SCORELCA

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LCA of projects and infrastructures

Summary

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RDC environment

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SCORE LCA is an association that has been created to financially support collaborative research on LCA and related topics. It aims to promote and organize cooperation between companies, institutional and scientists in order to support the evolution of LCA methods and its practical implementation at European and international level.

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- The views and recommendations expressed in this publication are those of the authors and do not necessarily reflect, unless otherwise stated, the views of all members of SCORE LCA.

- The information and conclusions presented in this document were established on the basis of scientific and technical data and regulatory and normative framework in force at the date of the publication of documents.

SUMMARY

The aim of this study is to take stock of existing methodologies and databases, studies and tools that can be used for infrastructure LCA, and to draw up recommendations for their use in support of design decisions or in order to assess this type of project, and the provision of reference data.

KEY WORDS

LCA, Infrastructures, Industrial building, transport infrastructure, Capital goods

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1 Context and goals

1.1 Context

The issue of infrastructure in LCA has been the subject of few dedicated studies. Some LCAs omit them on the grounds that they have little impact on a product's overall balance sheet. Others, such as databases, take them into account in a simplified manner.

LCA for residential buildings has developed significantly. One of the main reasons for this development is the large surface area that these buildings represent. Residential buildings (excluding tertiary buildings) account for 24.5 million square metres of new construction, while industrial and storage buildings account for 8.8 million square metres of new construction (Fédération Française du Bâtiment, 2024) . A second cause of this development is public policy issues (national low-carbon strategy, decarbonisation of certain sectors, including cement). In this sector, the carbon footprint of construction accounts for one third of the carbon footprint (the rest being linked to the operation of buildings).

In addition, LCAs of building construction products have become widely available due to the creation of Environmental Product Declarations (EPDs). National databases have been set up to record EPDs, such as the INIES database in France and the IBU.data database in Germany.

Certain materials represent considerable challenges on a global scale, such as cement, which accounts for 13.5 million tonnes of CO_2-eq in 2021 in France, or approximately 2% of France's carbon footprint. Cement linked to the construction sector is responsible for 4% of global emissions[1] .

Taking infrastructures into account in Life Cycle Assessment (LCA) remains a complex and little-explored subject. However, various methodologies have emphasised the importance of taking into account the impact of buildings and infrastructure, such as the GHG Protocol method and the Méthode pour la réalisation des Bilans d'Emissions de Gaz à Effet de Serre (BEGES) (ADEME, 2022) for calculating sub-category "4*.2 Fixed assets*".

Thus, although LCA is a widely used tool for construction products and residential buildings, it remains relatively little used for industrial and transport facilities. This is due to methodological and practical issues.

- When conducting an LCA of a good or service, in which cases should infrastructure be taken into account and in which cases should it be excluded?
- If it is included, in what cases is more detailed modelling than generic environmental data (e.g. ecoinvent) necessary?
- Is it sufficient to add up the impacts reported in the EPDs of the elements that make up the building?
- What should be done if, for certain elements, the EPDs only cover part of the life cycle, or if there are no EPDs at all?
- What is the relevant level of detail depending on the objective of the LCA?
- From whom should the data be collected?
- How can data be collected efficiently?

[1] https://www.ipcc.ch/report/ar6/wg3/chapter/chapter-9/

1.2 Goals

The study conducted by SCORE LCA aims to provide a state-of-the-art overview of the methodologies, databases and tools available, while offering specific recommendations for the application of LCA to infrastructure (industrial, transport, etc.). The main objective is to establish methodological guidance for conducting LCAs applied to infrastructure in order to effectively support decision-making and provide reliable reference data.

2 What is infrastructure?

The concept of infrastructure is central to Life Cycle Assessment (LCA) as applied to industrial and transport projects. There is no clear consensus or single definition for this term in the main methodological standards (ISO 14040, ISO 14044, PEF, GHG Protocol, etc.). This lack of precision leads to difficulties in interpretation and disparities in analyses.

Analysis of existing definitions

The analysis revealed significant differences. While the concept of "building" generally emphasises the function of shelter and permanence, "infrastructure" is often described as a complex set of equipment, facilities and services that are essential to an organisation. There is frequent confusion between "capital assets" and "infrastructure", with the former often encompassing the latter as well as other elements such as production equipment and maintenance.

Proposed definition

In response to these observations, an operational definition of infrastructure is proposed:

Infrastructure is a set of fixed assets (CAPEX) related to the service provided by that infrastructure, as well as the elements that enable its maintenance (which may be included in OPEX) and operation (consumption and associated emissions for building-related systems).

OPEX or operating expenditure are the current costs of operating a product, business or system.
CAPEX or capital expenditure refers to fixed assets, i.e. expenditure that has a positive long-term value.

3 State of the art

3.1 Inclusion of infrastructure in LCA of product/service

The question of whether or not to include infrastructure in product or service life cycle assessments (LCA) is a matter of debate. Inclusion varies greatly depending on the methodological, regulatory or normative frameworks applied, but also on the sectors concerned and the environmental indicators studied.

