple average of the sub-criteria scores generated the aggregate score for each criterion, which then contributed to the method's or tool's overall score.

A B C D E

Main findings

Based on the evaluation of the 7 methods, the following conclusion can be drawn. From an operational perspective, EC-CA, GeoPolRisk, and the Japanese NEDO assessment are highly applicable, receiving A+ scores. GeoPolRisk and ESSENZ also receive high scores (B+) for compatibility with life cycle approaches. However, only EC-CA scored highest in acceptance by EU policymakers. Notably, most methods exhibit overlap with at least one pillar of sustainability, which raises issues of potential double-counting. EC-CA, ESSENZ, and NEDO employ subjective elements, which could conflict with ISO standards for LCA (ISO, 2006a, 2006b). In terms of scientific robustness, GeoPolRisk leads (A), followed closely by ESSENZ and Yale method (A-), and then by EC-CA (B+).

Given these results, EC-CA and GeoPolRisk appear most promising for further development in the project. Potential research directions include integrating EC-CA's two dimensions into a single characterization factor per material, or enhancing one method using features from the other. Similarly, regular updates are recommended to account for temporal variability in material criticality.

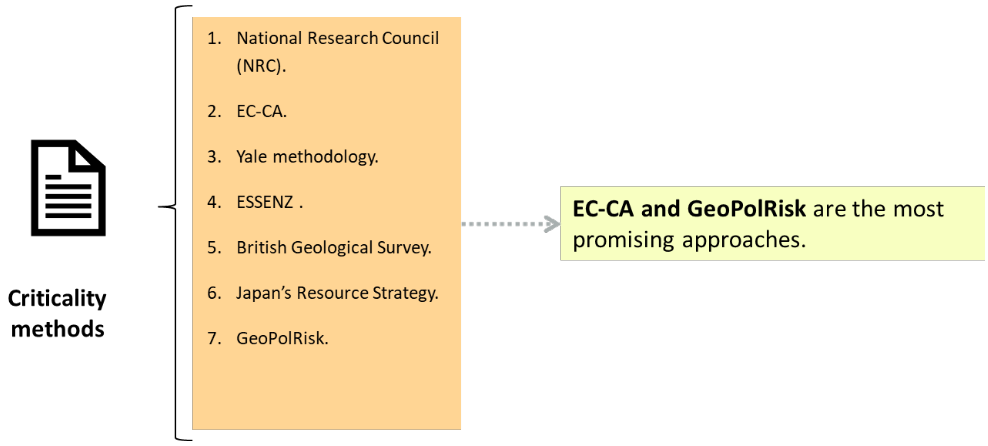


Figure 2-2: Criticality Methods

In the context of LCSA, multiple challenges related to the incorporation of material criticality have been identified. These scientific challenges encompass: 1) the systematic mapping of critical materials and associated elementary flows in the LCI; 2) the debate over whether material criticality should be integrated within LCA, LCC, S-LCA, or LCSA frameworks; 3) the employment of subjective elements in defining criticality; and 4) the relationship between material criticality and circular economy principles.

Applicability of ORIENTING evaluation in the TranSensus LCA context

The evaluation conducted by the ORIENTING project, which employed a structured approach to evaluate the seven most relevant methodologies for assessing criticality, offers valuable insights and justification for the applicability of these methodologies in the TranSensus LCA project. This applicability is particularly relevant when considering the RACER methodology as a guiding framework for method selection and ranking by experts.

1. Robustness: the ORIENTING project's evaluation assessed the robustness of various criticality assessment methodologies. If the TranSensus LCA project aims to provide a comprehensive and robust evaluation of the criticality of materials related to zero emission vehicles (ZEVs) and batteries, the methodologies that were ranked highly in terms of robustness in the ORIENTING project, such as EC-CA and GeoPolRisk, would be a logical choice. These methodologies have already demonstrated their robustness through expert evaluation.

2. Acceptance: methodologies that are widely accepted within the scientific and industrial communities are crucial for credibility and legitimacy. The ORIENTING project's ranking based on the RACER criteria takes acceptance into account. Since EC-CA and GeoPolRisk were among the top-ranked methodologies in the ORIENTING project, they are more likely to be accepted by stakeholders and experts in the field of LCA for ZEVs and batteries.

3. Credibility: the credibility of a methodology is essential when assessing criticality, as it directly impacts the reliability of the results. The fact that EC-CA and GeoPolRisk received high rankings in the ORIENTING project suggests that they have a strong foundation and credibility. This credibility can be leveraged to enhance the credibility of the TranSensus LCA project.

4. Ease of Use: when developing a framework for the TranSensus LCA project, it is essential to select methodologies that are easy to follow and implement. EC-CA and GeoPolRisk's high rankings in the ORIENTING project indicate that they are user-friendly, which will facilitate their integration into the TranSensus LCA framework.

5. Relevance: if EC-CA and GeoPolRisk performed well in the ORIENTING project's evaluation, it suggests that they are adaptable and relevant to different contexts. This adaptability makes them suitable for the TranSensus LCA project, as they can be tailored to the specific materials and processes associated with ZEVs and batteries.

Mineral resource depletion and dissipation: description of methods

ADP ultimate reserves

The Abiotic Depletion Potential method, ultimate reserves ($ADP_{ultimate\ reserves}$), is intended to capture the issue of mineral resource depletion; i.e., the contribution to exhaust the primary natural stock of a non-renewable resource, in turn limiting its availability to future generations. It was originally published by Guinée (1995), with updates in 2002 (van Oers et al., 2002) and 2020 (van Oers et al., 2020a). Extraction of mineral resources from ground is considered to contribute to the depletion/exhaustion of the stock in the environment (in contrast to stocks in the technosphere, like landfill, urban stocks etc.): "reserve", "reserve base", "resources" or "ultimate reserves", with a temporal timeframe form short to very long. In the latest recommendations by the UN (Berger et al, 2020), "stock" is set to *ultimate reserves*, which corresponds to the ADP$_{ultimate\ reserves}$ method. It adopts an infinite timeframe and builds on the ultimate reserve, a hypothetical upper limit of the amount of resources that may be extracted from common rock, with the average composition of earth crust, assuming that future technologies will make it possible to extract it (Sonderegger et al., 2020). ADP CFs apply to resource flows "extracted from ground" by the mining sector, as typically compiled in standard LCI databases (e.g., ecoinvent or Environmental Footprint – EF - databases).

EDP

The project SUPRIM developed both a conceptual framework, to develop characterization factors for resource use,and an operational method. The conceptual framework is intended to capture the decreased accessibility of mineral resources due to the net result of compromising actions, that is stated to be the problem induced by current resource use for future generations (van Oers et al., 2020b). Four compromising actions are distinguished: i) exploration, ii) dissipation to environment, iii) hibernation in technosphere (corresponding to unused stocks in technosphere, in the absence of economic drivers in the time horizon considered) and iv) occupation-in-use. The SUPRIM conceptual framework has so far been operationalized for a very long-term[60] perspective only. In order to make this conceptual framework operational, the authors make the following assumptions and choices:

- continental crustal content is used as a proxy for the accessible stock in the environment and technosphere (similarly to the approach undertaken in the ADP method);
- hibernation in use is considered to be negligible, due to economic and technological developments that will make the hibernating stocks accessible over the very long term;
- occupation in use is also considered to be negligible;
- and finally, exploration is irrelevant in the very long-term, as "*its maximum possible contribution is already included in the chosen proxy for the total accessible stock*" (van Oers et al., 2020b);

The authors claim that these assumptions correspond to a scenario that "*will happen at some point in the far future*" (van Oers et al., 2020b), with explicitly excluding any precise timeframe

[60] A proposal for a characterization model and characterization factors for dissipation based on a short-term time perspective is in development.

for the completion of this scenario (e.g., 100 years, 1000 years, or even more). Eventually only environmental dissipation is considered as relevant in this context. In the resulting Environmental Dissipation Potential (EDP) method, all emissions to environment are considered dissipative flows. EDP CFs aim at accounting for the severity of this dissipation. The dissipation of each element is considered equally bad. In other words, weighting across functions that the elements may have for society is equal, mainly because it is impossible to foresee which functions the elements (or configurations made by using the elements) have in the far future, and what the substitution possibilities are.

ARP

The ARP (Abiotic resources in PEF project) method (Owsianiak et al., 2021) is intended to capture the decrease of accessibility of mineral resources. The method enables to classify an emission of a metal to the environment as dissipative, or not, in product life cycles at the LCI stage of LCA. It aims at improving the former consideration of environmental dissipation in the EDP operationalized method, in which all emissions to environment are considered dissipative (Owsianiak et al., 2021). The ARP method instead intends to distinguish "*truly dissipative*" emissions from those that do not contribute to loss of accessibility of a given resource. This firstly requires the identification of emissions of resources, by opposition to emissions of non-resources. Emissions may indeed originate from a source of the element that would not be considered as a mineral resource now, or in the future within the timeframe considered ("*e.g., emission of a metal due to combustion of fossil coal, where it is present in trace amounts in the coal and is not expected to be considered as a metal resource*"; Owsianiak et al., 2021); therefore not contributing to mineral resource dissipation, as also advocated by Beylot et al. (2021).

Secondly the ARP method considers that part of the emissions to the environment may at some point (now or in a more or less long future) be accessible to some users, accordingly not contributing to resource dissipation. The implementation of the method is based on dissipation criteria developed specifically for a very long-term (infinite) timeframe. In addition, as an example of application to case studies, it is combined with EDP CFs, with associated CFs made available to users.

