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Chapter 9
Interpretation of LCA Results and EPD Comparability

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Abstract The chapter aims to facilitate the interpretation of Life Cycle Assessment (LCA) results and improve the comparability of Environmental Product Declarations (EPDs). This chapter provides guidance on analysing LCA data, grasping fundamental impact categories, and conducting data quality assessments during EPD development. By offering clear methodologies and criteria for assessment, it facilitates the simultaneous comparison of multiple EPDs or individual comparisons, thereby supporting more informed decision-making in the construction industry.

1 Environmental Product Declarations (EPD) Information

The results published in an EPD for any product is a selected sample from a larger and more extensive LCA report usually referred to as the background report which is not publicly available. The purpose of the background report is to convey information associated with conducting the LCA with all assumptions clearly stated, complete LCI results, data records used for modelling, and the allocation of the impact to different products or product groups, among more. Additional analysis is also included in the background report such as contribution and sensitivity analysis. This should enable a certified verifier to verify that the process and results are executed according to the prescribed standards and that the results are plausible.

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1.1 EPD Impact Categories

EPD documentation includes essential information that the readers of the EPD requires, for example, information on the definition of system boundaries, which modules are included in the study, definitions of different scenarios, which functional unit is declared, the data quality, and which allocation method is applied. The most valuable information from the EPD is the quantified results of the different impact categories, resource use, waste, and external flows (see Tables 1, 2, 3 and 4 for the included categories and parameters).

Table 1 Core impact categories that need to be declared according to PCR in EN 15804:A2 (2021)

Impact category	Unit
Global warming potential total, GWP—total	kg CO_2 eq
Global warming potential fossil, GWP—fossil	kg CO_2 eq
Global warming potential biogenic, GWP—biogenic	kg CO_2 eq
Global warming potential land use and land use change, GWP—LULUC	kg CO_2 eq
Depletion potential of the stratospheric ozone layer, ODP	kg CFC-11 eq
Acidification potential, Accumulated Exceedance, AP	Mol H^+ eq
Eutrophication potential, fraction of nutrients reaching freshwater end compartment	kg $(PO_4)^{3-}$ eq
Eutrophication potential, fraction of nutrients reaching freshwater end compartment	kg N eq
Eutrophication potential, Accumulated Exceedance, EP-terrestrial	mol N eq
Formation potential of tropospheric ozone, POCP	kg NMVOC eq
Abiotic depletion potential for non-fossil resources, ADP- minerals & metals	kg Sb eq
Abiotic depletion potential for fossil resources, ADP-fossil fuels	MJ, net calorific value
Water (user) deprivation potential, deprivation weighted water consumption, WDP	m^3 world eq. deprived

* IPCC—Intergovernmental Panel on Climate Change

Table 2 Additional impact categories addressing the dust, toxicity and impact on soil according to PCR in EN 15804:A2 (2021)

Impact categories	Unit
Potential incidence of disease due to PM emissions, PM	Disease incidence
Potential human exposure efficiency relative to U235, IRP	kBq U235 eq
Potential comparative toxic unit for ecosystems, ETP-fw	CTUe
Potential comparative toxic unit for humans (cancer effects), HTP-c	CTUh
Potential comparative toxic unit for humans (non-cancer effects, HTP-nc	CTUh
Potential soil quality index, SQP	na

Table 3 Resource use parameters addressing the use of primary and secondary resources according to PCR in EN 15804:A2 (2021)

Parameter	Unit
Use of renewable primary energy excluding renewable primary energy resources used as raw materials, PERE	MJ, net calorific value
Use of renewable primary energy resources used as raw materials, PERM	MJ, net calorific value
Total use of renewable primary energy resources, PERT	MJ, net calorific value
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials, PENRE	MJ, net calorific value
Use of non-renewable primary energy resources used as raw material, PENRM	MJ, net calorific value
Total use of non-renewable primary energy resources, PENRT	MJ, net calorific value
Use of secondary material, SM	kg
Use of renewable secondary fuels, RSF	MJ, net calorific value
Use of non-renewable secondary fuels, NRSF	MJ, net calorific value
Net use of fresh water, FW	m3