A thorough review of the main key LCA **standards** (ISO 14040-44, ISO 14025, ISO 14072, ISO 14069, PEF-OEF, GHG Protocol, French environmental labelling, BEGES NF EN 50 693, PAS 2050, various EPD programmes) **highlights a wide disparity in recommendations regarding the inclusion of infrastructure.** Product and organisational standards were studied.

All possible configurations are found:

- Mandatory inclusion;
- Possible inclusion;
- Conditional exclusion;
- Mandatory exclusion;
- No guidance.

In general, standards requiring the exclusion of infrastructure allow for its inclusion with justification.

In the literature, analysis of infrastructure contributions to LCA results shows that they can be significant for certain sectors and certain impact categories:

- Sectors with a high impact: renewable energies (wind, photovoltaic) and wastewater treatment;
- Particularly sensitive impact categories: depletion of mineral and metal resources, land use, human toxicity.

Academic work (Frischknecht, 2007; Tokede, 2023) reveals that the relative impact of infrastructure is generally underestimated or poorly represented in generic databases, leading to significant assessment biases.

The authors of this study recommend systematic consideration (using a conservative approach, i.e. maximising impacts) in the first iteration of calculations. After assessing their influence on the results and if their impact is significant, the infrastructure will be refined in a second iteration. If such refinement is not possible despite their significant impact, the infrastructure may be excluded, highlighting this limitation in the study's conclusions.

The NF EN 15978 standards and the RE 2020 regulations were investigated in particular.

The NF EN 15978 standard specifies key elements to be taken into account when conducting LCA for buildings, in particular the functional unit, the boundaries of the system, and the phases to be considered (construction, use, end of life). Similarly, the French environmental regulation RE2020 proposes a rigorous methodology and explicitly defines the physical and temporal boundaries to be considered. It provides useful elements for structuring the selection of environmental data to be used, which could be extrapolated to industrial and transport infrastructure.

3.2 Infrastructure datasets available in ecoinvent

The ecoinvent database offers a large number of infrastructure-specific inventories, classified by sector (energy, transport, materials, etc.). More specifically, 533 infrastructure datasets have been identified, divided into four main categories:

- Materials (175 datasets);
- Energy (154 datasets);
- Transport (137 datasets);
- Processing (67 datasets).

These inventories cover the main phases of the infrastructure life cycle: extraction and processing of raw materials, transport, construction and maintenance, and end-of-life management.

In-depth analysis reveals several major limitations of these infrastructure inventories:

- Age: most inventories date from before 2010, leading to a high risk of obsolescence and significant discrepancies with current practices.
- Uncertainty and lack of precision: many of the inventories include explicit warnings about the high degree of uncertainty in the results obtained. These inventories are often based on generic estimates that are not representative of specific realities.
- Structural flaws: many inventories rely directly or indirectly on a few fundamental generic data sets ("building, hall, steel construction", "building, hall, wood construction" or "building, multi-storey"), severely limiting their adaptability to specific cases and their actual representativeness.
- Approximate composition: some inventories do not accurately reflect actual compositions (e.g. erroneous presence or absence of certain materials such as copper in metal structures).

Methodological recommendations

In light of these findings, the study makes the following recommendations for practitioners:

- In product and service LCAs where infrastructure is not central,
  - Use ecoinvent infrastructure inventories as is, provided that their contribution to total impacts remains low.
  - When the contribution is significant **(>5-10% on at least one indicator relevant to the study**), clearly identify and document the uncertainties associated with these inventories to ensure the transparency and robustness of the LCA results.
- Where possible, prefer more recent data specific to the case studies when infrastructure represents a significant item.

These recommendations aim to improve the reliability of environmental assessments by limiting the methodological risks associated with the use of generic infrastructure data.

4 Issues identified for conducting LCA of infrastructure

The issues presented in this section are based on:

- Literature review;
- RDC Environnement's LCA expertise;
- Working meetings with Artelia (industrial facilities engineering expertise);
- Case studies (conducted in partnership with Artelia);
- Discussions within the steering committee with SCORE LCA members.

4.1 Issues associated with the "Goal and scope" stage

Quantitatively estimating the service(s) delivered

Estimating the services delivered by an infrastructure involves quantifying the value it brings throughout its lifetime. This requires calculating depreciation based on the actual or projected use of the infrastructure, which may vary depending on time and operating conditions. For example, a road used intensively for freight transport will have a different contribution to analyse than a rural road with little traffic. In addition, the multifunctionality of certain capital goods must be taken into account: a factory may produce various types of goods during its life cycle, or a building may have multiple uses (offices, storage space, etc.). These complex elements require flexible valuation methods that are adapted to each context.

Defining the boundaries of the system

Defining the boundaries of the system in an LCA is crucial to ensuring a consistent analysis and enabling comparability. This involves determining which stages of the life cycle are included (construction, operation, maintenance, end of life) and identifying the components of the infrastructure. For example, for a building, this includes not only the walls and roofs, but also the internal equipment (machinery), as well as related elements such as access roads and car parks.

