TranSensus LCA

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Towards a European-wide harmonised transport-specific LCA Approach

TranSensus LCA

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Executive Summary

Introduction

Zero tailpipe emissions vehicles (ZEVs) are a promising option for more sustainable mobility services. More serious action needs to be taken in Europe and globally to foster more sustainable road transportation prioritizing climate-neutrality targets. To this end, decision making processes need to be informed via robust methodologies to evaluate and monitor sustainability performance. Life cycle-based methodologies, such as Life Cycle Assessment (LCA), Social Life Cycle Assessment (S-LCA), and Life Cycle Costing (LCC), are the logical choice as these can provide a holistic sustainability perspective. LCA, S-LCA, and LCC are increasingly used within policy making, industry, and science to obtain sustainability information related to products, services, or technologies, as well as systems on a larger scale, including that of ZEVs. However, not all methods are equally mature (e. g. S-LCA being a newer method) and all methods include a number of choices that can lead to variations in results. Currently, there is not enough harmonization on these choices, which leads to variations in results for one and the same product, hinders the comparability of studies, and limits the usefulness of the methods for guiding decision makers.

TranSensus LCA aims at developing a consensus methodology for environmental LCA of ZEVs as a first priority, but aims also at casting light on similar issues in S-LCA and LCC. The consortium includes influential European partners in the mobility field. This report stands for Deliverable 1.2 of the TranSensus LCA project. It delivers the analysis of needs and gaps for the development of a harmonised LCA/S-LCA approach in the electromobility sector, in the context of the TranSensus LCA project.

Methodological Approach

This study started from the review of current practices on life cycle approaches along the electromobility value chain as reported in TranSensus LCA Deliverable 1.1. It moreover built on outcomes from the following activities, as specifically developed in Task 1.2 in the year 2023:

- Three workshops organized by Task 1.2, which gathered between 10-20 TranSensus LCA WP1/WP2 participants per session;
- A review of product environmental LCAs, complemented by a review of product S-LCAs;
- A survey, followed by targeted interviews;
- A review of position papers.

This final Deliverable 1.2 was eventually obtained in an iterative approach. Two intermediary draft documents were developed essentially by Task 1.2 partners and further circulated to, and open to feedback by, all WP1 and WP2 partners during Task 1.2 realization. This report accordingly benefited from hundreds of amendments as suggested by numerous TranSensus LCA consortium members, before reaching this final, consensual, version.

In this report, Chapter 1 first provides an introduction. Chapter 2 then details the method undertaken in this Task 1.2. Building on the activities led in this Task, Chapter 3 subsequently provides an analysis of the needs the TranSensus LCA method shall seek to cover. Chapter 4 and Chapter 5 moreover describe the gaps the TranSensus LCA method shall overcome towards a harmonised LCA/S-LCA approach in the electromobility sector. Chapter 6 finally provides a final discussion, a synthesis of the main conclusions from this study, and opens to further perspectives in the on-going TranSensus LCA project.

The main needs and gaps identified in Task 1.2 are synthesized in the following sections. This synthesis is to be seen as a first consensus on the key issues the TranSensus LCA project shall address.

Summary of Key Findings regarding needs for the TranSensus LCA method

This study enabled to identify, discuss and define the key needs the TranSensus LCA method shall seek to cover. It simultaneously provided a level of prioritization regarding these needs, as support to the development of the TranSensus LCA method in downstream WPs of the TranSensus LCA project.

As top priority, the TranSensus LCA method, and the resulting studies building on this method, shall be:

- Understandable, i. e. providing clear scope and results to audience (including limitations);
- Standardized, i. e. there shall be one clear, unique, TranSensus LCA method;
- Accurate, i. e. providing indicators close to the actual (true) value of the environmental and social performance of the system analyzed
- Auditable, i. e. with credible verification process (or audits) overcoming the challenge of confidentiality;
- Accepted by the scientific community and industrials;
- Trustworthy, i. e. the audience shall have confidence in how far the outcomes of a study correctly represent the environmental and social impacts of a product.

Of importance but of lower priority, the TranSensus LCA method shall be:

- Aligned with (i) current EU legislations (e. g. Battery Regulation, certification requirements, air pollutant emissions standards, green H2 additionality requirements, etc.) ; (ii) currently accepted LCA guidelines and standards; (iii) international developments (e. g. UNECE work). However in this case misalignment is considered possible whenever this is agreed to add value to the TranSensus LCA method;
- Simple, i. e. implementable easily, including easy verification/audit. However this shall be true as far as simplifications do not prevent the method to be Accurate, Auditable, Reliable and Trustworthy;
- Transparent, i. e. all the methodological choices, assumptions and data quality assessment shall clearly be stated (in the study report, or in the TranSensus LCA method). However a good balance shall be found between "confidence in and confidentiality of" data.

Summary of Key Findings regarding gaps on environmental LCA, and prescriptions for the TranSensus LCA method

This study enabled to identify, discuss and define the key gaps in Environmental LCA that the TranSensus LCA method shall enable to overcome. These key gaps pertain to the four steps of a LCA. In each case of “gaps”, this study additionally discussed prescriptions for the development of the TranSensus LCA method, i. e. reporting some aspects that the TranSensus LCA method shall accordingly include or cover. Task 1.2 enabled to reach a hierarchy in the priority to be given to overcome the identified gaps. Only the gaps and associated prescriptions with high priority are reported in the following conclusions. Other gaps have been identified in Task 1.2, with level of priority from low to medium. They are also extensively discussed in this report.

Goal and Scope definition

Regarding the setting of the functional unit, Task 1.2 identified the lack of a common, harmonized way to account for real-world product performance. This in particular implies the need to set clear rules for setting the lifetime activity of vehicles, and for accounting for the interaction of parts (e. g. batteries) with the overall vehicle system.

Moreover, regarding the setting of the system boundaries, Task 1.2 identified the lack of clear, detailed and agreed rules on inclusion/exclusion of elements. This current gap in particular implies that the TranSensus LCA method shall accordingly, for example, provide clear rules on the inclusion/exclusion of (but not limited to): water and gas cleaning/treatments, real fate of waste and output streams, infrastructure (e. g. charging cables and stations), maintenance, etc.

Life Cycle Inventory

There needs to be an unambiguous, reliable, and commonly agreed approach to solve multi-functionality issues, for both the foreground and background systems. This particularly pertains to raw materials co-production, process lines, parallel use of electric vehicles (e. g. V2G), waste treatment including recycling and battery second life, etc. The resolution of multi-functionality issues shall be linked to the Goal and Scope.

Moreover, regarding primary (supplier-specific) data, clear rules are needed on their mandatory use as opposed to secondary data. This implies that the TranSensus LCA method shall include robust and prescriptive guidelines for: i) data collection (including templates and convention for terminologies), and ii) hierarchy, traceability down to lower-tier suppliers, and verification. For example, for the use phase of the lifecycle, it shall be clear the extent to which “real-world" energy consumption data shall be used, versus data from regulatory cycles. Guidance on the mandatory use of primary data in the TranSensus LCA method shall consider ensuring a good balance between "confidence in and confidentiality of" data.

Moreover, there shall also be clear guidance and rules on secondary LCI databases to ensure consistency with primary data. In particular, guidelines for system boundaries, solving multi-functionality, etc. shall be consistent across foreground (primary) and background (secondary) datasets. The TranSensus LCA guidance shall also prescribe consistent modelling of all the used secondary datasets.

Furthermore, the use of proxies (in terms of "values" and "datasets") is classically not limited or guided by generally-agreed rules. This implies that clear guidance on proxies, either with default values/datasets (e. g. for mapping between materials used in vehicles and those in LCI databases), or conditions for the development and check of proxies, shall be given in the TranSensus LCA method.

Finally, two aspects of the lifecycle in the electromobiliy sector have been more specifically discussed with regards prescriptions on modelling in the TranSensus LCA method. First, there is a lack of harmonized and commonly agreed approach to model electricity and hydrogen consumption (in the production, vehicle use, and EoL phases). Accordingly, the TranSensus LCA method shall develop prescriptive guidance on these aspects, in particular with regards to electricity modelling: i) carefully addressing any risk of double counting, and ii) ensuring the time coherence condition is aligned with country legislation (monthly or annually). Second, there is still a need for harmonization regarding the end-of-life modelling. The CFF (Circular Footprint Formula) of the European Commission’s PEF (Product Environmental Footprint) methodology was intensively discussed but is not commonly agreed. The CFF is considered by several partners as too complex and uncertain, e. g. for what regards credits evaluation, prospective aspects, etc. In TranSensus LCA it shall be decided whether to start from the CFF or not, and whether to include battery second life and EoL in other countries, other than in a sensitivity analysis. If starting from the CFF, then the TranSensus LCA shall provide clearer prescriptions on its implementation regarding credits evaluation and prospective recycling processes.

Impact assessment

What is currently missing for vehicle LCA is a unique, standardized, set of impact categories and associated impact assessment methods, which are agreed to be relevant and robust (and widely applied). The level of comprehensiveness of such a still-missing method shall be addressed in WP2. It may be set as either extensively comprehensive (e. g. including circularity, biodiversity, criticality and dissipation of mineral resources, etc.); or as a more restrained list. Regarding these impact assessment methods, diverse levels of recommendations ("mandatory"/"optional") shall be considered in WP2. Eventually only relevant, reliable and accepted methods shall be selected.

Moreover, specific gaps have been identified for what regards mineral resource indicators. In this case potential alternative impact assessment methods must be evaluated, potentially considering diverse impact pathways (e. g. resources dissipation). Other indicators like cumulative energy demand (CED) and circularity indicators that have high policy relevance shall also be considered in downstream TranSensus LCA WPs for potential integration in the TranSensus LCA method.

Finally, a single guidance on whether to implement normalization and weighting, or not, is still missing. If recommended, normalization and weighting factors would need to be commonly agreed; however, including weighting would make the TranSensus LCA method non-ISO compliant.

Interpretation

It is observed that large uncertainties still sometimes remain in terms of completeness of system modelling, accuracy and geographical representativeness. However, this is still not always properly reflected in results and interpretation. Accordingly, a harmonized guidance is needed to support quality assessment, data sharing along the supply chain, and communication. Whether this may take the form of the Data Quality Rating as per the PEF method, or other approaches, shall be discussed and decided in WP2.

Moreover, there is still a lack of consistency in the definition and use of sensitivities and scenarios. This implies that clear guidance shall be provided on the definition of sensitivity analysis, uncertainty analysis and scenarios.

Finally, there is still a lack of commonly agreed guidelines for a credible data quality verification and audit process - leading to poor confidence in the shared data. The TranSensus LCA method shall therefore provide clear, unambiguous, guidelines for a credible verification process (or audits) overcoming the challenge of confidentiality while ensuring transparency. More generally, the TranSensus LCA method shall include a common framework and content for reporting.

Summary of Key Findings regarding gaps on Social-LCA, and prescriptions for the TranSensus LCA method

This study allows identifying the gaps in the S-LCA methodology that prevents its application in a consistent manner. These gaps were identified through a literature review with the perspective of the automotive sector. In order for the TranSensus LCA S-LCA methodology to be applied in a consistent manner, these gaps should be addressed in the subsequent steps of the TranSensus LCA project.

Goal and scope

In many of the assessed studies, the recommendations of the UNEP-SETAC guidelines were not fully followed regarding the goal and scope phase which indicates a lack of understanding around the guidelines. In particular, with regards to the goal of the study, better guidelines should be developed regarding the definition of the target audience, how the study will help with decision-making and what will be the potential opportunities associated to the study. Regarding the definition of the product system, clear recommendations on the inclusion/exclusion criteria are lacking. In S-LCA, the functional unit should consider both physical and effect perspectives and so technical and social aspects; recommendations on how to address the latter are today not taken into account. Finally, the main activity variable used nowadays in S-LCA is "worker-hour" that could be inconsistent with other stakeholder categories: a standardized method to develop and select activity variable based on stakeholders should be developed.

Social Life cycle inventory

Generally, to ease the primary data collection, specific data collection sheets are today missing from the general guidelines. Apart for collecting exchanges between unit processes, primary data can also be collected to quantify activity variables. To be representative, the activity variables should be quantified at the subcategory or at the stakeholder level; this level of granularity is today missing especially for complex supply chains. Lastly regarding activity variables, a way to quantify them should be developed while ensuring data confidentiality for company specific data. Primary data collection is also linked to the treatment of multi-functionality: the availability of social data specific to co-products is today not sufficient leading to mistreatment of multi-functionality. Regarding secondary data, due to their construction, data in S-LCA databases might be outdated and with a limited granularity and so inadequate to conduct hotspots assessment. There is today a lack of data representative of a specific regional area or a specific value chain. Furthermore, the expression of social risks in USD in S-LCA databases might lead to possible misrepresentations as this USD unit might fluctuate for various reasons and fail considering some specific social aspects.

The S-LCI step in S-LCA depends on the type of social impact methodology chosen to conduct the assessment (reference scale approach or impact pathway method). In the case of the reference scale approach, there is a need to standardize the quantification of performance indicators.

Social life cycle impact assessment

The impact pathway method is today not developed enough to be robust and implemented in S-LCA software. There is a call for further standardization of impact pathways and associated characterization models. This standardization will help enhance the comparability of S-LCA as well as their effectiveness.

The complexity of the approach and the under-development of cause-effect chain leads S-LCA practitioner to choose rather the reference scale approach to conduct impact assessment. In this approach, impacts are measured according to an ordinal scale with no absolute zero point; that does not allow performing quantitative measurements of social impacts, limiting the comparison between these impacts.

Interpretation

Overall, the interpretation phase suffers from a lack of standardization in the methods and tools to use. It is the case for example for the methods and tools to use to conduct sensitivity assessment or to conduct a critical review. The interpretation phase plays a crucial role in engaging stakeholders in prioritizing and evaluating social aspects. It should so help in understanding the complexity of the supply chain assessed and the diversity of stakeholders' perspectives. Better recommendations to consider different cultural nuances in this phase should be given.

Perspectives to guide harmonization efforts

Activities in Task 1.2 have been tailored to support other TranSensus LCA WPs, and in particular WP2, towards the ultimate objective of the TranSensus LCA project to develop a European-wide harmonised transport-specific LCA approach. The key findings from Task 1.2, in terms of the needs the TranSensus LCA method shall seek to cover, and the gaps in Environmental and Social LCA in the electromobility sector that it shall overcome, are reported and summarized in this Deliverable. This study also developed a hierarchy in the needs and gaps, in order to support the downstream WPs in selecting priority issues to be tackled in their respective work.

Task 1.2 has been developed in an iterative and collaborative approach. Outcomes from Task 1.2 have been continuously discussed with WP1 and WP2 partners all along the realization of Task 1.2, through multiple activities. Task 1.2 partners have engaged early in the project with WP2 in order to support the latter's work on the conceptualization of the TranSensus LCA approach. In particular, three workshops have been open to key WP1 and WP2 partners. These workshops included several sessions of break-out group discussions organized with a view to facilitating a common vision and understanding of the key needs and gaps the TranSensus LCA method shall seek to cover and overcome. Moreover, several draft versions of this Deliverable 1.2 have been shared with and open to consultation by WP1 and WP2 partners. Task 1.2 therefore aimed to support the developments in WP2 early in the project. It also benefited from the expertise of WP2 partners, and from the work realized in WP2 in terms of identifying limits in currently existing approaches in Environmental LCA and Social LCA.

This consensus on the needs and gaps in Environmental and Social LCA in the electromobility sector now paves the way to the key objective of the TranSensus LCA project, i. e., the development of a European-wide harmonised transport-specific LCA approach in downstream WP2 and onwards.

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Glossary

Note:

1) The glossary for Environmental Life Cycle Assessment was primarily adopted from Product Environmental Footprint Guidelines (PEF) (EC-JRC, 2021). Methodological points which are PEF-specific are re-formulated for general applicability. Any new term that did not come from PEF or deviates even slightly from the definition reported in PEF will be written in *Italic*.
2) The terms for Social Life Cycle Assessment were adopted from UNEP guidelines (Benoît, et al., 2009)
3) If same term was found to apply for both methodologies, the methodology intended is highlighted between parentheses next to the term.
4) The list of definitions is not limited to the terms appearing in the report since the other terms were thought to be helpful to the reader as well like some basic terms.

Acidification –Impact category that addresses impacts due to acidifying substances in the environment. Emissions of NOx, NH3 and SOx lead to releases of hydrogen ions (H+) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

Activity data - information which is associated with processes while modelling Life Cycle Inventories (LCI). The aggregated LCI results of the process chains, which represent the activities of a process, are each multiplied by the corresponding activity data1 and then combined to derive the environmental footprint associated with that process. Examples of activity data include quantity of kilowatt-hours of electricity used, quantity of fuel used, output of a process (e. g. waste), number of hours equipment is operated, distance travelled, floor area of a building, etc. Synonym of 'non-elementary flow'.

Activity variable - An activity variable is a measure of process activity or scale which can be related to process output. Activity variables, scaled by the output of each relevant process, are used to reflect the share of a given activity associated with each unit process. A relevant activity variable is worker-hours. Process-specific coefficients of worker-hours per unit of process output are used to estimate the share of total life cycle worker-hours associated with each unit process. The activity variable is useful to represent the product system in a way that gives an idea of the relative significance of each unit process in the whole system.

Additional environmental information – environmental information outside the impact categories that is calculated and communicated alongside LCA results.

Additional technical information – non-environmental information that is calculated and communicated alongside LCA results.

Aggregated dataset - complete or partial life cycle of a product system that – next to the elementary flows (and possibly not relevant amounts of waste flows and radioactive wastes) – itemises only the product(s) of the process as reference flow(s) in the input/output list, but no other goods or services. Aggregated datasets are also called 'LCI results' datasets. The aggregated dataset may have been aggregated horizontally and/or vertically.

Aggregation - The action of summing or bringing together information (e. g., data, indicator results, etc.) from a smaller scope into a larger scope, e. g., from inventory indicator to sub-category. In S-LCA, aggregation of data may be done at the life cycle inventory or impact assessment phase of the study and should not be done in a way that leads to loss of information about the location of the unit processes.

Allocation – an approach to solving multi-functionality problems. 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.

Application specific – generic aspect of the specific application in which a material is used. For example, the average recycling rate of PET in bottles.

Area of protection [The term "Damage category" can be used as a synonym] - A state that is desired to be sustained or protected which is of recognizable value to society, in the specific context of sustainability assessment. In the field of S-LCA, one area of protection has been defined and is referred to as human well-being (health and happiness) or simply social well-being. See also Box 17. For environmental LCA areas of protection include human health, natural resources, natural environment, and man-made environment.

Attributes [see "Life cycle attribute assessment"]- Properties or characteristics of a process, which are of interest to stakeholders. These are different from conventional quantitative input/output flows of processes but are of a qualitative nature, e. g. gender discrimination or safety as a whole, and thus also coincide with qualitative parameters of social issues in the context of S-LCA.

Attributional – process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects.

Attributional LCA – a type of LCA focusing on one specific functional unit of the system/product under study, while assuming that the system/product itself does not alter the larger system into which it is embedded/deployed. (e. g., an LCA of one EV, without considering the effects that a large-scale roll-out of EVs may be expected to have on: (i) the demand for LIB metals, and hence on the changing impacts of their supply chains, and (ii) the increased total demand for electricity due to the vehicle's use phase, which may necessitate deployment of new generators and changes in grid mix composition).

Average Data – production-weighted average of specific data.

Background processes – refers to those processes in the product life cycle for which no direct access to information is possible. For example, most of the upstream life-cycle processes and generally all processes further downstream will be considered part of the background processes.

Benchmark – a standard or point of reference against which any comparison may be made. In the context of PEF, the term 'benchmark' refers to the average environmental performance of the representative product sold in the EU market.

Bill of materials – a bill of materials or product structure (sometimes bill of material, BOM or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture the product. In some sectors it is equivalent to the bill of components.

Characterization – calculation of the magnitude of the contribution of each classified input/output to their respective impact categories, and aggregation of contributions within each category. This requires a linear multiplication of the inventory data with characterization factors for each substance and impact category of concern. For example, with respect to the impact category 'climate change', the reference substance is CO_2 and the reference unit is kg CO_2-equivalents.

Characterization (S-LCA) - In S-LCIA, the characterization models are the formalized, and - not always - "mathematical" operationalization of the social and socio-economic mechanisms. They may be a basic aggregation step, bringing text or qualitative inventory information together into a single summary, or summing quantitative social and economic inventory data within a category. Characterization models may also be more complex, involving the use of additional information such as performance reference points.

Characterization factor – factor derived from a characterization model which is applied to convert an assigned life cycle inventory result to the common unit of the impact category indicator.

Characterization factor (S-LCA) - Factor, derived from a characterization model, that is applied to convert an assigned Life Cycle Inventory Analysis result to the common unit of the category and/or subcategory indicator. ISO 14040 (2006).

Classification – assigning the material/energy inputs and outputs tabulated in the life cycle inventory to impact categories, according to each substance's potential to contribute to each of the impact categories considered.

Classification (S-LCA) - The classification step is the step where the Inventory results are assigned to a specific Stakeholder Category and/or Impact (sub)Category.

Climate change – impact category considering all inputs and outputs that result in greenhouse gas (GHG) emissions. The consequences include increased average global temperatures and sudden regional climatic changes.

Co-function - any of two or more functions resulting from the same unit process or product system.

Company-specific data – refers to directly measured or collected data from one or more facilities (site-specific data) that are representative for the activities of the company (company is used as synonym of organisation). It is synonymous to 'primary data'. To determine the level of representativeness a sampling procedure may be applied.

Company-specific dataset – refers to a dataset (disaggregated or aggregated) compiled with company-specific data. In most cases the activity data is company-specific while the underlying sub-processes are datasets derived from background databases.

Comparative assertion – an environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category).

Comparison – a comparison, not including a comparative assertion, (graphic or otherwise) of two or more products based on the results of an LCA study.

Consequential LCA: a type of LCA focusing on the changes induced by the deployment of the system/product under study, on the larger system into which it is embedded/deployed (e. g., an LCA explicitly modelling the expected changes in supply-chain impacts for LIB metals due to a large-scale uptake of EVs)

Consumer – an individual member of the general public purchasing or using goods, property or services for private purposes.

Co-product – any of two or more products resulting from the same unit process or product system.

Cradle to gate – a partial product supply chain, from the extraction of raw materials (cradle) up to the manufacturer's 'gate'. The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Cradle to grave – a product's life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle.

Critical review – process intended to ensure consistency between an LCA study and the principles and requirements of the applied LCA method.

Cut-off criteria - Specification of the amount of material or energy flow or the level of significance associated with unit processes or product system to be excluded from a study. Adapted from ISO 14040 (2006).

Data quality – characteristics of data that relate to their ability to satisfy stated requirements. Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.

Data quality rating (DQR) - semi-quantitative assessment of the quality criteria of a dataset, based on technological representativeness, geographical representativeness, time-related representativeness, and precision. The data quality shall be considered as the quality of the dataset as documented.

Delayed emissions – emissions that are released over time, e. g. through long use or final disposal stages, versus a single emission at time t.

Direct elementary flows (also named elementary flows) – all output emissions and input resource uses that arise directly in the context of a process. Examples are emissions from a chemical process, or fugitive emissions from a boiler directly onsite.

Direct land use change (dLUC) – the transformation from one land use type into another, which takes place in a unique land area and does not lead to a change in another system.

Directly attributable – refers to a process, activity or impact occurring within the defined system boundary.

Disaggregation – the process that breaks down an aggregated dataset into smaller unit process datasets (horizontal or vertical). The disaggregation may help make data more specific. The process of disaggregation should never compromise or threaten to compromise the quality and consistency of the original aggregated dataset.

Downstream – occurring along a product supply chain after the point of referral

Due diligence- The process through which organizations identify, consider, and address the potential environmental and social impacts related to their activities and the ones of their business relationships, as an integral part of their decision-making and risk management system. (OECD, 2016)

Ecotoxicity, freshwater – impact category that 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.

EF communication vehicles – all the possible ways that may be used to communicate the results of the EF study to the stakeholders (e. g. labels, environmental product declarations, green claims, websites, infographics, etc.).

EF-compliant dataset – dataset developed in compliance with the EF requirements, regularly updated by DG JRC2.

E-LCA - Environmental Life Cycle Assessment (E-LCA) is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a product, service or organization.

Electricity tracking – the process of assigning electricity generation attributes to electricity consumption.

Elementary flow - Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation. ISO 14040 (2006)

Elementary flows – in the life cycle inventory, elementary flows include 'material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation'. Elementary flows include, for example, resources taken from nature or emissions into air, water, soil that are directly linked to the characterization factors of the impact categories.

Endpoint impact / Endpoint (impact) indicator -Impact at the end of the cause-effect chain for a (social) issue, which can be represented by an endpoint indicator. It captures the impact on an area of protection. For example, impact on health, represented by the DALY indicator.

Environmental aspect (E-LCA) – element of an organisation's activities or products or services that interacts or can interact with the environment.

Environmental aspect (S-LCA) - Element of an organization's activities, products, or services that can interact with the environment. ISO 14040 (2006). The counterpart in S-LCA are social issues.

Impact assessment – phase of the LCA analysis aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product. The impact assessment methods provide impact characterization factors for elementary flows, to aggregate the impact so as to obtain a limited number of midpoint indicators.

Impact assessment method – protocol for converting life cycle inventory data into quantitative contributions to an environmental impact of concern.

Impact category – class of resource use or environmental impact to which the life cycle inventory data are related.

Impact category indicator – quantifiable representation of an LCA impact category.

Environmental impact – any change to the environment, whether adverse or beneficial, that wholly or partially results from an organisation's activities, products or services.

Environmental mechanism – system of physical, chemical and biological processes for a given impact category linking the life cycle inventory results to category indicators.

Environmental mechanism / Social mechanism - System of physical, chemical, and biological or socio-economic processes for a given impact category, linking the Life Cycle Inventory Analysis results to impact (sub)category indicators and to category endpoints.

Eutrophication – Impact category related to nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland that accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen, resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure, expressed as the oxygen required for the degradation of dead biomass.

External communication – communication to any interested party other than the commissioner or the practitioner of the study.

Extrapolated data – data from a given process that is used to represent a similar process for which data is not available, on the assumption that it is reasonably representative.

Flow diagram – schematic representation of the flows occurring during one or more process stages within the life cycle of the product being assessed.

Focus group - A focus group is a type of group interview organized to acquire a portrait of combined local perspective on a specific set of issues. What distinguishes the focus group technique from the wider range of group interviews is the explicit use of the group interaction to produce data and insights that would be less accessible without the interaction found in a group. Focus groups with a range of actors can be used to identify relevant stakeholder groups and indicators. Finally, focus groups can also be used in impact assessment when defining the relative importance (weight) of each impact (sub)category.

Foreground elementary flows - direct elementary flows (emissions and resources) for which access to primary data (or company-specific information) is available.

Foreground processes – those processes in the product life cycle for which direct access to information is available. For example, the producer's site and other processes operated by the producer or its contractors (e. g. goods transport, head-office services, etc.).

Functional unit (E-LCA) – defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions 'what?', 'how much?', 'how well?', and 'for how long?'.

Functional unit (S-LCA)- Quantified performance of a product system for use as a reference unit in a life cycle assessment study, and also valid for an S-LCA. ISO 14040 (2006)

Gate to gate – a partial product supply chain that includes only the processes carried out on a product within a specific organisation or site.

Gate to grave – a partial product supply chain that includes only the distribution, storage, use, and disposal or recycling stages.

Generic data - Refers to data that has not been collected for the specific process concerned. If can be data collected from other manufacturers of the same kind of product or in the same country. In other words, it is data with a lower resolution than site-specific data.

Global warming potential (GWP) – An index measuring the radiative forcing of a unit mass of a given substance accumulated over a chosen time horizon. It is expressed in terms of a reference substance (for example, CO2- equivalent units) and specified time horizon (e. g. GWP 20, GWP 100, GWP 500 – for 20, 100 and 500 years respectively). By combining information on both radiative forcing (the energy flux caused by emission of the substance) and on the time it remains in the atmosphere, GWP gives a measure of a substance's capacity to influence the global average surface-air temperature and therefore subsequently influence various climate parameters and their effects, such as storm frequency and intensity, rainfall intensity and frequency of flooding, etc.

Goal and scope -The first phase of an LCA or S-LCA; establishing the aim of the intended study, the functional unit, the reference flow, the product system(s) under study and the breadth and depth of the study in relation to this aim. For S-LCA, a unique aspect in practice is the specification of the stakeholder group(s) of interest and the type of assessment (type I or type II).

Horizontal averaging – the action of aggregating multiple unit process datasets or aggregated process datasets in which each provides the same reference flow, to create a new process dataset.

Human rights due diligence - An ongoing risk management process in order to identify, prevent, mitigate, and account for how [a company] addresses its adverse human rights impacts. It includes four key steps: assessing actual and potential human rights impacts; integrating and acting on the findings; tracking responses; and communicating about how impacts are addressed. (This is brought forward in the "UN Guiding Principles Reporting Framework")

Human toxicity – cancer – 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 – 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.

Impact category - A social impact category is a class that covers certain social issues of interest to stakeholders and decision makers. In practice, impact categories are logical groupings of S-LCA (subcategory) results.

Impact indicator / Impact (sub)category indicator - An indicator that represents a (social) impact, linked to a particular impact category, and in that context, can be called an "impact (sub)category indicator".

Impact pathway approach / Type II approach / Impact pathway (IP) S-LCIA approach -Impact pathway S-LCIA assesses potential or actual social impacts by using causal or correlation/regression-based directional relationships between the product system/organizations' activities and the resulting potential social impacts – a process called "characterization". Here, the analysis focuses on identifying and tracking the consequences of activities possibly to longer-term implications along an impact pathway.

In particular in S-LCIA, aggregation is a way of combining various elements and synthesizing complex phenomena in order to achieve a better understanding and for the communication of results. As such, it may involve the construction of a single, possibly synthetic, score with two or more subcomponents. Single indices or scores are a powerful way to combine and summarize multi-dimensional information.

Independent external expert – competent person, not employed in a full-time or part-time role by the commissioner of the LCA study or the user of the LCA method, and not involved in defining the scope or conducting the LCA study.

Indicator - An indicator is a measurement or value which gives you an idea of what something is like.

Indirect land use change (iLUC) – this occurs when a demand for a certain land use leads to changes, outside the system boundary, i. e. in other land use types. These indirect effects may be mainly assessed by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale. **Input flows** – product, material or energy flow that enters a unit process. Products and materials include raw materials, intermediate products and co-products.

Input - Product, material, or energy flow that enters a unit process. ISO 14040 (2006)

Intermediate product – output form of a unit process that in turn is input to other unit processes which require further transformation within the system. An intermediate product is a product that requires further processing before it is saleable to the final consumer.