Table 4 Categories addressing waste and other external flows according to PCR in EN 15804:A2 (2021)

Parameter	Unit
Hazardous waste disposed, HWD	kg
Non-hazardous waste disposed, NHWD	kg
Radioactive waste disposed, RWD	kg
Components for re-use, CRU	Kg
Materials for recycling, MFR	Kg
Material for energy recovery, MER	Kg
Exported electrical energy, EEE	MJ
Exported thermal energy, EET	MJ

Note All EPD results are relative and are only comparable to the same impact category for a similar product applying the same PCR or c-PCR with similar assumptions. The flexibility of the EPD frameworks allows for different assumption based on product/production specific information, different system boundaries, and the use of different databases for the quantification

The following sections emphasize crucial aspects necessary for interpreting EPD information, enabling meaningful comparisons between different EPDs within the same product category.

1.2 Understanding Core Impact Categories

As stated in the PCR of EN 15804:A2 (2021), there are 13 core impact categories that shall be declared in an EPD. It is important to understand what these categories mean and what they measure. Table 5 gives an overview of the core impact categories.

The EPD framework also outlines six additional impact categories which are not discussed in Table 5. This omission is because these categories are optional for disclosure in an EPD as per EN15804:A2 (2021) due to their high uncertainty. Similarly, the categories within resource consumption and waste reported in Tables 3 and 4 respectively, are not elaborated further as they rely directly on the Life Cycle Inventory (LCI) data.

2 Data Quality Assessment

Data quality assessment is an important step in developing the EPDs. This information is also essential for the reader of the EPD to assess the validity of the results. The assessment of data quality is based on the following:

- **Geographical representativeness** : LCA results are sensitive to the geographical representativeness of the data records used while modelling the different processes. For example, consider a hypothetical production process occurring in China that requires data referring to electricity use to calculate the impact. It's necessary that the data record used to model the electricity use accurately reflect the conditions specific to China, for example, the proportions of energy production sources (solar, wind, coal powerplant etc.), otherwise, there is a risk of overestimating or underestimating the environmental impacts.
- **Temporal representativeness:** The data records used for modelling the different processes shall not be older than 5 years in case of processes manufacturing of the product under assessment. In the instances where generic data is used, then the data records shall not be older than 10 years. Refer to Table E.1 in the appendix of EN 15804:A2 (2021) standard for further clarifications.
- **Technological representativeness** : The methods used for modelling the foreground processes shall be representative of the actual manufacturing process for the product and it should represent the state-of-the-art manufacturing process that exists at the manufacturing facility.

Refer to Table E.1 in the appendix of EN 15804:A2 (2021) standard that describes the data quality assessment scheme used to assess generic and specific data records in the LCA study. The assessment scheme is a direct extract from EN15804:A2 (2021) and should be used for EPDs on construction products.

Table 5 Brief overview of core impact categories (the definitions are drawn from sources such as EN 15804:A2 (2021) and EPD-Belgium)

Impact category	Description
Global warming potential total, GWP—total	Global Warming Potential total (GWP-total) which is the sum of GWP-fossil, GWP-biogenic, and GWP-luluc.
Global warming potential fossil, GWP—fossil	The global warming potential related to greenhouse gas (GHG) emissions that originate from the fossil fuels by means of their transformation (e.g. combustion, digestion, etc.).
Global warming potential biogenic, GWP—biogenic	The global warming potential related to carbon emissions to air (CO_2, CO and CH_4) originating from the oxidation and/or reduction of aboveground biomass through transformation or degradation (e.g., combustion, digestion, composting, landfilling) and CO_2 uptake from the atmosphere through photosynthesis during biomass growth—i.e. corresponding to the carbon content of products, biofuels, or above ground plant residues such as litter and dead wood.
Global warming potential land use and land use change, GWP—LULUC	The global warming potential related to carbon uptakes and emissions (CO_2, CO and CH_4) originating from changes in carbon stock caused by land use and land use change. This sub-category includes biogenic carbon exchanges from deforestation, road construction or other soil activities (including soil carbon emissions).
Depletion potential of the stratospheric ozone layer, ODP	Measures the impact on stratospheric ozone layer caused by the breakdown of certain chlorine and/or bromine-containing compounds (chlorofluorocarbons or halons). These compounds break down and catalytically destroy ozone molecules.
Acidification potential, accumulated exceedance, AP	Measure the impact of acid depositions on the environment. The main sources for emissions such as SO_2, NOx, and NH_3 are agriculture and fossil fuel combustion.
Eutrophication potential, fraction of nutrients reaching freshwater end compartment, EP-freshwater	The potential to cause over-fertilization of freshwater as a result of increased growth of algae in fresh water and the following impacts.
Eutrophication potential, fraction of nutrients reaching freshwater end compartment	The potential to cause over-fertilization of marine water, which can result in increased growth of biomass.