JRC-LCI

The JRC-LCI method applies at the LCI step. It builds on the definition of *resource dissipation* derived by Beylot et al. (2020) from their literature review of life-cycle-based studies (see definition in the above Introduction section). The JRC-LCI method consists in reporting dissipative flows of mineral resources at the unit process level, in mass units (Beylot et al., 2021), considering a predefined list of dissipative mineral resource flows to a number of dissipation (receiving) compartments. The dissipative nature of flows, and of dissipation compartments, depends on the temporal perspective. A short-term perspective (25 years) is suggested to be considered, as it is particularly adapted to support decision-making, and especially in contexts of policy-making. Any flow of resources to i) environment; ii) final waste disposal facilities (landfills and tailings final disposal facilities); and iii) products-in-use in the technosphere, in which the resource no longer provides any significant function (including due to low-functional recycling), is suggested to be reported as dissipative at the unit process level. This approach enables to capture four of the six actions compromising the accessibility to mineral resources, as defined by Dewulf et al. (2021): emitting, landfilling, tailing, downcycling/dispersing into the technosphere. "Resource flow analysis" (RFA, i.e. substance flow analysis of the resources) is at the core of the JRC-LCI method. LCA practitioners shall firstly map the flows of mineral resources into and out of the unit processes under study, then list the dissipative flows, and finally report them in the LCI at the unit process level. Please note that this is still quite a challenge:

- resource (element) composition of flows (waste and goods) should be known.
- unit processes should comply with the principle IN = OUT. So, what is consumed by a process should be equal to what comes out of the process, either as emission, waste or as component in a product in use (distinguishing between low quality and high quality).

Despite suggested to be implemented considering a short-term perspective, the JRC-LCI method is based on a framework that may be alternatively implemented considering different temporal perspectives. Beylot et al. (2020; 2021) accordingly test the JRC-LCI framework considering a long-term perspective, assuming that in the long-run only emissions of resources to environment are dissipative. In that case (long-term perspective), the JRC-LCI "long-term" method would become conceptually:

i. close to the EDP method; yet considering only *resources* emitted to environment as dissipative flow (while all emissions to environment, including of non-resources, are considered dissipative resource flows in the EDP method) ;

ii. and close to the ARP method; yet without considering any criterion to assess the future accessibility or inaccessibility of resources emitted to environment (contrarily to the ARP method).

JRC price-based

The JRC price-based method is an impact assessment method which builds on the price of resources, considered as a proxy for the multiple, complex and varied functions they can have for diverse economic sectors (electronics, automotive, aeronautics, etc.; Ardente et al., 2023). CF for a given resource is calculated as the ratio of its average price (in a certain timeframe) over the average price of a reference substance. It is neither based on the depletion nor on the dissipation approaches, but rather on the user value that the current and past generations attribute to metals and minerals, which also reflects market expectation for the coming years (forward looking short time frame).

These CFs are primarily intended to be used in combination with dissipation-based methods at the LCI step; that is, they are applicable to dissipative resource flows compiled in LCIs. The rationale is that dissipative flows (or losses; Beylot et al., 2020) of mineral resources are by definition not accessible anymore to humans in a given temporal perspective. This subsequently implies the loss of the value these resources can hold for humans in the technosphere. JRC price-based CFs have been tested so far in combination with the JRC-LCI method. All the flows of different mineral resources dissipated in the inventory phase are translated in an equivalent mass of a reference resource based on their relative values (Ardente et al., 2023). Said in other words, price-based CFs combined with the JRC-LCI method enable to quantify the mineral resource Value Loss along the life cycle of the system under study, expressed e.g., in kg Cu.€eq in case copper is chosen as the reference substance.

Potential for application in combination with other dissipation methods (e.g. the ARP method that classifies dissipative flows at the LCI step) could be further tested as well. Price-based CFs (or underlying price data) are additionally potentially applicable both i) directly with classical LCI datasets that account for resources extracted from ground, and ii) as potential complements to existing LCIA methods not capturing damage to resource value (as done e.g. in the case of the ADR and LPST methods extended to endpoint impact modelling; see in the following).

ADR and LPST

According to Charpentier Poncelet et al. (2022b), the Average Dissipation Rate (ADR) and Lost Potential Service Time (LPST) methods are intended to quantify respectively *"the relative contribution of a product system to the dissipation of mineral resources"*, and "*the relative contribution of a product system to the inaccessibility of mineral resources due to dissipation*". ADR and LPST CFs apply at the impact assessment step in combination with classical approaches for mineral resources elementary flows accounting at the LCI step ("extracted from ground"), as in current standard LCI databases (e.g., ecoinvent or EF).

The associated impact pathway captures the service time (ST) of resources, that is the duration over which resources provide a service within the economy, from their extraction from ecosphere until dissipation after one or several uses. The definition and scope of dissipation is identical to that developed by Beylot et al. (2021). In particular compartments of dissipation are essentially similar to those considered in the JRC-LCI method: final waste disposal facilities, emissions to environment and non-functionally recycled resources. ST is calculated as a function of product lifetimes and dissipation over the resource's life cycle. Dissipation primarily depends on process yields, dissipative uses, and collection and functional recycling rates.

The ADR method corresponds to a rate, by definition, which is the inverse of the total ST. This rate is a snapshot value depicting current status on dissipation and resources lifetimes in the economy, considering current performances in processes (including, recycling) and lifetimes of products extrapolated from now to a long-term horizon. It does not include any prospective scenario on future trends regarding resource applications in the economy and process (including recycling) performances. It was calculated by Charpentier Poncelet et al. (2021, 2022a) through dynamic Material Flow Analyses (MFAs), initially for 18 chemical elements and further updated for 61 elements. Moreover, LPST is a "distance-to-target" concept that is based on the difference between current situation on ST, for each resource, and a hypothetical absence of dissipation over a given temporal horizon (i.e., 100 or 500 years of optimal service time respectively over 100 and 500 years).

Charpentier Poncelet et al. (2022c) additionally suggest an extension from midpoint ADR and LPST CFs to endpoint CFs, intended to "*quantify the relative contribution of a product system to the potential mineral resource value lost due to dissipation*". Extension from midpoint to endpoint is based on price indices (ratio of the price of one metal over the price of a reference metal), conceptually very similar to the price-based CFs of the JRC price-based impact assessment method. The major difference relies on the way these CFs are applied: respectively directly on dissipative resource flows as reported in LCIs (JRC price-based CFs combined with JRC-LCI method; in Beylot et al., 2020a and Ardente et al., 2023), or in combination with midpoint ADR and LPST CFs which apply to resources extracted from ground in LCIs (in Charpentier Poncelet et al., 2022b).

6.4 Annex to Chapter 3.2.3

1 - Proposal (inspired by Catena X)

It follows this general hierarchy:

1. Subdivision
2. System expansion
3. Substitution
4. Allocation

DISCLAIMER: THIS HIERARCHY IS MEANT FOR ATTRIBUTIONAL LCA (WHICH WE ASSUME IS THE MODELLING APPROACH AT LEAST FOR "PRODUCT LCA" OF TRANSENSUS LCA).

THE ISO 14044 DOES NOT DIFFERENTIATE BETWEEN ATTRIBUTIONAL AND CONSEQUENTIAL MODELLING. HOWEVER, THE MODELLING APPROACH MIGHT HAVE CONSEQUENCES ON THE CHOICES TO SOLVE MULTIFUNCTIONALITY PROBLEMS, HENCE THE FOLLOWING HIERARCHY MIGHT NOT BE APPLICABLE IN CASE OF CONSEQUENTIAL MODELLING.

Allocation shall be avoided whenever possible by using :

1 - Subdivision of the multifunctional process into mono-functional processes

Subdivision refers to physical disaggregation of multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. The goal is to end up with two or more unit processes with single functional flows. This can be achieved by better data collection.

Illustrative example:

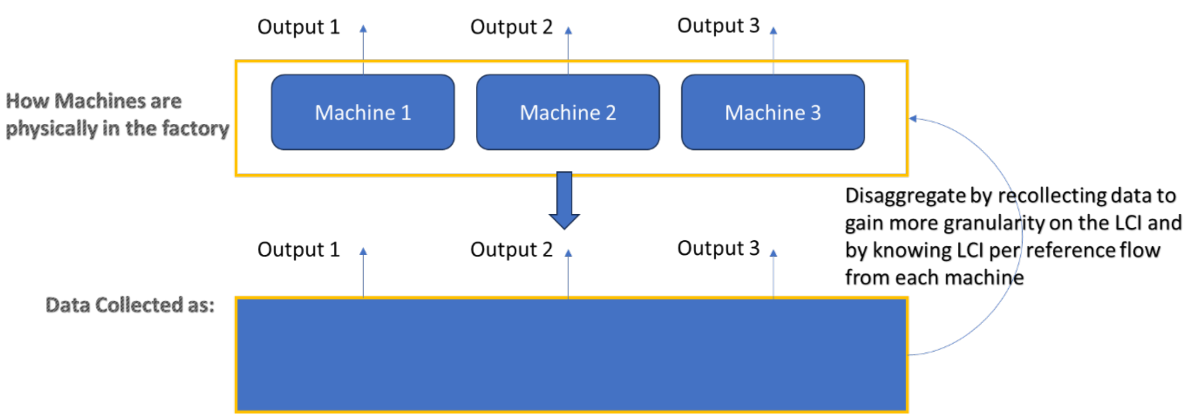


Figure 3-3: Illustration on subdivision

If subdivision is physically not possible or better data collection practice cannot solve the issue, proceed to the next step.