Inventory indicator - An inventory indicator is a type of impact indicator that directly relates to the product life cycle, e. g. hours at risk of child labour. An inventory indicator provides the most direct evidence of the condition or result that is measured. They are specific definitions of the data sought. Inventory indicators have characteristics such as type (e. g. qualitative or quantitative) and unit of measurement.

Ionising radiation, human health – impact category that accounts for the adverse health effects on human health caused by radioactive releases.

Land use – impact category related to 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).

Lead verifier – person taking part in a verification team with additional responsibilities, compared to the other verifiers in the team.

Life cycle – consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life cycle approach – takes into consideration the spectrum of resource flows and environmental interventions associated with a product from a supply-chain perspective, including all stages from raw material acquisition through processing, distribution, use, and end of life processes, and all relevant related environmental impacts (instead of focusing on a single issue).

Life cycle assessment (LCA) – compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life cycle attribute assessment [See "attribute"] - A method that enables to express the percentage of a supply chain that possesses (or lacks) an attribute of interest. Norris (2006)

Life cycle costing / Environmental life cycle costing - Life cycle costing, or LCC, or more specifically environmental life cycle costing, is a compilation and assessment of all costs related to a product, over its entire life cycle, from production to use, maintenance, and disposal.

Life cycle impact assessment (LCIA) – phase of life cycle assessment that aims to understand and evaluate the magnitude and significance of the potential environmental impacts for a system throughout the life cycle. The LCIA methods used provide impact characterization factors for elementary flows to aggregate the impact, to obtain a limited number of midpoint and/or damage indicators.

Life cycle impact assessment / Social life cycle impact assessment (S-LCIA) - Phase of an S-LCA that aims at understanding and evaluating the magnitude and significance of the impacts for a product system throughout the life cycle of the product. Adapted from ISO 14040 (2006)

Life cycle inventory (LCI) - the combined set of exchanges of elementary, waste and product flows in a LCI dataset.

Life cycle inventory (LCI) dataset - a document or file with life cycle information of a specified product or other reference (e. g., site, process), covering descriptive metadata and quantitative life cycle inventory. A LCI dataset could be a unit process dataset, partially aggregated, or an aggregated dataset.

Life cycle inventory / Social life cycle inventory (S-LCI) - Phase of an S-LCA where data are collected, the systems are modelled, and the LCI results are obtained.

Life cycle thinking - Going beyond the traditional focus on production site and manufacturing processes so to include the environmental, social, and economic impact of a product over its entire life cycle. UNEP-DTIE-Life Cycle Management, a Business Guide to Sustainability.

Loading rate – ratio of actual load to the full load or capacity (e. g. mass or volume) that a vehicle carries per trip.

Materiality assessment - Materiality assessment is a process to select topics that are more important because of their impact on stakeholders and/or on the business. The Global Reporting Initiative consider material issues to be the ones that reflect the organization's significant social impacts; or that substantively influence the assessments and decisions of stakeholders. This is also recommended by ISO 26000.

Materiality principle - Materiality (principle) constitutes social matter (information, data, performance, impact, stakeholder) that is of such relevance and importance that it could substantially influence the conclusions of the study, and the decisions and actions based on those conclusions. In the Interpretation section, we follow this definition.

Material-specific – a generic aspect of a material. For example, the recycling rate of polyethylene terephthalate (PET).

Method - Specific procedure within a technique.

Methodology - Coherent set of methods.

Midpoint impact / Midpoint (impact) indicator - Impact midway the cause-effect chain of a social issue, which can be represented by a midpoint indicator. It does not imply a fixed point halfway through the cause-effect chain.

Models: mathematical description/formula

Multi-functionality – if a process or facility provides more than one function, i. e. it delivers several goods and/or services ('co-products'), then it is 'multifunctional'. In these situations, all inputs and emissions linked to the process will be partitioned between the product of interest and the other co-products, according to clearly stated procedures.

Non-elementary (or complex) flows – in the life cycle inventory, non-elementary flows include all the inputs (e. g. electricity, materials, transport processes) and outputs (e. g. waste, by-products) in a system that need further modelling efforts to be transformed into elementary flows. Synonym of 'activity data'.

Normalization – after the characterization step, normalization is the step in which the life cycle impact assessment results are divided by normalization factors that represent the overall inventory of a reference unit (e. g. a whole country or an average citizen). Normalised life cycle impact assessment results express the relative shares of the impacts of the analysed system, in terms of the total contributions to each impact category per reference unit. Displaying the normalised life cycle impact assessment results for the different impact topics next to each other shows which impact categories are affected most and least by the analysed system. Normalised life cycle impact assessment results reflect only the contribution of the analysed system to the total impact potential, not the severity/relevance of the respective total impact. Normalised results are dimensionless, but not additive.

Organisation Environmental Footprint Sectorial Rules (OEFSRs) - sector specific, life-cycle based rules that complement general methodological guidance for OEF studies by providing further specification at the level of a specific sector. OEFSRs help to shift the focus of the OEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the OEF method. Only the OEFSRs developed by or in cooperation with the European Commission, or adopted by the European Commission or as EU acts are recognised as in line with this method.

Organization - Company, corporation, firm, enterprise, authority, or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration. ISO 14001 (2004)

Output - Product, material, or energy flow that leaves a unit process. ISO 14040 (2006)

Output flows – product, material or energy flow that leaves a unit process. Products and materials include raw materials, intermediate products, co-products and releases. Output flows are also considered to cover elementary flows.

Ozone depletion – 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).

Partially disaggregated dataset - a dataset with an LCI that contains elementary flows and activity data, and that yields a complete aggregated LCI data set when combined with its complementing underlying datasets.

Particulate matter – impact category that accounts for the adverse effects on human health caused by emissions of particulate matter (PM) and its precursors (NOx, SOx, NH3).

Performance reference point (PRP) - Performance reference points (PRPs) are thresholds, targets, or objectives that set different levels of social performance or social risk. PRPs allow to estimate the magnitude and significance of the potential social impacts associated with organizations in the product system. The PRPs are context-dependent and are often based on international standards, local legislation, or industry best practices – Comparing inventory indicator data with PRPs allows to qualify performance on a scale.

Photochemical ozone formation – 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.

Population - any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study.

Primary data (E-LCA)– data from specific processes within the supply chain. 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 the 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. In this report, primary data is a synonym of 'company-specific data' or 'supply chain specific data'.

Primary data (S-LCA)- Refers to data that has been directly collected by the practitioner, via interview, survey, or participant observation for instance.

Product (S-LCA) - Any good or service offered to members of the public either by sales or otherwise. ISO 26000 WD4.2 (2008)

Product (E-LCA) – any good or service.

Product category – group of products (or services) that can fulfil equivalent functions.

Product category rules (PCRs) – set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories.

Product environmental footprint category rules (PEFCRs) – product category-specific, life cycle-based rules that complement general methodological guidance for PEF studies by providing further specification for a specific product category. PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter most, and hence increase the relevance, reproducibility and consistency of the results by reducing costs, compared to a study based on the comprehensive requirements of the PEF method. Only PEFCRs developed by or in cooperation with the European Commission, or adopted by the Commission or as EU acts, are recognised as being in line with this method.

Product flow – products entering from or leaving to another product system.

Product system – collection of unit processes with elementary and product flows, performing one or more defined functions, which model the life cycle of a product.

Product utility - Product utility refers to the perception of the consumer in regard to what the product provides, besides its function (the capacity of a good to satisfy a need). This appreciation is linked with his/her cultural and social values, as well as his/her desires and satisfaction. Product utility can be identified in technical terms (quality, functionality etc.) or in social terms (convenience, prestige, etc.).

Prospective 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.

Qualitative indicator - Qualitative indicators are nominative; they provide information on a particular issue using words. For instance, text describing the measures taken by an enterprise to manage stress.

Quantitative indicator - A quantitative indicator is a description of the issue assessed using numbers, e. g. number of accidents by unit process.

Raw material – primary or secondary material used to produce a product.

Reference flow (S-LCA) - A reference flow is a quantified amount of product(s), including product parts, necessary for a specific product system to deliver the performance described by the functional unit.

Reference flow (E-LCA) – measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

Reference scale - Reference scales are ordinal scales, typically comprised of 1 to 5 levels, each of which corresponds to a performance reference point (PRP).

Reference scale approach / Type I approach / Reference scale (RS) S-LCIA - Reference scale S-LCIA assesses the social performance in the product system. More specifically, it assesses the social performance of activities of organizations in the product system (e. g. the practices implemented to manage social impacts) based on specific reference points of expected activity (called performance reference points - PRPs).

Refurbishment – the process of restoring components to a functional and/or satisfactory state compared to the original specification (providing the same function), using methods such as resurfacing, repainting, etc. Refurbished products may have been tested and verified to function properly.

Releases – emissions to air and discharges to water and soil.

Representative product (model) – this may be a real or virtual (non-existing) product. The virtual product should be calculated based on average European market sales-weighted characteristics for all existing technologies/materials covered by the product category or sub-category. Other weighting sets may be used, if justified – for example weighted average based on mass (ton of material) or weighted average based on product units (pieces).

Representative sample – a representative sample with respect to one or more variables is a sample in which the distribution of these variables is exactly the same (or similar) as in the population of which the sample is a subset.

Resource use, fossil – impact category that addresses the use of non-renewable fossil natural resources (e. g. natural gas, coal, oil).

Resource use, minerals and metals – impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals).

Retrospective LCA: 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.

Review – procedure intended to ensure that the process of developing or revising an LCA study has been carried out in accordance with the requirements provided in a certain document.

Review panel (in PEF context)– team of experts (reviewers) who will review the PEFCR
Reviewer – independent external expert conducting the review of the PEFCR and possibly taking part in a reviewer panel.

Review report - a documentation of the review process that includes the review statement, all relevant information about the review process, the detailed comments from the reviewer(s) and the corresponding responses, and the outcome. The document shall carry the electronic or handwritten signature of the reviewer (or the lead reviewer, if a reviewer panel is involved)

Reviewer – independent external expert conducting the review of the LCA and possibly taking part in a reviewer panel.

Salient social risks / impacts - Social impact subcategories that account for a greater share of the overall risk/impact. The UN Guiding Principles consider salient risks/impacts to be the ones that affect the most vulnerable stakeholders and that cause irreparable damages.

Sample – a subset containing the characteristics of a larger population. Samples are used in statistical testing when population sizes are too large for the test to include all possible members or observations. A sample should represent the whole population and not reflect bias toward a specific attribute.

Scope of the study -The scope is defined in the first phase of the study. It encompasses issues of depth and breadth of the study. It defines the limits placed on the product life cycle (that can be infinite) and on the detail of information to be collected and analysed. It defines where the data will be coming from, how up to date the study will be, how information will be handled, and where the results will be applicable.

Scoring system - Scoring may use quantitative, semi-quantitative, or qualitative scales, according to the availability of information and the impact (sub)category or impact category under consideration. Scoring systems usually seek to standardize the scores for purpose of comparison.

Secondary data (E-LCA) – data that is not from a specific process within the supply-chain of the company performing a PEF study. This refers to data that is not directly collected, measured or estimated by the company, but rather 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 and other generic data. Primary data that go through a horizontal aggregation step are considered to be secondary data.

Secondary data (S-LCA)- Refers to data that has been initially collected and manipulated by another person/institution than the practitioner or collected for another purpose than the one being currently considered or, often a mix of the two. For example, a publication, third party audit, or a database.

Semi-quantitative indicator - Semi-quantitative indicators are indicators that have results expressed into a yes/no form or a scale (scoring system): for example, presence of a stress management program (yes-no). Qualitative and quantitative indicator results may be translated into a semi-quantitative form.

Sensitivity analysis – systematic procedures for estimating the effects of the choices made regarding methods and data on the results of a LCA study.

Sensitivity analysis (S-LCA) -Systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study.

Single overall score – sum of the weighted LCA results of all environmental impact categories.

Site-specific data – directly measured or collected data from one facility (production site). A synonym of 'primary data'.

S-LCA - A social and socio-economic Life Cycle Assessment (S-LCA) is a social impact (actual and potential impacts) assessment technique that aims to assess the social and socio-economic aspects of products and their positive and negative impacts along their life cycle encompassing extraction and processing of raw materials, manufacturing, distribution, use, re-use, maintenance, recycling, and final disposal.

Social capital - The social conditions, such as institutions, rule of law, trust, and human networks, that are prerequisites or catalysts for production, but do not enter into the production themselves.

Social endpoint / Social category endpoint - A social attribute or aspect identifying an issue giving cause for concern Adapted from ISO 14040 (2006). It is thus an aspect of an area of protection, e. g. the payment for workers relating to their well-being. They are closely related to endpoint impact categories.

Social footprint - A social footprint refers to the end result of an S-LCA study, in term of adverse effects, overall or by impact category/subcategory (e. g. The total medium risk hours equivalent for labour rights and decent work by purchase category supply chain).

Social handprint - Social handprints are the results of changes to business as usual that create positive outcome or impacts. They can be changes reducing the social footprint, or changes that create additional/unrelated positive social impacts. Those changes can apply to the product or organization value chain, or they may be beyond its scope.

Social hotspots [The term "Bottleneck" can be used as a synonym for negative hotspots] - 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. It needs to contribute significantly to the impact (overall, by impact category or subcategory). 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 considered to be threatening social well-being or that may contribute to its further development.

Social impact assessment (SIA) - Social Impact Assessment (SIA) is the process of identifying the social consequences or impacts that are likely to follow specific policy actions or project development, to assess the significance of these impacts and to identify measures that may help to avoid or minimize adverse effects.

Social impact pathway [The term "Social mechanism" can be used as a synonym] - An impact pathway that covers the propagation of the cause-effect chain from social LCI results to impact, and is specified per social impact (sub)category.

Social impacts - Social impacts are consequences of positive or negative pressures on social endpoints of area of protection (i. e., well-being of stakeholders).

Social indicators - Social indicators are evidence, subjective or objective, qualitative, quantitative, or semi-quantitative being collected in order to facilitate concise, comprehensive and balanced judgements about the condition of specific social aspects with respect to a set of values and goals. In LCA social indicators are indicators of a social LCI result (inventory indicators) or represent impact per social impact (sub)category.

Social performance - Social performance refers to the principles, practices, and outcomes of businesses' relationships with people, organizations, institutions, communities, and societies in terms of the deliberate actions of businesses toward these stakeholders as well as the unintended externalities of business activity measured against a known standard (Wood, 2016). Commonly, social performance is measured at the inventory indicator level.

Social significance / significant - Social significance is a judgment on the degree to which a situation or impacts are important. It is highly dependent on context, based on criteria, normative, contingent on values, and entails considering trade-offs.

Social themes / Social issues - Social themes or issues are considered as threatening social well-being or that may contribute to its further development. Social themes of interest include but are not restricted to: human rights, work conditions, cultural heritage, poverty, disease, political conflict, indigenous rights, etc.

Socio-economic - Which involves a combination of social and economic factors or conditions.

Specific data – directly measured or collected data representative of activities at a specific facility or set of facilities. A synonym of 'primary data'.

Stakeholder category / Stakeholder group - Cluster of stakeholders that are expected to have similar interests due to their similar relationship to the investigated product system.

Stakeholder -Individual or group that has an interest in any activities or decisions of an organization. (ISO 26000, 2008)

Subcategory / Impact subcategory - It is a constituent of an impact category that is assigned to a stakeholder group, for example "Health and Safety" for the stakeholder group "Workers". Multiple subcategories, possibly across various stakeholder groups, may be part of an overarching impact category.

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.

Sub-population – any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study that constitutes a homogenous sub-set of the whole population. A synonym of 'stratum'.

Sub-processes – processes used to represent the activities of the level 1 processes (=building blocks). Sub-processes may be presented in their (partially) aggregated form.

Sub-sample - a sample of a sub-population.

Supply chain - A supply chain, or logistics network, is the system of organizations, people, technology, activities, information, and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials, and components into a finished product that is delivered to the end customer. In sophisticated supply chain systems used products may re-enter the supply chain at any point where residual value is recyclable. Supply chains link value chains. Nagurney (2006).

Supply chain – all of the upstream and downstream activities associated with the operations of the user of the LCA method, including the use of sold products by consumers and the end-of-life treatment of sold products after consumer use.

Supply chain-specific – refers to a specific aspect of a company's specific supply chain. For example, the recycled content of aluminium produced by a specific company.

System boundary – definition of aspects included or excluded from the study. For example, for a 'cradle-to-grave' LCA analysis, the system boundary includes all activities ranging from the extraction of raw materials, through processing, distribution, storage and use, to the disposal or recycling stages.

System boundary diagram – graphic representation of the system boundary defined for the LCA study.

System scope / System boundary - System scope = system boundary: set of criteria specifying which unit processes are part of a product system. ISO 14040 (2006)

Technique - Systematic set of procedures to perform a task.

Temporary carbon storage – this happens when a product reduces the greenhouse gases in the atmosphere or creates negative emissions, by removing and storing carbon for a limited amount of time.

Tool (S-LCA) - Instrument used to perform a procedure.

Tools (E-LCA) - software or applications supporting the analysis (e. g. LCA software or excel based tool)

Triangulation - Triangulation implies that different perspectives are brought together when investigating an object or research question. These perspectives can consist of different methods that are applied, in different theoretical approaches that are followed or more frequently in a combination of different types of data or data collection methods. It also refers to the collection of data from different persons or stakeholders or stakeholder groups which are contrasted.

Type III environmental declaration – an environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information.

Uncertainty - Uncertainty refers to the lack of certainty e. g. in the prediction of a certain outcome, in a measurement, or in an assessment's results. It is a general term used to cover any distribution of data caused by either random variation or bias. In LCA and S-LCA, evaluation or measurement of uncertainty is an on-going process and relates to all the elements of data quality as well the aggregation model used and to the general aims of the study as set in the Goal and Scope.

Uncertainty analysis – procedure for assessing uncertainty in the results of a LCA study due to data variability and choice-related uncertainty.

Unit process (E-LCA) – smallest element considered in the LCI for which input and output data are quantified.

Unit process (S-LCA) - Smallest portion of a product system for which data are collected when performing a life cycle assessment. ISO14040 (2006)

Unit process, black box – process chain or plant-level unit process. This covers horizontally averaged unit processes across different sites. Also covers multi-functional unit processes where the different co-products undergo different processing steps within the black box, hence causing allocation problems for this dataset.

Unit process, single operation - unit operation type unit process that cannot be further subdivided. Covers multi-functional processes of the unit operation type5.

Upstream – occurring along the supply chain of purchased goods/ services prior to entering the system boundary.

User of the PEFCR – stakeholder producing a PEF study based on a PEFCR.

Validation – confirmation – by the environmental footprint verifier – that the information and data in the LCA study, LCA report and communication vehicles are reliable, credible and correct.

Value chain – a synonym of 'supply chain'

Verification (in PEF context) – conformity assessment process carried out by an environmental footprint verifier to demonstrate whether the PEF study has been carried out in compliance with Annex I

Verification report – documentation of the verification process and findings, including detailed comments from the verifier(s), as well as the corresponding responses. This document is mandatory, but it may be confidential. The document shall carry the electronic or handwritten signature of the verifier or (where a verification panel is involved) the lead verifier.

Vertical aggregation – technical or engineering-based aggregation refers to vertical aggregation of unit processes that are directly linked within a single facility or process train. Vertical aggregation involves combining unit process datasets (or aggregated process datasets) together, linked by a flow.

Waste – substances or objects which the holder intends (or is required) to dispose of.

Water use – 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.

Weighting (E-LCA)– a step that supports the interpretation and communication of the analysis results. LCA results are multiplied by a set of weighting factors (in %), which reflect the perceived relative importance of the impact categories considered. Weighted LCA results may be directly compared across impact categories, and also summed across impact categories to obtain a single overall score.

Weighting (S-LCA) - Converting and possibly aggregating indicator results across impact categories using numerical factors based on value-choices; data prior to weighting should remain available. ISO 14040 (2006)

Abbreviations

BEV: Battery Electric Vehicle
BOM: Bill-of-Materials
CED: Cumulative Energy Demand
CFF: Circular Footprint Formula
E-LCA: Environmental Life Cycle Assessment
E-Mobility: Electromobility
EoL: end-of-life
EU: European Union
EV: Electric Vehicles
FCEV: Fuel-cell Electric Vehicle
GHG: Greenhouse gases
HDV: Heavy-Duty Vehicle
HEV Hybrid Electric Vehicle
ICE: Internal Combustion Engine
ICEV: Internal Combustion Engine vehicle
JRC: Joint Research Centre
kmyr: kilometre-year
LCC: Life Cycle Costing
LCP: lithium cobalt phosphate
LFP: lithium iron phosphate
LIB: Lithium-ion battery
LMO: Lithium manganese oxide
MaaS: Mobility as a service
MLC: Managed LCA Content (Former GaBi database)
NCA: Nickel cobalt aluminium (battery)
NFs: Normalization Factors
Ni-Cd: Nickel cadmium (battery)
NiMH: Nickel-metal hydride (battery)
NMC: Nickel manganese cobalt (battery)
OEM: Original Equipment Manufacturer
PEF: Product Environmental Footprint

Pb-Ac: Lead acid (battery)

PED: Primary Energy Demand

PHEV: Plug-in Hybrid Electric Vehicle

pkm: passenger kilometer (a unit of 1 passenger being transported 1 km distance)

REA: Rapid Evidence Assessment

S-LCA: Social Life Cycle Assessment

SotA: state-of-the-art

TaaS: Transportation as a service

tkm: tonne kilometer (a unit of 1 tonne of freight being transported 1 km distance)

TTW: tank to wheel

UNECE: United Nations Economic Commission for Europe

UNEP: United Nations Environment Program

V2G: Vehicle-To-Grid

vkm: vehicle kilometre

WFs: Weighting Factors

WLTC: Worldwide harmonized Light vehicles Test Cycles

WP: Work Package

WTT: Well to Tank

WTW: well to wheel

ZEV: Zero Emission Vehicle

1. Introduction

1.1 Background and context

Road transportation is a principal driver of multiple environmental problems, along with climate change. Emissions of greenhouse gases (GHGs) from transportation sector accounts for 20% of energy-related GHGs globally. If emissions from fuel supply chain are considered, this percentage can be even higher (Dillman et al., 2020). In the European Union (EU), the share of transportation's GHG emissions is around 22% excluding aviation and maritime emissions. Road transport alone emitted 77% of all EU transport GHGs in 2020 (including domestic transport and international bunkers) (European Environment Agency, 2020). Fossil fuels are currently the dominating energy carriers for transportation with around 94% of the total energy carriers (European Commission, 2016), which puts pressure on the EU to decrease this reliability on fossil fuels in mobility.

From the policy perspective, the European Green Deal, adopted by the Commission in December 2019, has at its core tackling climate change, including more ambitious action in the coming decade, and reaching the objectives of the Paris agreement and other environmental issues. As one of the key elements of the European Green Deal, the European Climate Law enshrines the EU's commitment to reaching climate neutrality by 2050 together with the intermediate target of reducing net GHG emissions by at least 55 percent by 2030, compared to 1990 levels.

Road vehicle electrification and Zero Emission Vehicles (ZEVs), or Zero tailpipe Emission Vehicles, have become one of the most significant climate change mitigation options in Europe, manifested by the rapid growth of ZEVs market in recent years, since they have been associated with promising environmental gains. The EU's Sustainable and Smart Mobility Strategy (European Commission, 2020a) calls for an irreversible shift to zero-emission mobility. Given transport's high proportion of total EU GHG emissions, the EU's climate goals will be reached only by introducing more ambitious policies to reduce transport's reliance on fossil fuels without delay.

However, it is acknowledged that focusing only on direct GHG emissions during vehicles use has the potential to lead to burden shifting to other environmental impacts like toxicity and resources depletion (or dissipation), or to other life phases of vehicles. A very pronounced example here is the concerns around rechargeable batteries supply chains which is a core element of Electric vehicles (EVs) supply chain (Xia and Li, 2022).

Methodologies like Life Cycle Assessment (LCA), Social LCA (S-LCA), and Life Cycle Costing (LCC), can play a paramount role in helping assess the sustainability of certain strategic choices in a more holistic way, to help identify options to prevent or mitigate for hotspots. LCA (the most mature methodology among the three aforementioned methodologies) is an established environmental assessment methodology supported by ISO standards (ISO, 2006, 2012, 2020) which takes into account all the life cycle of products and services and a wide spectrum of environmental concerns.

A plethora of LCA on ZEVs and batteries have been researched and reported in the literature and applied by automobile manufacturers (for both internal use and public reporting). However, subjectivity in critical modelling choices, such as choosing the functional unit or the electricity grid mix can lead to very diverse results even for the same product (Bouter and Guichet, 2022; Marmiroli et al., 2018; Nordelöf et al., 2014; Xia and Li, 2022).

This divergence hampers the utilization of these studies in further decision making as it complicates the comparability between results and diminishes the reliability of conclusions for policy making and strategic planning on corporate, country or regional level. In the public-forum, the lack of standardization can at best lead to confusion on the relative performance of different options, or at worst be used as a tool to provide a biased or deliberately misleading picture to support a particular viewpoint or interest. For example, choices could be deliberately made to promote products in a certain way (e. g. a battery manufacturer claiming “zero burdens” when using recycled materials, while an End-of-Life (EoL) battery treatment company claiming benefits for providing recycled materials).

Therefore, there is a need for a consensus on a single European harmonized approach of applying LCA for zero emission road transport where all stakeholders can calculate, monitor, communicate, and make decisions starting from a common ground. This becomes even more urgent in the light of the increasing adoption of LCA-based requirements in the European regulations. The proposal for a EU Regulation on batteries and waste batteries is a clear example, where providing a LCA-based carbon footprint declaration will be mandatory for any >2kwh-capacity batteries deployed in the European market (European Commission, 2020b). Similarly, the new life cycle based emissions reporting was proposed in the new regulation on CO_2 emission performance for light duty vehicles (European Parliament, 2021).

1.2 Aims of the TranSensus LCA project

The TranSensus LCA project (funded under the EU’s Horizon Europe programme) is a promising attempt to achieve such consensus by gathering a wide spectrum of influential European stakeholders in the zero-emission mobility sector ranging from academia and research, to industry which covers the whole value chain of ZEVs and batteries. As also indicated above, such a European single LCA approach is seen as a key element in achieving the Green Deal targets, making Europe the first digitally enabled circular, climate-neutral and sustainable economy. By consensus, TranSensus LCA aims to enable industry, mobility providers and planners to provide sustainable products and to optimise mobility solutions as needed to combat climate change and prevent burden shifting to other environmental concerns.

The project is structured into six content-related work packages (WPs), plus one work package related to project management as illustrated in Figure 1-1 below. The aim of Work Package 1 (WP1) is to account for the study's context and objectives (e. g., product environmental reporting, possible application for regulatory compliance/assessment, or policy/strategic analysis), and how these influence decisions on scope/boundary, methodology and data, subsequently implying different knowledge gaps and needs. WP1 has been subdivided into an assessment of the current state-of-the art of LCA concepts and approaches (Task 1.1, and the focus of Deliverable 1.1) and a subsequent assessment of the needs and gaps in the current LCA practice in ZEV field (Task 1.2, and the focus of this Deliverable 1.2). S-LCA is also addressed similarly in this report yet with less emphasis since LCA is the focal point of the project.

The review in Deliverable 1.1 covers all Zero Emission Vehicles, however a strong emphasis is placed on battery electric vehicles (BEVs) and traction batteries for electric powertrain vehicles (which also include Fuel Cell Electric Vehicles – FCEVs) since most of the state of the art (SotA) and guidelines available are related to these topics. Furthermore, the LCA practices are not expected to differ substantially for other powertrain types from a methodological perspective. Any differences that would emerge will be addressed in detail in WP2.

The identification of needs and gaps, as developed in Task 1.2 and reported in this Deliverable 1.2, partly builds on the outcomes of Task 1.1. Deliverable 1.2 paves the road to WP2 where these needs for harmonization and gaps in current practices will be addressed, to eventually achieve a harmonized methodology.

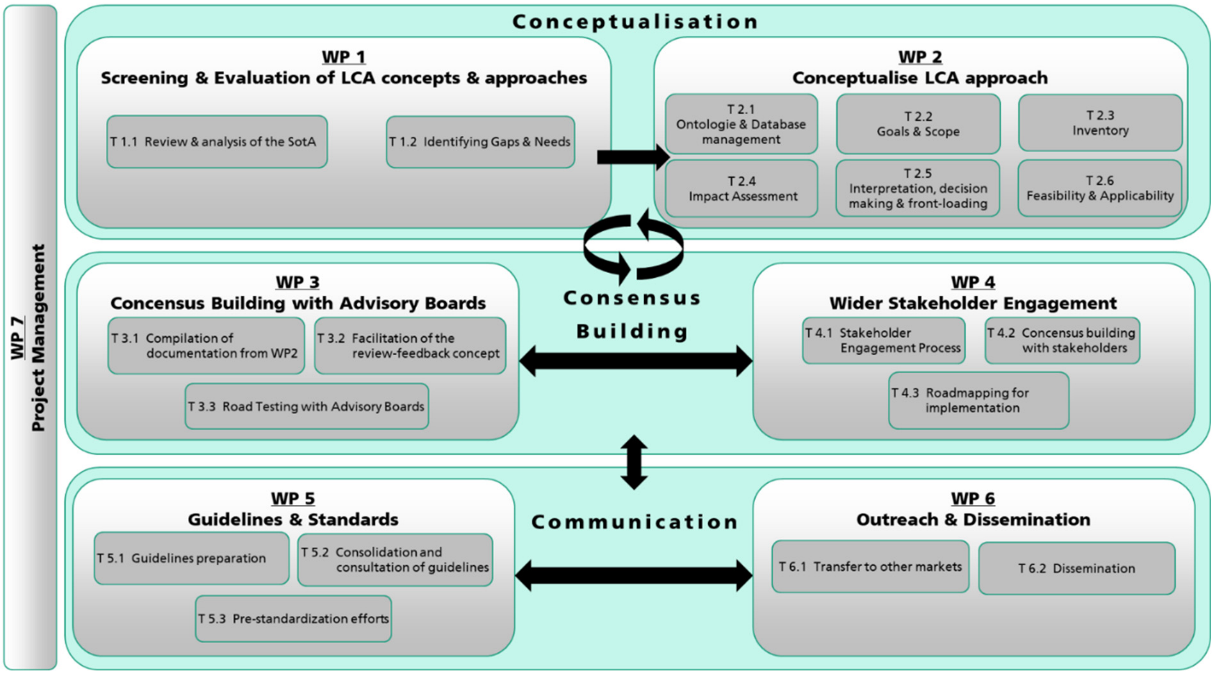


Figure 1.1: TranSensus LCA project structure

1.3 Aims of Task 1.2 and structure of this report

Task 1.2 of the TranSensus LCA project aims to deliver the analysis of needs and gaps for the development of a harmonised LCA/S-LCA approach in the electromobility sector. This Deliverable 1.2 first describes (in Chapter 2) the method undertaken in Task 1.2 to develop this analysis. Starting from the outcomes of Task 1.1, this Task 1.2 built its analysis essentially from i) workshops, ii) reviews of product environmental LCAs and S-LCAs, iii) a survey followed by targeted interviews, and iv) a review of position papers. These were finally integrated into a draft deliverable discussed among WP1 and WP2 partners.

