Life Cycle Assessment of Buildings
-
A Future-proofed Solution in the Digitalised World of Tomorrow

The Use of LCA for Environmental Building Assessment: A Vision of the Future

White Paper

September 2017

Executive Summary

The challenges ahead for the building sector are huge. The potential contribution of the sector to the circular economy will require a transition of the sector over the coming years.

This transition will be built on transparent performance information of the construction works throughout the value chain. In regard to environmental performance, this information will cover a range of impacts such as global warming potential, acidification and resource depletion. The Life Cycle Assessment methodology is a holistic tool which makes it possible to make such an assessment while avoiding burden shifting.

Using Life Cycle Assessment at the building level is not new, but has until now been used only on a very small scale. Currently we see building rating schemes and national legislations integrating Life Cycle Assessment at the building level as a tool for better decision-making to improve the environmental performance of buildings.

Further upscaling of this approach could be implemented over the coming years, as increasing digitalisation of the construction sector will make it easier to make such assessments; particularly those that are data-intensive. The increasing uptake of these assessments will create the need (and the subsequent delivery) of reliable data.

For the market to integrate the full potential of Life Cycle Assessments at building level, it will be key to obtain a more rigorous harmonisation of methods and to train the many and varied stakeholders within the value chain in function of their required level of expertise.

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Lexicon

BIM	Building Information Modelling
BNB	*Bewertungssystem Nachhaltiges Bauen* (Building Assessment Scheme from the Ministry in Germany, *Bundesministerium fuer Umwelt, Naturschutz, Bau und Reaktorsicherheit*)
CDW	Construction and Demolition Waste
CPR-BWR7	Construction Products Regulation - Basic Works Requirement 7 (“Sustainable Use of Natural Resources”)
eLCA	Building LCA tool developed by the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (*Bundesinstituts für Bau-, Stadt- und Raumforschung* (BBSR))
EPD	Environmental Product Declaration
EU	European Union
GHG	Green House Gas
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory (dataset)
NMD	*Nationale Milieudatabase* (Dutch national environmental database)
PCR	Product Category Rule
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rule
SBK	*Stichting Bouwkwaliteit*
WFD	Waste Framework Directive

1 EURIMA'S MOTIVATION AND GOALS FOR DRAFTING THIS WHITE PAPER

In recent months, Eurima has observed an increasing interest in and implementation of the principle of Life Cycle Assessment (LCA) of buildings. A number of initiatives have been noticed; two of the most important are the Framework for Core Indicators, from the European Commission's DG Environment[1] and the test phase of *Bâtiments à Énergie Positive et Réduction Carbone*[2] (Buildings of Positive Energy and Carbon Reduction) implemented in France. Eurima welcomes these developments and is keen to contribute to the implementation of the principle of LCA of buildings by publishing this white paper. The objective of this document is to show that LCA is a future-proofed method in the digitalised world of tomorrow.

Many technical documents already exist that present how LCA of buildings can be implemented. The perspective of this document is slightly different. Its objectives are as follows:

- Chapter 2 addresses the challenges faced by the building sector in terms of environmental impact
- Chapter 3 describes the need for LCA to assess the environmental performance of buildings and reduce the environmental impact of the construction industry
- Chapter 4 suggests that an LCA approach should be implemented by stakeholders throughout the value chain, and indicates the steps to follow, and the data required
- Chapter 5 describes the use of LCA results, some implementations in EU Member States and building rating schemes, and the advantages and limitation of LCA of buildings
- Chapter 6 emphasises the need for an IT-based approach as a prerequisite for initiatives aiming to implement LCA on a day-to-day basis
- Chapter 7 explains how implementing this approach on a daily basis requires a large amount of data to be made available, and considers the cost implications
- Chapter 8 discusses the role of training and communication of LCA principles, and its potential integration in university curricula
- Chapter 9 concludes the white paper by addressing next steps for further implementation of LCA of buildings.