2 - System expansion

System expansion refers to expanding the product system to include the additional functions provided by its co-products[61]. One could also say that system expansion, therefore, models a product system as it exists in reality, i.e. including the multifunctional processes and their co-products as they are. While this approach does not suffer from the limits of the next steps in this hierarchy (substitution and allocation), as it accounts for the system as a whole, it cannot answer the question of the environmental impacts related to just one of the co-products (Figure 3-7). Thus, if the aim of the study is to assess the environmental impacts related to just one of the co-products, system expansion is not the right approach, and the practitioner shall proceed to the next step in the hierarchy.

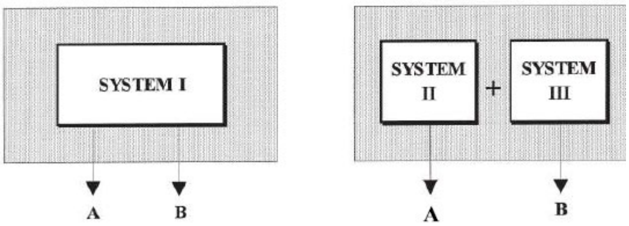


Figure 3-4: Illustration of system expansion. The LCA results of system 1 are the combined impacts of product A + B. In a comparative LCA, system 1 needs to be compared to another (set of) system(s) that provides the same basket of products as system 1.

3 - Substitution (avoided burdens)[62]

When a co-product of a multi-functional process leads to the reduced production of another product from another process, this is called substitution. The substitution approach thus accounts for the replacement of other products by the co-products of the multifunctional process. In this way the multiple functions of the overall system are reduced to a single function, thereby solving the multi-functionality problem. This is also known as the avoided burdens approach as it consists of accounting for the entire burdens of the multifunctional process and then subtracting the burdens of the substituted processes (Figure 3-8).

[61] In industrial processes there may be a wide variety of different types of materials produced in conjunction with the intended product. In business vocabulary, these may be identified as by-products, co-products, intermediate products, non-core products or sub-products. Here, these terms are considered as equivalent.
[62] Practically can also be called “system reduction” as stated by ILCD since something is “subtracted from” and not “added to” the studied system.

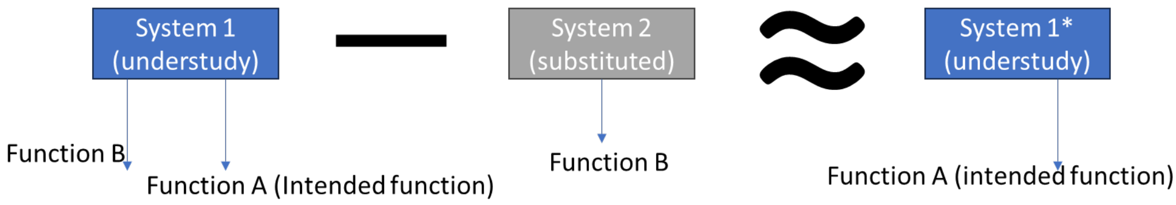


Figure 3-5: Illustration of substitution (avoided burdens approach).

Substitution shall only be used if all the following conditions are met:

1) There is a real, measurable substitution effect: for each co-product, there is an identifiable product that is directly replaced. The utilization of the co-product in another product system shall be proved, for example via contractual ties[63] or receipts. No market-mediated effects shall be considered, i.e. the assumption that a co-product will automatically avoid a specific or the average product from the market is not enough. Instead, the substitution of a specific product shall ensure that the need for the primary product has decreased. This is to avoid claims of substitution that in the end are not real substitutions, but market extensions (simply more of the same product is produced). See extra examples in the Annex.

2) Functional equivalence: each co-product must deliver the exact same function as the substituted product. It must further be available at the same geographical location and time as the substituted product.

3) Data is available: The LCI or emission factors (for TranSensus LCA mandatory impact categories) of the substituted system are available. Market average shall always be used. This is to prevent any attempts to substitute the worst technology.

4) Cascaded multifunctionality is avoided: there is an identifiable primary monofunctional production path that produces the co-product as single product. This is to avoid the need to solve the multifunctionality in a loop of systems which might lead to error propagation and can be out of scope of TranSensus.

Reporting: the assumptions for any substitutions must be reported and clearly documented. Any credits obtained from substitution shall be reported so that it is transparent to which degree substitution affects the overall LCA results.

[63] Any means of demonstrable proof is acceptable. In case of substitution within the same facility, no contractual ties or hard proofs are needed since the substitution effect is self-evident. In fact, this is the ideal case of a substitution.

<u>*Illustrative example 1*</u>:

*"Factory X produces sulfuric acid as a **co-product** of a certain unit process which has Product X as the main product intended from this unit process. In order to use substitution, Condition 1: factory X has to prove that this sulfuric acid is **purchased and consumed** in another factory Y hence reduced the need from primary sulfuric acid in factory Y.*

*Condition 2: "if factory X produces a sulfuric acid of low quality and **NOT** sulfuric acid that is readily available for factory Y. Then, factory Y has yet to apply additional process(s) to obtain high quality sulfuric acid. In this case, factory X cannot claim benefits for avoiding **primary sulfuric acid**."*

Condition 3: "Data in LCI or emission factor form for average sulfuric acid market should be available.

Condition 4: "There must be a way in the real world to obtain sulfuric acid as a primary product"

If these conditions cannot be fulfilled, proceed to the next step.

4 - Allocation

When allocation cannot be avoided, the LCA practitioner shall calculate the ratio of the economic value of the reference product (main product) to each co-product. The economic value is calculated as:

$$\text{Economic Value} = \text{Price} * \text{Flow quantity (e.g., in pieces, kg, m}^3\text{)}$$

This ratio is employed in the next step to determine the most suitable allocation approach. For the calculation of economic values, prices shall be averaged over the **last 5 years** to smoothen fluctuations. The following hierarchy is to be followed for to determine the prices:

1) Global market price[64]
2) Regional market price
3) Sales price

Finally, if sales prices are not available or not applicable, other economic factors (e.g., cost) can be applied to calculate the economic value in the equation above.

[64] Note that global market prices are usually only available for commodities.

If the calculated economic value ratio is **higher than four**[65], economic allocation shall be applied using economic value as criterion to partition inputs and outputs between the studied product and the co-product(s).

If the calculated economic value ratio is **equal or lower than four**, allocation shall be applied using a physical relationship to partition inputs and outputs between the studied co- product(s). The relationships to choose from are based on what is most suitable to the specific case according to the LCA practitioner:

▪ Produced pieces ▪ Produced masses ▪ Contained exergy ▪ Contained energy

If no underlying physical relationship between the co-products can be identified, economic allocation may still be used as the last option.

Illustrative examples:

Example 1: "if the sulfuric acid from factory X is coproduced with another product that is inherently defined by its mass (e.g. metal), then mass-based allocation can be applied. Contained energy is maybe not a good choice since it is not an inherent property of either product. This shall be done only after ensuring economic value ratio ≤ 4 between the sulfuric acid and the metal"

More examples on choosing the best physical relationship:

Example 1: "In a combined heat and power plant (CHP), contained exergy is perhaps the best choice that accounts for the different nature of electricity and heat although both are forms for energy"

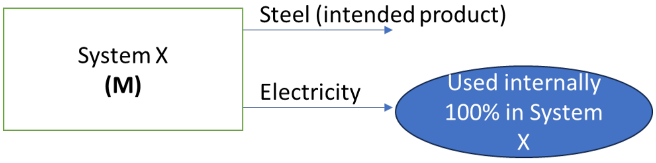
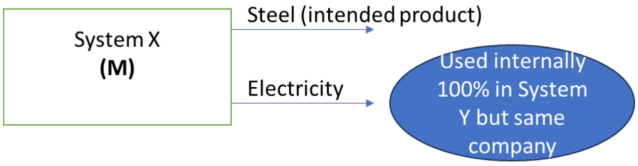
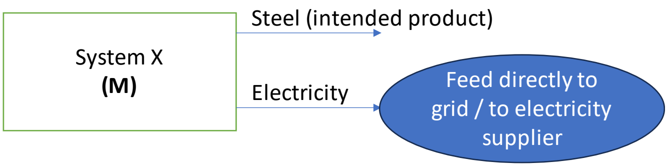
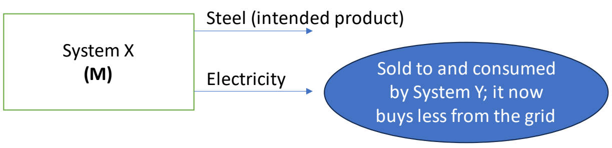
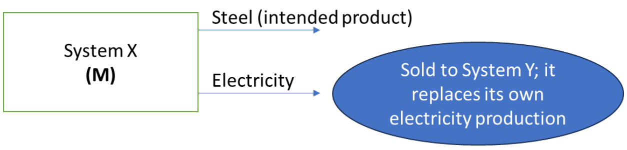
Example 2: "in case of an oil refinery where multiple types of fuels are produced, contained energy might be the reasonable solution that reflects the inherent/most important property of the products"

Reporting: the allocation approach and the allocation factors shall be reported transparently. This includes the prices or the other economic property (e.g. process cost) used and their sources.