Building on this work, Chapter 3 describes the key needs the TranSensus LCA method shall seek to cover. Chapter 4 then describes the gaps identified in current LCA/S-LCA implementation in the electromobility industry. This Chapter 4 is structured by the four phases of LCA (ISO, 2006), as illustrated in Figure 1.2 below, which are also the phases in S-LCA. This is the common structure for contents related to these methodologies and it also facilitates the information flow from WP1 to WP2, which also uses the four phases as a structuring element for its tasks. Chapter 5 moreover, and similarly, develops an analysis of the gaps identified in S-LCA. Finally, the report ends with a general discussion and conclusions in Chapter 6. It provides with a synthesis of the key needs the TranSensus LCA method shall seek to cover, and the key gaps it shall enable to overcome. Chapter 6 accordingly paves the road to the development of the

TranSensus LCA method in downstream WPs (from WP2 and onwards), as has already started and will continue until the end of the project.

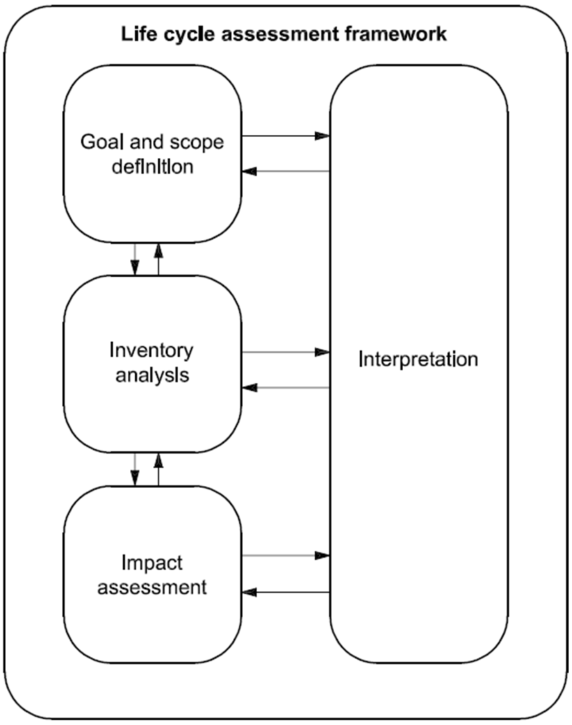


Figure 1.2: The four phases of LCA according to ISO 14040

2. Method

Starting from the review done in Task 1.1, which is reported in Deliverable 1.1, the analysis presented in this report adds to that by considering the following activities:

- Three workshops organized in the context of TranSensus LCA Task 1.2 (see description of the approach in section 2.1);
- A review of product Environmental LCAs (section 2.2), complemented by a review of product Social LCAs (section 2.3);
- A survey, followed by targeted interviews (section 2.4);
- A review of position papers (section 2.5).

This report is built on the outcomes from these diverse actions. It was then complemented through an iterative review work internal to the TranSensus LCA consortium. This enabled an additional panel of industrial and research partners to comment on what they consider are the needs and gaps that the TranSensus LCA method shall address. This review work included a specific review by several partners, including Umicore, Volkswagen and Northvolt (regarding version 1 of this report, in June 2023), and more generally by TranSensus LCA WP2 partners (regarding version 1.1 of this report, in July 2023).

Activities in Task 1.2 have been tailored to support other TranSensus LCA WPs, and in particular WP2, towards the ultimate objective of the TranSensus LCA project to develop a European-wide harmonised transport-specific LCA approach. The key findings from Task 1.2, in terms of the needs the TranSensus LCA method shall seek to cover, and the gaps in Environmental and Social LCA in the electromobility sector that it shall overcome, are reported and summarized in this Deliverable.

Task 1.2 has been developed in an iterative and collaborative approach. Outcomes from Task 1.2 have been continuously discussed with WP1 and WP2 partners all along the realization of Task 1.2, through multiple activities. Task 1.2 partners have engaged early in the project with WP2 in order to support the latter's work on the conceptualization of the TranSensus LCA approach.

The following Figure 2.1 depicts the tools and tasks carried out in order to generate this report.

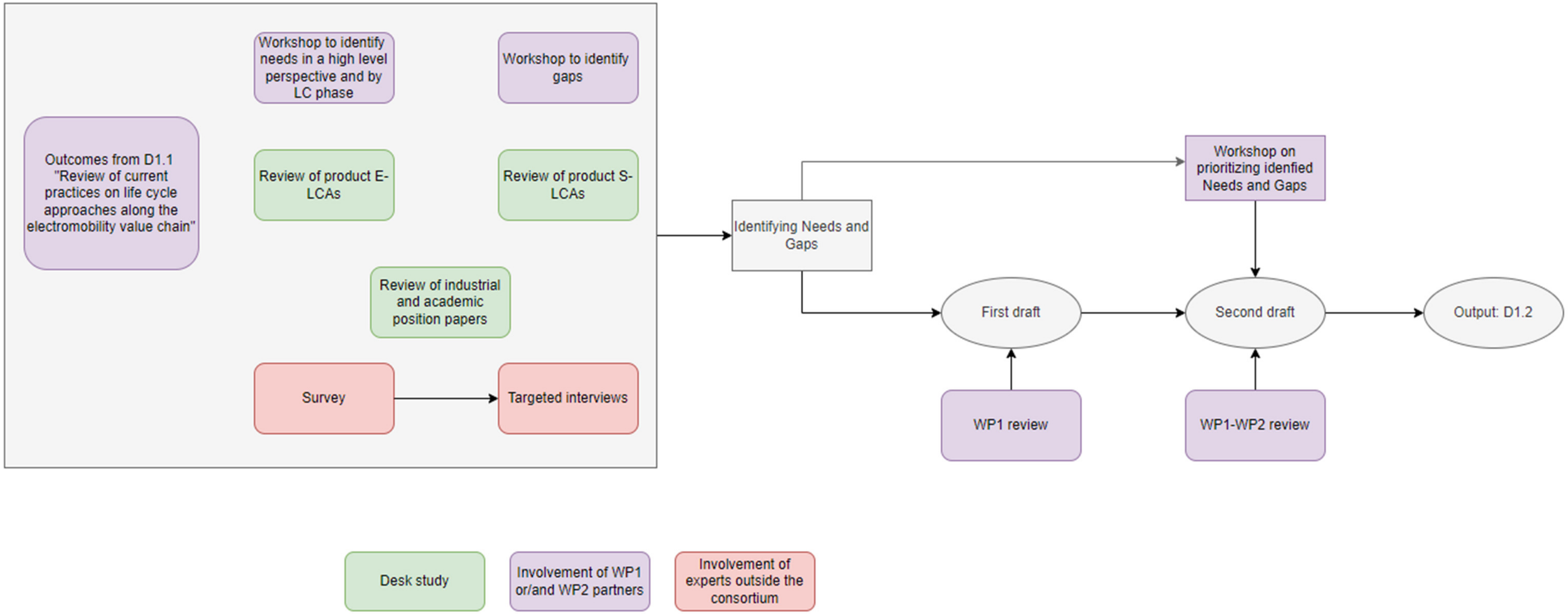


Figure 2.1 Method applied to report on needs and gaps for the development of a harmonised LCA/S-LCA approach in the electromobility industry

This approach reached a comprehensive view on the needs and gaps associated with LCA and S-LCA in the electromobility industry, as presented from the following Chapter 3 and onwards.

2.1 Workshops and Interviews

Two workshops were organized by BRGM and VALEO in March and April 2023. They gathered respectively 15 and 20 TranSensus LCA consortium members with expertise in LCA, with balance between industry partners and research partners. These workshops identified needs and gaps in current LCA practices in a bottom-up approach, i. e., building on the knowledge of participants.

The first workshop was dedicated to the identification of needs. Participants were divided into breakout discussion groups, and were guided through questions regarding i) high-level needs, and ii) more specific needs per phase of an LCA.

The second workshop was divided into two phases. In a first phase three industry partners (Volkswagen, Renault and Northvolt) were asked to make a presentation on "most important gaps" in LCA according to their own perspective (LCA "in general", and/or in view of specific guidelines of overarching importance for these industrials – e. g. JRC "Harmonised rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries"). In the second phase of the meeting, participants were split in break-out discussion groups, and asked to comment and complement - according to their perspective - the gaps previously presented by the three industry partners. This report compiles, and concisely analyses, the results of these two workshops (see from Chapter 3).

BRGM and Ricardo finally organized a third workshop in October 2023, gathering around 10 participants across WP1 and WP2 partners. This workshop was intentionally set after the round of revision of this report in its draft version, by WP1 and WP2 partners in the period from end of July to mid-September. It gave partners the opportunity i) to discuss some final critical points before reaching alignment (e. g. regarding the identified needs), ii) to raise some missing elements, and iii) to enable consensus on the prioritization in the needs and gaps identified.

In September and October 2023, interviews were conducted by RWTH Aachen and IVL with respondents who had answered S-LCA questions in a prior survey conducted for Deliverable 1.1. These interviews aimed to provide more qualitative insights into how social responsibility is managed within the companies and how S-LCA is utilized. Three interviews were held with automotive companies in Europe during this period. While the interviews provided valuable information about general social responsibility practices, there was limited information about S-LCA. Key results from this interview are discussed in the section specific to S-LCA.

2.2 Approach for review of product environmental LCAs

The literature review for this study was based on Rapid Evidence Assessment (REA), which has been previously applied within an extensive review study of published LCA literature for the European Commission by Ricardo (Ricardo, ifeu, & E4tech, 2020) to provide rigorous synthesis of the evidence available in the published literature.

The first stage of this review involved identifying and collecting promising sources of literature. This was followed by pre-screening, to evaluate their relevance to the object of analysis, goal of this study, quality of content, completeness, and reliability.

The collected literature was then subjected to a screening process to determine the nature of the literature collected, identifying gaps in data or specific methodological approaches and gauge if the collected literature pool is sufficiently equipped with the needed information or if further targeted additions need to be made.

There were 16 different vehicle OEM LCA reports that were also covered as a part of this review. The nature of these studies varied between environmental product declarations (2) and retrospective vehicle LCA studies (14).

The various aspects that were examined as a part of the review process included:

1. Vehicle (and battery) specifications: lifetime activity assumed, energy consumption patterns (including assumed drive cycle), battery size, capacity, and chemistry (if available)
2. Detailed definition of system boundary: vehicle and fuel/ electricity supply chain processes, foreground and background processes covered, cut-off and allocation procedures
3. Life cycle inventory and modelling methods – Specific and generic datasets, data sources used, data gaps, particularly with treatment of electricity in vehicle production and use phase, potential sensitivity scenarios accounted for
4. EoL modelling methods and assumptions used
5. Method and rationale for selection of impact assessment methods and indicators
6. Reporting and validation procedures
7. Alignment with reference standards and legislative guidance

2.3 Approach for review of product Social LCAs

The review is primarily divided into two sections: OEM interviews and desktop research. The first stage of the literature review was mainly focused on identifying and collecting the literature from various web search engines such as Google Scholar, Semantic scholar, Science Direct based on the search phrases "S-LCA automotive sector", "Social LCA", "Social Life Cycle Assessment", "Life Cycle Sustainability Assessment", "Social sustainability", "Social LCA and automotive", "Social sustainability and automotive". In second stage of the review, abstract screening was conducted, based on i) inclusion criteria such as: the study should mainly concern S-LCA, publication should be a journal article, S-LCA studies should address the automotive industry, studies with methodological gaps, study should be published between 2010-2023, study should be published in English; and ii) exclusion criteria such as: books and conference publications, publications that are older than 2010, any publication in a language other than English. Both inclusion and exclusion criteria were searched over the title, abstract, and the full text of the article. Relevant citations from the identified literature were included based on the same criteria. Third stage focused on the full text screening of the filtered scientific literature from previous stages. Then, after identification of the gaps of the S-LCA case studies, comparison with UNEP S-LCA guideline 2020 was reviewed. In addition to the literature analysis, three OEMs were interviewed to get first-hand knowledge of the challenges and requirements that businesses have while implementing S-LCA.

The identified gaps and needs of S-LCA methodology was based on the four phases – Goal and Scope definition, Social Life Cycle Inventory Analysis, Social Life Cycle Impact Assessment and Interpretation. In Goal and Scope definition phase, the study reviewed why the study is being conducted?", "target audience", "what do we want to assess?", "does the study intend to support decision making?", "what are potential opportunities produced by study?", "which stakeholders are affected?", functional unit, system boundary, reference flow, product system, activity variable, cut-off criteria. In Social Life Cycle Inventory Analysis phase, the study reviewed the gaps and needs in collecting data for impact assessment, primary data, secondary data, activity variable, handling co-product. In Social Life Cycle Impact Assessment phase, the study reviewed the gaps and needs of reference scale approach and impact pathway approach. Finally, the gaps and needs of interpretation phase were reviewed.

2.4 Consultation process: survey and interviews

To complement the desk research and literature review conducted for WP1, a range of stakeholder consultation activities were organised to gather insights and views on the use of LCA methods for road vehicles, including:

1. A **targeted survey** to identify the current practices used by the industry to undertake LCA of zero emission road vehicles (and key components) and understand the challenges of using LCA methods, now and in the future.
2. **Targeted interviews** with a selected number of stakeholders that responded to the survey to clarify and/or explore in more detail some of the topics that they covered in their survey responses.

These are outlined below in the following report sections.

2.4.1 Targeted survey

The objective of the targeted survey was to gather insights and views on the use of LCA methods for road vehicles from the current experience and knowledge of the EU automotive industry. The responses are used to inform and guide the harmonisation effort, especially focusing on the areas that have been identified as more critical.

The survey ran for three weeks, from 9 May 2023 to 30 May 2023, in an online platform. It was sent to all industrial partners of the TranSensus LCA project consortium and other industry contacts.

The survey was divided into six different sections including:

- LCA practice: This section included questions about the organisation's current and future LCA practice as well as data collection.
- LCA methodology: This section included key questions concerning methodological choices for LCA of ZEVs and batteries.
- Application and scenarios: This section was dedicated to topics beyond LCA that have an influence on the requirements of the LCA approach. This includes current and future mobility scenarios as well as current and future end of life (EoL) / circular economy (CE) scenarios.
- Social responsibility: This section included questions about the organisation's management of social issues, like human rights, health and safety and discrimination.
- Social LCA: This section was dedicated to more detailed questions about social LCA which were only to be answered by organisations that conduct an S-LCA.
- Life cycle costing assessment (LCC): This was a short section containing questions on whether and how organisations also use LCC.

Considering the breadth of the topics covered, it was recognised that respondents would not necessarily have expertise and knowledge across all areas. Therefore, they were allowed to select the survey sections that they could provide answers to and skip the sections not selected entirely. All TranSensus LCA project partners were required to engage with the first three sections as a minimum but external respondents could select any sections.

Overall, 17 stakeholders responded to the survey. An overview and analysis of their responses to what regards needs and gaps has been incorporated in the relevant sections in this report.

2.4.2 Targeted interviews

Following the review of the survey responses, targeted interviews were organised to clarify and explore some of the responses of selected industry stakeholders in more detail. Based on each stakeholder's response, a tailored interview guide was developed with 5-10 questions to guide the one-hour online discussions.

2.5 Position papers

Position papers are commonly used by organizations to express their opinions on a particular topic. Starting from a specific context, they often identify needs and gaps as well as proposals for addressing them. For this reason, eleven position papers around Attributional-LCA (A-LCA) were considered as relevant sources of information. Some of them are directly linked to the A-LCA approach and the need for harmonization identified by major automotive organizations (ACEA, 2021; CLEPA, 2022; UNECE-GRPE, 2023; VDA, 2022). Others are linked to the new European regulation on batteries and come both from organizations (ECOS et al., 2023; EUROBAT, 2021; Nickel Institute, 2021; VDA, 2022) and the academic world (Melin et al., 2021; Peiseler et al., 2022).

3. Analysis of needs for the TranSensus LCA method

This section describes the key needs the TranSensus LCA method shall seek to cover, while still acknowledging that some of these needs may eventually not be covered at the end of the project. These key needs and their level of priority in the development of the TranSensus LCA method are summarized in the following Table 3-1 and Table 3-2.

Table 3-1: Short synthesis of needs that the TranSensus LCA method shall seek to cover: the USADAC principles and their level of prioritization

High-level need	Description	Examples of practical implications for WP2 in the development of the TranSensus LCA method	Trade-off with other Need	(partial) overlap with other Need	Prioritization in TranSensus LCA
Understandable	Clear scope and results to audience (including limitations)	Either in the TranSensus LCA method or in the study: - **clear system boundaries** ("what is covered"?); - clear **data sources** (primary/secondary?), **representativeness**; - clear **units** for impact indicators; etc.	-	**Transparent**	High
Standardized	One clear, unique, TranSensus LCA method	- **Prescriptive guidance** (data collection templates, approach for multi-functionality etc.) - LCAs shall be reproducible. 2 studies shall deliver i) the same figures (impact values, within the range of uncertainty), and ii) the same conclusions.	**Aligned**: making the TranSensus LCA method truly "standardized" (clear and unique) implies departing from e. g. ISO 14040-44 for some aspects (e. g. multifunctionality solving)	-	High
Accurate	"*The term "accuracy" in general refers to the degree of closeness of a measured or calculated quantity to its actual (true) value.*" (ILCD Handbook, (EC-JRC, 2010))	- **Extensive mandatory use of primary data**, of good quality - Verification process includes a**ccess to disaggregated and transparent datasets**	**Simple**: access to primary data of good quality in the value chain is complex	-	High
Differentiating	Different results (indicators and uncertainty) for products with different adverse environmental and social impacts	- **Primary data along the whole lifecycle** (incl. from mine to recycling facility) to capture the true impact of the product	**Simple**: differentiation requires extensive reliable primary data collection	Standardized and Accurate	Low (already captured)
Auditable	A **credible verification process** (or audits) overcoming the challenge of confidentiality	- **Access to disaggregated datasets** in the value chain (for audit) - **Recommendations on certification capabilities** and **on-site verifications**	**Simple**	-	High

Comparable	The method shall ensure a level-playing field	Prescriptive guidance	-	Standardized	Low

Table 3-2: Short synthesis of needs that the TranSensus LCA method shall seek to cover: complements to the USADAC principles, and their level of prioritization

High-level need	Description	Examples of practical implications for WP2 in the development of the TranSensus LCA method	Trade-off with other Need	(partial) over-lap with other Need	Prioritization in Tran-Sensus LCA
Accepted	By the **scientific community** and **industrials**	- Impact categories and associated impact assessment methods with scientific consensus	**Comprehensive**: some methods may not be accepted by both industries and scientific community, or even within scientific community (e. g. **Impact Assessment**)	-	High
Aligned	with (i) **current EU legislations** (e. g. Battery Regulation, certification requirements, air pollutant emissions standards, green H2 additionality requirements, policy, etc.) ; (ii) **currently accepted LCA guidelines and standards**; (iii) **international developments** (e. g. UNECE work)	- Alignment with PEF, ISO 14040-44, Battery Regulation Delegated Act, etc. **yet with potential for deviations whenever they add a value**	**Standardized** (see above)	-	Medium - possible misalignment whenever this is agreed to add value
Comprehensive (impact coverage)	Coverage of **all relevant environmental and social dimensions**	- inclusion of indicators of **resources criticality, circularity, biodiversity, and cumulative energy demand**	**Simple, accepted and accurate**: comprehensiveness adds complexity; and methods not necessarily mature and agreed	Aligned – i. e. with EU policy (e. g. energy efficiency)	Low - **priority shall be given to Accuracy**

Simple	Easy implementation, including easy verification/audit	- **Limited mandatory use of primary data**	Accurate, reliable and trustworthy, auditable, aligned, comprehensive	-	Medium: as far as simplifications do not prevent the method to be Accurate, Auditable, Reliable and Trustworthy
Transparent	All the **methodological choices, assumptions and data quality assessment** shall clearly be stated (in the study report, or in the TranSensus LCA method)	For the method: - clear and prescriptive - transparency on what the methodological choices incentivize (e.g EoL) For the studies: requirement for detailed report	**Accepted**: confidentialty issues	**Understandable**	Medium: a good balance to be found between "confidence in and confidentiality of" data
Reliable and trustworthy	The audience shall have **confidence** in how far the outcomes of a study correctly represent the environmental and social impacts of a product	- Methodological choices and data shall help represent **real-world performance** as closely as possible: calls for extensive requirements on primary data	Simple	Accurate, comprehensive, understandable; though "trust" (perception)	High
Support process improvement + eco-design	Shall support the design of more sustainable products and systems	- sustainability dimensions shall be comprehensively covered - interaction with design tools shall be favored	-	Comprehensive	Low
Flexible	A framework that is not too rigid, i. e. that accounts for specificities of some products/companies, and the constant evolutions in diverse fields (LCA method, enhanced capabilities on data collection, etc.)	- different levels of complexity in method - regularly updated to consider evolutions in the LCA field (e. g. LCIA methods or collected data)	Standardized and reliable and trustworthy, because may lead to several methods (no one unique method)	-	Low

In general, the TranSensus LCA partners retained of interest the "USADAC" principles as defined by the Global Battery Alliance in the context of their Greenhouse Gas Rulebook Generic Rules (Version 1.4). The footprint calculations through LCA and S-LCA in the electromobility industry shall be performed in an **understandable, standardized, accurate, differentiating, auditable** and **comparable** way. This interest in the "USADAC" principles was also raised by the participants to the survey organized in the context of WP1 (see Section 2.4), in particular regarding the understandable and comparable aspects. These principles are developed, complemented and slightly amended in the following sections 3.1 to 3.4, essentially building on results from the TranSensus LCA workshops unless stated otherwise.

3.1 A standardized method enabling a level-playing field

Standardization of the LCA/S-LCA method appears as a core need. LCA/S-LCA results shall be independent of the practitioner. In general, the TranSensus LCA method shall ensure a level-playing field, in particular to ensure fair comparisons between products on an environmental and social basis.

The method shall ensure that the LCAs are reproducible. It is crucial that two LCAs of the same product, in the same decision-making context, deliver the same results. That is i) the same figures (impact values, within the range of uncertainty), and ii) the same conclusions.

The need for standardization is directly related to a core gap identified by the TranSensus LCA consortium members: despite the tremendous efforts of the LCA community in the last decades, there is still no common, standardized approach to LCA and S-LCA in the electromobility sector.

This need for standardization implies that the TranSensus LCA method shall be prescriptive and clear. Therefore there is a need for clear rules and guidance on the following issues of a LCA method (from Goal and Scope definition to Interpretation of results), reported as important by the TranSensus LCA consortium members who participated to the workshops. The Goal and Scope definition is the phase for which the need for standardization was the most reported by participants. There is a lack of (and associated need for) standardized system boundary and cut-off rules, functional unit by product type and associated reference flow, generalised rules for calculating lifetimes/use phase parameters (kilometres and years), etc. Regarding the latter point (lifetimes to be defined in the phase of Goal and Scope definition of the study), these rules do not necessarily mean fixed default values that shall be used in all studies. Although there is a need for defined and agreed default values for consistency, there should be an option to vary these if there is sufficient evidence to suggest for the specific product that they should be different, and/or application of alternative assumptions as sensitivities. E. g., if a vehicle is deemed to be less durable and/or more likely to be used for a shorter service life, then a reduced estimated lifetime should be set in the Goal and Scope of the LCA for such a vehicle. However some partners stressed the necessity to keep the calculation Standardized and Comparable, avoiding any risk that assumptions on lifetime might be left to the goodwill of the company or practitioner. The other phases of an LCA also need to be standardized: e. g. regarding the Inventory phase for which data format to report manufacturing data shall be standardized for actors in the supply chain (for use to create LCI-data); and regarding the Interpretation phase for which a standardized verification process shall be developed and implemented by all actors in the electromobility sector.

As a standardized (TranSensus)-LCA approach shall tackle existing gaps of the LCA method, this aspect is further explored in section 4 (relative to Gaps) of this report.

3.2 Other important high-level needs for the TranSensus LCA method

Besides the need for a **standardized** (TranSensus)-LCA approach for each of the four phases of the LCA method, other needs were identified as important by consortium members (as raised through workshops and survey), in order to offer a clear basis for comparison between products and technologies from the electromobility sector.

In a first place, the TranSensus LCA harmonized method shall be **accepted** by both the scientific community and the industrial sectors. Apart from being accepted, the method shall also (whenever possible) be **aligned** with (i) current European legislation for fleet compliance, such as EU Battery Regulation (in particular Article 7 relative to lifecycle carbon footprint calculations), various legislation setting out vehicle type-approval and certification requirements also feeding into the CO_2 regulations for cars, vans and HDVs, and air pollutant emissions standards); (ii) currently accepted LCA guidelines and standards, with deviations whenever they add a value to the overall method and are commonly accepted; (iii) international developments (e. g. also work ongoing under the UNECE on automotive LCA).

The method shall also be **comprehensive** for a large audience; from LCA or electromobility experts to the public. In particular, apart from being comprehensive in terms of the life cycle phases that are covered by the LCA, the method shall particularly be comprehensive regarding the LCIA phase in general. Some TranSensus LCA consortium members advocate that the method shall cover all environmental, social issues as well as issues regarding resources; this encompasses climate change, water scarcity or biodiversity for example. In other words, all relevant performance indicators shall be covered and explained. Other partners also advocate that apart from impacts from environmental and social LCA approaches, the TranSensus LCA method should ideally additionally encompass circularity metrics in order to offer a fully comprehensive overview of the results. These would support implementation of circular economy strategies that could reduce the impacts associated to the production of all electric vehicles parts. Other partners additionally mentioned the need to account for mineral resources criticality in an extended LCA framework. 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., 2020). Mineral resources criticality would be an additional dimension covered, as a complement to classical environmental LCA. The level of priority (and approach) for capturing mineral resources criticality shall be defined in the TranSensus LCA method. Moreover it is recalled that current classical methods that quantify impacts on mineral resources in LCA enable to address the contribution of a product or system to these resources' *depletion* (as e. g. recommended in the PEF context); i. e., the contribution to exhaust the primary natural stock of a non-renewable resource, in turn limiting its availability to future generations. More recent methods were developed to capture reduction of accessibility and *dissipation* of mineral resources. As defined by (Beylot et al., 2020), "*dissipative flows of abiotic resources are flows to sinks or stocks that are not accessible to future users due to different constraints […]*".

Making the method comprehensive must however be balanced versus the need to make it also **simple**: results shall be easily readable for non-LCA experts. Simplicity shall also be a component of the verification part; at this time, some partners expressed that audit procedures are very long. Levels in this verification part could be defined, depending on the case. Some partners advocated that once a TranSensus LCA method is available, an ISO review according to ISO14040:14044 may not be necessary – this shall actually be defined in the method as developed in WP2 of TranSensus LCA. Eventually, there is a need for the results to be **verified** and **auditable** by a third-party (the latter point being already captured in the above-mentioned "USADAC principles").

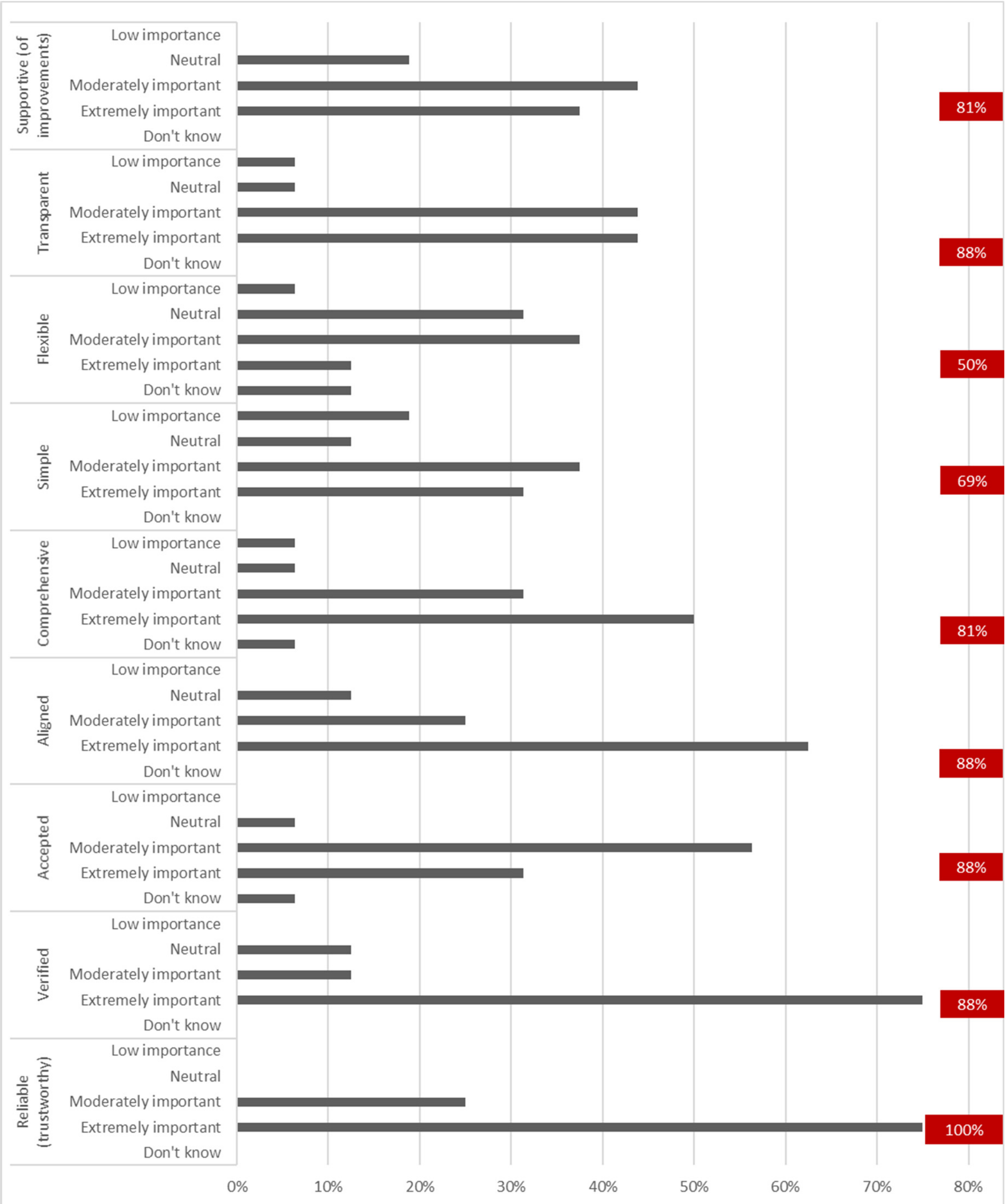
Results coming out of implementation of the TranSensus LCA method shall be **transparent**, while in compliance with industrial standards and needs to respect confidentiality in data. In that sense, all the data may not necessarily be required to be disclosed to all types of audience, but all the methodological choices, assumptions and data quality assessment shall clearly be stated.