(continued)

Table 5 (continued)

Impact category	Description
	This is focused on waterborne and airborne nitrogen emissions.
Eutrophication potential, accumulated Exceedance, EP-terrestrial	The potential to cause over-fertilization of soil, which can result in increased growth of biomass and following impacts.
Formation potential of tropospheric ozone, POCP	The potential to create ground-level ozone which is harmful to organisms. This is caused by chemical reactions brought about by the light energy of the sun creating photochemical smog.
Abiotic depletion potential for non-fossil resources, ADP- minerals & metals*	Consumption of non-renewable resources, their availability for future generations.
Abiotic depletion potential for fossil resources, ADP-fossil fuels*	Measure for the depletion of fossil fuels such as oil, natural gas, and coal. The stock of the fossil fuels is formed by the total amount of fossil fuels.
Water (user) deprivation potential, deprivation weighted water consumption, WDP*	Accounts for water use related to the local scarcity of water as freshwater is a scarce resource in some regions, while in others it is not.

*The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator

Besides considering the geographical, technical, and temporal representation, it is important to systematically address aspects of precision, completeness, representativeness, consistency, and reproducibility to ensure the validity of EPD results. Precision demands the data reflects the environmental impacts with minimal variability, whereas completeness involves covering all environmental flows from resource extraction to End-of-Life (EoL) (Note: This can vary depending on the system boundary). Representativeness ensures the data aligns closely with the actual conditions of the product's lifecycle, including geographical location, technology used, and relevant time frames. Consistency across the study guarantees that methodologies are applied uniformly, facilitating reliable comparisons between different products. Reproducibility emphasizes the importance of documenting the assessment process comprehensively, so independent practitioners can replicate the results. Moreover, specifying all sources of data is crucial, whether originating from datasets, models, or assumptions and expressing the uncertainty of information clearly, acknowledging any potential variability or assumptions made during the assessment. These elements collectively define the data quality.

3 EPD Programme Operators

The initial step in creating an EPD is to select an appropriate EPD program operator which are often regional. Several EPD program operators exist today whose purpose is to oversee the verification and publication of EPDs. At present, there are at least 18 EPD program operators that are in operation [7]. Table 7 provides an overview of a few common EPD program operators in Europe.

Rules and guidelines from different EPD programme operators are not completely harmonized. Occasionally, EPD program operators such as IBU supplement the core PCRs defined in EN 15804:A2 (2021) with c-PCRs, also called Part B PCRs. A Part B PCR provides additional rules and guidelines for a specific group of products