[65] The factor 4 is the dominant value in most of guidelines reviewed. This is can be brought back to the consideration of 25% as a threshold for significant economic difference found in literature (ISO, 2021; Santero & Hendry, 2016)

Additional information:

Table 3-3: More illustrative examples of condition 1

Case	Contract or other demonstrable proof available?	Condition one (substitution effect) satisfied?	Notes
	NO	Not applicable.	This is a closed loop since the electricity is used within the system boundary. No problem to solve.
	NO since it is the same company	Yes.	This is self-evident. It can be physically seen.
	Yes	NO.	unless it can be proven that it decreases electricity production from primary sources
	Yes	Yes	Clear case of condition 1 satisfaction
	Yes	Yes	When modelled market average LCI or emission factor shall be used although it replaces a specific technology

6.5 Annex to Chapter 3.2.4

Table 3-4. Level concept as proposed by the UNECE working group and as adopted by TranSensus LCA (see SG4 - 3nd meeting - Transport - Vehicle Regulations - UNECE Wiki)

SUPPLY CHAIN & PRODUCTION	Possible Comparison[1)]	Vehicle modelling	Representativeness[2)]	Supply chain modelling	OEM manufacturing Processes	Supplier manufacturing process	Individual decarbonisation measures
Level 1	General concept of drivetrains (e.g. BEV vs. ICEV)	Generic material composition & average vehicle curb weight	Global average / regional	generic footprint per kg of vehicle curb weight			none
Level 2	General concept of drivetrains (e.g. BEV vs. ICEV) based on exemplary „real" car vehicle model	BOM & Material information system (CMDS / IMDS[3)])	Global average / regional	global secondary data material footprints (incl. generic information for production processes)			none
Level 3	A representative vehicle of OEM A VS A representative vehicle of OEM B	BOM & Material information system (CMDS / IMDS) & „part-by-part" for hotspots	Regional & individual SC for hotspots	primary information for the vehicle hotspot parts	Optional: primary data for OEM's inhouse hotspot processes	primary information for the manufacturing of vehicle hotspot parts	included
				secondary information for the rest	Secondary information for the rest or average values per vehicle from OEM's Scope 1 & 2 emissions	secondary information for the rest	
Level 4	e.g. OEM A's BEV model vs. OEM B's BEV model	BOM („part-by-part")	individual SC	regional or primary data based part (& material) footprints	included	included	included

Table 3-5. Decomposition tree (zoom on the traction battery with Battery Regulation data requirements requirements)

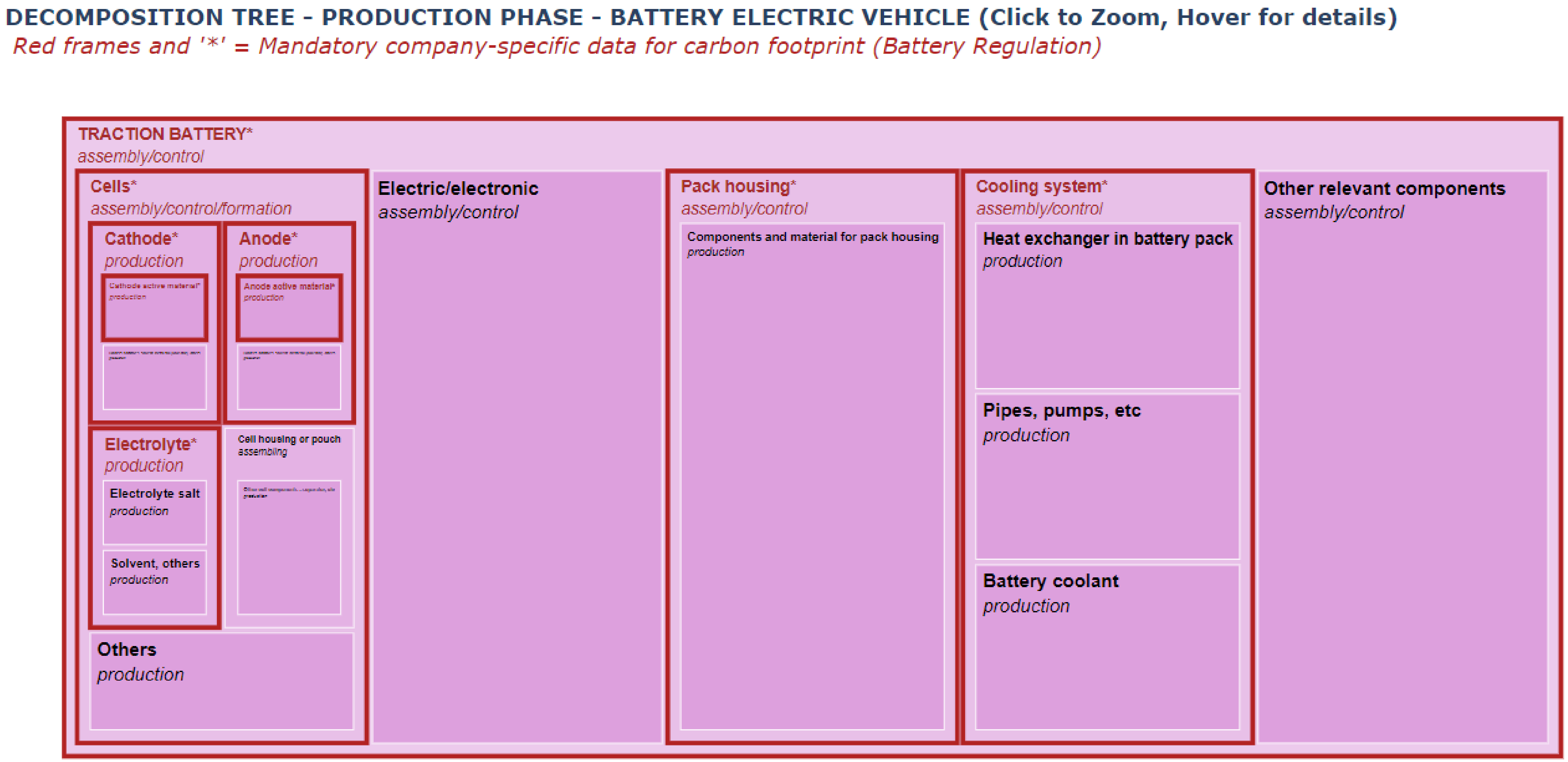


Table 3-6. Example of maintenance and servicing requirements for a passenger car (Source: UNECE A-LCA IWG: SG4 - 7th meeting - Transport - Vehicle Regulations - UNECE Wiki)

Passenger car example

	M1	Tracks	moto
Oilfilter	○	○	○
air cleaner element	○	○	○
fuel filter	○	○	○
timing belt	○	○	○
spark plug	○	-	○
Disk Pad (Front Wheel)	○	○	○
Brake shoe (rear wheel)	○	○	○
MT Clutch Plate	-	○	-
Regulator	-	○	-
Chain for driving vehicle body side	-	-	○
engine oil	○	○	○
brake fluid	○	○	○
Long Life Coolant	○	○	○
Tires	○	○	○
Auxiliary Battery (Lead Battery)	○	○	○
MT Mission Oil	-	○	-
AT Oil	-	○	-
differential oil	-	○	-

	BEVs		Gasoline ICEVs		Diesel ICEVs	
Maintenance Request	Mileage	Time	Mileage	Time	Mileage	Time
Passenger Air Filter	36,000 km	2 years	36,000 km	2 years	72,000 km	2 years
Electric Drive Unit Fluid	72,000 km	-	-	-	-	-
Hood Lift Support Gas Struts	161,000 km	10 years	161,000 km	10 years	-	-
Body Lift Support Gas Struts	161,000 km	10 years	161,000 km	10 years	-	-
Coolant Circuits	240,000 km	5 years	-	-	-	-
Brake Fluids	-	5 years	-	5 years	156,000 km	5 years
Air Conidtioning Desiccant	-	7 years	-	7 years	-	7 years
Engine Filter	-	-	12,000 km	12 months	12,000 km	12 months
Engine Oil	-	-	12,000 km	12 months	12,000 km	12 months
Engine Air Filter	-	-	12,000 km to 24,000 km	-	72,000 km	4 years
Automatic Transmission Fluid	-	-	72,000 km	-	-	-
Automatic Transmission Filter	-	-	72,000 km	-	-	-
Spark Plugs	-	-	96,000 km to 156,000 km	-	-	-
Transfer Case Fluid (if 4WD)	-	-	161,000 km	-	72,000 km	24 months
Rear Axle Fluid (if AWD)	-	-	240,000 km	-	-	-
Engine Cooling System	-	-	240,000 km	6 years	240,000 km	6 years
Fuel Filter	-	-	-	-	36,000 km	2 years
Front Axle Oil	-	-	-	-	96,000 km to 156,000 km	12 months
Front Axle Bearing Grease	-	-	-	-	156,000 km	12 months
Power Steering Fluid	-	-	-	-	144,000 km	-
Power Steering Filter	-	-	-	-	144,000 km	-
Windshield Wiper Blades	-	-	-	-	12,000 km	6 months

6.6 Annex 1 to Chapter 4.2.3: Full Guidance on Multifunctionality

DISCLAIMER # 1: This guidance to solve multifunctionality problems is the fourth step of a framework to identify and solve a multifunctional problem adapted from j. Guinée et al., (2021) (SEE ANNEX 1.1 FOR INFORMATION AND IMPORTANT DEFINITIONS).

DISCLAIMER #2: This guidance is meant for attributional LCA (The modelling approach decided for TranSensus LCA)

1. General Hierarchy

To be employed in all cases of MF except for the End of life.

Summary of the hierarchy:

1. Subdivision
2. System expansion
3. Substitution
4. Allocation

Allocation shall be avoided whenever possible by using:

1-Subdivision of the multifunctional process into mono-functional processes

Subdivision refers to physical disaggregation of multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. The goal is to end up with two or more unit processes with single functional flows. This can be achieved by better data collection (Figure 4-10).