Disclosing methodological choices will help having **reliable and trustworthy** results. Methodological choices and data shall help represent real-world performance as closely as possible while respecting practical and resources constraints (linked to the method simplicity). Modelling, at least for the main hotspots, shall be based predominantly - as far as feasibly possible - on primary (or supplier-specific) data, as explored further in the following section 4 on Gaps. Reliable results require data for all lifecycle phases that are geographically and temporally relevant. This entails a particular emphasis on the use phase for energy mix over the lifetime of the vehicle. Region-specific data are also important for other stages of the vehicles' lifecycle – including in particular the production stage. The modelling step shall also reflect and **support**

process improvement and eco-design efforts occurring in the sector. The resulting implications of the TranSensus LCA methodological choices made in the development of the method shall not adversely affect the fundamental principles of sustainability. More generally, what the TranSensus LCA methodological choices incentivize (e. g. in terms of recycling, electricity modelling, etc.) shall be made transparent in the description of the TranSensus LCA method itself.

The TranSensus LCA method shall be **flexible** in different ways. Firstly, depending on the application, different levels of complexity could be chosen. Secondly the developed framework shall be easily adaptable to future developments. For that it shall be regularly updated to consider future improvements or changes in the LCA field, in particular regarding LCIA methods or collected data. Moreover, the TranSensus LCA could recommend to use parameterised models, e. g. to make scenario analyses easier. The parameters can be used to combine different sets of data, extending the scope of the model. For a material production model for example, the parameters may correspond to composition, location, process route, etc.

Finally, all these aspects shall lead the TranSensus LCA method to be **understandable**, which is here again one of the above-mentioned "USADAC principles". The importance of all these principles has been rated by the survey participants and illustrated in Figure 3.1. In particular, results being **reliable** is of importance for 100% of survey participants.



x% Sum of inputs 'Moderately important' and 'Extremely important'

Figure 3.1: Relative importance of specific principles in the future TranSensus LCA harmonised method rated by survey participants (Original question: "When adopting the TranSensus LCA harmonised method in the future, LCA shall be…")

3.3 Specific needs per LCA phase

Through the TranSensus LCA workshop on Needs, these above-mentioned high-level needs were further complemented with specific, operational, needs per LCA phase. Overall, it was reported that the TranSensus LCA method shall provide specific guidelines related to the following different aspects of an LCA:

- Making sure that the product LCAs are, at the end, comparable. Product LCA was defined in section 3.1.1 of Deliverable 1.1 (Eltohamy et al, 2023) for retrospective studies (already existing products) and prospective studies (emerging technologies or products) as two distinct scopes, however both are on product scale;
- The choice of the functional unit shall be based on the goal and application of the LCA. For example, a study on a single vehicle life cycle is different from dealing with the same vehicle on a fleet level.
- For the LCI phase, guidelines regarding data collection shall be proposed; this includes:
  - Standardized data format for the actors in the supply chain to report manufacturing data without necessarily having LCA knowledge. Such effort in standardization will primarily build on other reference initiatives (e. g. Catena-X which is a big consortium of influential actors in the European automotive sector). Such initiatives will be considered as the starting point of the TranSensus LCA method. This TranSensus LCA method may however depart from or complement such initiatives if deemed relevant and necessary; in particular potentially extending the scope (in particular in terms of emissions, and impacts, covered) whenever required, and checking wider alignment of such initiatives with methodological choices and assumptions in other overarching LCA guidance ;
  - Guidance on where to collect specific data and where more generic data are acceptable;
  - Guidelines on a data collection hierarchy, i. e. which type of data is preferable over another one;
  - Guidelines on default data (e. g., if deemed relevant in TranSensus LCA WP2: any guideline on conservative default data, rather than market average to incentivise collection of primary data)
- The conclusion of the interpretation phase shall be aligned with results quality and reliability, and guidance shall be given for conducting sensitivity assessment;
- A third party verification approach – to be defined - that could be simplified for the TranSensus LCA needs.

Several of the above points are further explored and complemented in the following Section 4 relative to Gaps.

3.4 Conclusion on needs

TranSensus LCA consortium members who participated to the two workshops on Needs and Gaps generally agreed that the TranSensus LCA method shall be based on USADAC principles, i. e. shall be Understandable, Standardised, Accurate, Differentiating, Auditable and Comparable. Furthermore, these same partners identified that the method shall additionally be Accepted, Aligned, Comprehensive, Simple and Flexible, Transparent, Verified, Reliable, and Supportive (of improvements).

The identified key needs and their level of priority in the development of the TranSensus LCA method are summarized in Table 3-1 and Table 3-2.

Among all these needs, potential incompatibilities may arise. For example, some partners advocated for a Simple method; yet others (or the same) also advocated for a Comprehensive and Accurate method – which may make the method complex (not Simple). A contradiction may similarly arise between the need for accuracy (data specificity) and the need for standardization of analysis and for comparability (data standardization). To overcome these possible incompatibilities, trade-offs might have to be defined. Priorities to be given shall be reflected in the development of the TranSensus LCA method.

These high-level needs may be complemented, and somehow translated, in terms of specific needs per LCA phase. Eventually, the overall goal of the TranSensus LCA method is to deliver reliable results that are trustworthy for the audience they reached, and that can support sound decision-making.

4. Gaps identified in E-LCA

This Section describes the gaps identified (through the approach described in Section 2) in current LCA/S-LCA implementation in the electromobility industry. Gaps are detailed per LCA phase, from Sections 4.1 (on Goal and Scope) to 4.5 (on Transversal issues).

A more general analysis is first provided building on outcomes from the survey. When asked where harmonization is needed (on methods and data) between stakeholders and actors all around the supply chains, the survey respondents identify general aspects as well as specificities related to three out of the four LCA phases (Goal and Scope, Life Cycle Inventory and Life Cycle Impact Assessment). These are illustrated in Table 4-1 and some of them are rated in Figure 4.1. It particularly shows that both the electricity supply modelling and the data collection/data sources are aspects of particular importance for the survey participants, as further discussed in the following sections.

Table 4-1: Respondents' answers to the open question "Where do you see the need for harmonisation (methods and data) between stakeholders or actors along the supply chain?"

Goal and scope	LCI	LCIA
• Functional unit • System boundaries • Modelling choices: on maintenance, second life evaluation (e. g. CFF) or electricity	• Primary data: that are harmonized, collected through a data platform and with same rules, that are comparable • Secondary data: that are standardized, that considered processes and electricity differences • Provision of harmonized methods for OEM to report data • Data quality • Emission factors for energy carriers	• Methods including biogenic and generally sequestration evaluation
Transversal needs for harmonization		
• Compatible with regulatory requirements • On the full methodology / everywhere in the LCA • In order to be comparable		

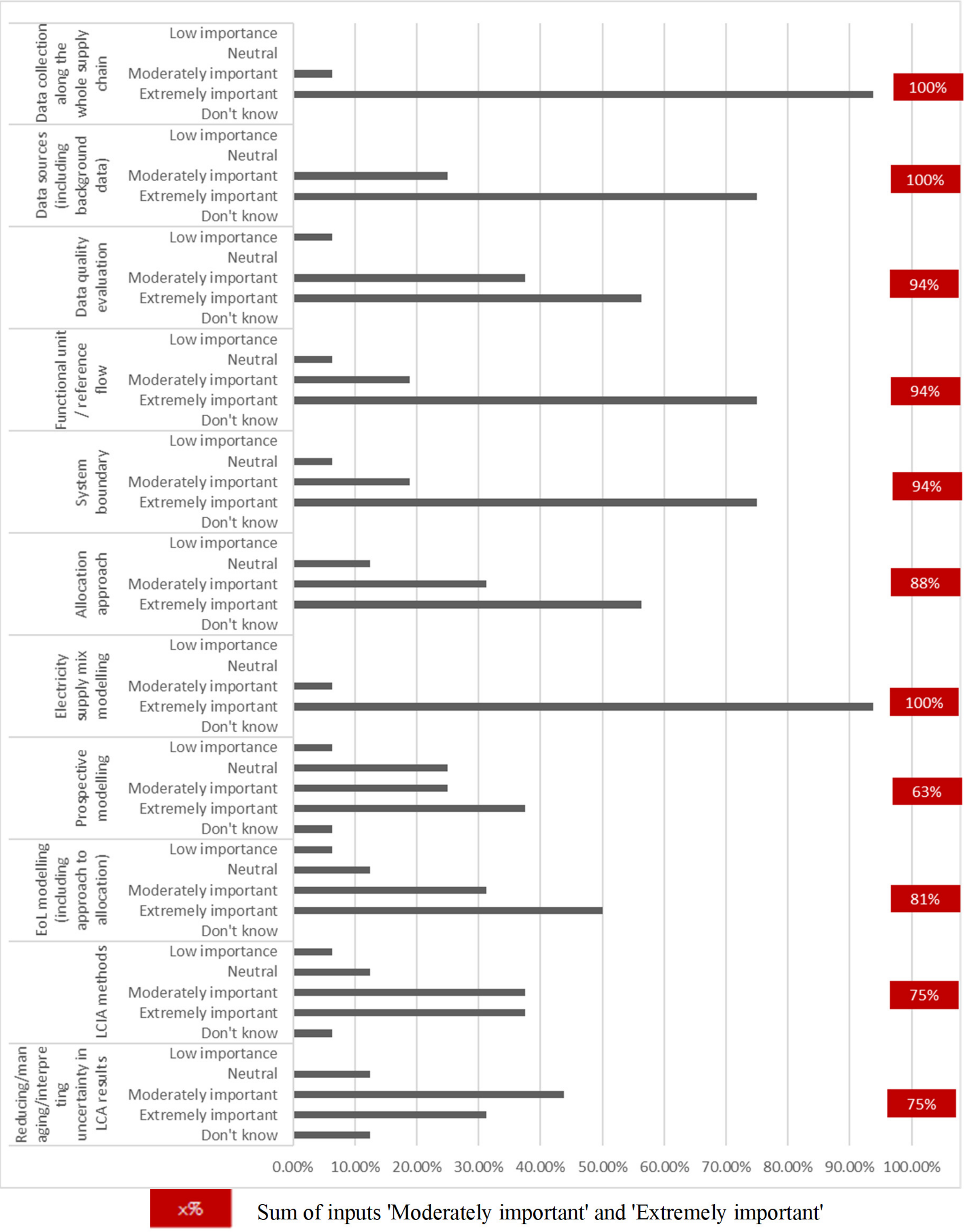


Figure 4.1: Relative importance of harmonisation between stakeholders or actors along the supply chain regarding the following aspects as rated by the survey participants

4.1 Goal and scope definition

Summary of main outcomes on gaps in Goal and Scope definition

This section is about the main gaps identified in the goal and scope definition phase of an LCA, focusing on two aspects: the **functional unit** and the **system boundary**.

The importance of determining a **functional unit** that accurately reflects the real-world use of the product being studied is first pointed out. There is currently a lack of a common, harmonized way to account for real-world use product performance, including life-time kilometers. The document notes that different guidelines (e. g., VDA, PFA or CATARC) set different vehicle lifetimes for different segments, which can impact LCA studies. If it is not possible to determine lifetime kilometers, harmonized default values should be used. For parts, the functional unit shall consider interaction with the overall vehicle system and be consistent with a more global approach to the problem. As pointed out for example in the case of the European Battery Regulation, a functional unit based on “energy provided over the service life”, could perversely incentivize vehicles with higher energy consumption.

Regarding the **system boundaries**, it is noted that they should be set at each level of the system and should fit in with the overall boundary at the vehicle level. OEMs have been observed to have unanimously adopted “cradle-to-grave" life cycle stages for the environmental impact assessment of their vehicles, irrespective of the goal or scope of study. However, inconsistencies in the omissions were observed particularly within the “vehicle maintenance” or the “end of life” phases. Here again, there is a need for a single harmonized set of rules and guidance on the methodology choice to adopt for different processes and scenarios embedded in the life cycle of road vehicles.

This is further synthesized in the following Table 4-2. Then the following sections deliver a more in-depths description of the outcomes from the tasks undertaken in this Task 1.2 (as described in Chapter 2); i. e. outcomes from workshops, review of product LCAs, survey, and review of position papers.

Table 4-2: Short synthesis of gaps on Goal and Scope definition in E-LCA, for the development of a harmonised approach in the electromobility sector

Gap regarding	Short description	Prescriptions for the TranSensus LCA method: it shall cover/include (though not be limited to):	Level of importance in the development of the TranSensus LCA method
Functional unit	Lack of a common, harmonized way to account for **real-world product performance**	i) for vehicles: including lifetime kilometers	High
		ii) for parts (e. g. batteries): accounting for the interaction with the overall vehicle system	High
System boundary	Lack of clear, detailed and agreed rules on **inclusion/exclusion of elements** from the system boundaries	In particular regarding (but not limited to): water and gas cleaning/treatments, real fate of waste and output streams, infrastructures (e. g. charging cables and stations), maintenance, etc.	High
	Consequence of the above: each level of the system shall fit in with the overall boundary at vehicle level	-	High

4.1.1 Functional Unit

Outcomes from workshops

When setting the Functional Unit in LCAs of the electromobility sector, a common, harmonized, way to account for real-world use and product performance, including lifetime kilometres, is often missing. For instance, as the current state-of-play in different guidelines (e. g. Verband der Automobilindustrie (VDA) from Germany, Plateforme Automobile (PFA) in France and CATARC guidance in Asia), different vehicle lifetimes are set for different segments. In general terms, if a car is built to last longer, it is expected that this should be reflected in the Functional Unit; and if it is not possible to make a specific accurate estimate of lifetime kilometres, harmonized default values shall be used. Moreover, the method shall clarify which driving cycle (based on WLTC or real-world driving conditions) shall be considered in the study, with additional clear prescriptions on how this shall be done in the study.

Outcomes from review of product LCAs and survey

Review of the published OEM report and consultation with relevant OEMs and organizations revealed a selection of them employing dedicated functional unit estimation methodologies. These methodologies support this quantification accounting for regional lifetime performance of specific vehicle segments accessing the national or regional statistics and subjecting them to a regression analysis. However, this approach is not harmonized. This is undertaken majorly by vehicle OEMs operating in France, Germany and Asia, adhering to their regional LCA guidance for vehicles (VDA from Germany, PFA from France and CATARC in Asia). Nevertheless, the remaining reviewed reports were observed to have used a functional unit of transport of passengers or goods over the whole *vehicle service lifetime* (km), without indications on how the functional unit is arrived at. Almost all of the passenger car studies adopted a vehicle lifetime figure of 150,000 – 200,000 km, although recent analyses for the European Commission suggest the average lifetime could be even higher than this based on analysis of real world data from registration statistics and second hand vehicles from (CE Delft, 2017), (TML et al, 2016), and (Ricardo-AEA, 2014). A breakdown for different types of LDV (cars and vans/LCVs) is presented in Table 4-3 below, based on these studies (average for all powertrains calculated by Ricardo for this study).

Table 4-3: Assumptions on vehicle mileage by vehicle segment and powertrain

LDV type	**Passenger cars**					**LCV /vans**			
Market segment	Small	Lower medium	Upper medium	Large (others)	All	Small	Medium	Large	All
Average for all powertrains	**172,000**	**223,000**	**249,000**	**259,000**	**209,000**	**188,000**	**208,000**	**244,000**	**227,000**

Source: Aggregation by Ricardo analysis (2023) for all powertrain types and based on (CE Delft et al., 2017), (TML et al, 2016) (Ricardo-AEA, 2014), and rounded to the nearest 1000.

The truck reports reviewed used vehicle lifetime references that ranged between 100,000 km to 1,600,000 km (with lifetime activities increasing broadly with vehicle size class). 100,000km to 1,300,000km was used in one study to illustrate break even and the impact of the chosen service lifetime on the environmental impact per tonne kilometers (tkm). The bus reports reviewed used service lifetimes that ranged between 800,000 km to 1,300,000 km. In some cases, the bus-related and freight truck-related LCAs used passenger kilometers (pkm) and tkm respectively as functional unit, calculated over the above-stated respective service lifetime. A similar observation was also made from the review of the responses to the survey questionnaire.

From the regulatory context, only assumptions on annual km activity are defined for different use cases in European HDV fuel consumption and CO_2 emissions certification (e. g.

Table **4-4** below) and the HDV CO_2 regulations and proposed revision of these (European Commission, 2023a). These are used in combination with cycle and loading/occupancy weighting factors to determine an overall weighted performance (which are defined in the regulations) for different HDV categories, but do not define a typical lifetime (in terms of years or total km).

Table 4-4: Average yearly mileage depending on the application area (ACEA, 2018)

Type	Vehicle category/application	Average yearly run distance [km]
Lorries	Long haul	120 000
Lorries	Regional delivery	60 000
Lorries	Urban delivery	40 000
Lorries	Municipal utility	25 000
Lorries	Construction	60 000
Buses	Citybus	60 000
Buses	Interurban	60 000
Buses	Coach	70 000

Outcomes from position papers

Two position papers address the issue of the functional unit determination for parts of a vehicle, which shall account for the interaction with the overall vehicle system.

VDA (Position paper on decarbonization of LCA of a car; (VDA, 2022)) proposes that "*when evaluating individual components and materials, the interaction with the overall vehicle system must always be taken into account. Vehicles and individual components as well as materials form a functional unit and influence each other's CO_2-footprint*."

The implication of the choice for a functional unit, and in particular what this incentivizes, shall be made clear.

For the battery (when treated separately from the overall vehicle), ECOS et al. (Warning letter against shortcomings of future CF evaluation rules for new batteries; (ECOS et al., 2023)) point out that the main concerns revolve around the Carbon Footprint Functional Unit, which is a proposed measure for comparing the environmental impact of batteries. There is a risk that the current proposal could incentivize the production of larger, heavier vehicles with higher energy consumption, as the functional unit is based on energy provided over the service life and takes into account battery durability and vehicle energy consumption. This goes against the environmental intentions of the Battery Regulation and undermines the performance classification and maximum thresholds for the battery carbon footprint. To address this, they suggest countermeasures such as using a fixed consumption for M1 vehicles based on market data to avoid distortions due to vehicle energy efficiency. It also suggests making the absolute battery carbon footprint available for each battery, in addition to the functional unit, to provide more comprehensive information.

Regarding the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM highlighted that "*the proposed functional unit and calculation methodology present serious limitations in the framework of battery carbon footprint declaration*" (CEA and BRGM, 2023). In particular, they state that "*the calculation based exclusively on a number of cycles is […] biased*".

4.1.2 System boundaries

Outcomes from workshops

Feedback from the workshops suggested that currently a clear, harmonized, approach for system boundaries is missing. This relates in particular to clear (and detailed) rules on inclusion and exclusion of elements of the systems life cycle. One may cite in particular the following processes or systems for which clear rules shall be defined: water and gas cleaning/treatments, real fate of waste and output streams, infrastructures (e. g. industrial plants, charging cables – e. g. supplied with the vehicle – and charging stations for electric vehicles, etc.), maintenance (tires, liquid cooling, brake fluids, refrigerant, brake pads, other parts likely to be replaced in the vehicle lifetime), etc. It shall be ensured that the constraints for scope at each level of the system (that is, the union of all sub-boundaries) fit in with the overall boundary at vehicle level.

Outcomes from review of product LCAs and survey

Despite the lack of a clear harmonised guidance on setting a vehicle's system boundary, OEMs have uniformly adopted "cradle-to-grave" life cycle stages for the environmental impact assessment of their vehicles/ models, in line with the goal and scope of the study. The most relevant life cycle phases were adopted by all vehicle OEMs for their vehicle's LCA, categorising the phases and relevant processes as "foreground" and "background" processes, however, with inconsistencies in the cut-off criteria and other omissions, observed. This was particularly observable for "vehicle maintenance" and EoL life cycle phases. In terms of maintenance, while some studies have predominantly chosen to focus on tyre replacements over the vehicle's assumed service life, some studies have either completely omitted this life cycle stage or have chosen to exclude any details pertaining to their inclusion, such as assumptions or other particular, in the publicly available reports. Similarly, while all the OEMs have adopted EoL, the consideration of processes within the EoL stage were also observed to be restricted with key processes omitted. Almost all OEM studies adopted stages pertaining to dismantling and shredding of vehicle components and parts, while excluding key EoL processing routes such as recycling. However, incineration of non-recyclable fractions and landfilling were found to be included.

In the case of the BEVs, traction batteries, a key component of the vehicle, which is also of very significant environmental importance, is rarely explored in detail similar to that of the rest of the vehicle. This may be attributed to the lack of a single harmonised approach for application to their traction batteries or due to the lack of visibility of the supply chain, particularly the processes and materials invested in the production of those batteries. However, the recent publication of carbon footprint guidance for EV batteries by the JRC (EC-JRC, 2023) and GBA (GBA, 2023) is likely to provide future guidance for OEMs and their relevant batteries suppliers (though needs further harmonisation still).

Fuel and electricity supply chains are often included in the system boundary through the use of third-party LCA tools and databases. However, some studies were observed to have excluded fuel/electricity infrastructure emissions from capital goods and machinery, particularly those dedicated towards renewable energy generation. These studies generally account for renewable energy (RE) as "zero-emission" energy supply, deviating from specific RE accounting approaches recommended within a number of LCA guidance such as the GBA or JRC batteries carbon footprint guidance.

Considering a significant part, or almost all, the respondents of the survey are members of the OEMs producing these product LCAs, the review of survey results did not result in any noteworthy observations.

Overall, while all of the product LCAs reviewed have adhered to the ISO14040/44 guidance for setting the system boundary for their studies, the need for clear definition of rules and guidance on the list of processes and associated activities associated with the life cycle of low and zero emission vehicles is evident. Informed by the outputs of the review of literature presented in TranSensus LCA D1.1 (on the state-of-the-art) and D1.2 (this report), these rules and guidance must be established to exhaustively cover the various vehicle segments, powertrain configurations, associated maintenance routine and end of life management protocols, so a single harmonised but overarching set of guidance is available to address the diversity in road vehicles LCA.

Outcomes from position papers

The outcomes from the workshops, product LCAs review and survey are further corroborated by three position papers. At the international level, the UNECE GRPE (Informal Working Group on A-LCA; (UNECE-GRPE, 2023)) proposes that *"System boundaries shall be defined. Temporal, Geographical and Technical scope shall be defined*." Moreover CLEPA (Inputs for a CO2-LCA workshop at GRPE) points out that there is a "*Need for standardization of the LCA rules, in particular for system boundaries"*.

In the context of the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM also highlighted issues regarding the system boundaries, and in particular subsequently recommended (CEA and BRGM, 2023):

- "*To specify that the inverter is excluded, like the charger*
- *To specify that the junction box is included*
- *To include only the heat transfer fluid and pipes that are contained in the battery pack, up to the plug and exclude all other parts of the heat management system of the vehicle*
- *To include transport of inputs in all LCI tables, but not create a distinct life cycle phase*"

4.2 Life Cycle Inventory

Summary of main outcomes on gaps in LCI

Multi-functionality: there is a lack of an unambiguous, reliable, and commonly agreed approach for addressing multifunctionality in LCA of electromobility, in a harmonized way, in both the foreground and background systems. Stakeholder consultations could help to better understand the current industrial practice in this respect.

Primary data: in environmental LCA practice in the electromobility sector, there is in general a lack of supplier specific data. Clear rules are needed on the mandatory use of primary, supplier-specific, data versus secondary data. Doing so, it shall be decided whether these rules shall incentivize the use of primary data. Robust and prescriptive collection guidelines and templates (including convention for terminologies) are required, potentially up to automation of supplier-level data collection and reporting processes; along with well-documented framework and associated guidelines for data hierarchy, traceability down to lower-tier suppliers, and verification. A good balance shall be ensured between confidence in the data received and business confidential information protection. For the use phase, clear rules shall be specified for the use of either “real-world" vehicle energy consumption data or the use of adjustment factors for values based on regulatory cycles.

Secondary data: clear guidance and rules on databases that OEMs or other LCA practitioners could use to undertake vehicle LCA need to be defined, including to ensure that the scope for secondary datasets (system boundaries, approach to solve multi-functionality, etc.) is similar to that for primary datasets. Standard secondary datasets are moreover limited by issues of incompleteness and imprecision. A larger level of granularity in secondary datasets is required, including regionalized datasets. Conservative default data, rather than market average, is an option to be considered and discussed in TranSensus LCA to potentially incentivise collection of primary data. LCI secondary datasets are moreover too static. Databases change over time, with updates that have a significant influence on the impact assessment results, which implies the requirement in guidance on update frequency and acceptable deviations. Clear guidance on proxies shall accordingly be developed.

Electricity (and hydrogen) modelling: the approach to handle electricity consumption in the production phase and for the use of the vehicle (the latter also for hydrogen), including reliable future grid mix scenarios to be considered (electricity/hydrogen consumed at the use phase, electricity for recycling processes at EoL, etc.) shall be clarified, harmonized and commonly agreed. Two main approaches of modelling may be distinguished: i) location-based (average grid mix) and ii) market-based modelling. Both hold pros and cons, with some of the latter that may be related to gaps, and different options may be more suitable for production (i. e. current/'known' mix, where a residual or market mix might have particular advantages) versus use/EoL (where a future market/residual mix might not be relevant/appropriate). The TranSensus LCA method i) shall carefully address any risk of double counting, and ii) shall ensure the time coherence condition is aligned with country legislation (month or annual).

End-of-Life modelling: the approach to model end-of-life shall be clarified, harmonized and commonly agreed. Among WP1 partners, there is no general agreement on the Circular Footprint Formula (CFF) as developed in the PEF. The CFF is considered by several partners as too complex and leading to uncertain calculations. Uncertainty pertains to credits evaluation and prospective aspects (future recycling processes, substituted materials, etc.). Commonly agreed proxies and assumptions shall be set. Conservative EoL practices and assumptions shall be considered and discussed in WP2. Rules shall also be defined regarding modelling of battery second life, and approach to deal with EoL in other countries than those of production and use of the vehicles.

This is further synthesized in the following Table 4-5. Then the following sections deliver a more in-depths description of the outcomes from the tasks undertaken in this Task 1.2 (as described in Chapter 2); i. e. outcomes from workshops, review of product LCAs, survey, and review of position papers.

Table 4-5: Short synthesis of gaps on the Life Cycle Inventory in E-LCA, for the development of a harmonised approach in the electromobility sector

Gap regarding	Short description	Prescriptions for the TranSensus LCA method: it shall cover/include (though not be limited to):	Level of importance in the development of the TranSensus LCA method
Primary data	Lack of **supplier-specific data** of quality	TranSensus LCA is a method-oriented project (not data-oriented)	Low
	Clear rules needed on the mandatory use of primary, supplier-specific, data versus secondary data	Incentivizing the use of primary data, or not: shall be clear	Medium
		Robust and **prescriptive guidelines** for: i) **data collection** (including templates and convention for terminologies), and ii) **hierarchy, traceability down to lower-tier suppliers, and verification**. E. g. for the use phase: **"real-world"** energy consumption data vs from regulatory cycles	High
		Ensuring good balance between **"confidence in and confidentiality of" data**	High
Secondary data	**Clear guidance and rules** needed on secondary LCI databases to ensure consistency with primary data	**Guidelines** for system boundaries, solving multi-functionality, etc. shall be consistent between **foreground (primary) and background (secondary)** datasets	High
		Shall prescribe **consistent modelling** of all the used **secondary datasets**	High
	Incompleteness and imprecision of some secondary datasets	**Larger level of granularity** in secondary datasets is required, including regionalized datasets	Low
		To be considered: **prescribing use of conservative default data**, rather than market average	Medium
	LCI secondary datasets are too static	Effort required on parameterized, potentially dynamic and prospective, LCI models	Low
	Databases evolve over time, with significant effect on impact assessment results	**Guidance on update frequency** and acceptable deviations	Medium
	Use of proxies (in terms of "**values" and "datasets**") is not limited or guided by rules	**Clear guidance on proxies**, either with default values/datasets (e. g. for mapping between materials used in vehicles and those in LCI databases), or conditions for the development and check of proxies	High

Electricity (and hydrogen) modelling	Lack of **harmonized and commonly agreed** approach to model **electricity and hydrogen consumption** (in production phase, vehicle use, and EoL)	The TranSensus LCA method shall carefully address **any risk of double counting**	High
		The TranSensus LCA method shall ensure the **time coherence condition is aligned with country legislation** (month or annual)	High
Multifunctionality	Context: "*There is no correct way of solving the multi-functionality problem, not even in theory*" (Guinee et al. 2002): there needs an **unambiguous, reliable, and commonly agreed approach** to address this issue (for foreground and background systems)	Particularly pertains to raw materials co-production, process lines, parallel use of electric vehicles (e. g. V2G), waste treatment including recycling and battery second life, etc.	High
		Shall be linked to the Goal and Scope	High
		Shall be complemented with operational recommendations regarding implementation	Medium
End-of-Life modelling	EoL modelling needs to be **harmonized and commonly agreed**. **CFF intensively discussed** and not commonly agreed.	To be decided: **starting from the CFF, or not?**	High
		To be decided whether to: i**nclude battery second life and EoL in other countries**, other than sensitivity	High
	CFF (major modelling approach) is considered by several partners as **too complex and uncertain** (e. g. **credits evaluation, prospective aspects**)	If starting from the CFF: clearer prescriptions on the CFF implementation regarding **credits evaluation and prospective recycling** processes	High
		Shall include **commonly agreed proxies and assumptions** - with conservative EoL practices and assumptions to be considered	Medium
		Revisiting default values towards common agreement (e. g. **'A' factors for different material categories**, potentially also factors relating to **material quality**)	Medium

4.2.1 Multi-functionality

Outcomes from workshops

There is a lack of an unambiguous, reliable and commonly agreed approach for addressing multi-functionality in LCA of electromobility, in a harmonized way in both the foreground and background systems (i. e. harmonised for both primary and secondary datasets). In TranSensus LCA Deliverable 1.1 (Eltohamy et al, 2023) three types of multifunctionality are described: 1) multi-output during production, 2) multi-input for recycling and 3) multifunctional applications. Regarding type 1, for instance, one may cite multi-functionality that applies to battery raw materials co-extraction and production, as well as secondary raw materials co-produced from recycling at end-of-life. One may for example mention i) the case of battery-grade lithium production from geothermal brines that may also be exploited for power and heat generation, and ii) the case of graphite, whose co-products (and their potential for substitution on the market) are unclear so far in LCA practice. Other relevant examples of multi-functionality in the life cycle of xEVs (here of type 3) are to do with: i) potential second life re-use of EoL EV batteries; ii) second functionality provided by EV batteries through “vehicle-to-grid" (V2G) schemes.