Characterising the system under study

Each type of structure has its own technical specifications, terminology and specific requirements, which makes it essential to collaborate with experts from different fields, such as a civil engineer or a road or rail infrastructure specialist. The LCA practitioner conducting the analysis must immerse themselves in the context of the project to fully understand its specificities, working with engineers, architects or experts to ensure an accurate representation/modelling of the system.

One modelling challenge for LCA practitioners is to fully understand the specifications provided. The vocabulary used in building and construction is particularly detailed for each construction trade and can differ from one sector to another. Furthermore, the vocabulary used in the different phases of a construction project is not standardised. LCA practitioners should therefore ensure that they have correctly understood and modelled the installations and have their assumptions and models confirmed, particularly for the parts that make a major contribution.

Take into account local geographical and climatic specificities

The environmental impacts of infrastructure can depend heavily on its geographical location. Climate influences the durability of materials (e.g. freeze-thaw cycles affect roads), soil type can influence foundation techniques, and local hydrology plays a crucial role in water management and drainage. LCA practitioners' recommendations should incorporate these specificities and go beyond generic recommendations for facilities. Infrastructure located in protected natural areas also requires special attention to limit disruption to surrounding ecosystems.

4.2 Issues associated with the inventory phase

Time-consuming nature of the inventory phase for a complex system

Infrastructure construction involves many different construction trades, materials and equipment. Given the large number of components in an infrastructure and the dissemination of information among project stakeholders, the inventory phase of an infrastructure LCA is often very time-consuming. Data collection requires exchanges with multiple specialists (architects, structural engineers, electricians, etc.), thorough verification of sources and, in some cases, assumptions about missing data. This poses a real organisational challenge.

For example, the construction of a bridge involves civil engineers, concrete specialists and steel suppliers, involving a variety of materials and processes. Establishing a model that includes all the relevant elements used and identifying the associated flows requires rigorous data collection (which involves numerous exchanges and confirmations).

Working with heterogeneous sources

The data required for LCA often comes from a variety of sources, such as contractors, project owners and suppliers, who use different formats, assumptions and methods. These disparities can lead to inconsistencies in the information collected (e.g., discrepancies in quantities or material specifications), requiring harmonisation work to ensure the reliability of the results.

LCA practitioners must therefore work closely with project management teams to structure the data, while using appropriate tools to integrate this information into a coherent environmental model. An example of data used by project management is presented below.

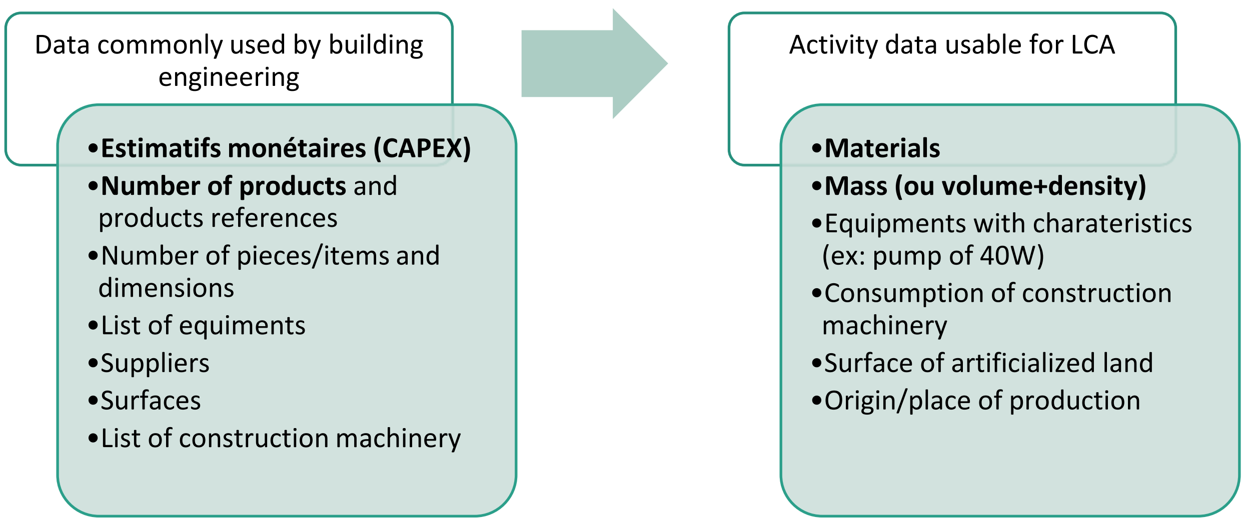


Figure 1 : Illustration of the need for "conversion" between the data used by building engineering and the data that can be used by LCA

Working with non-definitive data

At the start of a project, the information available is often incomplete and approximate, evolving as the project progresses. For example, building plans may change, leading to modifications in the materials or equipment planned. Depending on the objective of the study and whether or not it is carried out in iterations, the analyst must therefore manage provisional uncertainties by estimating the uncertainty associated with the data.