[1] http://susproc.jrc.ec.europa.eu/Efficient_Buildings/
[2] http://www.batiment-energiecarbone.fr/

2 CHALLENGES FACING THE BUILDING SECTOR

The building sector is one of the most resource-intensive sectors in the EU. It accounts for about half of all extracted materials and energy consumption in the EU, and about a third of water consumption. The sector also generates about one third of all waste and is associated with environmental pressures that arise at different stages of a building's life cycle including the manufacturing of construction products, building construction, use, renovation and the management of building waste[3].

In a study commissioned by DG ENV entitled "Assessment of Scenarios and Options towards a Resource Efficient Europe[4]", it is stated that, at EU level, the construction work sector is accountable for 9% of total GHG emissions, 7% of acidification, 12% of human toxicity and 15% of photochemical ozone creation potential (summer smog).

In spite of the extent and significance of this resource use and the related environmental impact, no policy exists at EU level addressing resource use in the building sector and there are only a few Member States and business initiatives addressing the problem.

Over their lifetime, insulation products can save a hundred to a thousand times more energy than is used to produce them – and consequently lead to proportionate reductions in CO_2 emissions. In the EU, buildings account for more than 36% of total GHG emissions and 40% of total primary energy demand, which means that using insulation could cut energy consumption by 50-90%. On a global scale, buildings account for more than 33% of all final energy and half of global electricity consumption. Using insulation, here too 50-90% energy savings could be generated.

In 2013, the EU was the largest energy importer in the world, paying more than €400 billion per year (in 2015 the bill was €264 million due to decreased energy prices). Today, 53% of the energy used within the EU is imported. An energy efficiency policy that includes ambitious renovation targets could reduce gas consumption in the building sector by 100% by 2050 and make the region independent of geopolitical power shifts.

More than 90% of buildings standing today in the EU will still be standing and occupied in 2050. 70-90% of the existing buildings are energy inefficient and could be retrofitted and become energy efficient through the use of thermal insulation. Insulation could help reducing the energy demand in the building stock by 80% by 2050. This would save the EU over 30% of its total energy use compared to 2005.

Two-thirds of energy consumption in buildings is used for heating, ventilation and air conditioning. Without additional mitigation policies, global energy demand for air conditioning is projected to increase 12.3 times from 2000 to 2050. The use of insulation is a necessary and cost-effective solution to limit and decrease this consumption.

Buildings and construction in the EU account for:

- 40% of final energy consumption
- 35% of greenhouse gas emissions
- 50% of all extracted materials
- 30% of water consumption
- 33% of total generated waste

(Source: communication of EC on Resource Efficiency Opportunities in the Construction Sector)

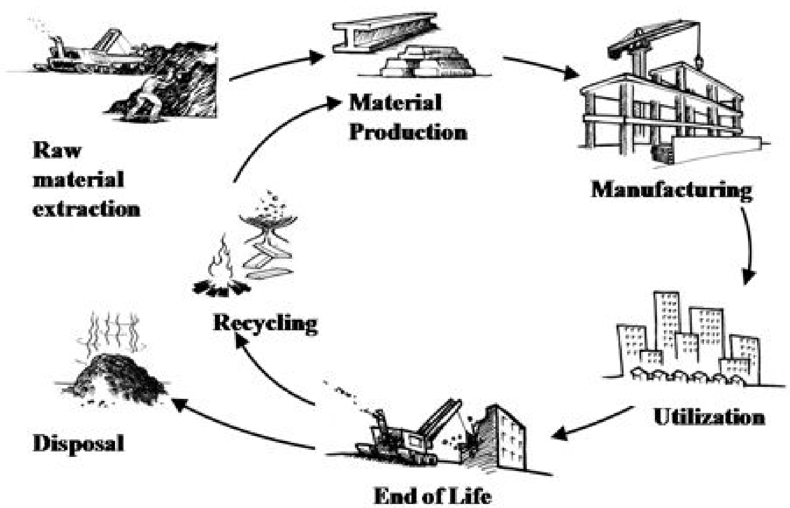
[3] http://ec.europa.eu/environment/eussd/pdf/SustainableBuildingsCommunication.pdf
[4] http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/TP_report.pdf

3 THE NEED FOR A LIFE CYCLE BASED APPROACH

3.1 WHAT IS LCA

Life Cycle Assessment (LCA) is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle[5].