Clarification on the solving of multi-functionality issues shall come along with clarification on which type of modelling approach (attributional/consequential) shall be undertaken when implementing the TranSensus LCA method. This clarification on the type of modelling approach shall be: i) linked to the goal and application of the LCA, and ii) complemented with operational recommendation on how such modelling approaches shall be implemented. Some partners also raised that alignment is needed between TranSensus LCA recommendations and approaches implemented in secondary databases. They also underlined the need to use consistent allocation rules, especially consistent price values in case of economic allocation. Moreover, wherever default allocation keys shall be used, there shall be harmonised default values. These are currently missing in LCA practices and guidelines.

Outcomes from review of product LCAs and survey

Among the 16 OEM reports reviewed, all of which are attributional LCAs, none explicitly mention the consideration of multifunctionality within processes in their publicly available versions. This is particularly crucial to product LCAs considering ICE vehicles where primary fuels and a large number of different materials is used, where multifunctionality needs to be dealt with. One potential reason why it is not mentioned explicitly, could be that multifunctionality for generic datasets is already taken care in the chosen LCI database and does not require any additional modelling by the LCA practitioner. The product LCAs or surveys do not provide additional information on the multifunctional processes associated with the vehicle manufacture or their end-of-life treatment. Among the 17 respondents to the survey questionnaire, only two were observed to have adopted the CFF, suggesting the potential for the consideration of circularised materials and multifunctionality of that process. Nevertheless, this is little to no detail added on the consideration of appropriate allocation procedure for the materials generated (mass or economic as per the guidance within PEF or PEFCR for batteries). This could be overcome through the consideration of appropriate sensitivity studies, however, further information on the current industrial practice in this respect needs to be understood through stakeholder consultations. Overall, as already pointed in the above section detailing the outcomes from workshops, there is a need for a single harmonised set of rules and guidance on the methodology choice to adopt for different processes and scenarios embedded in the life cycle of transport vehicles.

Outcomes from position papers

CLEPA position paper (Inputs for a CO2-LCA workshop at GRPE; (CLEPA, 2022)) also supports the findings from the TranSensus LCA's workshops (mentioned above in this report), product LCAs review and survey, by stating that there is a "*Need for standardization of the LCA rules, in particular for allocation scheme*."

Moreover in the context of the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM "*recommend that the JRC provides unambiguous default values of allocation keys for implementation of CF calculations […] . These default values should be used in the same way for primary and secondary datasets*" (CEA and BRGM, 2023).

4.2.2 Primary data

Outcomes from workshops

Primary data along the whole life cycle of the system would be ideal, for the LCA to be based on so-called "real data"; i. e. based on technologically, geographically, and temporally representative data that would enable true depiction of the environmental impact induced by the studied vehicle or battery. Yet in LCA practice in the electromobility sector, there is, in general, a **lack of supplier specific data** to some extent. This pertains to a **lack of a harmonized approach to collect and to share the primary data**. This gap on primary data is perceived by several stakeholders, including in TranSensus LCA, as very important and challenging, in a context where i) using only primary data is far from common practice; and ii) current advancements in diverse initiatives (e. g. currently CatenaX and GBA CO_2 footprint rules for EV batteries) are promising but still limited to CO_2 emissions. Despite their core importance, CO_2 emissions are only one dimension of the multiple, complex, environmental and social impacts of the electromobility sector. However it should be acknowledged that these dimensions are intended to be at least partly addressed in the future by some of the above-mentioned initiatives (e. g. CatenaX). The use of secondary data implies limited ways to track improvement in the environmental performance of the system under study; e. g. only through lower mass, changes in materials, recycled content, more bio-based materials, etc., whereas (untracked) changes in the supply-chain may also significantly contribute to improved environmental performance.

Currently, various databases (and associated nomenclatures of flows) are classically used by value chain actors in the electromobility sector, together with various approaches for impact assessment and solving of multi-functionality. A unique framework for LCI datasets compilation is missing, including harmonization of impact assessment methods in case characterized values (at the level of impacts, and not flows) are shared along the value chain (see also section 3.3 below).

The lack of (and need for) primary data is especially core regarding raw material acquisition and processing for components. There is the need (still so far not fully properly covered) for **clear rules on the mandatory use of primary, supplier-specific, data versus secondary data**. These prescriptions shall properly balance the need for primary data regarding the whole life cycle of the system, and the need for reasonable effort in performing the LCA. **Robust, prescriptive, collection guidelines and templates are required**, in particular beyond greenhouse gases. These guidelines shall include clear specifications on boundaries and scope (in particular on inclusion and exclusion), and details on how data quality shall be considered. These guidelines shall additionally set requirements on mass balances, considering both the whole masses of products at stake, and the substances these products are made of. So far in current LCA practice in the electromobility sector, there is no commonly agreed approach to report and validate consistent mass balances along the life cycle of the products studied. They shall additionally strike a good balance between **confidence in the data received and business confidential information protection**. The International Material Data System (IMDS) is the automobile industry's material data system. It is classically used for LCI data collection. It may in particular be improved to better fit with LCA needs; which was not the intended application of IMDS.

This overarching gap on primary data as in current LCA practice in the electromobility sector implies that the TranSensus LCA method shall deliver well-documented **framework and associated guidelines for data hierarchy, acquisition and verification**. These guidelines shall support the compilation and sharing, all along the supply chain, of both i) LCI models (in a format to be defined in TranSensus LCA), and ii) associated reports.

Outcomes from review of product LCAs

Similar to the findings reported from the responses over the workshops, the review of product LCAs generally points to lack of guidance on primary data collection yet highlighting additional specific points pertaining e. g., to **common terminologies and reporting a vehicle's performance in the use-stage**, as detailed below.

Overall, product LCAs (16 studies) demonstrate the general practice of compliance with the ISO 14040/44 standards, to identify and source the data for processes across the established vehicle system boundary. Some studies were observed to have established these data quality requirements by categorizing processes. While there are clear definitions of "foreground"[1] and "background"[2] processes, detailed review of product LCAs has identified a clear trend in the consideration and increasing requests/prioritization of supplier specific data for a specific set of processes. The availability of primary data for all processes and sub-processes across a vehicle's supply chain is highly desirable, while availability of primary data from the relevant members from such a complex network of a vehicle's supply chain may not be currently viable in the short-medium term reporting. Identical to our findings from the workshop, this is attributed to the lack of guidance or current industrial practice **on data traceability down to lower-tier suppliers**, and also as informed by our survey responses and our one-to-one interviews from a diverse range of LCA practitioners and vehicle OEMs.

In terms of inventory modelling, "bill-of-materials" (BOM) is developed by sourcing component and parts material data from a digital OEM-specific resources such as the IMDS. However, in the case of data required from suppliers for newer components and parts used in vehicle manufacture such as EV batteries, most OEMs simply utilize the LCA results sourced from their battery suppliers (or sometimes even use more generic models). Where there is any level of data collection, for components and parts in general, manual collection of data is practiced. **Manual collection of data** from suppliers and their interpretation has particularly been a challenge due to poor data quality checks and variability in reporting formats at the source. It is noteworthy that some standard template for data collection already exists; e. g. the VDA Data Collection Format for Life Cycle Assessment. But there still does not exist one unique standard that would be commonly and widely acknowledged, and implemented, in the electromobility sector in the EU. This demonstrates a **need for a standardized template**, commonly agreed in the electromobility sector in the EU, **and a convention for terminologies** (materials and parts) for data collection that is consistent with the nature and the products (parts or components)

[1] Foreground processes: those processes in the product life cycle for which direct access to information is available. For example, the producer's site and other processes operated by the producer or its contractors (e. g. goods transport, head-office services, etc.). (from Glossary section of Transensus D1.1)

[2] Background processes: those processes in the product life cycle for which no direct access to information is possible. For example, most of the upstream life-cycle processes and generally all processes further downstream will be considered part of the background processes (from Glossary section of Transensus D1.1).

supplied within the vehicle supply chain. This could support the **automation of supplier-level data collection and reporting processes**, leading to establishing uniformity in the reporting procedure from the various parts of the supply chain to final reporting at the product level.

In the case of reporting a vehicle's performance in the use-stage, OEMs were observed to have adopted primary data, in the form of their vehicle performance data (energy consumption) recorded by subjecting them to specific regionally-regulated drive cycles (i. e. for type approval). Some studies have reported LCA results for multiple regulated drive cycles, as a means of targeting the study at audience of varied geographic backgrounds (i. e. where different standards apply). This may be a good practice; however, it **must be ensured that the choice of regulatory drive cycles are temporally and geographically representative**. That, said, accounting for vehicle operations data through this approach overlooks the **key factor: driver behavior and "real-world" conditions** that creates a new set of challenges for the "representativeness" criteria. New regulatory developments in the monitoring and reporting of vehicle fuel consumptions require the need for **the use of either "real-world" vehicle energy consumption data or the use of adjustment factors for values based on regulatory cycles** (European Commission, 2021)). However, although fuel consumption monitoring and reporting has been introduced as a requirement for light duty vehicles with ICEs (i. e. including plug-in hybrids), there are no such requirements for mass data collection for ZEVs (i. e. BEV, FCEV, etc), nor for heavy duty vehicles. Nevertheless, such information is still usually collected/stored by such vehicles, and may become more widely available in the future (e. g. through expansion of the current regulatory monitoring requirements, or collection directly by OEMs).

Outcomes from survey

The surveys enabled to detail further the issues associated with the lack of a harmonized approach to collect and to share the primary data, highlighted in the above sections. Among the 15 respondents, ten were product OEMs most of whom indicate consulting and drawing their vehicle's bill of materials, particularly for their components and parts from the IMDS database, which is fed into and shared by most vehicle OEMs and their suppliers. Some of these respondents highlight the challenges, particularly the **time-consuming interpretation** of that data due to the lack of harmonized approaches for data collection, reporting or conventions in terms of terminologies for materials. As for data required for use-phase, some respondents indicate the use of type approval data. In some cases, to overcome the **data confidentiality hurdle**, some product OEMs draw direct battery LCA results from their battery suppliers, leading to their vehicle OEMs reports suffering from **lack of details around underlying assumptions and other particulars** due to the lack of dedicated reporting standards.

When asked the open question "Where do you expect challenges in the future with the way you apply LCA at the moment?", survey's respondents mentioned in 5 out of 11 answers concepts related to the LCI. These concepts are depicted in Figure 4.2.

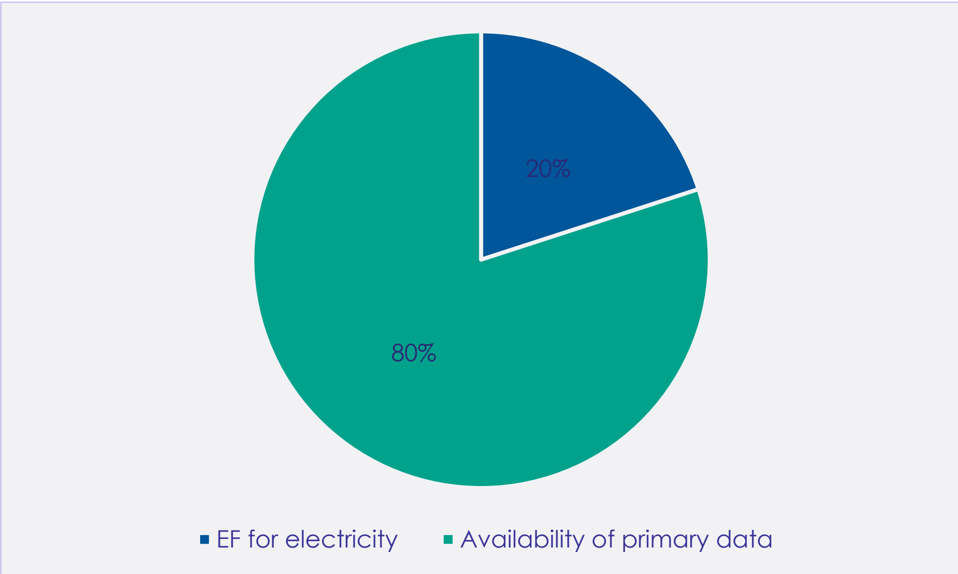


Figure 4.2: Survey's answers to the open question "Where do you expect challenges in the future with the way you apply LCA at the moment?" and related to the LCI phase

Outcomes from position papers

Position papers also support the development of **well-documented framework and associated guidelines for data hierarchy, acquisition and verification**, as highlighted in the above sections. It is noteworthy that several organizations pledge for a clear hierarchy of data, supporting the use of primary data as opposed to secondary data (e. g. (CLEPA, 2022), (EUROBAT, 2021)), in particular with **setting rules that incentivize the use of primary** (disaggregated) data (e. g. (Peiseler et al., 2022)).

GRPE (A-LCA Informal Working Group; (UNECE-GRPE, 2023)) proposes to define the methodology for obtaining primary data, and possible sources for secondary data (internationally recognized database). It also proposes to define the assumptions and scenarios for the activities at each stage, as well as the data quality requirements including the temporal scope, geographical scope, technical scope, accuracy, completeness, representativity, consistency, reproducibility, etc. Data derivation, accompanying metadata and formats should conform with existing international guidelines and nomenclature systems, including ISO 14048, the UNEP Global Guidance Principles for LCA Databases, and UNEP Global LCA Data Access network standards.

The VDA (Position paper on decarbonization of LCA of a car; (VDA, 2022)) recommends a harmonisation in LCA for efficient data collection across the supply chain: "In *addition to the constant further development of the generally accepted method for calculating the CO_2-Footprints (ISO 14040) means collecting raw data instead of using generic data for high-quality life cycle assessment. […] At this point, the federal government can politically flank and support the industry's commitment to harmonizing data sets and increasing transparency in the value chain through innovation projects such as Catena-X*."

CLEPA (Inputs for a CO2-LCA workshop at GRPE; (CLEPA, 2022)) recommends the use of primary data first and the standardization of CO_2 accounting rules throughout the supply chain, whatever the company size. It advocates a right level of data transparency throughout the supply chain to enable comparisons between suppliers. It also points out to take into account existing works on the subject (Catena-X, Catarc, … for example).

EUROBAT (Position paper on Carbon Footprint provisions in the new batteries regulation; (EUROBAT, 2021)) proposes that the Primary data should prevail over secondary for all the hotspots within the supply chain, allowing for more differentiation and hence faster progress. It recommends to develop individual methodologies to calculate the CF of all battery technologies concerned. Rules for the frequency of calculations and reporting of CF should be developed.

Peiseler et al..(Toward a European CF rule for batteries; (Peiseler et al., 2022)) point out that:

- Concerns about the disclosure of primary data, which can be misused to reverse-engineer company secrets, highlight the need for independent auditors to collect and verify individual CF calculations confidentially.
- Cell producers would provide auditors with detailed CF calculations that are based on a granular breakdown of components, processes, and associated emissions. Once verified, auditors can aggregate the underlying data into an overall battery CF and report this value to the JRC. This confidentiality should also apply to future battery technologies and manufacturing practices. Auditors need to liaise with the regulator to harmonize methodological guidelines about upcoming technologies without compromising company-specific details.
- To strike a balance between practical implementation and effectiveness, the EC should provide standardized CF default values for specific upstream processes or battery components if a supplier cannot provide credible and transparent calculations. The JRC should regularly update these default values, which should be informed by industry self-declarations and independent sources. To incentivize corporate engagement and disclosure, the default CF values of the components should be high enough that if a battery producer does not disclose any primary data but instead only relies on default values for processes and procured components, the overall CF of its batteries is above the maximum CF threshold defined in the

regulation. Batteries with no underlying data disclosure would thus be assigned the lowest CF performance class (in 2026) or not allowed on the European market (from 2027 onward).

Nickel Institute (position paper on European Commission proposed EU batteries regulation; (Nickel Institute, 2021)) recommends that, in view of data provision requirements in the value chain, common systems should be put in place to reduce the administrative burden on upstream actors and to facilitate efficient and harmonized sharing of data. Any mechanism should also be aligned with business confidentiality laws and competition law.

Finally in the context of the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM state that "*The CF Rules lack prescriptiveness regarding inventory data collection and reporting*" (CEA and BRGM, 2023). They subsequently "*recommend that the Data collection requirements, […], are clarified. This revision shall include i) a larger level of details and of prescriptiveness in the list of activity data to be reported; and ii) a clear link between the activity data to be collected and some EF-compliant secondary datasets recommended to be used*".

4.2.3 Secondary data

Outcomes from workshops and survey

It is acknowledged that TranSensus LCA **does not intend to develop new secondary LCI datasets**. Yet, a number of gaps relative to the latter arose in the TranSensus LCA workshop dedicated to gaps.

Firstly, there is the need for **harmonized guidelines** to ensure that the **scope for secondary datasets is similar to that for primary datasets**. In particular inclusion and exclusion of processes or life cycle stages, approach to solve multi-functionality, etc. shall be consistent between foreground (primary) and background (secondary) datasets. This moreover requires ensuring consistent modelling of all the used secondary datasets. As of today, there is no common rule that governs the secondary dataset modelling choices. Secondary datasets from diverse standard secondary databases may be modelled in diverse ways, so that it is hard to combine them for a more robust LCA. This subsequently impedes to support comparability in the assessment.

Moreover, standard **secondary datasets are limited by issues of incompleteness and imprecision**, which in some cases implies poor representation of markets. Incompleteness of standard LCI databases in particular relates to the absence of datasets regarding some raw materials (e. g. in current version of the EF database: absence of production of lithium carbonates and hydroxides; battery-grade graphite, either natural or synthetic; cobalt compounds; nickel compounds; battery precursors; etc.). Absence of secondary datasets may additionally also be observed regarding production of recycled materials, and new (emerging) materials used in vehicles. More generally, including and beyond raw materials, the availability of secondary datasets necessary for LCA in the electromobility industry is lower than what is required in reality; e. g. regarding material composition, types of processes (transformation, shaping, etc.), geographical and temporal representativeness, etc. Secondly imprecision of standard LCI databases relates to sometimes poor technological, geographical or temporal representativeness that is not always fully captured and reported in the information supporting datasets.

Furthermore a **larger level of granularity** in secondary datasets is required. In current standard LCI databases, average data in aggregated datasets may induce the risk of an illusion that all the materials on the market have the same environmental impacts, which is not the case. There is a need for **regionalized datasets**, in order to capture and inform regional differences in the environmental impacts of productions, linked to diverse technologies and product properties, as well as diverse background systems (e. g. diverse electricity mixes). Beyond regionalization, any differentiation in datasets of products/systems (e. g. technological) shall be accounted whenever this is relevant. These complements in secondary databases shall enable to take benefit from any higher-quality information on traceability along the value chain. That is to say, providing **secondary datasets representing different technological/geographical/temporal differences instead of just an average value** would lead to ability to represent the impacts of different choices in material sourcing. Moreover providing Unit Process[3] secondary datasets instead of aggregated datasets (which contain only elementary flows) would enable to actually understand the driver of impacts in the associated process.

As a complement to this larger level of granularity, there may be the need to provide TranSensus LCA recommendations on **conservative default data, rather than market average to incentivise collection of primary data**. This is particularly crucial in contexts where secondary datasets do not actually represent the "average" activities, but a small share extended through a number of estimations/assumptions/proxies in order to represent the World market.

In addition, secondary datasets face two issues linked to time (and to their static versus dynamic nature). Firstly, LCI secondary datasets are **too static**. Some TranSensus LCA partners call for an effort to be made on parameterized, potentially dynamic and prospective, LCI models; in particular regarding materials (steel, aluminium, plastics, etc.), and standard manufacturing processes (stamping, casting, heat treatment, etc.), and especially for electricity generation mixes and projections (which have a profound impact over the use-phase). Survey participants also underline that secondary data must be updated at least every year as illustrated in Figure 4.3. Secondly, **databases change over time, with updates** (including additions of new datasets and modification of existing datasets) which are required, but in the meantime **have a significant**

[3] Unit process (E-LCA) – smallest element considered in the LCI for which input and output data are quantified.

influence on the impact assessment results. There needs a guidance on i) update frequency, in order to impose that updates are sufficiently frequent to properly reflect evolutions in technologies, processes, markets, etc. and ii) acceptable deviations associated with these updates (for those changes not reflecting changes in the true impacts of processes/systems, but rather induced by changes in methodological choices; e. g. system boundaries, addition of new flows, etc.).

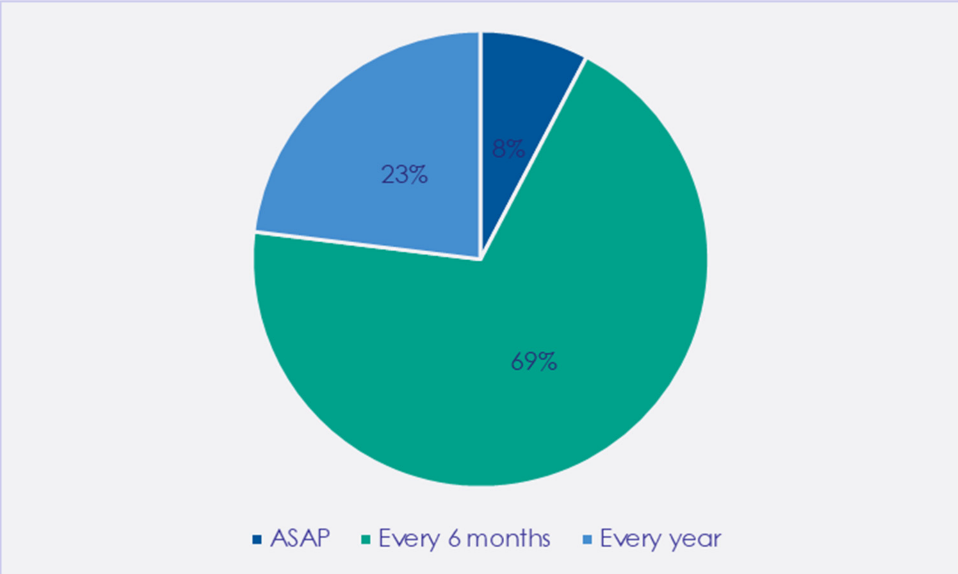


Figure 4.3: Survey participants answer to the question "How often would you like the background/secondary data to be updated by your data provider?" (based on 13 answers)

Moreover, the approach to report and validate consistent mass balances along the life cycle of the products studied, to be defined in the TranSensus LCA method (see above section on Primary data), shall also be applied to secondary datasets. In particular, the recently developed JRC-LCI method involves the implementation of a so-called "resource flow analysis", i. e. the use of the mass balance equation in order to ensure the consistent mass balance of resources along the life cycle of products (Beylot et al., 2021). Yet this resource flow analysis at the resource (including metals) level is so far not common practice in LCA and secondary LCI databases, which may lead to (untraced) incomplete and inconsistent mass balances – for the whole masses of products, and per substance (Beylot et al., 2021).

Finally, so far in LCA practices and guidelines, the use of proxies (here to be understood in a large sense, including proxy values and proxy datasets) is not limited or guided by rules to be respected. Lack of transparency on some aggregated LCI datasets i) sometimes includes lack of transparency on the proxies used to build these datasets, and ii) may hamper clear understanding of how these datasets may be used as fit-for-purpose proxies to represent other processes. **Clear guidance on proxies** shall accordingly be developed, either providing default values/datasets to be used, or conditions for the development and check of proxies (e. g. minimal requirement to check the correlation between datasets and proxies used).

Outcomes from review of product LCAs

In line with the responses from the TranSensus LCA survey, secondary data, within product LCAs, have been predominantly adopted for processes and activities that are not under the direct influence of the vehicle manufacturers. These processes mainly include raw material acquisition, pre-processing (production of vehicle components and parts) and finally for EoL processing routes (if any are accounted for within the study). Secondary data are also used to bridge gaps in primary data required for and used within "core processes" such as the vehicle manufacturing phase. Nevertheless, the vehicle OEMs and the industry-level LCA practitioners have unanimously stated the **lack of a harmonised approach and template for data collection, quality checks and reporting requirements in industry practice** being as a key drawback. This has been found to contribute to some challenging consistency issues leading to potential variations in processing of data (required to be undertaken by the OEMs) and impacts on data accuracy, relevance and quality assurance, when aiming to comply with relevant LCA standards and guidance, or future regulatory requirements. **Geographic variations,** for example, the complex nature of a vehicle supply chain (Figure 4.4), often spread across a number of geographies and working through organised logistics, increases the complexities associated with data collection, reporting, interpretation and traceability by the requesting OEMs. The supply chain being a global one, even collation of industry average datasets could suffer from inconsistencies due to differences in the target market, lack of training, data interpretation and relevant audience, an observation similar to the findings reported under workshops and outcomes, pertaining to secondary data.

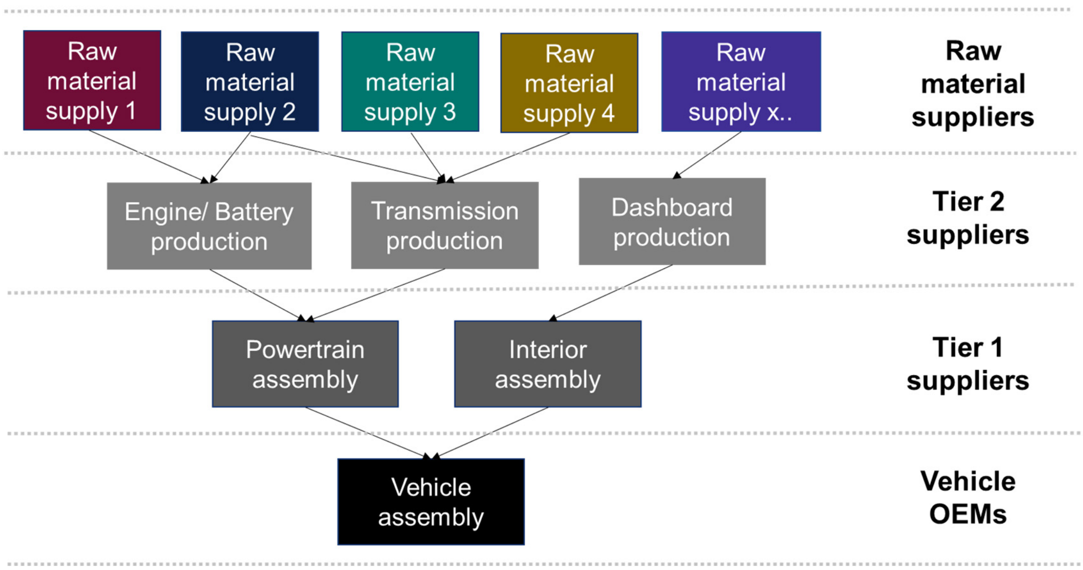


Figure 4.4: An Overview of the Vehicle supply chain

Some examples from where LCA is prevalent include product LCAs from the US which employ GREET database, while those from Japan employing JLCA (Society for Life Cycle Assessment of Japan), as opposed to studies in the EU that utilise ecoinvent and Sphera's MLC/LCA FE (former GaBi database/software). While it is rational to use geographically-relevant databases, **clear guidance and rules on databases that OEMs or other LCA practitioners could use to undertake vehicle LCA need to be defined**, following a thorough investigation of the various databases from the viewpoint of reliability, transparency, quality and representativeness.

Beyond these results from the review of product LCAs, it is noteworthy that recent scientific literature on the LCA of battery raw materials raised a number of concerns regarding existing LCI datasets, including outdated and non-representative data, also in standard LCI databases (e. g. regarding battery-grade graphite and Li_2CO_3 productions; (Engels et al., 2022; Schenker et al., 2022)). This may have so far resulted in underestimated life cycle carbon footprint of some battery raw materials (Engels et al., 2022; Schenker et al., 2022; Surovtseva et al., 2022). Moreover, LCI modelling of raw materials' chains, and associated impacts on toxicity and eco-toxicity, are particularly sensitive to the modelling of tailings final disposal, and more specifically to metals mobility (Beylot et al., 2022). These long-term emissions of toxic substances from tailings disposal were identified a hotspot in the LCA literature applied to hybrid, plug-in hybrid, and battery electric vehicles (Nordelöf et al., 2014).

Secondary datasets do not actually represent the "average" activities, but a small share extended through a number of estimations/assumptions/proxies in order to represent the World market.

For example, a number of datasets representative for battery raw materials, as available in standard LCI databases (and/or provided by industrial associations), build on a share of the market only; yet with limited knowledge so far on the influence of this missing share. This is e. g. the case of LCI datasets associated with cobalt compounds, as compiled by the Cobalt Institute: inventory for Crude Cobalt Hydroxide covers 37% of the global production (Tri-Cobalt Tetraoxide: 8%; and Cobalt Sulphate Heptahydrate: 9%; (Cobalt Institute, 2023)). Similarly, the inventory compiled by the Nickel Institute regarding nickel sulphate production is derived from four plants respectively in Belgium, Finland and Japan. It builds on 15% of the production in the World (SPHERA, 2020).

Outcomes from position papers

Peiseler et al. (Toward a European CF rule for batteries; (Peiseler et al., 2022)) positions pertain to the above-identified **potential need to provide TranSensus LCA recommendations on conservative default data**, rather than market average to incentivise collection of primary data (see section on Outcomes from workshop). This position paper points out that relying on secondary data sourced from existing LCI or reports rather than on primary data directly collected, bears the **risk of being too generic and obtaining inaccurate estimates**, undermining the effectiveness of the regulation. They advocate the use of standardized CF default values provided by EC for specific upstream processes or battery components, if a supplier cannot provide credible and transparent calculations. According to Peiseler et al., the JRC should regularly update these default values. As mentioned in the above section relating to primary data, these values should be high enough that if a battery producer does not disclose any primary data but instead only relies on default values for processes and procured components, the overall CF of its batteries is above the maximum CF threshold defined in the regulation.