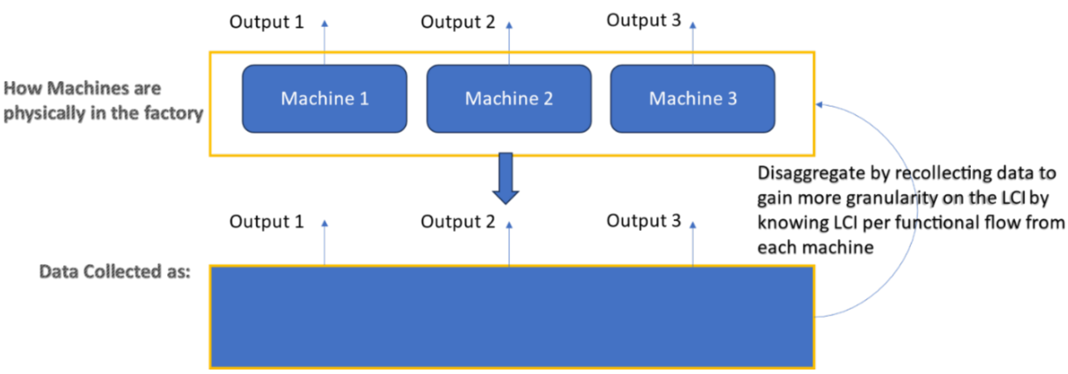


Figure 4-6 : Illustrative example on subdivision

If subdivision is physically not possible or better data collection practice cannot solve the issue, proceed to the next step.

2-System expansion

System expansion refers to expanding the product system to include the additional functions provided by its functional flows or in business terms: co-products[66] in case of co-production process.

One could also say that system expansion, therefore, models a product system as it exists in reality, i.e. including the multifunctional processes and their co-products as they are. While this approach does not suffer from the limits of the next steps in this hierarchy (substitution and allocation) as it accounts for the system as a whole, it cannot answer the question of the environmental impacts related to just one of the functional flows (Figure 4-11). Thus, if the aim of the study is to assess the environmental impacts related to just one of the functional flows, system expansion is not the right approach, and the practitioner shall proceed to the next step in the hierarchy.

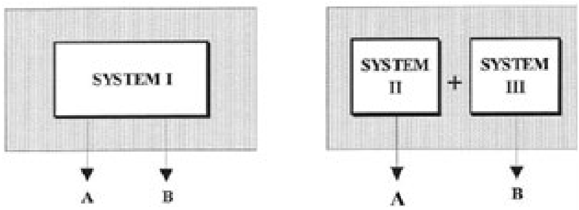


Figure 4-7 : Illustration of system expansion. The LCA results of system 1 are the combined impacts of product A + B. In a comparative LCA, system 1 needs to be compared to another (set of) system(s) that provides the same basket of products as system 1

3-Substitution (avoided burdens)[67]

When a functional flow of a multi-functional process leads to the reduced production of another product from another system, this is called substitution. The substitution approach thus accounts for the replacement of other products by the co-products of the multifunctional process. In this way, the multiple functions of the overall system are reduced to a single function, thereby solving the multi-functionality problem. This is also known as the avoided burdens approach as it consists of accounting for the entire burdens of the multifunctional process and then subtracting the burdens of the substituted processes (Figure 4-12). While some scholars argue that substitution concept in general is only suitable for consequential modelling (Schrijvers et al., 2016a), other references allow it in attributional modelling under certain conditions (EC-JRC, 2010; Koffler and Finkbeiner, 2018). In practice, it is widely used in attributional modelling (Provost-

[66] In industrial processes there may be a wide variety of different types of materials produced in conjunction with the intended product. In business vocabulary, these may be identified as by-products, co-products, intermediate products, non-core products or sub-products. Here, these terms are considered as equivalent.
[67] Practically can also be called “system reduction” as stated by ILCD since something is “subtracted from” and not “added to” the studied system.

Savard and Majeau-Bettez, 2024). Therefore, we allow it here but under some conditions and safeguards.

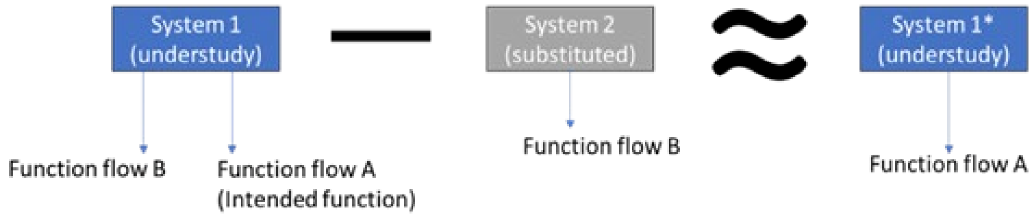


Figure 4-8 : Illustration of substitution (avoided burdens approach)

Substitution shall only be used if all the following conditions are met:

1) There is a real, measurable substitution effect[68]: for each co-product (functional flow B in Figure 4-12 example), there is an identifiable product that is directly replaced. The utilization of the co-product in another product system shall be proved, for example via contractual ties[69] or receipts. No market-mediated effects shall be considered, i.e. the assumption that a co-product will automatically avoid a specific or the average product from the market is not enough. Instead, the substitution of a specific product shall ensure that the need for the primary product has decreased. This is to avoid claims of substitution that in the end are not real substitutions, but market extensions (simply more of the same product is produced). See extra examples in Annex 1.2.

2) Functional equivalence: each co-product (functional flow B in Figure 4-12 example) must deliver the exact same function as the substituted product. It must also be available at the same geographical location and time as the substituted product.

3) Data is available: The LCI or emission factors (for TranSensus LCA mandatory impact categories) of the substituted system are available. Market average shall always be used. This is to prevent any attempts to substitute the worst technology. Also following ILCD handbook "C1" decision making situation (EC-JRC, 2010).

4) Cascaded multifunctionality is avoided: there is an identifiable primary monofunctional production path that produces the co-product (functional flow B in Figure 4-12 example) as single product. This is to avoid the need to solve the multifunctionality in a loop of systems which might lead to error propagation and can be out of scope of TranSensus.

[68] it is not the job of attributional modelling to quantify the impact of substitution on societal level (Koffler and Finkbeiner, 2018). Therefore here we follow the concept of (Zink et al., 2018, 2016; Zink and Geyer, 2017) which argue that unless a true displacement of primary material in the market takes place, the environmental benefit is diminished or relinquished entirely

[69] Any means of demonstrable proof is acceptable. In case of substitution within the same facility, no contractual ties or hard proofs are needed since the substitution effect is self-evident. In fact, this is the ideal case of a substitution.

Any assumptions related to substitution must be clearly documented. Any credits obtained from substitution shall be documented so that it is transparent to which degree substitution affects the overall LCA results.

> *Illustrative example on the conditions for substitution:*
>
> *"Factory X produces sulfuric acid as a **co-product** of a certain unit process which has Product X as the main product intended from this unit process." In order to use substitution:*
>
> *Condition 1: factory X has to prove that this sulfuric acid is **purchased and consumed** in another factory Y hence reduced the need from primary sulfuric acid in factory Y.*
>
> *Condition 2: "if factory X produces a sulfuric acid of low quality and **NOT** sulfuric acid that is readily available for factory Y. Then, factory Y has yet to apply additional process(s) to obtain high quality sulfuric acid. In this case, factory X cannot claim benefits for avoiding **primary sulfuric acid**."*
>
> *Condition 3: "Data in LCI or emission factor form for average sulfuric acid market should be available.*
>
> *Condition 4: "There must be a way in the real world to obtain sulfuric acid as a primary product"*

If these conditions cannot be fulfilled, allocation is to be followed.

4-Allocation

When allocation cannot be avoided, the LCA practitioner shall calculate the economic value of each functional flow. The economic value is calculated as:

$$\textit{Economic Value}\ (€) = \textit{economic factor}\ (€/\text{piece or kg, } m^3 \text{ ..etc}) * \textit{flow quantity}\ (\text{e.g., in pieces, kg, } m^3)$$

Equation 4-1 : Calculating economic value

For the calculation of economic values, the following hierarchy is to be followed to determine the "*economic factor*" in equation 4-1:

1. Global market price[70]
2. Regional market price
3. Processing cost[71]
4. Other factors (e.g. Sales price)

This hierarchy is meant to strike a balance between transparency, level of uncertainty and accessibility beyond industry. The first two options are openly available to everyone, and process cost comes before sales price because it is less volatile and more transparent. Only if the

[70] Note that global market prices are usually only available for commodities.
[71] Unlike price, this refers to expenditure rather than proceeds. It comprises 1) the real costs of processing the input material in this unit process until and including the production of output 2) to treat waste and residues and 3) all potential losses.

respective prioritized factor is not available, the next factor in the hierarchy may be chosen. The chosen factor shall always be averaged over the last 5 years to smoothen fluctuations.

If the calculated economic value ratio between *any of* the functional flows is **higher than four**[72], economic allocation shall be applied consistently on the entire unit process using economic value as a criterion to partition the inventory between the functional flows following the equation:

$$Allocation\ factor\ (functional\ flow\ n) = \frac{Economic\ value\ of\ function\ flow\ (n)}{\sum_1^n Economic\ values}$$

Equation 4-2 : Calculating economic allocation factor

If the calculated economic value ratio is **equal to or lower than four** between all functional flows, allocation shall be applied using a physical relationship to partition inputs and outputs between the functional flows. The relationships to choose from are based on what is most suitable to the specific case:

▪ Produced pieces ▪ Produced masses ▪ Contained exergy ▪ Contained energy

Table 4 in annex 1.2 provides a list of which physical relationship shall be followed in some of the typical situations. If the case under study does not fit in any situation in the table, it is up to the LCA practitioner to choose the most suitable physical relationship.