The data available by project definition class and their accuracy are presented below.

Table1: Extract from the AACE International Recommended Practice No. 18R-97

AACE class	ANSI classification	Common use	Project definition	Expected range of accuracy	
				Expected minimum actual cost	Expected maximum actual cost
Class 5	Order of magnitude	Strategic planning; concept review	0 to 2	-50 to -20%	+30 to +100%
Class 4		Feasibility study	1 to 15	-30 to -15%	+20 to +50%
Class 3	Budget	Budgeting	10 to 40	-20 to -10%	+10 to +30%
Class 2	Definitive	Tendering; project controls; change management	30 to 75	-15 to -5%	+5 to +20%
Class 1			65 to 100%	-10 to -3%	+3 to +15%

Working with missing activity data/strong assumptions

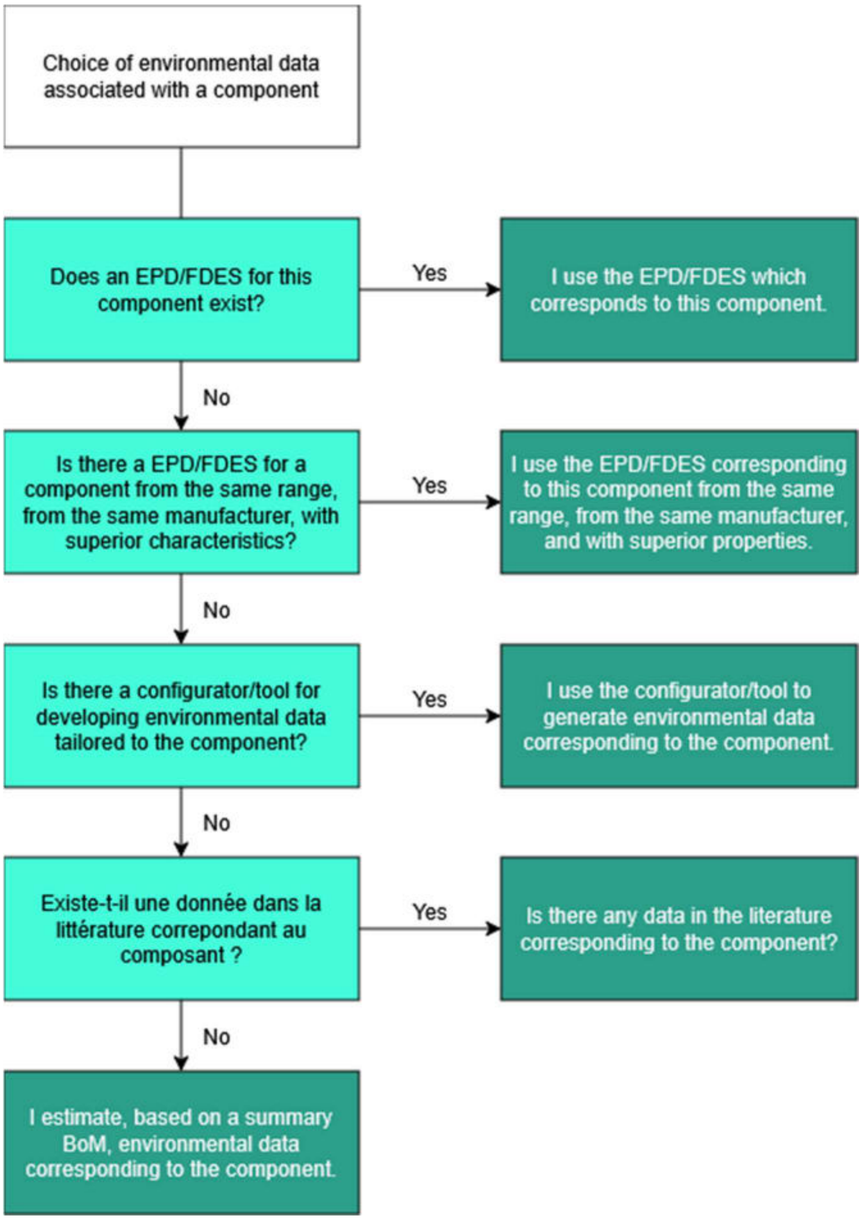
Some data needed for analysis may be missing, particularly for specific materials or equipment (multi-materials). In these cases, assumptions must be made to fill in the gaps, but these assumptions can have a significant impact on the results.

For example, an incorrect estimate of the lifespan of a material can greatly influence the calculation of environmental impacts.

Using incomplete, generic or inaccurate inventory data

The databases used in LCA do not cover certain specific characteristics of materials, equipment or construction methods. For example, the stages of steel processing (and in particular losses) are generally based on generic data available in LCA databases, but the actual data may differ substantially from the generic values. If the transformation activities are not negligible (with conservative modelling), it is advisable to try to refine the data or acknowledge substantial uncertainty on this point.