In the context of the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM(CEA and BRGM, 2023) "*recommend the following actions:*

1) *Limitations in the LCDN, in particular regarding battery raw materials, shall be better highlighted and acknowledged. Improvement needs shall be included in the first version of these CF Rules and in the planning of updates;*
2) *the JRC shall increase completeness of datasets in the LCDN, in particular including secondary datasets regarding primary battery raw materials production;*
3) *when completing the LCDN with additional datasets relative to primary raw materials production, the JRC shall ensure the highest level of quality possible. This implies the following recommendations:*

4) *the JRC shall pay particular attention to avoid underestimating CF of primary raw materials in the LCDN; which would subsequently disincentivize the use of primary data, failing to drive the market towards larger reliability of CF values, and any support actions towards reducing this footprint.*

5) *the JRC shall assess the opportunity to provide regionalized datasets, at a level of granularity to be defined. This may be relevant in particular for several cases of battery raw materials (lithium, graphite, etc.), for which geographical and technological diversities in the production imply diverse carbon footprints; […]*" (CEA and BRGM, 2023)

4.2.4 Electricity modelling

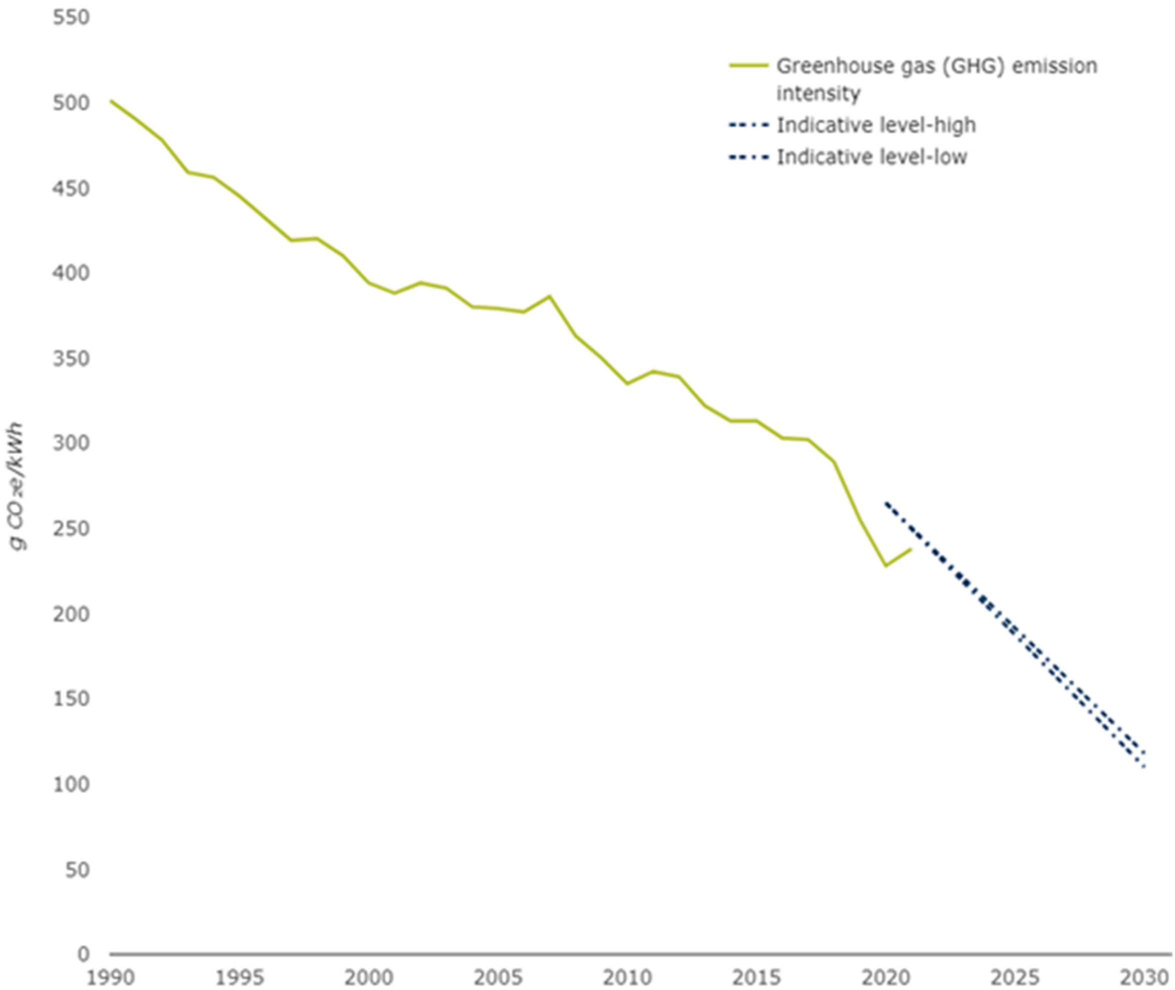
<u>*Outcomes from workshops*</u>

The approach to **handle electricity consumption in the production phase and for the use of the vehicle shall be clarified, harmonized and commonly agreed**. Two approaches of modelling may be distinguished: i) location-based (average grid mix) and ii) market-based modelling, accounting for renewable energy certificates, supplier-specific emission rates, and the ensuing residual mix. Option (i) is clearly more suitable for modelling electricity consumption during the use phase, because of the changing generation mix over time, and the impossibility of making informed assumptions on the share of the consumed electricity that will be sourced from specific suppliers. Conversely, both approaches have pros and cons when modelling electricity consumption in the production phase. In particular, the location-based approach (i) is a "real-life" approach, and pushes for lower carbon electricity contents at country/regional scales. Yet, it does not account for the capacity of some suppliers that are located in contexts of "worse" electricity mixes to afford purchasing additional renewable energy. In this context of pros and cons, there is the need for a common, harmonized, method for electricity modelling for the production phase and for the use of the vehicle. This method may either go in the sense of one of these two approaches (i. e. either location-based or market-based), or it may be a balance between the two (market-based or location-based) approaches. Diverse TranSensus LCA consortium members expressed diverse preferences on how they consider electricity modelling shall be performed. This will be explored further in WP2 of the TranSensus LCA project.

A number of "cons" of each method may be considered as "gaps". For example regarding the market-based approach, one may consider **it is questionable whether renewable energy certificates (RECs) fully ensure that the purchaser actually contributes to a reduction in GHG emissions**. The key differentiating factor with regards to RECs is whether they are sold "bundled" with power purchase agreements (PPAs) that ensure additionality (i. e., that the purchased renewable energy is provided by new generation capacity that adds to the pre-existing renewable energy capacity in the grid mix), or not. It has been argued that only in the former case, do RECs actually result in a net decrease in the overall GHG emissions, while in the latter case a mere re-shuffling of the pre-existing GHG emission quotas is achieved.

Moreover, **at this stage not all countries outside the EU and the US have such a contractual instrument**, but this is currently being pursued in China, UK and South Korea. Moreover, particular attention shall be given to electricity modelling at the use phase in "product LCAs". LCAs are performed considering a vehicle as produced today, but in a context where electricity has not been purchased yet. OEMs do not have control on the use phase. **Clear rules, including on scenarios for electricity modelling at the use phase, shall be described in the TranSensus LCA method**. More generally, the TranSensus LCA method is expected to provide clear guidelines regarding **how to handle future electricity grid mixes**. In a context where the lifetime of a vehicle can last until 10-20 years, changes in the electricity grid mix is expected (and has indeed been clearly demonstrated in many studies) to influence the impact of any process or life cycle stage that is not occurring "now"; e. g. electricity consumed by the vehicle over its use phase, consumed by recycling at end-of-life (and consumed to produce the materials considered to be substituted at the time the recycling will occur), etc. The historical record shows a clear, significant and continuous reduction in greenhouse gas emissions from electricity generation in Europe since 1990 (per kWh) – as illustrated in Figure 4.5. This trend is only being amplified/accelerated further by recent increase in actions aimed to tackle climate change and meet longer-term objectives for Net Zero. The current policy already in place continues to drive trends downwards in Europe. This should be further debated in WP2.

Finally, in general when providing guidance regarding electricity modelling: **i) there is the need to carefully address any risk of double counting, and ii) the time coherence condition shall be aligned with country legislation (month or annual)** (here, e. g. the GHG Protocol will provide a helpful discussion basis).



Source: (European Environment Agency, 2023): Greenhouse gas emission intensity of electricity generation in Europe (europa.eu)

Figure 4.5 : Overview of the historical and projected GHG intensity of electricity generation in Europe

Outcomes from product LCAs and survey

Product LCAs, in the current timeframe, were found to account for electricity consumption by considering the residual/consumption mix, specific to the country of vehicle manufacture. It is unclear as to which specific studies account for renewable energy and which do not. However, **most studies have adopted geographically-representative grid emission factors**. Among these, one specific OEM used default energy consumption values for specific manufacturing processes such as welding, forging, parts assembly, etc., which was then applied to model energy consumption over vehicle manufacturing phase in varying geographies. While this method may provide more representative activity data, compared to secondary datasets, this practice is likely to lead to some inaccuracies unless the manufacturing equipment, operations, monitoring and quality check etc, are accurately replicated in these different geographies. However, it should also be highlighted that existing (regional) average electricity mix datasets available in LCI databases/LCA models for electricity are usually at least 2-3 years out of date compared to the manufacturing year/study date.

Recently, there have also been further developments in the recommended methodologies for electricity treatment for the production phase, where **GHG reporting guidance by standards, industry alliance and associations** are recommending a more nuanced approach to addressing renewable energy utilisation. These guidelines provide specific criteria and rules for the consideration of electricity use emission factors, by identifying renewable energy used in vehicle production as either sourced through “market-mechanisms” such as through the purchase of Renewable Energy Certificates [RECs]) or as “location-based” (demonstrated by most product LCAs) (GBA, 2023; IEC, 2022; RECHARGE, 2023). None of the product LCAs have been observed to have implemented these models in their LCA studies. One of the OEM, over a survey response, has indicated that these rules and guidance need to be evaluated independently or through the framework recommended by relevant LCA standards/ guidance. Relevant framework needs to be established internally as a part of the OEM’s LCA practice, to overcome potential “greenwashing” issues associated with the “Guarantee of Origin” (GOs).

Out of the 16 OEM reports, **only five account for future grid mixes in alignment with their vehicle lifetime**, as a part of either core analysis or sensitivity studies. Product OEMs that have implemented future grid evolution into the sensitivity study of their vehicle LCAs have either adopted their local regional grid mix data projected over the service life of their vehicles. Where unavailable, some studies have adopted global energy scenarios published by the International Energy Agency (IEA) or US Energy Information Administration (EIA) and implemented in LCI databases. Some studies have excluded relevant long-term modelling due to the lack of dedicated local, regional or national projections on future grid mixes. **Most survey respondents, therefore, recommend the need for harmonized rules and recommendations on reliable future grid mix scenarios** that could be adopted within those LCAs (Figure 4.6). There are also similar issues for hydrogen-fueled vehicles, which are actually even more acute as there are not similarly authoritative forecasts for this available from the IEA or elsewhere to draw upon, partly due to much higher uncertainty on this aspect. However, rules requiring additionality have at least been introduced for ‘green’ hydrogen in the EU recently (European Commission, 2023b).

Value	Percent	Responses
Lack of readily accessible information on regional grid mixes for some regions	52.9%	9
Lack of harmonisation on which future grid mix evolution scenarios to adopt	58.8%	10
Others:	29.4%	5
Don't know	5.9%	1
Not applicable	11.8%	2

Others:	Count
How to model the residual mix	1
Lack of residual emission factor	1
TImely updates	1
forecasted electricity not accepted by SBTi	1
potential greenwashing of GO	1
Totals	5

Figure 4.6: Survey participants answer to the question “What are the main challenges in electricity background modelling? “

<u>*Outcomes from position papers*</u>

ECOS *et al.* (Warning letter against shortcomings of future CF evaluation rules for new batteries; (ECOS et al., 2023)) note that the document on the future CF evaluation rules for new batteries, raises concerns about the potential for greenwashing in the reporting framework for battery carbon footprints. In particular, it calls for stricter requirements to strengthen the credibility of renewable energy claims based on GOs, including:

- A stricter time consistency criterium between energy generation and use than the 12 months period proposed in the draft JRC report to ensure coherence between renewable electricity that is being produced and consumed.
- A stricter geographic link between the energy generation and use, including that the battery producing plant be located in and connected to the same bidding area or adjacent interconnected bidding areas, or in the same country as the energy generating plant.

In the context of the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM underline that

- “*The physical tracing of electricity is extremely difficult and not performed in existing grids,*

- *The electricity travels on average 100 km in the transport network (French example, the figure is increasing)*
- *Existing contractual instruments are flawed by time and space inconsistencies, and lack of universality,*
- *Even a perfect traceability and uniqueness of claim would not avoid circumvention by resource shuffling*" (CEA and BRGM, 2023).

They then provide recommendations in view of the JRC Carbon Footprint rules. They recommend "*only allowing the following hierarchy to model electricity input of the factory:*

1. Average consumption grid mix for the amount sourced from the grid and read on TSO or DSO counter.

2. On-site electricity production, only:

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

b. For the fraction of the consumption that is not sourced from the network.

c. No credits of any kind can be granted for electricity produced in excess and sent to the network" (CEA and BRGM, 2023).

Moreover they highlight that "*EF3.1 consumption grid mixes are outdated and sometimes inconsistent*." They accordingly "*recommend updating and completing EF datasets with recent values of average consumption grid mixes. These consumption mixes should be calculated from the production grid mixes in each zone and the imports/exports between zones via a flow tracing method […]*" (CEA and BRGM, 2023).

4.2.5 End-Of-Life modelling

<u>Outcomes from workshops</u>

Similarly to the approach to handle electricity consumption, the **approach to model end-of-life shall be clarified, harmonized and commonly agreed**. In particular, the TranSensus LCA internal workshops on Needs and Gaps highlighted that, among TranSensus LCA research and industrial partners, **there is no general agreement on the Circular Footprint Formula (CFF) as developed in the PEF** (with e. g. specific CFF prescriptions in the JRC "Harmonised rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries"). At this stage in the TranSensus LCA project, there is no agreement on whether End-of-Life modelling shall build on the CFF, or shall depart from it. This will be explored, discussed and eventually decided in other WPs of the project, and in particular in WP2. Some partners consider that the CFF is needed to incentivize the eco-design efforts to ensure the recyclability of the designed systems.

Instead, other partners consider that the CFF implementation in the JRC CF Rules for Batteries (as of today) gives limited incentive to purchase recycled material, as driven by A factor in these rules set to 0.2 for most metals and materials (except polymers – set to 0.5). **The TranSensus LCA method shall also provide guidelines on the default-A factors for different material categories** (if the CFF, or any similar formula, is actually recommended to be implemented).

Moreover, the **CFF is considered by several partners as too complex and leading to uncertain calculations**. If CFF is needed, there still misses a software that can help to ease the CFF practical implementation. Uncertainty in particular relates to:

i) **Credits evaluation**, due to so far not fully-harmonized approach to the identification and consideration of the substituted materials. The quantification of the benefits enabled by substitution classically **does not enable to precisely capture the actual quality** (e. g. presence of impurities) **of the secondary materials** as compared to the quality of the substituted primary materials;

ii) **Prospective in the assessment**. This in particular relates to the recycling processes that will be implemented from 10 to 20 years from now, for products in the electromobility sector put on the market today. It is expected that **some recycling processes (including efficiencies) will be significantly different from those of today**, and implemented in different contexts than that of today (e. g. potentially different electricity grid mixes). Some of the technologies of the future are emerging technologies, at low Technology Readiness Level (TRL) – yet there is no commonly agreed approach to capture these low-TRL processes in LCI modelling. Beyond the modelling of the recycling processes, **other aspects of the CFF are sensitive to uncertain futures (substituted materials, quality of recycling, etc.)**. The missing harmonized approach to deal with LCI compilation of future recycling processes shall be **complemented by commonly agreed proxies and assumptions**. Some partners in particular **advocate for conservative EoL practices and assumptions**, and rules to allow for demonstration of improvements.

Clearer prescriptions on the CFF implementation are therefore needed regarding credits evaluation and prospective aspects (in particular regarding EoL recycling processes). Moreover other parameters in the CFF need to be prescribed through clear and differentiating rules; e. g. differentiating the A factor based on application type and lifetime, and maturity of the recycling processes.

Finally, beyond the case of the CFF, a number of difficulties arise in the modelling of EoL of vehicles in LCA, e. g. i) when **EoL processing occurs out of the country** where the vehicle is utilized, or ii) regarding modelling of the **battery potential second life**. The TranSensus LCA-TranSensus LCA method shall prescribe clear rules on these aspects.

Outcomes from review of product LCAs and surveys

A number of product LCAs were also reviewed to evaluate the current trends in EoL modelling practices adopted by vehicle OEMs. Our review of the publicly available and confidential literature, in addition to the consultation of the survey responses from vehicle OEMs, showcases **inconsistencies in the coverage of EoL stages for their vehicles within these LCAs**. Among the 16 product LCAs, only one excluded EoL stage altogether, while the remaining set of studies included processes pertaining to dismantling and shredding of vehicles. The **current lack of consistency in the approach to covering all the key life cycle stage (omission of specific EoL stages)** may be due to the lack of visibility of the processes and activities associated with the EoL supply chain. There is, therefore, a need to establish consistent and harmonised rules on the data requirements pertaining to the EoL stages, for example, on the generation of products and co-products and their reuse within potential closed-loop systems. If adopting the CFF approach as discussed in the "responses from the workshop" earlier, **prescriptive guidance and sources of data relating to market share and quality of the secondary material** generated and **guidance to interpret other very-specific data requirements**, **potential sources** etc, need to be made available.

Outcomes from position papers

EUROBAT (Position paper on CF provisions in the new batteries regulation; (EUROBAT, 2021)) points to the **difficulty (and associated uncertainty) to include recycling activities** in the assessment, in a context where **they will be achieved in 10-15 years from now** (i. e. after production). Accordingly EUROBAT proposes to exclude end-of-life and recycling from the CF calculation, as including an imprecise assessment of carbon footprint recycling would not help when selecting the greenest battery.

Instead CLEPA (inputs for a CO2-LCA workshop at GRPE; (CLEPA, 2022)) points out that **it is more and more important to include a full lifecycle analysis** into regulatory approaches: production of the vehicle itself, use phase (WTT, TTW), recycling or/and disposal of the vehicle. Supplier design choice takes part in recyclability at end of life.

In the context of the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM state that "*The definition and the default values of the parameters of the CFF chosen by the JRC raise several limitations such as:*

- The high weight given to EOL recycling that will occur in 15 years and is highly prospective,

- The compensation of 76% of impacts of raw materials by future, possible, avoided emissions

- The risk of resource shuffling for commodity materials […]

- *The gaps in recycling datasets,*

- *The multi-functionality of recycling,*

- *The quality of outgoing secondary material*." (CEA and BRGM, 2023).

4.3 Impact assessment

Summary of main outcomes on gaps in Impact assessment

A **standardized impact assessment method**: there misses a unique, clear, set of impact categories and associated impact assessment methods that are commonly considered relevant and robust, and accordingly accepted and implemented. Within TranSensus LCA, there shall be an agreement on the comprehensiveness of the recommended method for environmental and social impact assessment; either extensively comprehensive (e. g. covering environmental, social and resource issues; potentially including aspects such as circularity, impacts on biodiversity and ecosystem services, criticality of raw materials, etc.); or a more restrained list of most relevant impact categories, potentially with diverse levels of recommendations ("mandatory"/"optional"). The selected methods shall be relevant, reliable and accepted.

Impact categories and indicators seldom or not conventionally considered in the literature of product LCAs (but have much more widespread use elsewhere – e. g. in the scientific literature) include Cumulative Energy Demand and Abiotic Resource Depletion, minerals and metals, despite their potential core importance in the context of the electromobility sector, and from the policy/regulatory perspective.

LCA results in the literature are classically neither normalized nor weighted. There shall be clear guidance on whether the **normalization and weighting** steps are made optional, mandatory or forbidden in TranSensus LCA. Concern was raised regarding existing normalization and weighting factors, which in particular imply hiding potential for impact transfers to those other impact categories that are considered – disputably - as minor. If recommended, normalization and weighting factors shall be harmonised and commonly agreed in TranSensus LCA.

This is further synthesized in the following Table 4-6. Then the following sections deliver a more in-depths description of the outcomes from the tasks undertaken in this Task 1.2 (as described in Chapter 2); i. e. outcomes from workshops, review of product LCAs, survey, and review of position papers.

Table 4-6: Short synthesis of gaps on Impact assessment in E-LCA, for the development of a harmonised approach in the electromobility sector

Gap regarding	Short description	Prescriptions for the TranSensus LCA method: it shall cover/include (though not be limited to):	Level of importance in the development of the TranSensus LCA method
A **standardized impact assessment method**	There misses a **unique set** of impact categories and associated impact assessment methods, agreed to be relevant and robust (and applied)	**Comprehensiveness** to be addressed in WP2; either extensively comprehensive (e. g. including circularity, biodiversity, criticality and dissipation of mineral resources, etc.); or a more restrained list	High
		Diverse levels of recommendations (“mandatory”/”optional”) to be considered in WP2	High
		Eventually **only relevant, reliable and accepted methods** to be selected	High
Specific gaps per impact category	**Mineral resource use**: depletion-based characterization factors acknowledged as imprecise and insufficient Moreover missing indicators for **lifecycle energy efficiency** in current recommendations like the PEF	Potential **alternative impact assessment methods** to be evaluated, potentially considering diverse impact pathways (e. g. **resources dissipation**). Consideration of also **other *indicators*** for prioritisation like **cumulative energy demand** (CED) and **circularity indicators** that have high policy relevance (e. g. EU climate and energy)	High
Normalization and weighting	There misses one single guidance on whether **to implement** normalization and weighting, **or not**	If recommended, **Normalization and Weighting approach to be commonly agreed**	High
		If recommended, the TranSensus LCA method would be non-ISO compliant	High
	Currently recommended **weighting factors disputable**	Industry-own weighting factors may be considered an option	Medium

4.3.1 A standardized impact assessment method

Outcomes from workshops

It is commonly accepted in TranSensus LCA that there is as yet no single, harmonized, approach for impact assessment quantification; i. e. a **unique, clear, set of impact categories and associated impact assessment methods that are commonly considered relevant and robust, and accordingly accepted and implemented, and additional supporting indicators where relevant**. The work in WP2 is expected to build on existing impact assessment methods; i. e. TranSensus LCA does not intend to develop new characterization models but to build on existing ones. Several partners in TranSensus LCA consider that impact assessment methods and indicators recommended by TranSensus LCA **shall be comprehensive**, i. e. shall extensively cover **environmental, social and resource issues**; potentially including aspects such as **circularity**, impacts on **biodiversity and ecosystem services**, **criticality of raw materials**, etc. Instead, some other partners consider that what is required (and is currently missing) is **a more restrained list of most relevant impact categories and indicators**, for which (generally agreed as) robust impact assessment and indicator approaches exist. Another option would be a comprehensive list of impact categories and indicators, **with diverse levels of recommendations**; e. g. some categories being priority ones (and whose implementation would be set to be **mandatory**), some others being **optional**. Some partners additionally raised that the list of most relevant important impact categories may vary depending on the goal and scope of the study; e. g. whether BEV, HEV and/or ICEV are considered as case studies.

It is expected that the TranSensus LCA project enables to reach a (still missing) consensus on such list of harmonized indicators and impact assessment approaches. It is noteworthy that the PEF method recommends the study of environmental impacts in terms of 16 mandatory impact categories (and associated mandatory impact assessment methods; (Zampori, L. and Pant, R., 2019)). It is recalled that the PEF/OEF methods were promoted through a EC Recommendation published in 2013 (European Commission, 2013). In particular the PEF method is planned to be the basis for implementation of LCA in binding EU regulations (including the Battery Regulation and proposal for CRM Act). The decision to use the PEF recommendations also in TranSensus LCA regarding environmental impact assessment categories and associated impact assessment methods shall be further explored, discussed and decided in TranSensus LCA WP2 and subsequent WPs.

Impact pathways of the selected impact assessment methods shall be **relevant, reliable and accepted, regarding all impact categories**. Impact assessment results, and what they cover, shall be understandable by the targeted audience.

Outcomes from review of product LCAs and survey

While the prevalence of PEF recommended impact categories and impact assessment methods is discussed in the earlier sub-section, the reviewed product LCAs showed that the choice of impact categories were often driven by preferences and the life cycle impact assessment methods chosen are **often arbitrary**, inspired by the review of other published product LCAs. In some cases, **regional relevance is pursued** due to the demand for compliance with regional or national guidance. For example, LCA studies from German OEMs adhere to the LCA guidance by Verband der Automobilindustrie (VDA), studies from France conforming to the guidance within Plateforme Automobile (PFA), while studies from Asia were observed to adhere to or attempting to model their LCAs towards the guidance within CATARC or LIME method. Among the reviewed there are five other and growing number of vehicle OEMs who have developed and implemented their own custom impact assessment methods.

Outcomes from position papers

This lack of harmonization in the impact assessment is also pointed out by ACEA (Position paper on LCA in the automotive industry; (ACEA, 2021). The latter recommends that **only globally accepted indicators are included in impact assessments** (such as global warming potential, photochemical ozone generation potential, eutrophication potential). According to ACEA some indicators are not yet mature enough and / or not suitable for LCA. For example, **toxicity** is heavily dependent on local background concentration levels and chemical interactions between pollutants, which cannot be adequately modelled in LCA approaches. However, ACEA states that these methods can be used for internal environmental management to identify possible risks.

Mikosch et al. developed an approach for the identification of relevant impact categories for the automotive sector (Mikosch et al., 2022). Their results show that, from both automotive and stakeholder perspectives, **Climate Change** is by far the most relevant impact category followed by **Resource Use**, **Human Toxicity** and **Ecotoxicity**. Based on the evaluation of the LCIA methods, a combination of different methods can be recommended.

4.3.2 Main gaps in impact categories and indicators

Outcomes from workshops

The following are environmental impact and pressure categories for which specific gaps have been identified, either in terms of methodological robustness, or alternatively in terms of their insufficient application in pre-existing LCAs of ZEVs:

i) **Resource use minerals and metals**, classically addressed using depletion-based characterization factors which are acknowledged as imprecise and insufficient; while impacts associated with mineral resources use are important for comparisons in the electromobility sector;

ii) **Energy efficiency** is a key pillar of Europe's climate and energy framework. The PEF recommended list is importantly missing a more complete measure of lifecycle energy efficiency, which may be provided by indicators such as Cumulative Energy Demand (CED), and non-renewable CED (nr-CED) In particular, the latter indicator was suggested by some TranSensus LCA partners as a more comprehensive possible replacement for the PEF-recommended "Abiotic Depletion Potential, fossil fuels" (nr-CED also includes uranium resources).

Outcomes from review of product LCAs and survey

All the 16 product LCA reports considered global warming, while **only half of those studies report additional set of impact categories or indicators.** Regarding surveys results, if 100% of the respondents report global warming impacts, a bit more of two third report additional set of impact categories (see **Figure 4.7**). The cause for the lack of more elaborate reporting could be due to the lack of regulatory mandates and/ or demand from consumers for a vehicle's detailed environmental profile. Nevertheless, consideration of only GWP may limit an LCA's potency, undermining its potential to highlight a wider spectrum of environmental burdens and credits associated with the vehicle. The review of the collected literature highlighted some key gaps in the choice of impact categories and indicators. Some example of key impact categories and indicators that are **seldom or not conventionally considered in these studies include Cumulative Energy Demand (CED)**, which is crucial to highlight the overall efficiency of primary energy utilisation and **Abiotic Resource Depletion, minerals and metals** (ARD_MM) which is crucial in highlighting the impacts associated with the extraction and consumption of non-renewable materials required for manufacture of components, parts of vehicle body and battery systems. Answers from the survey differ a little bit from the ones from the literature as 56% of the respondents report CED and 69% report on ARD_MM or other resource scarcity or depletion indicators (see Figure 4.7)

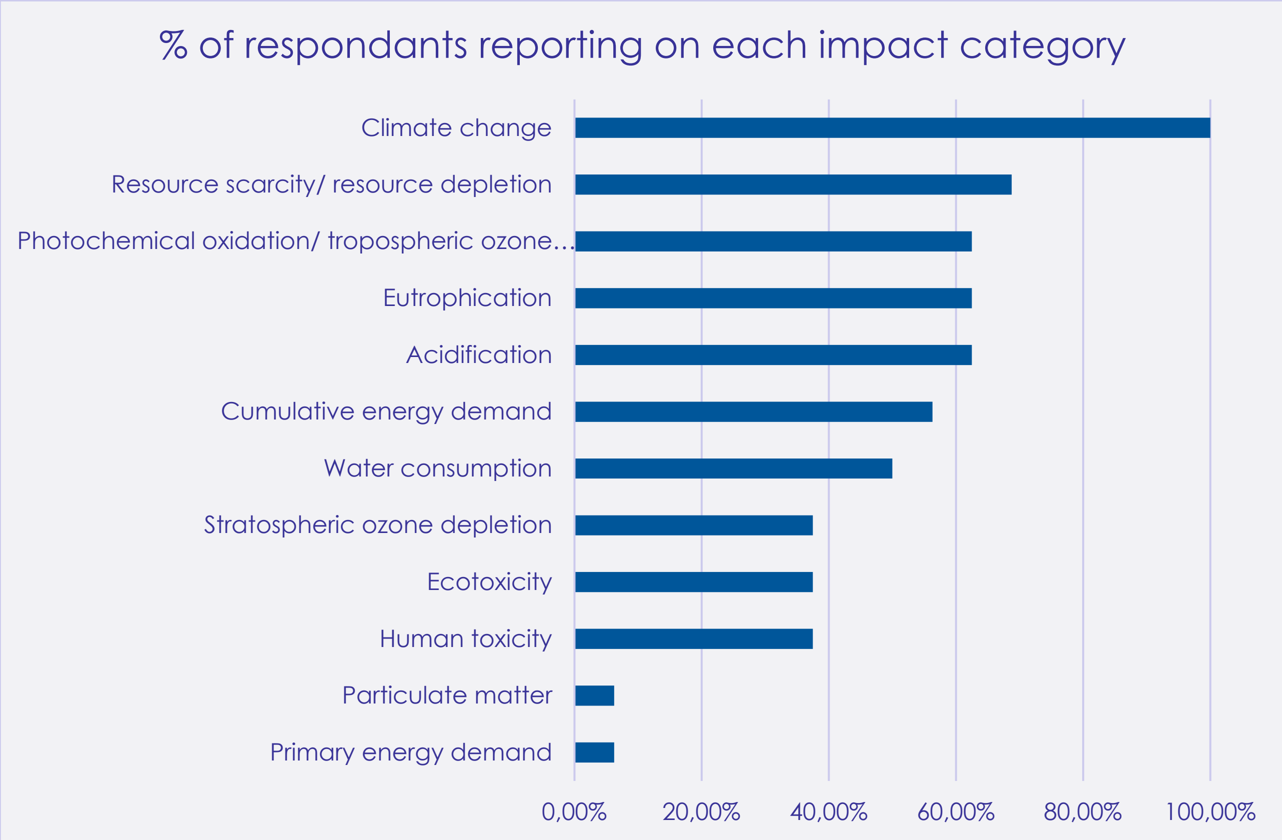


Figure 4.7: Survey's answers to the question "Which impact categories/indicators are you calculating?"

Among the reviewed literature and survey responses, only four studies report these impact categories, while two other organizations discuss the significance and plans for the inclusion of CED into future vehicle LCA reporting. Therefore, a **clear set of rules and guidance on the choice of impact categories and indicators that are appropriate** for addressing the whole life impacts of road vehicles need to be established, upon a thorough investigation of the material and energy flows across the different sets of vehicle-powertrain configurations, their operational patterns and end of life management scenarios. This need is also underlined by survey's respondents in two different sets of answers:

- Two respondents highlight the need of harmonization of life cycle impact assessment methods in an open question on the "Need for harmonization between stakeholders or actors along the supply chain";
- Three quarter of the respondents see this need moderately to extremely important when asked in a close question.