> *Illustrative example on choosing the best physical relationship :*
>
> *Example 1: "if the sulfuric acid from factory X is coproduced with another product that is inherently defined by its mass (e.g. metal), then mass-based allocation can be applied. Contained energy is not a good choice since it is not an inherent property of either product.* ***This shall be done only after ensuring economic value ratio ≤ 4 between the sulfuric acid and the metal"***

[72] The factor 4 is the dominant value in most of guidelines reviewed. This is can be brought back to the consideration of 25% as a threshold for significant economic difference found in literature (European Union, 2021; Santero and Hendry, 2016)

More examples on choosing the best physical relationship (from other fields):

Example 1: "In a combined heat and power plant (CHP), contained exergy is perhaps the best choice that accounts for the different nature of electricity and heat although both are forms for energy"

Example 2: "in the case of an oil refinery where multiple types of fuels are produced, contained energy might be the reasonable solution that reflects the inherent/most important property of the products"

"

Finally, if no underlying physical relationship between the functional flows can be identified, economic allocation may still be used as the last option following equations 1 and 2 to calculate allocation factors.

The allocation approach and the allocation factors shall be documented transparently. This includes the prices or the other economic property (e.g. process cost) used and their sources, in addition to the chosen physical relationship in case of physical allocation.

2. The exceptional case of the End of life

Multifunctionality in the end of life (EoL) of a vehicle or battery shall be dealt with using the cut-off approach which is also referred to as "recycled content" or "100:0" approach. Future updates of the TranSensus LCA method can consider shifting to the Circular Footprint Formula (CFF) if its applicability is improved in the future. The cut-off point shall come at least after sufficient separation and sorting including all transportation until this point. In practice, this means the processes of collection, pretreatment, dismantling and shredding. After this, the exact position shall be based on the market value of each individual waste stream resulting from previous processes. This is the point where the waste stream goes from a "waste" with negative market value to a "good" with positive market value (see annex 1 for more information). This applies to open-loop reuse, recycling and energy recovery systems. Co-products of waste treatment that can clearly be identified as sellable products (i.e. with a positive market value) shall be cut-off (i.e. they will come burden-free for the subsequent product system that uses them). In the case of energy recovery, such sellable products are heat and/or electricity. In case the market value of a waste or product flow cannot easily be determined, and as a last resort, we provide a general vehicle EoL management scheme with preset cut-off points for typical waste streams (Figure 4-15).

Context

Multifunctionality in the end of life of a vehicle or battery typically arises from open-loop recycling producing secondary materials, and/or open-loop energy recovery from incineration (electric or heat energy) and landfilling (via biogas collection), and/or open-loop reuse (second use in another system or life cycle). This means that in addition to the function identified in the functional unit, there are additional functions delivered to another subsequent system[73], therefore there is a need to allocate burdens and benefits between the system understudy and any subsequent systems that will use these secondary commodities.

The cut-off approach which is also referred to as "recycled content" or "100:0" approach (Frischknecht, 2010; Schrijvers et al., 2016b, 2016a) excludes any additional functions that might arise from waste treatment from the first life cycle, hence attributing the impact of obtaining these co-functions entirely to the function of the system understudy (i.e. the waste-generating system) until what is known as the "cut-off point", after which the resulting co-functions (i.e. recyclable materials or energy) come "burden-free" for a subsequent system to use as input (Nordelöf et al., 2019; Schrijvers et al., 2016b; Zackrisson et al., 2010). Consequently, this approach follows the polluter pay principle as indicated in the international EPD program (EPD, 2021) and modules A to C in EN 15804 (European Union, 2021). The cut-off approach is mentioned in ISO 14067 (ISO, 2018) under the name "process subdivision" which makes it also compatible with ISO 14044 (ISO, 2020) as stated by Schrijvers et al., (2016b). See a simple depiction of the cut-off approach in Figure 4-13.

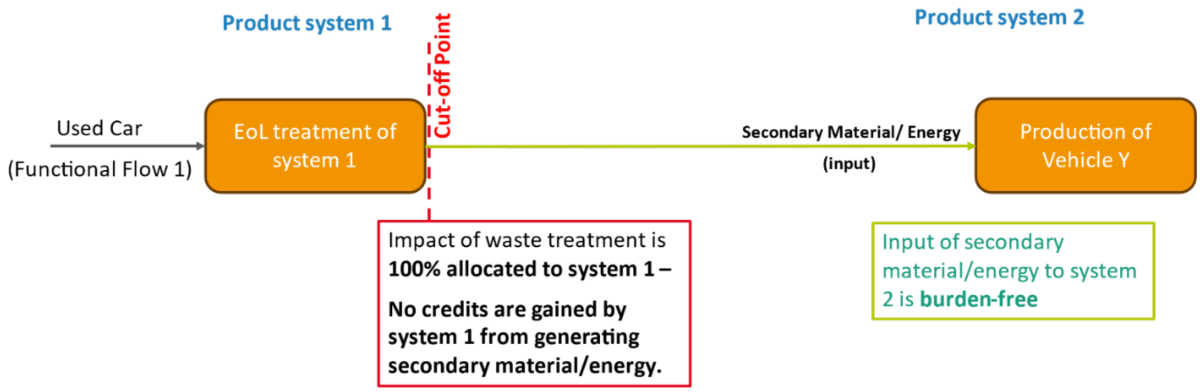


Figure 4-9 : Depiction of cut-off approach

The cut-off approach is typically associated with a simple application and environmental conservativeness. As indicated by Frischknecht, (2010), it adopts a risk-averse approach as it aims not to shift any burdens into the future. Moreover, it follows what's called the "strong sustainability" concept which considers that natural capital shall be kept constant, independent of man-made capital (non-substitutability concept) (Frischknecht, 2010). The cut-off approach is a

[73] This is not the case for 100% closed loop reuse, recycling or energy recovery where secondary commodities generated are explicitly consumed within the system boundary of the same system generating it, hence no multifunctionality problem to start with because these flows never cross its system boundary to another system or to the market.

default choice when companies have control over the recycled content in their product (to balance the cycle upstream with burden-free recycled content input), when the time frame of the life cycle is very long (increased uncertainty about the future), or in a market with a higher supply than demand for the recycled material (providing a balance by encouraging the consumption of recycled material) (Schrijvers et al., 2016a). At least the first two conditions apply in the case of vehicles. Moreover, it fits into an attributional LCA context (Ekvall et al., 2020).

The Circular Footprint Formula (CFF) is not part of the TranSensus LCA method in this current version, however it is to be considered in the future if improvements are carried out on the formula, especially those related to applicability and complexity concerns (Ekvall et al., 2020) (See also Deliverable D1.1 and D2.2 for more information)

Cut-off point

The cut-off point is the point where the system boundary of the waste-generating system ends, and outputs come burden-free to other systems. The cut-off point can lie immediately after the use stage ceases (Frischknecht, 2010) or at any point of the waste treatment value chain after. (Nordelöf et al., 2019; Schrijvers et al., 2016b). The former, however, aligns neither with the aspired conservativeness discussed above (because it still shifts impacts to the future), nor with the system boundary decided in TranSensus LCA (i.e. cradle to grave). Furthermore, it is not the common choice in literature (Catena-X Automotive Network, 2023; Filière automobile & mobilités (PFA), 2022; Global Battery Alliance (GBA), 2022; Wernet et al., 2016). So, TranSensus LCA opted for the latter option.

For used ZEVs, the EoL value chain can get quite complex, so at least a handful of pre-treatment processes always exist. This typically includes at least collection, pretreatment (depollution), dismantling, shredding (ISO, 2002; The European Parliament, 2000). It was agreed in TranSensus LCA that the impact of these activities including the transportation in between are always attributed to the EoL of the product under study (i.e. waste generating system). An obvious reason to model the EoL at least until sufficient sorting and separation[74] is to make a clear distinction between the types of resulting waste streams whether it is recyclable materials or non-recyclable materials for incineration or landfilling (Nordelöf et al., 2019).

Given the variability of the subsequent activities that each waste stream goes through, we adopt the “market value” as a general reference to determine where the cut-off point should ideally be for each waste stream resulting from pretreatment, dismantling, and shredding. The market value can be perceived as a numerical translation of the End of Waste (EoW) status condition of having an existing market or demand for the substance or object (EPD, 2021; European Council, 2008). This means that the generator of the waste shall bear the full environmental impacts until the point in the product life cycle in which the waste stream no longer has negative

[74] ecoinvent cut-off system model places the cut-off point after vehicle shredding and sufficient separation and sorting (Wernet et al., 2016)

market value. Negative market value comes from the fact that money must be paid to get rid of the waste. In other words, moving from "waste" to "good" following the terminology of Guinée et al., (2004) which associates a "good" with positive market value and a "waste" with negative market value (see annex 1). In case the positive value is obtained for a waste stream immediately after pretreatment, dismantling or shredding, then this becomes its cut-off point.

If it is impossible to follow the economic value of a certain flow, it was decided within TranSensus LCA to provide general vehicle EoL management scheme with preset cut-off points (Figure 4-15). It was developed considering the ELV directive (The European Parliament, 2000), and ISO 22628 (annex B) (ISO, 2002) and with further input from Accardo et al., (2023). For each waste stream, we provide a default cut-off point striking the balance between conservativeness and compatibility with current practices (e.g. databases). For example, for conservativeness, we mandate that incineration should always be borne by the waste-generating system, but on the other hand advanced material recycling lies within the boundary of the subsequent system which is the common practice (e.g. ecoinvent).

This reference model can be used partially (if market value of ***some*** waste streams are hard to trace) or fully (if market value of ***all*** waste streams are hard to trace).

Acknowledged risks in application

The main limitation of this approach is potential double counting or between-systems treatment processes omission. The first is expected when the subsequent system (could be other industries than automotives) accounts for impacts that were already accounted for in the first life cycle. The omission of in-between processes is the other face of the same coin, when material flows enter the next system burden-free without ensuring that all processes leading to these flows were considered (i.e. knowing where the EoL of previous system ceased). Until a global harmonization of cut-off points across sectors is realized, this problem will persist.