3.2 HOW DOES LCA APPLY TO BUILDINGS?



3.3 FIRST MEASURE THE IMPACT IN ORDER TO LOWER IT

A common saying that is applicable in this context is "You can only manage what you can measure." The study of Paleari[6] concludes that life cycle analysis is a useful tool to identify solutions that ensure the lowest overall environmental impact of a building by helping designers find the best balance of energy requirements between pre-use (e.g. the production of materials) and operational stages. It can also help designers to compare impacts of, and options for, different components and guide their choices towards options that are low in overall environmental impact, and not just energy use; for example, building components with low production impacts or with a longer lifespan.

However, when considering LCA, one has to keep the overall concept in mind that "LCA is like a sharp knife. It can be used and abused. A doctor can certainly do well with a sharp knife, a murderer presumably not. It makes no sense to blame knives or LCAs for misuse. It is rather important to urge users and performers of LCA to follow established standards and rule sets, …"[7]

[5] ISO 14040 Draft: Life Cycle Assessment - Principles and Guidelines
[6] Paleari, M., Lavagna, M. & Campioli, A. (2016). The assessment of the relevance of building components and life phases for the environmental profile of nearly zero-energy buildings: life cycle assessment of a multifamily building in Italy. The International Journal of Life Cycle Assessment, 1-24. DOI: 10.1007/s11367-016-1133-6.
[7] Curran M.A., 2016, Overview of Goal and Scope Definition in LCA

3.4 LCA-BASED APPROACH TO AVOID BURDEN SHIFTING

When improving the environmental performance of products and buildings, analysing trade-offs and burden shifting is key. Burden shifting can occur between different life cycle stages and it can also occur between different environmental impacts.

When a product or building is being improved with regard to its cradle-to-gate environmental impact, also the gate-to-grave functionality and impact needs to be analysed to ensure that no burden shifting takes place in time. For example, fewer raw materials might be used to produce a certain product and therefore lower the cradle-to-gate impact. However, at the same time the product might not be as durable and therefore not perform in the use phase for as long as the previous product, or it might not be possible to disassemble the new product at its end-of-life. Through LCA one can assess if the improvements up to the factory gate are bigger than potential trade-offs in the subsequent use stage or end-of-life stage.

On the other hand, when a product or building can be improved with regard to one specific environmental impact, the other impact pathways also need to be analysed, to ensure that no burden shifting takes place. For example, a product might be produced in a water scarce region where measures to reduce water use are put in place. However, at the same time, those measures might increase energy consumption. Through LCA one can assess the relative reduction in water used and how this stacks up against the increase in global warming potential due to the higher energy use.

If production, design, policy or other decisions are made by only focusing on a certain part of the whole life cycle and/or only one environmental impact category, then burden shifting cannot be addressed (see Figure 1).

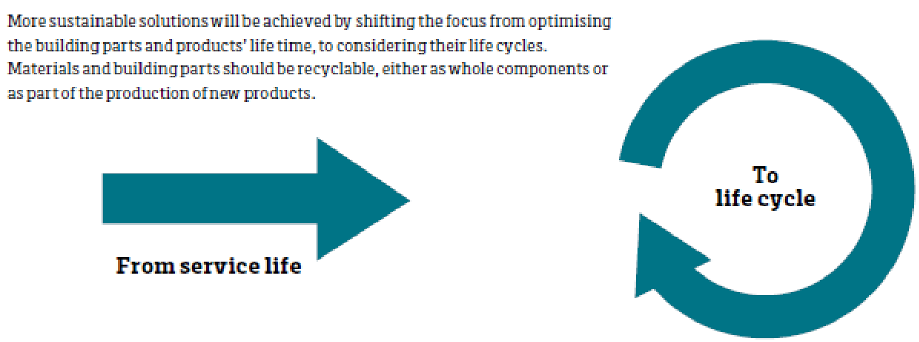


Figure 1. The life cycle approach shifts focus from factors related to the completed building, to involving the entire life cycle of the building[8].