4.3.3 Normalization and weighting

Outcomes from workshops

Finally, there shall be clear **guidance on whether the normalization and weighting steps are made optional or mandatory**. Weighting classically eases the decision-making process, by reducing the number of indicators that sometimes result in contradicting conclusions. However, some partners advocate that these steps shall be made optional, as they make the results less transparent by combining the impact indicators for different impact categories into a single metric (despite the impact categories themselves being incommensurable from a scientific standpoint). Also, the weighting factors are always subjective by nature, and are in fact prohibited by ISO 14040/44 for all comparative LCAs. Therefore, it is acknowledged that **making normalization and weighting mandatory would automatically make the TranSensus LCA harmonized methodology non-ISO compliant in most cases** (since comparison across ZEVs is almost always required or at least implied).

Moreover, **concern was raised regarding existing normalization and weighting factors** (NFs and WFs). In particular WFs recommended in the PEF lead to emphasis on few impact categories of interest in the electromobility sector. The key focus on some impact categories only (after using the PEF WFs) implies **hiding potential for impact transfers to those other impact categories that are considered – disputably - as minor** (e. g., acidification and particulate matter). This concern leads some industrials to use their own weighting factors. **If recommended, normalization and weighting factors shall be harmonised and commonly agreed** in TranSensus LCA. A key aspect regards the importance that is given to impact on climate change through this weighting, and in general in the TranSensus LCA method development. Some partners consider that a core focus of the TranSensus LCA method shall be on climate change. Such a focus, somehow similar to giving a 100% weighting score to impact on climate change, would have implications not only regarding the impact assessment LCA phase, but more generally regarding all phases of a LCA (including Goal and Scope, LCI and Interpretation).

Outcomes from review of product LCAs and survey

Similar to the observations from the workshop, there appears to be a disparity in the choice of impact assessment methods, number of impact categories to report and whether to implement normalization and weighting. Among the reviewed LCA studies, a majority were observed to have reported LCA results for midpoint indicators. **These results, in the publicly available versions are neither normalized nor weighted**. However, amongst the survey respondents, one out of the 17 respondents has indicated implementing the normalization of LCA results regarding European population.

Outcomes from position papers

ACEA (Position paper on LCA in the automotive industry; (ACEA, 2021)) recommends that only globally accepted impact categories (indicators) should be included in public impact assessments and **aggregated single scores should not be used** in any LCA disclosure. According to ACEA any weighting of different impact category results to one single score is based on subjectivity and bias.

GRPE (Terms of reference of IWG on automotive LCA; (UNECE-GRPE, 2023)) recommends that for LCIA, the format and minimum contents of the Automotive - LCA report shall be defined.

4.4 Interpretation

Summary of main outcomes on gaps in Interpretation

This part discusses **data quality, sensitivity/scenario/uncertainty analyses** as well as **verification** and **auditing** of results.

LCA of complex products such as motor vehicles involves high uncertainties in terms of completeness of considered parts, accuracy and geographical representativeness of the data or the allocation methods. There is a need to increase confidence in LCA data shared along the supply chain. This requirement could be supported by a harmonized, potentially easy-to-use guidance to support quality assessment and communication, implemented in LCI databases and LCA tools. This indicator should be both qualitative as well as quantitative.

This section moreover points to lack of consistency in the definition and use of sensitivities and scenarios. Guidance shall be provided on the definition of sensitivity analysis, uncertainty analysis and scenarios. WP2 needs to consider whether any of these options (including specific sensitivities) should be mandatory, recommended, or optional.

This section also calls for the adoption of common agreed guidelines for a credible data quality verification/audit process, overcoming the challenge of confidentiality in sharing detailed primary data, while ensuring the right level of transparency. In this regard, externally reviewed data, shared on an aggregated level only, shall be discussed as a relevant option. More generally there is a need for a common framework and content for reporting, distinguishing public and confidential versions.

Table 4-7: Short synthesis of gaps on Interpretation in E-LCA, for the development of a harmonised approach in the electromobility sector

Gap regarding	Short description	Prescriptions for the TranSensus LCA method: it shall cover/include (though not be limited to):	Level of importance in the development of the TranSensus LCA method
Uncertainty	Sometimes still **high uncertainties** in terms of completeness of the system modelling (parts), accuracy and geographical representativeness; though not properly reflected in results and interpretation	A **harmonized guidance to support quality assessment**, **sharing** along the supply chain, and **communication** (**Data Quality Rating?**)	High
		Guidance potentially **easy-to-use**	Medium
		Approach integrated in LCI databases and LCA tools	Low
		Communication of Data Quality Rating to be considered to be **mandatory**	Medium
		Quantitative uncertainty evaluation (beyond qualitative rating) and propagation to be considered	Medium
Sensitivities, Scenarios	Lack of consistency in the definition and use of **sensitivities and scenarios**	Guidance provided on the definition of **sensitivity analysis, uncertainty analysis and scenarios.** To be considered whether any of these options (including specific sensitivities) should be **mandatory, recommended, or optional**	Medium
Reporting and Verification/audit	Lack of **common framework** for reporting, and **commonly agreed guidelines for a credible data quality verification/audit process** - leading to poor confidence in shared data	**Common** framework and content for **reporting**	High
		Guidelines for **a credible verification process (or audits)** overcoming the challenge of confidentiality while ensuring transparency	High
		Externally reviewed data shared on an aggregated level only, to be considered	Medium

4.4.1 Data quality, and sensitivity, scenario and uncertainty analyses

Outcomes from workshops

Data Quality Rating (DQR) is advocated by some partners to be needed **to quantify the quality and the uncertainty of data used in LCA, and to communicate these** together with the LCA results. Some partners (in particular from industry) call for **an easy-to-use score indicator** associated with data quality, which can be implemented and used through LCI databases and LCA tools (for example, DQR as per the PEF guidelines is available in OpenLCA but not in Sphera's MLC/LCA FE [former GaBi database/software], in which another approach for Data Quality Rating is implemented and reported). Current use of DQR in LCA practice is currently **time-consuming**, in particular if the choices made are properly documented for each specific Quality parameter (technology, temporal, geographic, and completeness).

Moreover, some partners consider that the criteria to be met to qualify data as of "good quality" in current overarching guidelines such as the PEF and JRC CF Rules for batteries are **not stringent enough**. It is also disputable to stick to only qualitative information when addressing data quality and uncertainty. **Quantitative uncertainty consideration and propagation**, from inventory data to impact assessment, shall be considered and discussed in TranSensus LCA based on current state-of-the-art approaches in the LCA field. Any recommendation on uncertainty accounting at the interpretation stage of a LCA necessarily pertains to uncertainty accounting in secondary LCI databases, in addition to uncertainty accounting for primary data. Some partners of TranSensus LCA called for an approach to account for uncertainty that shall be as easy and quick as feasible. Consideration of the uncertainty/quality of data may eventually lead to incentivizing primary data.

In general, there is agreement among TranSensus LCA partners that there needs to be developed/agreed a **harmonized guidance** i) to account for **data quality and uncertainty**, both at foreground and background levels, and ii) to **share/communicate this information** along the supply-chain, in addition to impact assessment results.

Outcomes from review of product LCAs

Product LCAs have been predominantly observed to establish compliance with ISO14040/44 for undertaking whole life environmental impact assessments of their vehicles. While almost all product LCAs have consistently adopted minimum criteria for the data sources that is representative of the time, geographic and technological scope of study, the data sources for core-processes or "foreground processes" are often confidential or drawn from other supply chain members for vehicle components. This may lead to issues pertaining to transparency or reproducibility. As a result, product LCAs seldom provide information on the evidence of data completeness and consistency checks.

In line with the observations made from the "workshop" sessions, almost all OEM reports have consistently adopted minimum criteria for the data sources that is representative of the time, geographic and technological scope of study. However, the data sources for core-processes or foreground processes are often confidential or drawn from other supply chain members for vehicle components. As a result, OEM reports seldom provide information on the evidence of data completeness and consistency checks. This may be attributed to their strategies to avoid competitive risks or data confidentiality concerns, which nevertheless has led to issues pertaining to transparency or reproducibility.

The product LCAs reviewed do **not make a clear distinction between sensitivity, scenario and other uncertainty analysis** in the reporting. However, all but one study reviewed has performed some kind of sensitivity/scenario analysis. The most common analysis considers the electricity grid mix during the use of BEVs. Most studies compare at least one or more (usually static) electricity grid mixes (national and/or regional) to electricity produced from renewable sources, such as wind or hydropower. Five studies explore future electricity grid mix scenarios and the effect on the results and conclusions. All OEMs use an adaptation of the future scenarios proposed in the World Energy Outlook from the International Energy Agency (IEA, 2023). However, only very few studies utilise a dynamic mix (i. e. based on average over the lifecycle of the vehicle, rather than a static example for a specific year). Different kinds of fuels such as diesel, gasoline, biodiesel and hydrogen from different sources are included in some of the studies that cover ICEV and FCEV. Three studies explore different lifetime mileage for the vehicle and two OEMs briefly discuss the sensitivity of the supply chain and therefore compare global averages for material production and refining to European ones for selected materials. One OEM includes the potential impact of introducing "fossil free steel" as an alternative to conventionally produced steel.

Most product LCA reports **do not explicitly discuss how the analyses were used to support the conclusions** of the study but some report that the inclusion of different current and future electricity mixes gave insight into the importance of electricity mix during use and the key contributors to environmental impact. No other uncertainty analysis (such as Monte Carlo simulations for uncertainty propagation) was reported by any OEM.

Since all but one study out of sixteen reports some kind of sensitivity/scenario analysis, it highlights that the industry understands **the importance of these kinds of analyses** and utilises some of the tools available within uncertainty analysis to better understand their results. There might however be a need to harmonise and investigate other important life cycle phases and/or tools of uncertainty analysis that might be important to include. This relates to the agreement among TranSensus LCA partners, as outcomes from workshops, on **the need for a harmonized guidance to account for data quality and uncertainty** (see above dedicated section).

Some challenges/limitations disclosed in the product LCA reports, that might affect the uncertainty of the studies, include lack of coverage of component production, lack of primary data, real-world data for the use phase and fast development of battery production and technology. Some product LCAs disclosed that non-exhaust emissions during usage of the vehicle is excluded due to lack of data and that water and toxicity impact indicators are not included due to uncertainties.

<u>Outcomes from position papers</u>

According to GRPE (Terms of reference of IWG on automotive LCA; (UNECE-GRPE, 2023)), quality requirements for data should be defined. Quality requirements may include the temporal scope, geographical scope, technical scope, accuracy, completeness, representativity, consistency, reproducibility, etc. Data derivation, accompanying metadata and formats should conform with existing international guidelines and nomenclature systems, including ISO 14048, the UNEP Global Guidance Principles for LCA Databases, and UNEP Global LCA Data Access network standards.

CLEPA (Inputs for a CO2-LCA workshop at GRPE; (CLEPA, 2022)) points out that vehicle manufacturer's specifications to suppliers need to be harmonized in terms of type of data requested: scope of the data, level of detail (scope 1&2 vs 1,2,3up, measurement vs estimation using commercial tools (ERP), GHG or GHG & energy & recycled content).

ACEA (Position paper on LCA in the automotive industry; (ACEA, 2021)) clearly points out that LCA for complex products such as motor vehicles bear high uncertainties with regard to completeness of considered parts, accuracy and geographical representativeness of data or allocation methods. The large-scale application of LCA for vehicles would require the simplification and generalization of data, methods and tools to a large extent. This would only lead to reliable, but not to correct results, which would be needed for fair comparisons. Such a generalized system could lead to an active disincentive for certain types of action.

Peiseler et al. (Toward a European carbon footprint rule for batteries; (Peiseler et al., 2022)) point out that, because a regulator needs to balance data quality with feasibility and compliance costs, it is unrealistic to expect complete data transparency throughout the entire Litium Ion Battery value chain.

In the context of the JRC Harmonized rules for the calculation of Carbon Footprint of Electric Vehicle Batteries (in their version of March 2023), the CEA and BRGM "*recommend that the two key output pieces of information from the implementation of the [Carbon Footprint] Rules are explicitly reported (i. e., labelled, and not reported in the CFB supporting study):*

- *the [Carbon Footprint] value and/or class of value;*

- *the quality associated with the assessment (i. e., the DQR value associated with the calculated [Carbon Footprint]).*" (CEA and BRGM, 2023).

The CEA and BRGM moreover "*recommend that, by a time horizon to be defined (e. g., 5 years), the JRC and the EC explicitly plan a revision of section 6.4 Data quality requirements. […] this revision shall in particular include:*

- *increasing the level of requirements (i. e., of constraints) for those data referred to as of Good, Very Good and Excellent quality, both regarding company-specific datasets and secondary datasets.*
- *creating additional sub-categories (i. e., intermediates to Fair, Good, Very Good, etc.) in order to better differentiate between levels of uncertainties."*

4.4.2 Reporting and verification/auditing

Outcomes from workshops

Industrials in the automotive industry need to carefully follow and support the deployment of LCA within their supply chains. Primary data collection through questionnaires is classically observed **to result in non-reliable LCI datasets**. Cell makers are in the process of improving in-house LCA expertise, and do not fully master LCA-related data and results. It is agreed that there is **a need to increase confidence in the shared modelled LCA results along the supply chain**. Commonly agreed **guidelines for a credible verification process (or audits) are necessary** for all suppliers in the value chain, including those outside the EU. This is expected to support improved data quality, as shall be reflected by the DQR or other approaches to account for data quality. The developed verification process shall overcome the confidentiality challenge in sharing the detailed primary data collected to complete the modelling, while at the same time ensuring the maximum feasible transparency. In this regard **externally reviewed data shared on an aggregated level only shall be discussed as a potentially relevant option**. More generally, it is agreed that there is a **lack of a common framework for reporting** of the LCA study.

Outcomes from review of product LCAs and survey

Only five out of sixteen reviewed product LCA studies were verified by a third party. Three were verified against the ISO 14040/14044 standards and two LCA studies (EPDs) were verified against the PCR for buses. The results from the review of the surveys does not deviate from the findings for product LCA review. Again**, this calls for commonly agreed guidelines for a credible verification process (or audits)**.

<u>*Outcomes from position papers*</u>

In line with outcomes from workshops, and from the review of product LCAs and survey, position papers also highlight the need for harmonization in the verification process, while overcoming the confidentiality challenge in sharing the detailed primary data collected to complete the modelling.

CLEPA (inputs for a CO2-LCA workshop at GRPE; (CLEPA, 2022)) points out that vehicle manufacturer's specifications to suppliers need to be harmonized in terms of required verification: audit by third-party external/internal vs. ISO standards or specific rulebooks. According to Peiseler et al. (Toward a European carbon footprint rule for batteries; (Peiseler et al., 2022)), battery producers have voiced concerns that disclosure of primary data, such as energy usage or used materials, can be mis-used to reverse-engineer company secrets. This highlights the need for independent auditors to collect and verify individual Carbon Footprint calculations confidentially.

4.5 Transversal issues

Summary of main outcomes on gaps regarding transversal issues

There shall be a commonly agreed approach regarding the **frequency in LCA updates**. This pertains to all the aspects of a LCA, e. g. default parameters, update in standard LCI databases and Characterization Factors, etc. There shall also be a harmonized and agreed approach to address **prospective dimension** in LCA.

Lack of interoperability between data in different **tools** is moreover considered by some TranSensus LCA partners as an overarching gap.

4.5.1 Temporal dimension in TranSensus LCA

<u>*Outcomes from workshops*</u>

There shall be **a commonly agreed approach regarding the frequency in LCA updates**. This pertains **to all the aspects** of a LCA, e. g. **default parameters** used in modelling (e. g. related to the CFF implementation), **update in standard LCI databases** of secondary datasets, update **in Characterization Factors of impact assessment** methods (and associated NFs and WFs), etc. There is a particular issue with regards to the electricity mix, affecting all lifecycle stages, as new models will typically be supplied to the market for at least 5 years (and sometimes significantly longer), which will mean that the electricity mix will most likely change not only for vehicle production over the period the vehicle is on the market, but also as well as for the projected mix based on the actual year of manufacture (and similarly for the EoL year). With the rapid development of battery technology, changes to manufacturing and even chemistries can happen during the course of a model's market lifetime, which could substantially affect the results.

Moreover, the **prospective dimension in LCA** (i. e. the modelling of any aspect of the system in a future-oriented perspective) **shall be clarified and harmonized**. This regards in particular agreed methods for extrapolating to different vehicle variants and specifications, modelling of electricity consumption and recycling (in particular of batteries) at end-of-life, etc.

4.5.2 Tool-oriented gaps

Outcomes from workshops

Some of the identified gaps relate to LCA tools in a large sense, including tools for LCI datasets management and LCIA calculations. In the electromobility sector, integration of a LCA model in a design process faces difficulties linked to still uncommon and not harmonized parameterized approaches. Some partners consider that **interoperability between data in different tools**, within the "LCA world" and beyond (e. g. design tools) is an overarching gap. It is acknowledged that TranSensus LCA is not intended to develop tools or databases. Yet, these TranSensus LCA consortium members expect that the **TranSensus LCA method will set the ground for increased interoperability between tools used in the electromobility sector**, especially to support eco-design of products and systems.

Outcomes from review of product LCAs

OEM LCA reports have not identified or highlighted any specific concerns with the tools used for undertaking their vehicle LCA. However, concerns related to the lack of guidance and rules on the use of specific secondary datasets have been highlighted by the OEMs through their survey response. This has been covered in further detail in section 4.2.

Outcomes from position papers

The need for increased integration and interoperability between tools used in the electromobility sector is further highlighted by position papers. According to CLEPA (inputs for a CO2-LCA workshop at GRPE; (CLEPA, 2022)), vehicle manufacturer's specifications to suppliers need to be harmonized in terms of type of tools (commercial software tools and databases like Sphera's MLC and LCA FE (former GaBi), Ecoinvent etc.).

ACEA (Position paper on LCA in the automotive industry; (ACEA, 2021)) points out that the complexity of motor vehicles and related supply chains makes it difficult to compare LCAs of vehicles from different manufacturers. More time is needed to develop methods and tools that are flexible enough to consider environmental improvement.

5. Gaps and Needs identified in S-LCA

This section builds on the methodology described in section 2.3. Based on the review on products S-LCA, this chapter offers a census of needs and gaps as identified in the literature. Section 5.5 mainly reports on findings from interviews.

5.1 Goal and scope definition

Summary of main outcomes on gaps and needs regarding Goal and Scope definition for S-LCA

- The guideline specifies that the goal definition must address the purpose of the study, target audience, assessment objectives, decision-making support, potential opportunities, and affected stakeholders. Many did not fully comply with the recommended goal definition, lacking elements such as target audience, decision-making support, and potential opportunities.
- The functional unit should encompass the main function and utility of the product, including technical and social aspects, as per the UNEP S-LCA guideline 2020, but some studies did not consistently include the required components of the functional unit, deviating from the guideline's recommendations.
- The identification of system boundaries should consider physical and effect perspectives, and be consistent with the study's goal, according to the UNEP S-LCA guideline 2020 but some studies did not provide clear justification for the inclusion/exclusion of life cycle stages, deviating from the guideline's recommendations.
- The product system should consist of interconnected unit processes, considering geographic location and company involvement, as per the UNEP S-LCA guideline 2020, but some studies did not consistently adhere to the guideline's recommendations for defining the product system.
- The UNEP S-LCA guideline 2020 should develop compatible activity variables for different stakeholders and standardize the method for selecting activity variables. The current use of "worker-hour" as an activity variable was noted to be incompatible with other stakeholder categories.

5.1.1 Goal definition

According to UNEP S-LCA guideline 2020, the goal definition must specify *"why the study is being conducted?", "target audience", "what do we want to assess?", "does the study intend to support decision making?", "what are potential opportunities produced by study?", "which stakeholders are affected?"*. In comparison of ISO 14040/44 and UNEP S-LCA guideline 2020, the specification of the goal definition is similar, but the ISO 14040/44 does not consider the affected stakeholders.

Baumann et al. (2013) has defined the goal without involving the target audience, affected stakeholders and failed to describe whether the study supported in decision making. This goal definition focuses only on the reason for the study being conducted, which violates the specification of the goal definition recommended by UNEP S-LCA guideline 2020. Also, Aboushaqrah et al. (2020) has not followed the phases of conducting S-LCA and only focused on the few components of the scope definition. In many studies (Koese et al., 2023; Shi et al., 2023) the specification of the goal definition does not include whether the study intend to support decision making and the potential opportunities produced by the study.

5.1.2 Functional Unit

According to UNEP S-LCA guideline 2020, the specification of functional unit comprises of main function and utility of the product. The product utility is the perception of the consumer regarding the product at its use phase which satisfies his/her desires and cultural or social values. The product utility can be represented in technical aspects (e. g. quality, functionality) or in the social aspects (e. g. Well-being, convenience, prestige).

When modelling the product system using the S-LCA database (e. g. PSILCA), the functional unit may be described as a currency amount (e. g. dollars, euros). The social impact of the product system which depends on behaviour of the company and key life stakeholder does not provide scaled result to the functional unit of the product, due to practical (shortage of data, confidentiality) or conceptual reasons (e. g. linear scaling of social impacts). For instance forced labour can be addressed, but cannot be scaled to the functional unit of the product system. In comparison of UNEP S-LCA guideline 2020 with ISO 14040/44, the functional unit should be consistent with goal and scope of the study, measurable and include the main function of the product. In contrast with ISO 14040/44, the UNEP S-LCA guideline 2020 should include product utility with the main function of the product.

In the Life Cycle Sustainability Assessment (LCSA) of sports utility vehicle at Qatar, authors have defined the functional unit as "*1 km of vehicle travel*" for assessing the environment, social and economic impacts in the use phase operation (Aboushaqrah et al., 2020). However, the specification of functional unit defined in Aboushaqrah et al. (2020) is not compliant with the UNEP S-LCA guideline 2020. The various components of functional unit such as the product utility in terms of technical and social terms are missing. The selection of the functional unit for LCSA must also satisfy methodologies for S-LCA. In many studies which focus on the use phase (Baumann et al., 2013; Koese et al., 2023) the specification of the functional unit, product utility along with the main function of the product recommended by the UNEP S-LCA guideline 2020 is not followed. Dunuwila et al. (2022) carried out S-LCA of raw rubber production for cradle to gate, for instance from plantation (fresh rubber latex is extracted) to factory (processed fresh latex). As per UNEP S-LCA guideline 2020, the concept product utility is applicable only for the use phase therefore (Dunuwila et al., 2022) highlighted only main function as the functional unit of the product.

Osorio-Tejada et al. (2020) integrated S-LCA of freight transport systems in Malaysia, also discusses about the constrains in relating the social aspects with functional unit. The UNEP S-LCA guideline 2020 describes how to describe the steps to define the functional unit, but also need to develop steps in relating the social aspects in the functional unit.

5.1.3 System Boundaries

According to the UNEP S-LCA guideline 2020, the identification of system boundary is to determine the life cycle stages of a product system to be assessed and involves the background and foreground processes of a product system. The setting of system boundary is based on two perspectives - physical and effect perspectives. The physical perspective allows to define production cycle and life cycle stages of a product, the effect perspective allows relation among key life cycle stakeholder. As per ISO 14044, the identification of the system boundary is an iterative process based on the input and output at its boundary, which are elementary and product flows. In ISO 14044, the level of detail to be assessed and which unit processes shall be included or omitted should be justified in the study. Both in ISO 14044 and UNEP S-LCA guideline 2020, the system boundary should be consistent with the goal of the study and carried out cradle to grave. The system boundary can be narrowed down due to the pragmatic limitations in an iterative way. This must be explained in the study, for instance considering unavailability of data for a unit process. Moreover, in both methodologies, the refinement of system boundary is carried out by sensitivity analysis on inventory data conducted in interpretation phase. In UNEP S-LCA guideline 2020, the setting up of system boundary takes account of physical and effect perspectives whereas in ISO 14044, the initial identification is based on the availability of data.

Additionally, Aboushaqrah et al. (2020) only considered operation/use-phase for the study due to *"high environmental impact"*, the reason for excluding the other life cycle stages was also not justified. Many studies (Baumann et al., 2013; Dunuwila et al., 2022) has not clearly explained the reason for excluding/including the life cycle stages of the product being studied.

5.1.4 Reference flow

According to the UNEP S-LCA guideline 2020, the reference flow translates functional unit into specific product flows and enables the practitioners to identify the material input necessary for the fulfilment of the functional unit. As per the example provided by UNEP S-LCA guideline 2020, the components of the reference flow include actual quantity of the product to fulfil the function of the functional unit, desirable function within a specified time span depending on the goal of the study. The specification of reference flow in ISO 14040/44 focuses only on the *"measure of the output from processes in a given product system required to fulfil the function expressed by the functional unit"*.

(Baumann et al., 2013) considered the reference flow as *"annual production of airbag systems and the lives and injuries that are saved and lost annually"*, for the functional unit *one autoliv driver airbag system.* As per the UNEP S-LCA guideline 2020, the reference flow should be described in the goal and scope phase, instead in (Baumann et al., 2013) the data for annual production of the airbag system is found in the inventory table. Also, in many studies (Dunuwila et al., 2022; Koese et al., 2023; Osorio-Tejada et al., 2020; Pastor et al., 2018) the reference flow was not found in the goal and scope phase of these respective studies.

Moreover, Shi et al. (2023) described reference flow as *"an uncharged LFP battery with a total weight of 5.409 kg",* for the functional unit "*LFP battery that can release a total of 1000 kWh of electric energy throughout 2000 charging and discharging cycles in the whole use phase to support EVs, before its end-of-life disposal or recycling"* in the goal and scope phase.

The specification of the reference flow in UNEP S-LCA guideline 2020 should be developed in such a way that it should describe the components like actual quantity of the product to fulfil the function of the functional unit and desirable function within specified time span depending on the goal of the study.

5.1.5 Product system

According to UNEP S-LCA guideline 2020, the specification of the product system includes collection of interconnected unit process in the life cycle of the product. The unit process can be linked with an activity (eg. washing vegetable, activity of workers to wash vegetables) and their geographic location which is necessary for the adequate quality of S-LCA study. The product system is developed based either on life cycle data, economic input-output data, environmental data, purchase/expenditure, or combination of these. In ISO 14040/44, the product system is modelled as input and output at its boundary are elementary and product flows. In ISO 14040/44 and UNEP S-LCA guideline 2020, the specification of the product system is similar, both norms aim to define the collection of interconnected unit process in the life cycle. In contradiction, ISO 14040/44 and UNEP S-LCA guideline 2020 has elementary flows, but the concept of elementary flows is different in both norms. In LCA the elementary flows are the materials or energy entering the system being studied that have been drawn from environment without previous human transformation, or the materials or energy released into the environment without subsequent human transformation. In S-LCA, the elementary flows enter the product system as same as in LCA, but output elementary flows cause risk to society.

In many studies (Baumann et al., 2013; Shi et al., 2023) the product system is represented as flow chart of interconnected unit processes. These processes are based on only technological processes and the geographic location of these unit processes are not taken into consideration. As per UNEP S-LCA guideline 2020, it is crucial to involve the geographic location and name of the companies involved in the unit processes. Therefore, the specification recommended by the UNEP S-LCA guideline was not followed by these studies.

Moreover, the definition of product system in the UNEP S-LCA guideline 2020, should consider how to involve the geographic context of the complex supply chain (eg. Automobile sector).

5.1.6 Activity Variable

According to the UNEP S-LCA guideline 2020, the activity variable is the measure of the process activity. The activity variable helps to represent the significance of the unit process in the whole product system. The commonly used activity variable are "worker-hours" or "added value", worker-hours provide information such as number of worker-hours required to complete the unit process and added value considers the amount of added value created in each process. The chosen activity variable can be scaled to the functional unit of the study. If a unit process has increased worker-hours or added values, which in turn increases the social issues of that unit process and vice versa. If a specific unit process is impactful and it contributes relatively small worker hours compared to whole product system (e. g. the displacement of local community for the construction of hydropower plant) leads to negligence of the social issue. If a unit process is associated with high added value, this might result in increased labour cost and implementation of high degree of technology or most efficient method and resource saving method. The highly technologized and high value process with less working time could be related to high social impact. Therefore, it is questionable to choose an appropriate activity variable in a complex product system. Some practitioners do not use activity variable, instead they assume the importance of unit process is associated with the cost/economic value or weight or consider all unit processes have the same importance. In the ISO 14040/44, the specification of the activity variable is not defined, as the LCA focuses only on the environmental impact of a product/service and does not consider social impacts.

Moreover, the activity variable "worker-hour" is more referred to the stakeholder category workers, which is not compatible with other stakeholder categories such as consumers, local communities, society, children and other value chain actors. Therefore, the UNEP S-LCA guideline 2020 should develop the different compactible activity variable for different stakeholders. Additionally, there is a need for standardized method in selecting the activity variable recommended by UNEP S-LCA guideline 2020.

5.1.7 Cut-off criteria

According to UNEP S-LCA guideline 2020, the cut-off criteria is necessary to exclude some of the unit processes from initially identified system, due to practical limitations (e. g. data collection can be obtained through only on-site). Therefore, it is necessary to reduce the breadth of the product system. There are three possible ways to identify cutoff criteria: Social significance, Identical element and Available resource. The social significance cutoff criteria of the processes are carried out in quantitative approach (e. g. using activity variable) and/or qualitative approach (e. g. processes which are more prone to social concern). The identical element is a way to cutoff processes, when analysing the comparative S-LCAs, different processes need to be included and same processes should be eliminated. Based on the availability resource cutoff criteria, those processes whose data available are included in the product system. The concept of cut-off criteria is similar in both ISO 14040/44 and UNEP S-LCA guideline 2020, used to decide which input and output processes are to be included in the assessment, but in the ISO 14040/44, the cut-off criteria is also based on mass, energy and environment significance.

In many studies (Aboushaqrah et al., 2020; Dunuwila et al., 2022; Shi et al., 2023) the cut-off criteria were not transparent and consistent, according to the UNEP S-LCA guideline 2020. Aboushaqrah et al. (2020) has conducted the LCSA for sports utility vehicle for Qatar, focused only on operation phase due to its environmental significance.

5.2 Social Life Cycle Inventory (S-LCI)

Summary of main outcomes on Gaps and Needs regarding Social Life Cycle Inventory

The S-LCI step in S-LCA depends on the type of social impact methodology chosen to conduct the assessment (reference scale approach or impact pathway method). Overall, the associated pitfalls are identified within the S-LCI stage:

- In the case of a S-LCA conducted using the reference scale approach, the lack of standardization regarding performance indicators leads to assessments that are not comparable between companies;
- Regarding the impact pathway method, there is a need for further methodological developments regarding the development of cause-effect chains to enhance the robustness of the approach and for the implementation of these developments into S-LCA software;
- For secondary data, the expression of social risks based on USD currency leads to possible misrepresentations as the unit misses to consider specific aspects such as currency fluctuations, purchasing power parity or inflation and cost of living that are specific to each country;
- Secondary data available in S-LCA databases might be outdated and inadequate to conduct hotspots assessment due to their granularity. There is a lack of data representative to specific regional area or specific value chain;
- For the ease of primary data collection, sector-specific data collection sheets are missing;
- Regarding the quantification of activity variables, they should be quantified at the subcategory or at the stakeholder level. In the meantime, detailed activity variables of complex supply chain processes are also missing. These should be developed while ensuring data confidentiality of company specific data;
- The availability of social data specific to co-products should be enhanced to model multifunctionality properly.