Table 7 List of EPD program operators

EPD Operator	Description
EPD International [2]	EPD International oversees the global EPD system with the headquarters located in Sweden, providing a framework for the development and verification of EPDs across various industries and regions worldwide. Their standards ensure consistency and comparability of EPDs on a global scale. The program operates in accordance with ISO 14025, ISO 14040, ISO 14044, and EN 15804:A2 (2021). The International EPD System has a global service network with exclusive representations in countries such as Argentina, Australia, Bangladesh, Brazil, Chile, Egypt, India, Mexico, New Zealand, Russia, Southeast Asia (Indonesia, Malaysia, the Philippines, Singapore and Vietnam) and Turkey.
IBU (Institut bauen und umwelt e.V.) [3]	IBU is a German EPD program operator primarily focused on construction and building materials. They provide EPD services for various construction products in compliance with European standards such as EN 15084:A2. (2021).
EPD-Norway [1]	EPD-Norge is the Norwegian EPD program operator responsible for managing EPDs in Norway. The program allows the publication of EPDs which accordance with ISO 14025, ISO 21930, and EN 15804:A2(2021) on their platform.
EPD Denmark [4]	EPD Danmark serves as the operator of the Danish EPD program, tasked with managing Environmental Product Declarations (EPDs) in Denmark. Their responsibilities include overseeing the verification and publication of EPDs for construction products in compliance with ISO 14025 and EN 15804:A2 (2021).
EPD Ireland [5]	EPD Ireland is an EPD program operator focusing on Ireland. They manage the EPD process for various products and sectors within the Irish market, ensuring compliance with relevant standards and guidelines.
EPD Belgium [6]	EPD Belgium is an EPD program operator focusing on the Belgian market. The main aim of the Belgian EPD program is to support sustainable construction and procurement practices in the Belgian market. B-EPD issues EPDs for construction products that comply with ISO 14025 and EN 15804:A2 (2021).

like specific construction materials. The program operators can issue these Part B PCRs independently which has led to inconsistencies while developing EPDs for the same product [7, 8]. In addition, there are some differences due to different stakeholders being involved in setting these rules and guidelines on a product level. These can be methodological differences such as cut-off rules, modelling approaches, or allocation rules. Although EN 15804:A2 (2021) has been successful to a certain extent in harmonizing the EPDs of the same product category, a study by Gelowitz and McArthur [8] finds that 3–12% of the EPDs are incomparable even while following the same PCR, and 73–87% of the EPDs for the same product category following different PCRs are incomparable.

However, there are some mutual recognition agreements in place. The EPD operators in Sweden, Denmark, and Norway have an agreement on mutual recognition of EPDs, including the PCR and c-PCR they operate under. This implies that owners of EPDs, namely manufacturers, will gain significantly different visibility and access to a broader market. Concurrently, it will simplify the process for consultants, contractors, and others involved in calculating the climate impact of buildings to obtain data on the building products employed in their construction projects.

4 Comparability of EPDs

When comparing EPDs there is an option to compare multiple EPDs at the same time or comparing one-on-one. In most cases, one-on-one comparison occurs. Comparing multiple EPDs at once is labour intensive as compiling information from multiple EPDs for statistical analysis is still a very manual process. This will hopefully improve as digital EPDs become more readily available. It can, however, be highly beneficial for the creator of an EPD to get information on how they stack up to the rest of the industry. Comparing an individual EPD to another is more common for customers receiving the EPDs in business-to-business communication and deciding on a better option based on multiple criteria.

Statistical Analysis

Benchmarking[1] product impacts from EPDs is a challenging task for multiple reasons, as discussed in the previous section. There are several factors influencing the comparability of different EPDs. These are, for example, based on the selection of the Programme Operator, the PCR or c-PCR, data used for the quantification, involved databases, and how the data collection has been performed, to name a few. On top of sources of uncertainty from the EPD process, there is also an uncertainty in the benchmarking as well: how well do the available EPDs represent the overall market?

[1] Benchmarking is a systematic approach for comparing business process and performance metrics to the industry performance distribution.