Procedure for searching inventory data (inspired by the INIES database procedure) for the LCA of residential buildings within the framework of RE2020



Characterising a system with a long service life

As infrastructure has a lifespan of between 20 and 100 years, some of its components will be replaced during its lifetime. It is necessary to establish different lifespans for different materials/equipment.

For example, road surfaces may require several cycles of repair, and electrical equipment may be replaced to incorporate newer technologies. The assessment should therefore take these temporal dynamics into account.

Identification of tools to facilitate modelling

The complexity of modelling entire infrastructures makes it desirable to develop or use appropriate tools. Some tools already exist, such as FDES configurators, the CIOGEN tool (Calculation of the Impacts of Civil Engineering Works, using the DIOGEN database) and BIM, particularly in application of ISO 22057. BIM (Building Information Modelling) is a working method that improves collaboration by using one or more digital models representing the structure in three dimensions (Fédération Française du Bâtiment, 2021) . BIM complements traditional 3D modelling with additional information (part/element references, materials, weight, delivery times, etc.). However, each of these tools has its shortcomings:

- EPD/FDES configurators only apply to certain well-defined elements;
- The CIOGEN tool only applies to SETRA (Services d'Etudes Techniques des Routes et Autoroutes) type bridges;
- The quality and accuracy of the BIM model depends on how it is used by those involved in the construction industry. It is often incomplete.

There is therefore still room for improvement or new tools.

It is important to include maintenance in the modelling because it can have significant impacts**,** depending on the structure and the technologies used.

- For a factory, the replacement of equipment will depend on its use and wear and tear.
- For a dam, operations related to sediment accumulation depend on the river and the systems implemented to prevent accumulation.
- For a road, maintenance will depend on wear and tear (which itself depends on usage/traffic/location), the type of asphalt, and also how the sub-bases were laid.

Modelling stages of the life cycle that will occur in the future, particularly the end of the infrastructure's life.

Modelling the end of life of infrastructure is complex, as it involves managing uncertainties about technological developments, demolition methods, waste management channels and recycling benefits (future materials are expected to be significantly less carbon-intensive). For example, infrastructure designed today could be dismantled at a time when recycling techniques are radically different, influencing the associated environmental impacts.

The SCORE LCA study on dynamic LCA (SCORE LCA No. 2023-02) addresses this issue in particular. In this study, the conventional LCA practice is detailed in order to highlight the discrepancies between it and reality: "*In conventional LCA, it is customary to bring end-of-life impacts back to time t_0. For buildings, the end of life generally occurs several decades after construction. Thus, for materials whose production stages are particularly significant (e.g. steel, concrete, etc.), allocating the benefits associated with recycling these materials to time t_0 of production counterbalances the adverse impacts associated with the production stages. Conversely, for bio-based materials (e.g. wood) whose end-of-life stages (usually incineration) have a significantly greater impact than the production stages (growth through CO2 storage), bringing the end-of-life impacts back to time t_0 ultimately results in comparable results between the two types of materials*.

4.3 Issues associated with the impact characterisation phase

Working with impact categories widely used in building LCA, taking regional issues into account

The work of the European Commission within the framework of the PEF (Product Environmental Footprint) and the publication of the update to standard EN 15804+A2 in 2019 tend to standardise LCA practices for the choice of impact categories. In order to enable practitioners to use published environmental data (DEP), it is necessary to use the same impact categories for infrastructure LCA.

The number of indicators available is sufficiently broad to allow the specific characteristics of a project to be taken into account and to focus the in-depth analysis on a smaller number of indicators that are considered relevant to the study. For example, for a building located in an arid area, the impact on fresh water may be more significant than other categories that are often prioritised in temperate zones.

Working with characterisation methods that evolve over time

The standards and guidelines governing LCA are constantly evolving, with the emergence of new methods for characterising impacts and the updating of existing factors. For example, the latest work by GLAM (Global Guidance for Life Cycle Impact Assessment Indicators and Methods) is changing resource depletion indicators and promoting the use of damage indicators (such as impacts on ecosystems/biodiversity). This makes it difficult to compare LCAs carried out at different times, as the data and methods used are often different.

4.4 Issues associated with interpreting results

Working iteratively to focus efforts on what is important for the desired conclusions

The iterative approach is essential in LCA, as it allows human resources to be concentrated on the aspects that most influence the results and conclusions. The preliminary analysis (first iteration) identifies the stages or materials with the greatest impact, so that they can be evaluated in greater depth in subsequent iterations. This avoids unnecessary overinvestment in marginal aspects and prevents major uncertainties from remaining, thereby increasing the relevance of the analysis.

Linking data quality to the relevance of identified hotspots

The quality of the data used in an LCA directly affects the reliability of the results obtained, particularly when identifying environmental hotspots (the elements with the highest impacts). Poor-quality or approximate data can distort the identification of these critical points, leading to truncated assessments.

Underestimated components in an LCA pose a major methodological problem, as they can go unnoticed and skew the final results. Conversely, overestimated elements are often easier to spot through cross-checking or comparisons with standard databases. For example, equipment whose impacts are absent or greatly minimised in the inventory could be overlooked, thereby distorting eco-design or impact mitigation priorities.