Collecting data for Impact assessment

According to UNEP S-LCA guideline 2020, one of the specifications of the data needed for S-LCI is based on the type of impact assessment approach chosen – Reference Scale approach (RS S-LCIA) or Impact Pathway approach (IP S-LCA). The reference scales are established in the inventory phase and main aim of RS S-LCA is to assess the social performance or social risk of product life cycle. For RS S-LCA approach, the data collection should contain the data for reference scales, different stakeholder groups and different subcategories which are identified as relevant for the study based on international, national, regional and industry standards. S-LCA databases (e. g. PSILCA, SHDB) follow a common PRP (Performance Reference Points) and PIs (Performance Indicators) for all sectors and corresponding country level. This creates a huge gap in the result of impact assessment, because different products or services along its life cycle has different social conditions, national or regional laws. Karlewski et al. (2019) has highlighted the concern in the non-standardization of performance indicators for a product and therefore S-LCA studies cannot be compared with different companies. The methodological development in S-LCA has to focus on concretization and standardization of the PIs, which helps in setup of reference scale for different sectors and countries.

For IP S-LCA, the data collection should contain the data for inventory indicators to express the identified impact categories in the study and characterization factors like in LCA for underlying characterization model. In UNEP S-LCA guideline 2020, IP S-LCA is explained with increased complexity, most of the S-LCA studies are based on RS S-LCA, because the IP S-LCA has a clear gap in understanding and implementing the methodology to assess social impacts along the life cycle of products or services. The unavailability of IP S-LCA in existing S-LCA database, software and lack of methodological development in the different cause effect chain between inventory indicators and impact categories according to the cultural and regional background has also hindered the usage in S-LCA studies. Further research, collaboration and development of cause effect chain for most of the subcategories and characterization model enhances the robustness of the impact pathway approach for assessing social impacts in S-LCA.

As per UNEP S-LCA guidelines 2020, the secondary data (or generic data) can be collected through literature review, web search and existing database (e. g. PSILCA and SHDB). Shi et al. (2023) has mentioned the comparison of social risk condition between developed countries and developing countries based on USD (US Dollars). The risk per dollar (RPD) of products in developed countries is usually lower than developing countries because the total economic value produced by industries in the developed countries is much higher than that produced by industries in the developing countries. There are huge number of concerns when the social data is related to USD, for instance, currency fluctuations, purchasing power parity, inflation and cost of living are specific to each country. To overcome the problem of relating social data with USD, these factors should be considered. Some of the identified hotspots in generic analysis based on sectoral and country specific data does not end up in representing a problem in the specific product life cycle. The use of secondary data for S-LCA has numerous challenges such as absence of site-specific social condition of product system, provide generic representation of social aspects which overlook the potential social impacts at different region or communities, reliance on existing database might provide outdated information and also inadequate coverage of country and sector specific data.

The primary data (or site-specific data) can be collected directly visiting the specific or relevant production sites or by working with the organizations (e. g. NGOs or comparable organizations). The primary data can be collected through a range of methods with great deal of effort. Most of companies do not publish their social data for individual processes along the life cycle of a product. Most of the cases, the social data is available at organizational level, therefore social impacts should be allocated according to the products considered. Moreover, several companies consider the feasibility of collecting social data at process and organisational level as very difficult and these social data at different levels may also be subjected to confidentiality (Karlewski et al., 2019). The primary data across supply chain of a product can significantly impact the quality and accuracy of S-LCA, some of the challenges include lack of transparency and standardized data formats, measurement units, reporting standards, conduct on-site assessment of collected data. Karlewski et al. (2019) has also used data collection form to analyse the social data and indicators based on feedback of the companies, but some of the companies did not complete the questionnaire due to lack of capacity. Sector-specific data collection sheets need to be further developed for the effective collection of data for S-LCA specific application, as in LCA.

In compliance with UNEP S-LCA guideline 2020, there are three approaches used to collect activity variable data – through site-specific data collection, use of dedicated S-LCA database (PSILCA or SHDB), through input-output or other databases. The collection of activity variable through on-site may be calculated using hypotheses and estimates, which carry some level of uncertainty. The collection of activity variable through S-LCA databases (e. g. PSILCA, SHDB) provides the default calculation of activity variable data per process to identify the social risk and opportunities. The activity variable data from input-output databases (e. g. GTAP (Global trade Analysis Project), EORA, EXIOBASE, etc) and intergovernmental organizations such as ILO (International Labour Organization) can be based on generic information on location and activity type/sector. S-LCA databases also use worker hours an activity variable for the stakeholder groups such as local communities. Using worker hours as an activity variable for stakeholder groups like local communities and society, is not meaningful. The activity variable can also be taken from the LCA database GaBi within framework of Life Cycle Working Environment (LCWE) approach. However, the information of these activity variable is based on US economy and cannot be used for any other countries (Karlewski et al., 2019). Karlewski et al. (2019) has tried to use working hours as an activity variable to represent the significance along the product life cycle, but most companies maintain confidentiality of the process level data which affected the data collection of activity variable for the study. There are numerous challenges when using organizational level data as activity variable for each unit process. The organizational level data can be averaged over different countries, activities and product of the company, for example the company produces same product in several countries with difference in activity variable, lead to misinterpretation of hotspot of the product system. Karlewski et al.

(2019) also tried to use the activity variable data directly incorporated with process level and its reference values, but this method is very time consuming. Therefore, the UNEP S-LCA guideline must develop relevant activity variable with respect to the subcategory or stakeholder level. There is also a need of detailed information for activity variables of complex supply chain processes (e. g., mining, production and disposal process) which could be listed as industry or sector specific data in S-LCA database (analogous to LCA database) and thus maintain confidentiality of company specific data (Karlewski et al., 2019).

According to UNEP S-LCA guideline 2020, handling co-product arises when a product system generates multiple co-products or fulfils multiple functions. The allocation should be avoided by subdividing activities and gather specific data for the production of co-products separately. If subdivision is not possible, the system boundary should be expanded to include additional products and activities and their social issues. If the products produced are independently varied, relevant risks and impacts can be allocated causally by using appropriate activity variable. If the causal modelling is not possible or when goal and scope is sought the specific issue in the value chain, process impacts can be allocated based on share of revenue coming to the process of its product output. When the system boundary is expanded to include additional products and processes, the former goal and scope definition should be iteratively changed accordingly. This might introduce complexity and uncertainty, as it involves decision making about which life cycle stages, processes, inputs, outputs, and impacts to include or exclude from the analysis. The complexity can lead to different results and interpretations based on the choices made (Pelletier et al., 2015). Moreover, the limited availability of data on social impacts of co-products can also lead to difficultly in assessing the social impact of co-products.

In comparison with UNEP S-LCA guideline 2020, ISO 14040/44 recommends that LCI is carried out by collecting the input data of energy, raw material, products, co-products, emissions and other environmental aspects for each unit processes, within the system boundary. The S-LCA focuses on the social aspects of stakeholders such as labour condition, human rights, fair wage, etc. In LCA, the activity variable, reference scale approach and stakeholder data are not used.

5.4 Social Life Cycle Impact Assessment

Summary of main outcomes on Gaps and Needs regarding Social Life Cycle Impact Assessment

- Ordinal scales lack standardized interval scale, an absolute zero point, and do not allow for quantitative measurement, posing limitations in accurately quantifying and comparing social impacts.
- There is a need to develop reference scales into a ratio scale method to enable meaningful comparison, standardized measurements, and statistical flexibility in evaluating and interpreting social impacts.
- The complexity in comprehensive data availability and under-developed cause-effect chain for most subcategories in Impact Pathway (IP) S-LCA leads to practitioners choosing Reference Scale approach (RS) S-LCA.
- Lack of standardization for the development of impact pathways and challenges in assigning numerical values to qualitative social data hinder the comparability and effectiveness of S-LCA studies.
- The mechanistic modelling approach for single unit health or well-being indicators lacks representation of the severity of worst-case scenarios for human well-being, while RS S-LCA provides better representation of the state.
- The upcoming S-LCA guidelines or studies can focus on further developing standardization of impact pathways and the characterization model for impact assessments to improve comparability of S-LCA studies.

According to UNEP S-LCA guideline 2020, reference scales are ordinal scales comprised of 1 to 5 levels, each level corresponds to a Performance reference point (PRP). The PRPs are different levels of social risks or social performances, allowing to determine the magnitude and significance of potential social impacts associated with organizations in the product system. The reference scales can be ascending-from negative to positive performance or descending-very low risk to very high risk of potential negative impacts. These reference scales help to develop a list of performance indicators (PIs) for each of the scale levels, by assigning inventory data against reference scales. The use of ordinal scales for the reference scales in RS S-LCA has its own potential limitations for instance, lack of standardized interval scale (the difference between each level in the scale cannot be measured in a standard way), no absolute zero point (if an automobile company has completely prohibited child labour, it can be assigned to zero reference scale level, but the other levels of that scale will be based on the relative scores of previous levels which can be only compared relatively with each other) and non-quantitative measurement (it is not possible to take the ratio between the values of two levels).

In LCA, the characterization model is used to convert the inventory data (based on functional unit) into potential impact by multiplication of characterization factor, but when evaluating the social life cycle inventory (quantitative or qualitative data), a scoring system with reference scales and PRP is used to determine the social risk or performance of the product system. Therefore, the impact assessment results with scoring system cannot be directly related to the inventory analysis based on functional unit, as in LCA (Hosseinijou et al., 2014).

In LCA the reference scale approach is not followed, as in S-LCA. There is a need for the development of reference scales into ratio scale method because of several advantages such as meaningful comparison between various social impacts by quantification, provides absolute values of reference scales, equal intervals of reference scale enables consistent and standardized measurements of social impacts, statistical flexibility in evaluating and interpreting the social impact, helpful in tracking the changes in social performance and identifying area of improvement.

Given the complexity in comprehensive data availability and under-developed cause effect chain for most of the subcategories in IP S-LCA, most of the S-LCA practitioners tend to choose the RS S-LCA. The development of impact pathways in the IP S-LCA may involve subjective judgments and interpretations, which can introduce variability and subjectivity into the assessment process. This concern can affect the reliability and consistency of the results, potentially limiting the robustness of the S-LCA study (Benoit Norris, 2020; Soltanpour et al., 2019). Moreover, lack of standardization for the development of impact pathways, leading to variations in the application of the IP S-LCA approach across different assessments can hinder the comparability of the S-LCA studies. When quantifying the social impacts along the impact pathways, there are challenges in assigning the numerical values to the qualitative social data. This limitation may make it more difficult to accurately quantify and evaluate social impacts, which potentially affects the effectiveness of the study (Soltanpour et al., 2019).

In mechanistic modelling approach for calculation of single unit health or well-being indicators, the characterization factor should be based on process level of that organization. At present, the result of social impacts at broader level can be derived from the existing characterization model (DALY-/QALY) used for LCA but if regional characterization factors should be applied, LCA models may have limitations. Moreover, the mechanistic approach in IP S-LCA fails to represent the severity of the worst-case scenario for the well-being of human, but RS S-LCA has better representation of the state (UNEP, 2020).

In comparison with UNEP S-LCA guideline 2020, ISO 14040/44, impact pathway approach is used for assessing potential environmental impacts, but in S-LCA, the impact pathway is used for assessing the potential social impact using the cause-effect chain. In the upcoming S-LCA guidelines or studies can focus on the further development of standardization of the impact pathways, characterization model for the impact assessments to improve the comparability of S-LCA studies.

5.5 Interpretation Phase

Summary of main outcomes on Gaps and Needs regarding Interpretation

The interpretation phase plays a crucial role in engaging stakeholders in prioritizing and evaluating social aspects. However, some pitfalls are identified, this section reports the following:

- The interpretation should help understanding the complexity of the supply chain assessed. In particular, the social impacts should be interpreted in line with the diversity of perspectives of the engaged stakeholders and so consider the different cultural nuances;
- Interpretation should be a dynamic assessment and consider the context-specific nature of social impacts;
- The interpretation phase suffers from a lack of standardization and methodological consistency that could lead to inconsistencies between studies treating with a similar value chain;
- Tools and methodologies to conduct sensitivity assessment in S-LCA are lacking;
- Critical review guidelines are lacking for S-LCA.

The final phase of an S-LCA is Social Life Cycle Interpretation, in which all preceding phases are examined. For extracting insights, information and data may be pooled and/or split down at the level of life cycle phases, impact categories, impact subcategories, stakeholder categories, and process levels.

S-LCA Interpretation involves making sense of complex social data, which can be subjective and influenced by value judgments. The automobile sector involves a wide range of stakeholders, including manufacturers, suppliers, consumers, communities, and regulatory bodies. It is crucial to engage these stakeholders to capture diverse perspectives on social impacts and ensure a comprehensive understanding during the interpretation phase. The automotive industry has a complex and globalized supply chain. The interpretation phase needs to address the social impacts associated with the entire life cycle, from raw material extraction to end-of-life disposal. Understanding the complexities of the supply chain is essential for a thorough interpretation. Different stakeholders may interpret the results differently based on their perspectives, values, and priorities since different stakeholders have different cultures and temporal aspects, thus each stakeholder may perceive results from previous phases of S-LCA differently. What is considered a positive impact in one cultural context may be viewed as negative in another. The interpretation must also be sensitive to these cultural nuances and the manifestation of social impacts over time. Some impacts may be immediate, while others may have long-term consequences that become apparent only after a certain period. Static analysis may not reflect changes in social dynamics, policies, or cultural attitudes. Recognizing and accounting for the context-specific nature of social impacts is crucial.

During the Completeness Check, there is a need for a comprehensive evaluation of all relevant social impacts throughout the life cycle of automobile products, including raw material extraction, production, distribution, use phase, and end-of-life considerations. Methodological consistency and standardization in S-LCA studies are lacking, leading to inconsistencies and contradictions in the assessment process. This highlights the need for standardized approaches and guidelines to ensure consistency across different S-LCA studies in the automotive sector. Conducting sensitivity analysis to understand the impact of different assumptions and input parameters on the results of S-LCA, particularly in the context of the automotive industry where complex supply chains and diverse social impacts are involved. While there are many tools and methods available to support conducting a sensitivity check for E-LCA studies, there aren't many available to conduct a sensitivity check for S-LCA. In fact, most of the time, the tools and methods designed for E-LCA are also used for S-LCA sensitivity checks. Similarly, there are currently no critical review rules specifically for S-LCA; therefore, as more S-LCA experience is gained, guidelines for critical review that are tailored to the S-LCA should be created.

Not considering the interpretation phase in S-LCA for the automobile sector can have several implications (Gompf et al., 2022; Karlewski et al., 2019). Without considering the interpretation phase, there is a risk of having an incomplete understanding of the social impacts associated with the automobile sector. This can lead to overlooking important social aspects and indicators, potentially resulting in inadequate mitigation strategies and decision-making. So, it is important to carry out the interpretation phase. The interpretation phase plays a crucial role in involving stakeholders from the automotive industry in prioritizing and evaluating social aspects. Not considering this phase may lead to a lack of stakeholder engagement, which is essential for obtaining a comprehensive understanding of the social impacts of the industry. The interpretation phase is essential for the further development of impact assessment methods to comprehensively evaluate the social impacts of the automobile industry. These implications underscore the importance of considering the interpretation phase in S-LCA for the automobile sector.

5.6 Key Insights from Social Responsibility and S-LCA Interviews

Legal requirements, regulations, and soft laws related to social responsibility and supply chain are the primary drivers motivating companies to engage in social responsibility initiatives, with mention of the supply chain act. The primary challenges concerning social responsibility pertain to transparency in life cycle issues, as obtaining necessary information and data from the supply chain and value chain proves to be a difficult task. Companies in the automotive industry face substantial challenges when sourcing raw materials, particularly in countries with low social standards. Specific concerns relate to critical raw materials from China and human rights issues associated with materials like cobalt.

The harmonization of social impact sub-categories and indicators, the establishment of a uniform calculation method, and the creation of a standardized database are noted as major challenges when implementing the S-LCA method. In all the three interviewed companies the responsibility for addressing social topics related to the supply chain lies with the purchasing department. Noteworthy quotes from the interviews emphasize the need for tools that reduce administrative burdens and help with supplier selection, including systems that provide social information about suppliers. There are concerns that overly stringent systems and standards might drive production out of Europe. Additionally, respondents express the need to handle social issues in a manner similar to environmental issues, with the ability to assess and rate the social impact. The development in this area is expected to be driven by laws and customer requirements, although the implementation of S-LCA is seen as costly and time-consuming.

6. Final discussion, conclusions and perspectives

This report stands for Deliverable 1.2 of the TranSensus LCA project. It delivers the analysis of needs and gaps for the development of a harmonised LCA/S-LCA approach in the electromobility sector, in the context of the TranSensus LCA project. It started from the review of current practices on life cycle approaches along the electromobility value chain as reported in TranSensus LCA Deliverable 1.1. It moreover built on outcomes from the following activities, as specifically developed in Task 1.2 in the year 2023:

- Three workshops organized by Task 1.2, which gathered between 10-20 TranSensus LCA WP1/WP2 participants per session;
- A review of product environmental LCAs, complemented by a review of product S-LCAs;
- A survey, followed by targeted interviews;
- A review of position papers.

This final Deliverable 1.2 was eventually obtained in an iterative approach. Two intermediary draft documents were developed essentially by Task 1.2 partners and further circulated to, and open to feedbacks by, all WP1 and WP2 partners during Task 1.2 realization. This report accordingly benefited from hundreds of amendments as suggested by numerous TranSensus LCA consortium members, before reaching this final, consensual, version.

The main needs and gaps identified in Task 1.2 are synthesized in the following sections, respectively focusing on needs (section 6.1), gaps in Environmental LCA (section 6.2) and gaps in Social LCA (section 6.3). This synthesis is to be seen as a first consensus on the key issues the TranSensus LCA method shall enable to address and overcome.

6.1 Conclusion on needs for the TranSensus LCA method

This study enabled to identify, discuss and define the key needs the TranSensus LCA method shall seek to cover. It simultaneously provided a level of prioritization regarding these needs, as support to the development of the TranSensus LCA method in downstream WPs of the TranSensus LCA project.

As top priority, the TranSensus LCA method, and the resulting studies building on this method, shall be:

- Understandable, i. e. providing clear scope and results to audience (including limitations);
- Standardized, i. e. being one clear, unique, TranSensus LCA method;
- Accurate, i. e. providing indicators close to the actual (true) value of the environmental and social performance of the systems analysed;

- Auditable, i. e. with credible verification process (or audits) overcoming the challenge of confidentiality;
- Accepted by the scientific community and industrials;
- Reliable and trustworthy, i. e. the audience shall have confidence in how far the outcomes of a TranSensus LCA-compliant study correctly represent the environmental and social impacts of a product.

Of importance but sill of lower priority, the TranSensus LCA method shall be:

- Aligned with (i) current EU legislations (e. g. Battery Regulation, certification requirements, air pollutant emissions standards, green H2 additionality requirements, etc.) ; (ii) currently accepted LCA guidelines and standards; (iii) international developments (e. g. UNECE work). However in this case misalignment is considered possible whenever this is agreed to add value to the TranSensus LCA method;
- Simple, i. e. implementable easily, including easy verification/audit. However this shall be true as far as simplifications do not prevent the method to be Accurate, Auditable, Reliable and Trustworthy.
- Transparent, i. e. all the methodological choices, assumptions and data quality assessment shall clearly be stated (in the study report, or in the TranSensus LCA method). However a good balance shall be found between "confidence in and confidentiality of" data.

6.2 Conclusion on gaps in E-LCA

This study enabled to identify, discuss and define the key gaps in Environmental LCA that the TranSensus LCA method shall enable to overcome. These key gaps pertain to the four steps of a LCA. In each case of "gaps", this study additionally discussed prescriptions for the development of the TranSensus LCA method, i. e. reporting some aspects that the TranSensus LCA method shall accordingly include or cover. Task 1.2 moreover enabled to reach a hierarchy in the priority to be given to overcome the identified gaps. Only the gaps and associated prescriptions with high priority are reported in the following conclusions. Other gaps have been identified in Task 1.2, though with level of priority from low to medium. These gaps are also extensively discussed in the previous sections of this report, and not recalled here.

Goal and Scope definition

Regarding the setting of the functional unit, Task 1.2 identified the lack of a common, harmonized way to account for real-world product performance. This in particular implies the need to define clear rules for setting the lifetime kilometres of vehicles, and for accounting for the interaction of parts (e. g. batteries) with the overall vehicle system.

Regarding the setting of the system boundaries, Task 1.2 identified the lack of clear, detailed and agreed rules on inclusion/exclusion of elements from the system boundaries. This current gap on a clear setting of the system boundaries in particular implies that the TranSensus LCA method shall accordingly, for example, provide clear rules on the inclusion/exclusion of (but not limited to): water and gas cleaning/treatments, real fate of waste and output streams, infrastructures (e. g. charging cables and stations), maintenance, etc.

Life Cycle Inventory

In a context where “there is no 'correct' way of solving the multi-functionality problem, even not in theory" (Guinée et al., 2004), there needs an unambiguous, reliable, and commonly agreed approach to address this issue, for both the foreground and background systems. This particularly pertains to raw materials co-production, process lines, parallel use of electric vehicles (e. g. V2G), waste treatment including recycling and battery second life, etc. The resolution of multi-functionality issues shall be linked to the Goal and Scope.

Moreover regarding primary (supplier-specific) data, clear rules are needed on their mandatory use as opposed to secondary data. This implies that the TranSensus LCA method shall include robust and prescriptive guidelines for: i) data collection (including templates and convention for terminologies), and ii) hierarchy, traceability down to lower-tier suppliers, and verification. For example for the use phase of the lifecycle, it shall be clear how far “real-world" energy consumption data shall be used versus data from regulatory cycles. Guidance on the mandatory use of primary data in the TranSensus LCA method shall come along with ensuring good balance between "confidence in and confidentiality of" data.

Moreover there shall also be clear guidance and rules on secondary LCI databases to ensure consistency with primary data. In particular guidelines for system boundaries, solving multi-functionality, etc. shall be consistent between foreground (primary) and background (secondary) datasets. The TranSensus LCA guidance shall also prescribe consistent modelling of all the used secondary datasets.

Furthermore the use of proxies (in terms of "values" and "datasets") is classically not limited or guided by generally-agreed rules. This implies that clear guidance on proxies, either with default values/datasets, or conditions for the development and check of proxies, shall be given in the TranSensus LCA method.

Finally two steps of the lifecycles in the electromobiliy sector have been more specifically discussed with what regards prescriptions on modelling in the TranSensus LCA method. Firstly there is a lack of harmonized and commonly agreed approach to model electricity and hydrogen consumption (in production phase, vehicle use, and EoL). Accordingly the TranSensus LCA method shall develop prescriptive guidance on these aspects, in particular regarding electricity modelling: i) carefully addressing any risk of double counting, and ii) ensuring the time coherence condition is aligned with country legislation (month or annual). Secondly there is still need for harmonization regarding the end-of-life modelling. The CFF of the PEF was intensively discussed and not commonly agreed. The CFF is considered by several partners as too complex and uncertain, e. g. for what regards credits evaluation, prospective aspects, etc. In TranSensus LCA it shall be decided whether to start from the CFF or not, and whether to include battery second life and EoL in other countries, other than in a sensitivity analysis. If starting from the CFF, then the TranSensus LCA shall provide clearer prescriptions on its implementation regarding credits evaluation and prospective recycling processes.

Impact assessment

There misses a unique, standardized, set of impact categories and associated impact assessment methods, agreed to be relevant and robust (and applied). The level of comprehensiveness of such a still-missing method shall be addressed in WP2. It may be set as either extensively comprehensive (e. g. including circularity, biodiversity, criticality and dissipation of mineral resources, etc.); or as a more restrained list. Regarding these impact assessment methods, diverse levels of recommendations ("mandatory"/"optional") shall be considered in WP2. Eventually only relevant, reliable and accepted methods shall be selected.

Moreover specific gaps have been identified for what regards mineral resource indicators. In this case potential alternative impact assessment methods must be evaluated, potentially considering diverse impact pathways (e. g. resources dissipation). Other indicators like cumulative energy demand (CED) and circularity indicators that have high policy relevance shall also be considered in downstream TranSensus LCA WPs for potential integration in the TranSensus LCA method.

Finally there still misses one single guidance on whether to implement normalization and weighting, or not. If recommended, normalization and weighting need to be commonly agreed; while the TranSensus LCA method would be non-ISO compliant.

Interpretation

It is observed that there still sometimes remains relatively large uncertainties in terms of completeness of the system modelling (parts), accuracy and geographical representativeness. However this is still not always properly reflected in results and interpretation. Accordingly there needs a harmonized guidance to support quality assessment, data sharing along the supply chain, and communication. Whether this may take the form of the Data Quality Rating as per the PEF method, or other approaches, shall be discussed and decided in WP2.

Moreover there is still lack of consistency in the definition and use of sensitivities and scenarios. This implies that clear guidance shall be provided on the definition of sensitivity analysis, uncertainty analysis and scenarios.

Finally, there is still a lack of commonly agreed guidelines for a credible data quality verification and audit process - leading to poor confidence in the shared data. The TranSensus LCA method shall therefore provide clear, unambiguous, guidelines for a credible verification process (or audits) overcoming the challenge of confidentiality while ensuring transparency. More generally, the TranSensus LCA method shall include a common framework and content for reporting.

6.3 Conclusion on gaps in S-LCA

This study allows identifying the gaps in the S-LCA methodology that prevents its application in a consistent manner. These gaps were identified through a literature review with the perspective of the automotive sector. In order for the TranSensus LCA S-LCA methodology to be applied in a consistent manner, these gaps should be addressed in the subsequent steps of the TranSensus LCA project. As a complement to the concluding description of gaps, in the following sub-sections, it is noteworthy that in most cases there should be expected to be consistency where at all possible (and particularly, in the goal and scope) in E-LCA and S-LCA studies.

Goal and scope

In many of the assessed studies, the recommendations of the UNEP-SETAC guidelines were not fully followed regarding the goal and scope phase which indicates a lack of understanding around the guidelines. In particular, regarding the goal of the study, better guidelines should be developed regarding the definition of the target audience, how the study will help with decision-making and what will be the potential opportunities associated to the study. Regarding the definition of the product system, clear recommendations on the inclusion/exclusion criteria are lacking. In S-LCA, the functional unit should consider both physical and effect perspectives and so technical and social aspects; recommendations on how to address the latter are today not taken into account. Finally, the main activity variable today use in S-LCA is "worker-hour" that could be inconsistent with other stakeholders categories: a standardize method to develop and select activity variable based on stakeholders should be developed.

Social Life cycle inventory

Generally, to ease the primary data collection, specific data collection sheets are today missing from the general guidelines. Apart for collecting exchanges between unit processes, primary data can also be collected to quantify activity variables. To be representative, the activity variables should be quantified at the subcategory or at the stakeholder level; this level of granulometry is today missing especially for complex supply chains. Lastly regarding activity variables, way to quantify them should be developed while ensuring data confidentiality for company specific data. Primary data collection is also linked to the treatment of multi-functionality: the availability of social data specific to co-products is today not sufficient leading to mistreatment of multi-functionality. Regarding secondary data, due to their construction, data in S-LCA databases might be outdated and with a limited granularity and so inadequate to conduct hotspots assessment. There is today a lack of data representative of a specific regional area or a specific value chain. Furthermore, the expression of social risks in USD in S-LCA databases might lead to possible misrepresentations as this USD unit might fluctuate for various reasons and fail considering some specific social aspects.

The S-LCI step in S-LCA depends on the type of social impact methodology chosen to conduct the assessment (reference scale approach or impact pathway method). In the case of the reference scale approach, there is a need to standardize the quantification of performance indicators.

Social life cycle impact assessment

The impact pathway method is today not developed enough to be robust and implemented in S-LCA software. There is a call for further standardization of impact pathways and associated characterization models. This standardization will help enhance the comparability of S-LCA as well as their effectiveness.

The complexity of the approach and the under-development of cause-effect chain leads S-LCA practitioner to choose rather the reference scale approach to conduct impact assessment. In this approach, impacts are measured according to an ordinal scale with no absolute zero point; that does not allow performing quantitative measurements of social impacts, limiting the comparison between these impacts.

Interpretation

Overall, the interpretation phase suffers from a lack of standardization in the methods and tools to use. It is the case for example for the methods and tools to use to conduct sensitivity assessment or to conduct a critical review. The interpretation phase plays a crucial role in engaging stakeholders in prioritizing and evaluating social aspects. It should so help understanding the complexity of the supply chain assessed and the diversity of stakeholders perspectives. Better recommendations to consider different cultural nuances in this phase should be given.

6.4 Perspectives towards a European-wide harmonised transport-specific LCA approach

Activities in Task 1.2 have been tailored to support other TranSensus LCA WPs, and in particular WP2, towards the ultimate objective of the TranSensus LCA project to develop a European-wide harmonised transport-specific LCA approach. The key findings from Task 1.2, in terms of the needs the TranSensus LCA method shall seek to cover, and the gaps in Environmental and Social LCA in the electromobility sector that it shall overcome, are reported and summarized in this Deliverable. This study also developed a hierarchy in the needs and gaps, in order to support the downstream WPs in selecting priority issues to be tackled in their respective work.

Task 1.2 has been developed in an iterative and collaborative approach. Outcomes from Task 1.2 have been continuously discussed with WP1 and WP2 partners all along the realization of Task 1.2, through multiple activities. Task 1.2 partners have engaged early in the project with WP2 in order to support the latter's work on the conceptualization of the TranSensus LCA approach. In particular, three workshops have been open to WP1 and WP2 key partners. These workshops included several sessions of break-out group discussions organized with a view to facilitating a common vision and understanding of the key needs and gaps the TranSensus LCA method shall seek to cover and overcome. Moreover several draft versions of this Deliverable 1.2 have been shared with and open to consultation by WP1 and WP2 partners along Task 1.2 realization. Task 1.2 therefore aimed to support the developments in WP2 early in the project. It also benefited from the expertise of WP2 partners, and from the work realized in WP2 in terms of identifying limits in current existing approaches in LCA and S-LCA.

This consensus on the needs and gaps in Environmental and Social LCA in the electromobility sector now paves the way to the key objective of the TranSensus LCA project, that is the development of a European-wide harmonised transport-specific LCA approach aimed at in WP2 and subsequent TranSensus LCA WPs.

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