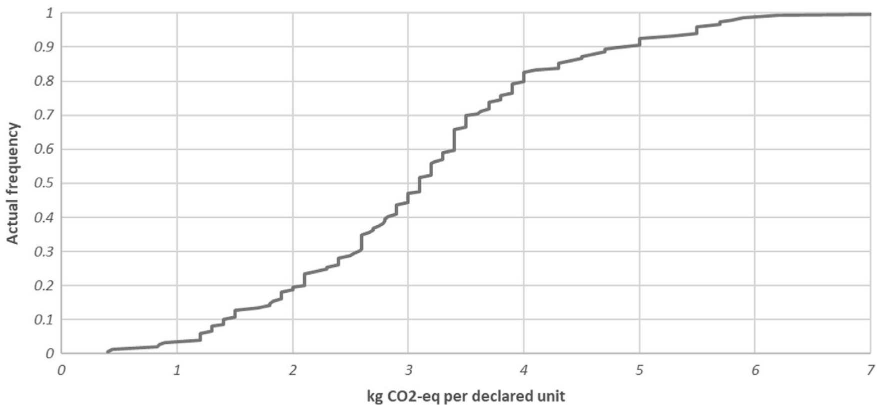

Fig. 1 Cumulative distribution for GWP contribution for aggregates

The number of EPDs is continuously increasing and for some products, there are enough for statistical analysis. For example, for aggregates in Sweden, there are EPDs for 148 product groups from 28 quarries. This enables us to get a representative distribution curve of the impacts. Figure 1 illustrates the cumulative distribution of GWP of aggregates in Sweden. The number of similar construction products containing nanoparticles are still too low to perform similar benchmarking to the industry distribution, as can be done for aggregates. With the introduction of digital EPDs though, the compilation of information could be automated and kept up to date for even smaller product sample sizes.

The shape of the distribution curve in Fig. 1 is close to a normal distribution curve, and other products follow a similar pattern with a narrow and steep inclination centrally. In these cases, the mean and median values are of a similar value. However, the distribution curve is not always normally distributed. If there is a significant difference in the mean and median, the distribution can be skewed or even bimodular, especially if you are evaluating multiple impact categories. The mean and median of the distribution of GWP for aggregates in Sweden is 3.13 kg CO2 eq. per tonne and 3.1 kg CO2 eq. per tonne respectively. This indicates a close to normally distributed sample. With the collected product EPD results from multiple EPDS at hand, producers could compare their performance with the overall industry performance. If aggregate producers have a product that has GWP impact of 2 kg CO2 eq. per tonne then they would be able to assess that they were outperforming 80% of the industry's product groups. The same approach could be done on all impact categories to evaluate the overall impact of the product. This can help individual manufacturers determine if major improvements could be achieved in their production process from the perspective of its environmental performance, and encourage competition for more environmentally friendly manufacturing processes. For an additional example on the impact distributions, see the Welling and Ryding study on insulation material [9].

Comparative Analysis

While comparing the results for different impact categories in EPDs for the same product from different manufacturers, it is essential to understand the differences in methodological choices, databases used, cut-off criteria, allocation methods and the assumptions in the LCA framework. This is because these aspects will influence the overall results of an LCA study. The following section provides a brief description of how the differences in different methodological choices and databases used for the LCA study will influence the results.

- Differences in Functional or Declared Unit

An EPD for a construction product can be published by using either a functional (FU) or declared unit (DU) (Part 4, Chap. 8, Sect. 2.2 for further information). Although the LCA standards, ISO14040 and ISO14044, specify that a FU should be used while conducting an LCA, the core PCR in EN15804:A2 (2021) allows for the use of a DU in the place of a FU. For example, a DU can be 1 kg of paint without reference to the function it performs. A DU is recommended to be used when a product has multiple functions, or the function is unknown. Using a DU usually results in the exclusion of the use phase (module B1-B7) from the study. Choosing DU or FU while conducting an LCA study influences the system boundary definition, along with the input process that is included in the study. Therefore, a comprehensive understanding of both the DU and FU is imperative while comparing the EPDs of a construction product under the same product category.

- Differences in System Boundary

As described in earlier chapters, defining a system boundary is dependent on the goal of an LCA study. In the context of an EPD, the inclusion or exclusion of a life cycle module from the assessment depends on the scope, the choice between FU or DU, and the availability of data. The core PCR allows for publishing EPDs with different system boundaries (Refer to the system boundary section in Part 4, Chap. 8, Sect. 2.2). Consequently, EPDs for a construction product under the same product category manufactured by different manufacturers can only be compared across the same system boundary. The reason is that the system boundary defines the unit processes to be included in the assessment. This influences the LCA results reported in the EPD. For example, consider the EPDs for a steel structure manufactured by two different manufacturers located in the same area. The EPD from the first manufacturer covers the product phase (A1-A3) and the EoL phase (C1-C4), and the EPD of the second manufacturer covers all life cycle phases (A1-A3, A4, A5, B1-B7, C1-C4). In this case, these EPDs cannot be directly compared due to the differences in system boundary.