Currently, OEM LCA practitioners mostly use secondary datasets to model the supply chain of the recycled material (e.g. an average of EU recycling processes for a certain material). The exact source of the recycled material is often unknown as it is bought from a scrap market (in case of steel or aluminium for example). The recycled material enters the OEM's system boundary "burden-free" but the impact of necessary processing steps to produce the final recycled component must be accounted for by the OEM. Moreover, it is always recommended to read the documentation of used commercial datasets to explore what activities are already included there and what might need to be added. This practice is crucial to reduce the aforementioned risk of both double counting and omission. This will appear in the impact distribution between production and EoL stages like in Figure 4-14.

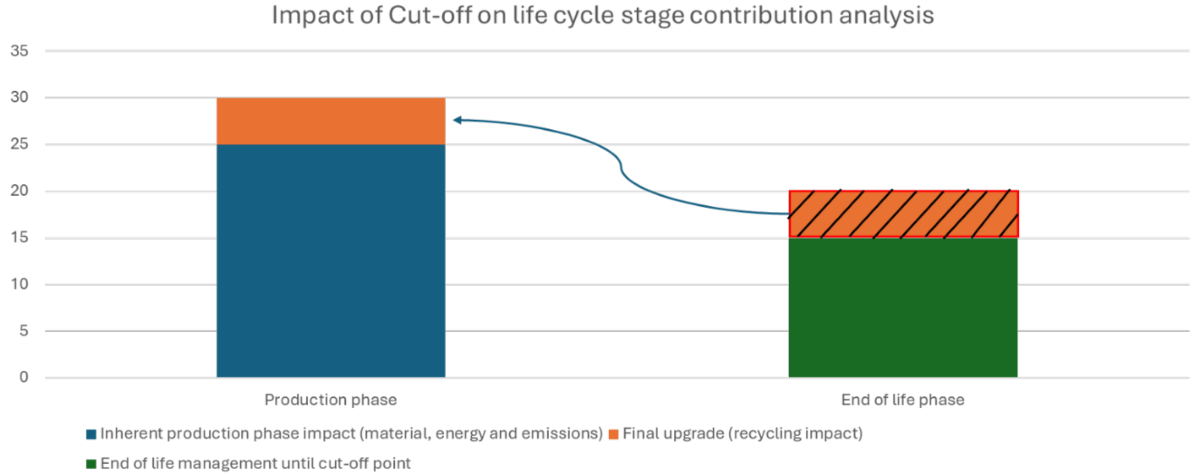


Figure 4-10 : Expected effect of cut-off approach on the impact distribution between production phase and end of life phase

Stepwise procedure for implementation

1. Model EoL until sufficient sorting that leads to distinct waste streams (incl. all transportation). This includes the processes: collection, pretreatment, dismantling and shredding.
2. After having clear waste streams, follow the market value of each waste stream (with negative market value) until it turns positive. This is where the point of cut-off should be placed for that flow. Market values should be based on market investigations of each waste stream (knowing who pays to whom).
3. If the point of cut-off cannot be determined via this procedure, e.g. because it proves difficult to determine the market value, use the general reference model provided in Figure 4-15 to determine the cut-off point for typical streams.
4. If a recycled content exists in the production/manufacturing phase, the LCA practitioner must account for any additionally needed upgrading/processing of the burden-free input until the intended component of the new vehicle is obtained. Carefully reading datasets documentation is recommended to reduce omission and double counting risks.

General reference for cut-off point (Figure 4-15)

It is important to note we do not mandate Figure 4-15 as a strict EoL model to follow. The EoL model in regards of granularity and fate of waste streams can vary between companies and is subject to regulations in place (e.g. (The European Parliament, 2000). For instance, it is indicated that plastic/polymer fraction of Automotive shredder residues (ASR) go to recycling, this does not mean that the LCA practitioner must model this way. He/she can assume that all ASR go to landfilling (the common practice until 2015) (Accardo et al., 2023).

The aim of this reference EoL model is to provide a guidance on cut-off point for typical waste streams. Therefore, it was attempted to be a comprehensive catalogue in that regard. This reference is to be utilized only for waste streams of which the market value evolution cannot be traced.

Furthermore, the activities in Figure 4-14 should not be perceived as "unit processes". Instead, they represent different stakeholders in the value chain in an economic sense. Which means that, for example, the "glass preparation facility" can be represented by many unit processes in an LCA model.

All transportation (with reasonable assumptions) between facilities is to be included until the cut-off point of the specific stream.

Second life of traction batteries

The two typical modes of giving a battery a second life are: remanufacturing (reusing it again as traction battery) or repurposing (using it for stationary energy storage applications) (DeRousseau et al., 2017). Both possibilities are represented by the term "reuse" in Figure 4-15. Following the cut-off method and the system boundary in TranSensus LCA (Task 2.2), these applications are excluded (no negative emissions credit is given to the first life cycle) in Product LCA type. Nonetheless, according to the cut-off method, the reusable battery comes burden-free for the next application. In case of remanufacturing this is simple to model by replacing a brand-new battery. However, for repurposing it is complex to model because it feeds into the background electricity provision systems which means that systematic modification of electricity background systems is needed. This is not practical, therefore for product LCA, this is to be omitted for simplification. However, this can be explored in scenario analysis, or in the other LCA types (i.e. prospective or fleet level LCA).

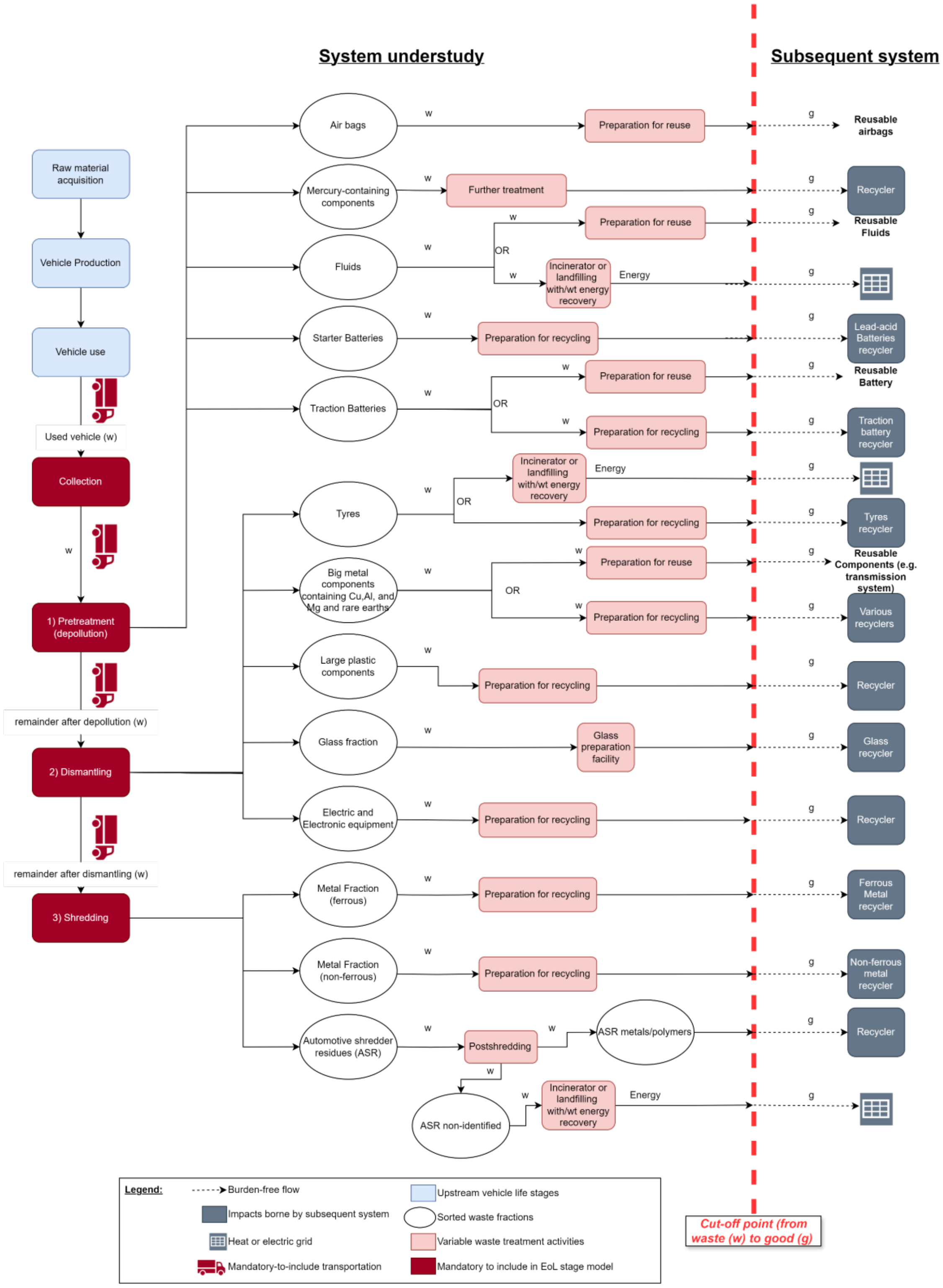


Figure 4-11 : A reference vehicle EoL model (a guide for waste streams whose market values are untraceable)

3. Prospective LCA (pLCA)

The general hierarchy above shall be used in case of conducting a prospective LCA, however we provide additional considerations (Table 4-5) that LCA practitioners should heed to. These considerations can be translated into parameters and combined into scenarios to be explored within a prospective LCA.