Interpreting the mineral and metal resource depletion indicator

This indicator is very important for infrastructure and therefore deserves special attention.

- Prioritise the use of the "Future Welfare Loss" method recommended by GLAM, to obtain results that are more in line with qualitative assessments and therefore easier to interpret.
- Correct inventories produced using a characterisation method different from that used in the study.
- Check the default allocations included in the databases, as some do not respect the mass balance (co-extraction) concerning the allocation of inputs. For example, in background data, the way in which emissions or resource consumption are distributed among several co-products or systems can significantly change the results. This requires increased transparency and vigilance to ensure that the indicator accurately reflects the reality of the system under study.

Achieving sufficient quality and accuracy when the objective of LCA is to eco-design infrastructure

When LCA is used as an eco-design tool, it is essential to have detailed and accurate data on the environmental impacts of the main materials, technologies and processes under consideration. If this is not done accurately, it can lead to the selection of solutions that are less than optimal from an environmental impact perspective. When eco-designing, it is also necessary to identify the influences of infrastructure elements on each other. For example, if a tank is chosen in a material that is heavier than the initial one but has a lower environmental impact, it will be necessary to quantify the environmental impacts associated with reinforcing the beams supporting the tank. Conversely, however, the heavier tank may have a longer service life or be easier to maintain.

5 Case studies

Three detailed case studies illustrate the practical application of the recommendations:

1. Chemical industrial facility;
2. Battery production plant;
3. Tramway line.

These cases illustrate the effective implementation of the methodological guidelines proposed in the report.

Eco-invent data is relevant in the first iteration and is generally sufficient for product LCAs, provided that the inventory is adapted to the situation under study.

However, the limitations of this generic data become problematic, even unacceptable, when moving on to more in-depth analyses. In addition, it introduces significant uncertainty into the mineral and metal resource use indicator (which is sensitive to the type of metals or alloys used).

Modelling with field data for iteration 2 (and 3 for the mineral and metal resource use indicator) significantly reduces uncertainty by better representing the diversity of infrastructure elements.

Iteration 2, which incorporates material quantities for heavy assemblies, and **iteration 3**, with refined modelling by element, show that the use of **specific field data** for heavy elements significantly improves accuracy.

The transition to iteration 3 shows smaller deviations on the climate change indicator, confirming that the transition to iteration 2 could be sufficient to meet the simple quantification objectives of a project.

Table2: Working time per iteration and effect on results for the three case studies

	CC (EF3.1)	ADP 2002 (EF3.1)	FWL (GLAM 3)	Additional time to move to the next iteration
Fine chemicals				
Iteration 1	100%	100%	100%	1 hour
Iteration 1.1 – Correction based on production	2	2	2	a few extra hours (total iteration 1: 0.5 days)
Iteration 1.2 – Surface correction	0.3	0.3	0.3	
Iteration 2	0.3	0.1	0.2	×10
Iteration 3	0.3	0.1	0.2	×2.5
Batteries				
Iteration 1	100%	100%	100%	1 hour
Iteration 1.1	22	22	22	a few extra hours (total iteration 1: 0.5 days)
Iteration 2	4	0.2	3	×13
Iteration 3	9	3	11	×2.3
Tram				
Iteration 1	100	100%	100%	1 hour
Iteration 1.1	123	223	161%	a few extra hours (total iteration 1: 0.5 days)
Iteration 2	493	464	405	×6
Iteration 3	628	477	499	×2

Even with data collection from a good source, there are still significant gaps in the data collection.

In the three case studies presented, the data collection has the following shortcomings:

- **Detailed technical characteristics of equipment and materials**: specific type of steel (this information is sometimes provided), exact class of cement (this information is sometimes provided), detailed composition of composite materials, recycled content, composition of multi-material systems;
- **Details on material implementation techniques**: actual energy consumption during the construction phases;
- Insufficiently integrated **estimates of on-site losses** and detailed logistics: transport, installation methods. If on-site losses can be taken into account, care must be taken not to double-count them. Either "material supply" data that already includes losses or "implementation" data that does not include losses can be used. If "material supply" data is used, losses should not be added as they are already taken into account.
- **Information on the actual maintenance and replacement conditions for equipment** throughout the infrastructure's lifetime. The CAPEX estimated by the project manager includes routine maintenance (e.g. minor maintenance required every 4 to 6 years for industrial process infrastructure). However, major maintenance is excluded from the estimated CAPEX (e.g. maintenance required every 20 to 30 years for industrial process infrastructure).

There is a major benefit to further developing infrastructure modelling when infrastructure is the subject of the LCA.

The case studies confirm the major benefit of a structured LCA approach to infrastructure modelling. They also clearly highlight that the reliability and usefulness of the results obtained depend on the quality and accuracy of the data used, as well as the relevance of the methodological framework adopted. These points are the priority areas to be integrated into future LCA approaches for infrastructure to make them truly useful for decision-making, eco-design and environmental optimisation of projects.