- Differences in Databases

EPDs for construction products can be created using data from different databases. Using manufacturer-specific data is important while developing an EPD though. To develop an LCA, manufacturer-specific data (i.e., Foreground data) is collected, which can then be modelled by using data records from different databases such as Ecoinvent, GaBi, Ökobaudat, and others to provide information on the environmental impact. Taking electricity as an example, the data record used for the modelling of the electricity should be representative of the national electricity production where the product is manufactured. In the context of EPDs, this can vary depending on the EPD program operators. For instance, in order to model electricity consumption during the manufacturing of a certain construction product in LCA, the GPI of different program operators, for example IBU and international EPD system, allow for the use of both Ecoinvent and GaBi, however, in the case of EPD Norway, Ecoinvent should be used. Using different databases to assess the same product can lead to differences in the results. The difference in results can depend on several factors such as the version of the database and quality of the data record.

In addition to differences in FU or DU units, system boundaries, and databases used in an LCA study to develop an EPD, there are other factors influencing the comparability of the product. These include allocation methods, assumptions regarding transportation, and more. One more aspect that could specifically be influenced by the integration of nanoparticles into the product is the Reference Service Life (RSL) since in most application the purpose of integrating nanoparticles is to improve the product longevity. However, this should not be included in the EPD according to c-PCR-017 *Technical-chemical products (for construction sector)*. Therefore, when interpreting and comparing EPDs for the same product from different manufacturers, it's crucial to consider all these aforementioned factors and be aware of the GPI, PCR and c-PCR involved. This comprehensive approach ensures a more accurate and meaningful comparison of environmental impacts between products, facilitating informed decision-making.

5 Sensitivity Analysis in LCA

In LCA studies, sensitivity analysis explores possible future scenarios based on manufacturer-specific assumptions. A sensitivity analysis can be used to assess the sensitivity of the LCA results. The scenarios described in this section provide insight into multiple ways of conducting a sensitivity analysis in an LCA study. The scenario is often chosen to provide insights to the manufacturer about the possible future. Hence the sensitivity analysis described under this section is directed towards the manufacturer of the product.

Sensitivity analysis can be performed in multiple ways, for example:

1. Sensitivity analysis based on the quantity of the input raw material and quality of the data record used for modelling.
2. Sensitivity analysis based on the transportation to the installation site.
3. Sensitivity analysis based on EoL treatment.
4. Sensitivity analysis based on the allocation method.
5. Sensitivity analysis based on changes in process configuration.

Table 8 Comparison of different scenarios covering A1-A3

Core impact categories	Baseline (total for A1-A3 per DU for a product)	Scenario—increase in significant input by X %	Scenario—using lower quality data
GWP-total	–	–	–
GWP-fossil	–	–	–
GWP-biogenic	–	–	–
GWP-LULUC	–	–	–
GWP-GHG	–	–	–
ODP	–	–	–
AP	–	–	–
EP-freshwater	–	–	–

The following section provides a brief description of the first three examples. Steel as a product will be used as an example to illustrate the different possibilities for sensitivity analysis.

Note: Within the EPD framework the scenarios are usually described in detail in the LCA background report. Only a brief description and the results of these scenarios is later reported in the EPD, if at all, depending on the scope of the EPD.

Sensitivity Analysis Based on Raw Material Quantity

Let's consider a manufacturing process to produce structural steel components. For such a process, raw material such as iron ore, ferrosilicon, ferromanganese, ferrochromium, and ferrovanadium are required in different quantities to manufacture a certain quality of steel. In a baseline[2] assessment, the LCA model is developed from real data from the manufacturer to assess the environmental impact of the steel structure. To explore a possible scenario where the quantity of one of the raw materials needs to be increased by "X %" to manufacture a different quality of steel, a sensitivity analysis can be conducted. The influence of such change can be modelled in LCA to assess its influence on the environmental impact of the product by increasing the material flow of the raw material for "X %" in a hypothetical model. This scenario can be expanded to include the influence of data quality on the LCA results. For example, a lower-quality data record can be used to calculate LCA results and compare them with the results from the baseline assessment.