Table 4-7 : pLCA Multifunctionality additional considerations

Multifunctionality solution	Questions to be considered (for system understudy)	Questions to be considered (for reference system in case of comparison)
System expansion	Would the multiple functions provided by the system change in the future?	Will there be clear mono-functional reference systems in the future to compare with?
Substitution	• Which reference products might change due to quality changes of the output product? • Does the substitution ratio might change due to… o quality changes of the output product? o up-scaling of the process under research? o changes of the input(s) in future?	• Does the process efficiency of the reference process(es) might change in a future scenario? • Do the environmental burdens of the reference process might change in a future scenario?
Economic allocation	• Would the product price change due to… • New applications of secondary by-products (circular economy)? • Technology diffusion? • Changing consumer preferences? • Process improvements?	N.A.
Physical allocation	• Does the future technology setup change the physical flows? • Does upscaling change the physical flows?	N.A.

In the EoL, the cut-off method shall be used as indicated in section 2, however as for the hierarchy, further considerations are pointed out which can be considered in pLCA scenarios:

- Change in recycling technologies in the future
- Change in incineration technologies (e.g. lower emissions)
- Battery second life (repurposing) can be considered by integrating it in future background electricity provision system as a burden-free input. (Figure 4-15)

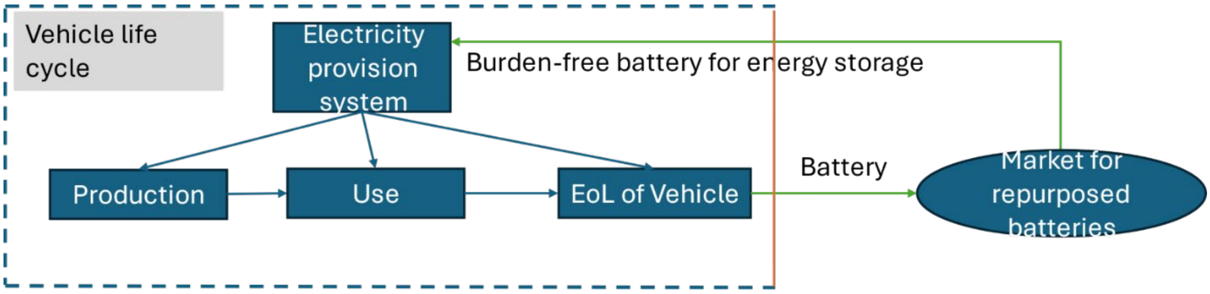


Figure 4-12 : A way to consider the benefits of traction battery repurposing (for stationary applications) in the vehicle prospective life cycle assessment (pLCA for a vehicle)

4. Fleet Level LCA

Given the overall attributional approach of TranSensus LCA, the rules of dealing with multi-functionality should not change from what is stated in section 1 and 2. However, in Macro fleet-level LCA, overlooking the strict substitution condition number 1 (i.e. There is a real, measurable substitution effect) can be accepted if justified and clearly stated.

A possible novel multifunctional situation in fleet-level LCAs is vehicle to grid services (V2G) which are expected to be a possible scenario in future fleet level studies. The hierarchy as in section 1 should be sufficient to deal with the situation.

The rules to deal with end of life in section 2 still apply in fleet-level LCA. If second life of batteries are part of the main system or tested in a scenario, it should be handled the same way as mentioned in pLCA section number 3.

Annex 1.1: Determining a multifunctionality problem [Step 1 – 3] adapted from (Guinée et al., 2018)

The definition of what a multifunctionality problem exactly comprises of is crucial for any scientific approach trying to deal with it, which is often lacking in many approaches to multifunctionality today. The first definition to be introduced is that of 'economic flow' (Guinée et al., 2002):

- **Economic flow**: a flow of goods, materials, services, energy or waste from one unit process[75] to another, with either a positive (e.g. steel, transportation) or zero/negative (e.g. waste) economic value.

In follow-up work, (Guinée et al., 2004), building on previous work by Huppes (1992, 1993, 1994), introduced the concept of functional flow to define the problem of multifunctionality in an encompassing way, including co-production, combined waste processing, recycling as well as any combination of these three typologies of multifunctional processes. They introduced several other basic definitions:

- **Functional flow**: any of the (economic) flows of a unit process that constitute its goal (or part of its goal), viz. the product outflows (including services) of a production process and the waste inflows of a waste treatment process.
- **Non-functional flow:** any of the flows of a unit process that are not a functional flow. These include product inflows and waste outflows, as well as elementary inflows and outflows (natural resources and pollutants).

What is important to note is that a flow is not intrinsically a functional flow, but only with respect to a certain unit process. An outflow that is a functional flow for one unit process is a non-functional inflow for one or more other unit processes, and an inflow that is a functional flow for a specific unit process is a non-functional outflow for one or more other unit processes.

Since the TranSensus LCA method is meant for process-based LCA[76], the multifunctionality issue should be dealt with on the unit process level where every unit process in the LCA model needs to be investigated for potential multifunctionality.

- **Multifunctional process**: a unit process yielding more than one functional flow.

Bearing these definitions in mind, multi-functionality problems can be identified for each LCA study in practice by going through the following three steps:

1. **The identification of each flow between two processes as either a product or a waste.**

[75] smallest element considered in the LCI for which input and output data are quantified. (ISO, 2020)

[76] process-based LCA (with unit processes as building blocks) as conceived by the Society of Environmental Toxicology and Chemistry (SETAC) and ISO which is different from input/output-based LCAs.

A product is a flow between two processes with an economic value higher than or equal to zero, whereas a waste is a flow between two processes with an economic value smaller than zero. Note that any other criterion to distinguish between products and wastes could be applied as long as it can be consistently applied over different product systems.

2. **The identification of a process' functional flow(s).**

   Having identified product and waste flows, the functional flow(s) of each process can now be identified: these are either products that are produced by a process or wastes that are treated by a process. Note that every process needs at least one functional flow.

3. **The identification of multi-functional processes.**

   Having identified the functional flows of all processes, multifunctional processes can now be identified: they are unit processes yielding more than one functional flow.

There can be different typologies of multi-functional problems. Depending on the number of functional flows and the combination of functional flows, co-production, combined waste processing, recycling and all sorts of combinations of these three typologies can be distinguished. Table 4-6 summarizes these typologies, while also including a mono-functional production process as well as a mono-functional waste process as references and only including one example of a combination of the three basic typologies.

Table 4-8 : Typologies of mono- and multi-functional processes

Typology #	Typology	Example*	Functional Flow(s)	#Functions
1	Mono-functional production process		g4	1
2	**Co-production process**		**g4;g5**	**2**
3	Mono-functional waste process		w1	1
4	**Combined waste processing**		**w1;w2**	**2**
5	**Recycling**		**w1;g3**	**2**

6	**Combined waste processing and recycling**		**w1;w2;g2;g3**	**4**

*g=good; w=waste

Annex 1.2: Supplementary information

Table 4-9 : More illustrative examples of condition 1 of substitution (coproduction of electricity is chosen because of its complexity, however in reality it is not expected to occur in the foreground system unless in the End of life (i.e. energy recovery), in this case the EoL exception applies and not the hierarchy.)

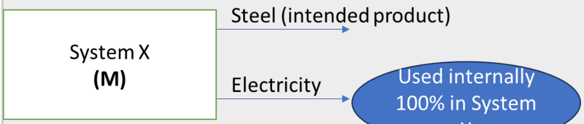
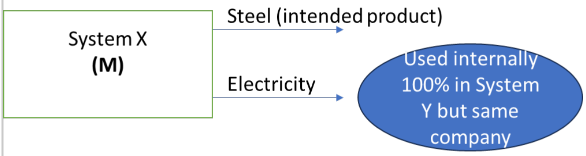
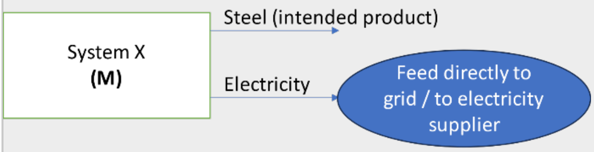
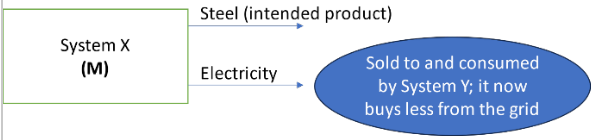
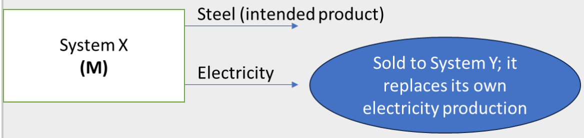
Case	Contract or other demonstrable proof available?	Condition one (substitution effect) satisfied?	Notes
	NO	Not applicable.	This is a closed loop since the electricity is used within the system boundary. No problem to solve.
	NO since it is the same company	Yes.	This is self-evident. It can be physically seen.
	Yes	NO.	unless it can be proven that it decreases electricity production from primary sources
	Yes	Yes	Clear case of condition 1 satisfaction
	Yes	Yes	When modelled market average LCI or emission factor shall be used although it replaces a specific technology

Table 4-10 : Cases where some physical relationships for allocation shall be followed

Case	Mandatory physical relationship
Energy Provision	contained exergy
Metals and alloys coproduction	Mass
Co production of Components	Units/Pieces, mass, other relationship based on engineering judgement
Coating	Coated surface area
Cutting/stamping (e.g. steel sheets)	Final piece area OR Piece perimeter
Vehicle Assembly	Pieces Time Or Mass
Welding	Welding length

Quality checks	Time Or Pieces
Storage	Volume Or Square footage