6 Recommendations

Recommendation 1: Adopt a progressive iterative approach

It is recommended to use a simplified first iteration with conservative impact assumptions (particularly via LCA databases) to identify high-impact items. The inventory data from the databases can be adapted using correction factors based on the most relevant parameter for the study (surface area, track length, annual production volume, etc.). This initial modelling serves as a basis for subsequent, more detailed iterations, incorporating specific and higher-quality data where necessary.

The second iteration will incorporate project-specific data for heavy assemblies (concrete, cement, steel, aluminium, machinery), and iteration 3 will focus on refining heavy elements such as material grade, origin, and quantity of recycled materials incorporated.

The iterative approach is presented in the figure at the end of this chapter.

Recommendation 2: A clear definition of the objectives and scope of the study makes it possible to calibrate the effort required for the LCA of projects and infrastructure

The functional unit must reflect the actual service provided by the infrastructure (transport, accommodation of activities, processing, etc.), incorporating parameters such as lifespan, intensity of use, location and expected performance.

Infrastructure provides services that must be quantified from the earliest stages of the study. This information is not detailed enough in databases, making it difficult to compare and reuse data later on.

The lifespan of the infrastructure is also key. This information is generally available in the documents provided to the project manager. In order not to neglect maintenance, the main impacts of which will occur when the infrastructure element is replaced, different lifespans for the main elements of the infrastructure may be established at the time of data collection.

Recommendation 3: Work with a multi-indicator approach, giving priority to the impact categories recommended by EN 15804+A2:2019, as well as the Future Welfare Loss indicator for resources

Many EPDs are published by manufacturers of building materials and equipment. In order to be able to use the environmental impacts of these elements, the study must employ the same methods.

Furthermore, the multi-indicator approach ensures that certain significant contributors that would not appear with the climate change indicator are not overlooked.

This is particularly true with the mineral and metal resource use indicator, which will be particularly sensitive to the use of non-ferrous metal resources that are rarely quantified in the first iterations of the calculation. The use of a second indicator (such as the Future Welfare Loss indicator published by GLAM 3[2] for case studies) also helps to reinforce (improve) the interpretation of this impact category, which is highly sensitive to certain modelling assumptions in the databases.

[2] https://www.lifecycleinitiative.org/activities/life-cycle-assessment-data-and-methods/global-guidance-for-life-cycle-impact-assessment-indicators-and-methods-glam/

Recommendation 4: Limit the use of database data to cases where its impact is marginal

Eco-invent infrastructure data, which is often outdated and lacking in detail, can only be used if the infrastructure represents a small proportion of the overall impact. This will therefore be the case in most product LCA studies.

Case studies on industrial infrastructure have shown that using default ecoinvent data results in an overestimation of impacts by 1 to 2 orders of magnitude (compared to the reality quantified in case studies with iterations 2 or 3). Adjusting ecoinvent data using a correction factor to obtain an infrastructure amortised over the same quantity of output products or the same surface area produces an overestimation of 0 to 1 order of magnitude.

This recommendation cannot be established for transport infrastructure based on the tram line case study, which shows a factor 5 underestimation of ecoinvent data compared to reality.

Recommendation 5: Structure data collection by project phase and collaborate closely with technical stakeholders

Data collection during an infrastructure LCA generally involves a wide variety of sources (CCTP, DQE, DOE, BIM models, etc.) and a multitude of stakeholders (project managers, project owners, suppliers).

The documents available (and therefore the granularity of the available data) depend on the stage of the project (preliminary design, detailed design, final design, construction, etc.).

Data collection will be facilitated by the establishment of a common data repository or a systematic correspondence table between the technical formats used by engineering teams (volumes, linear metres, etc.) and the formats required for the LCA (masses, type and grade of materials, recycled content, origin).

As an infrastructure can consist of a large number of small elements, it is necessary to go through a phase of grouping by categories and sub-categories in order to collect detailed data on a representative element of the sub-categorisation created.

Recommendation 6: Prioritise data collection efforts according to hotspots

As the inventory phase is time-consuming, efforts should be focused on the elements with the greatest environmental impact, using approximations or generic values for minor items or those common to several alternatives. The iterative approach must therefore be preceded by an analysis of hotspots and simple sensitivity analyses to validate whether additional data collection efforts will result in a real gain in accuracy in the final results.

Recommendation 7: Integrate eco-design of infrastructure from the earliest stages of the project

The eco-design of infrastructure is greatly facilitated during the very early stages of the project (planning, preliminary design, sketching), i.e. while there is maximum room for manoeuvre and the broad outlines have not yet been finalised.

Once the project has entered the preliminary design or detailed design phases, the ability to influence the design and therefore the environmental impacts is greatly reduced.

It is essential to adopt a holistic approach:

- Design choices must be evaluated at the system level (rather than element by element), as changing one parameter (e.g. a change in material) can have consequences for other elements (structure, maintenance, uses, overall cost, etc.).