Table 8 is an example of how such results from a sensitivity analysis covering modules A1—A3 could be presented.

Sensitivity Analysis Based on the Transportation to Manufacturing Site

In industries like steel manufacturing, transport distance plays a significant role in the overall assessment. Take, for instance, the shift towards circularity in steel production, where 'green iron' is now being utilized. This transition is motivated by

[2] Baseline refer to the LCA model for the actual manufacturing process NOT the scenario.

Table 9 Comparison of different scenarios covering transportation

Core impact categories	Scenario 1—baseline results per DU for steel using conventional iron with a default distance of 100km	Scenario 2—baseline results per DU for steel using green iron with a default distance of 100 km	Scenario 3—baseline results per DU for steel using green iron with a distance of 2000 km
GWP-total	–	–	–
GWP-fossil	–	–	–
GWP-biogenic	–	–	–
GWP-LULUC	–	–	–
GWP-GHG	–	–	–
ODP	–	–	–
AP	–	–	–
EP-freshwater	–	–	–

Note An EoL route need not be one or the other. Depending on the type and complexity of a product, an EoL treatment route can be a combination of reuse and recycling. In the case of steel, a hybrid EoL route can be that a portion of steel scrap is subjected to reuse and the remainder is recycled

its lower environmental impact compared with steel manufactured using traditional processes, as it removes fossil fuels from the manufacturing process, replacing it with green hydrogen [10].

Here is where the transport distance and transport mode play a pivotal role. Hence conducting a sensitivity analysis is necessary to effectively compare the two manufacturing routes—one utilizing conventional iron and the other relying on green iron. In the case of green iron, the distance between the steel manufacturer and the green iron producer could be much larger and if the transport distance is significant, it could potentially offset the environmental benefits gained from avoiding conventional iron. Hence conducting a sensitivity analysis could be beneficial to understand the trade-offs.

Table 9 shows an example of how scenarios encompassing the influence of changes in transport distance and change in the mode of transportation[3] could be presented. This scenario can be expanded to include the influence of changes in transportation mode on the LCA results.

Sensitivity Analysis Based on EoL Treatment

By examining various scenarios, such as different disposal methods or recycling options, one can better understand the environmental impacts of products throughout their entire life cycle.

Considering a steel product as an example within the cradle-to-grave system boundary of LCA, it becomes essential to include the EoL treatment stage when the steel product reaches its End of Waste (EoW) state. For instance, the steel product

[3] Mode of transportation refers to the different transportation modes such as truck, train, ship etc.

Table 10 Example for presenting the sensitivity analysis for EoL treatment

Core impact categories	Results for C1-C4 per DU for a product			
	Scenario—reuse	Scenario—recycle	Scenario—combined reuse and recycling	Scenario—landfilling
GWP-total	–	–	–	–
GWP-fossil	–	–	–	–
GWP-biogenic	–	–	–	–
GWP-LULUC	–	–	–	–
GWP-GHG	–	–	–	–
ODP	–	–	–	–
AP	–	–	–	–
EP-freshwater	–	–	–	–

at its EoL can either be reused without additional treatment if it meets quality standards, or it can undergo treatment as scrap steel and enter a recycling process. In such cases conducting thorough sensitivity analyses can be beneficial. By exploring various EoL treatment routes, such as reuse, recycling, or disposal, a manufacturer can gain insights into how each option affects the steel product's environmental profile throughout its life cycle.

In conclusion, a sensitivity analysis can encompass the whole life cycle of a product or just a portion of it. It mainly depends on the goal and scope of the LCA study and also the availability of data to conduct a robust scenario analysis. For producers of construction material that could potentially incorporate nanoparticles, they could evaluate the performance per DU of including nanoparticles in their products, evaluate different quantities, look at different suppliers or set up different scenarios based on EoL associated with different strategies.

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