- Decisions must therefore be made on coherent sets of technical options, rather than on specific changes.

The use of simplified modelling will therefore be necessary and should be reinforced by sensitivity analysis to identify whether eco-design choices could be called into question when more accurate data is obtained in later phases of the project.

Recommendation 8: Structure project data to facilitate LCA and reinforce the use of advanced digital tools (BIM)

Project managers should be encouraged to structure data from the design stage onwards according to LCA requirements (masses, types of materials, technical specifications), using DQE or standardised BIM exports, to avoid costly back-and-forth exchanges and limit assumptions.

It is necessary to develop interoperability between BIM models and existing LCA tools in order to improve the accuracy, speed and efficiency of assessments. Initially, BIM models could at least be used to quantify recurring/standardised equipment (foundations, piping, etc.), while specialised equipment would be quantified "by hand".

Ultimately, LCA could be directly integrated into building information modelling (BIM) tools, facilitating rapid updates of environmental impact results as the project evolves.

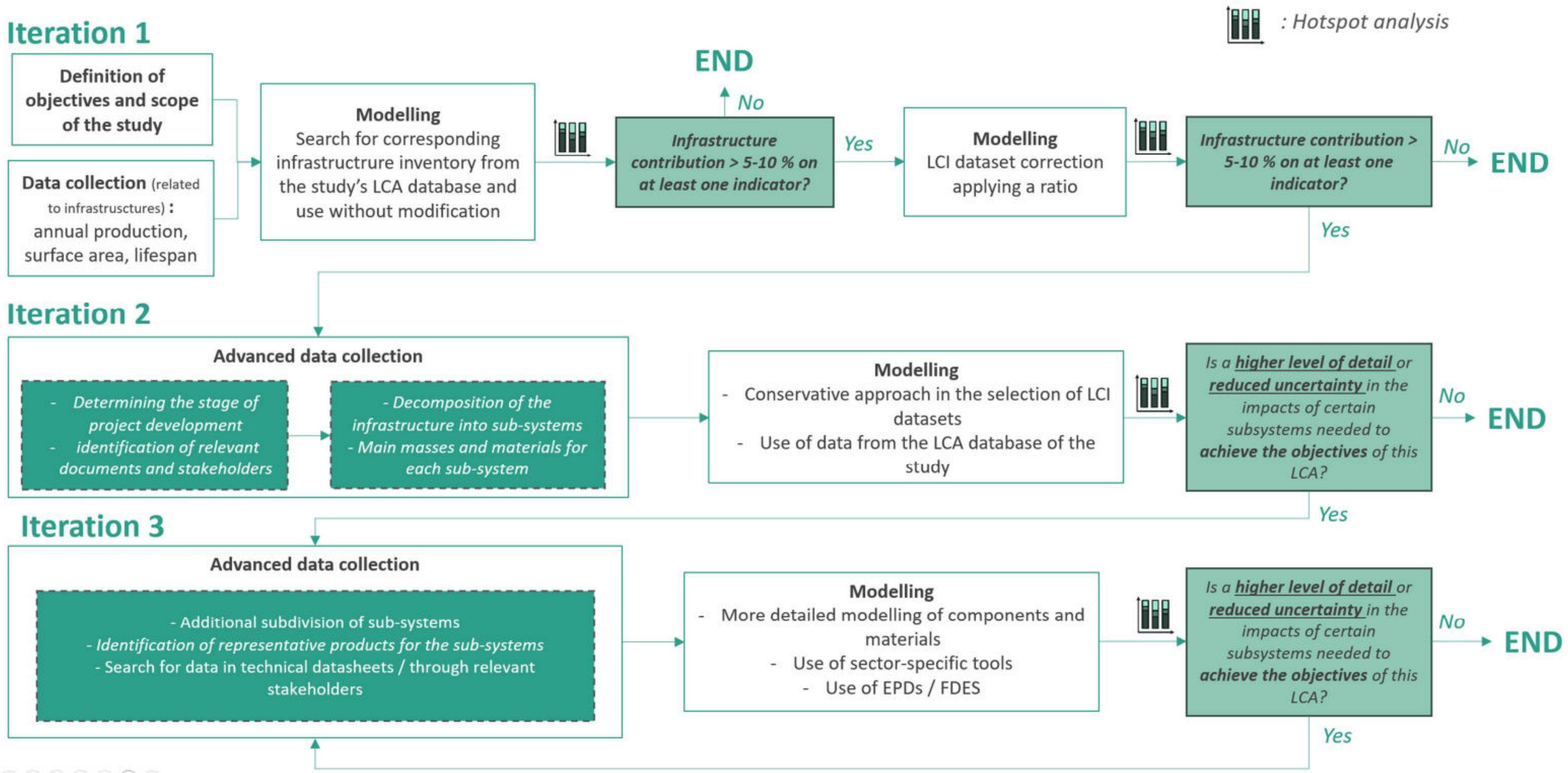


Figure1: The iterative approach to modelling infrastructure in LCA