LCA at building level is needed in order to assess the building environmental profile in a holistic approach. The LCA methodology avoids the risk of burden shifting between impacts or between life cycle stages. At a building level, LCA can be used to:

- Optimise the building design
- Compare different building solutions
- Benchmark environmental building performances
- Communicate to users
- Improve environmental policies
- …..

[8] Introduction to LifeCycle of Buildings; Trafik-Og Byggestyrelsen, Danish Transport and Construction Agency, 2016

No other methodologies are currently available to correctly assess environmental building performance.

When an LCA is performed at building level it will then be possible to normalise impacts. By using appropriate weighting methodologies, an easy to communicate single score index can be obtained. These single score systems are heavily debated as they create an additional layer of scenarios and uncertainties to the results. Their big advantage is that obtaining a single score makes it possible to compare different buildings or to compare different designs for the same building.

3.5 HOT SPOTS ARE BUILDING SPECIFIC

Environmental impacts over the life cycle of a building have a large number of sources, differing from each other as to their life cycle stage (Figure 2).

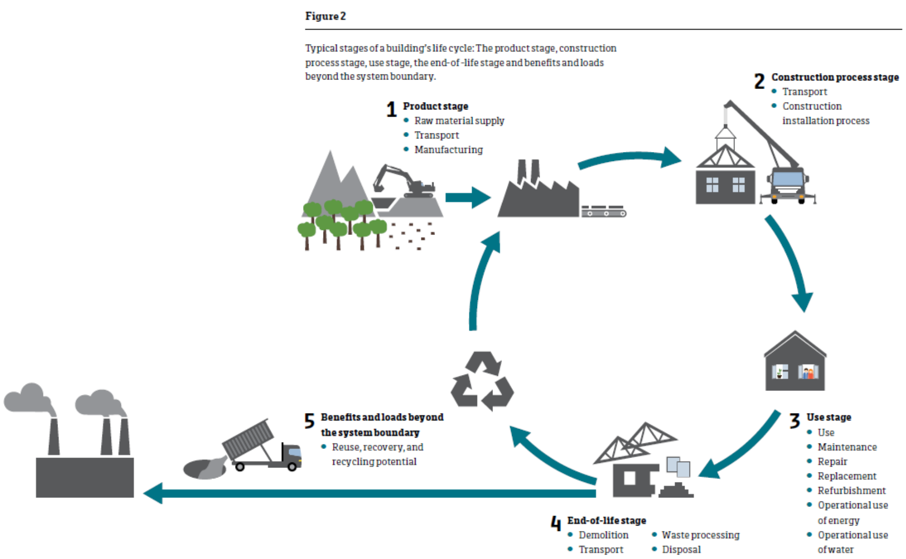


Figure 2. The typical life cycle for a building and which stages and processes are involved[9].

At the same time, "environmental hot spots" can be in very different stages depending on their environmental impact. To correctly assess this difference, it is necessary to take them all into account. The size of the impacts in different life cycle stages is a function of the environment, the specific building, the building's technical construction, the location of the building and other influencing factors. This makes it difficult to predefine for a specific type of building which will be the hot spots for the environmental impacts of a building. They can vary significantly from one building to another.

3.6 THE ROLE OF LCA

LCA is the only methodology to assess the environmental impacts of a building. How the tool is used (e.g. to show performance in comparison to benchmarks, to compare different designs, …) and how it indicates the selection of the best design scenario, will lower the overall environmental impact of the build environment.

[9] Introduction to LifeCycle of Buildings; Trafik-Og Byggestyrelsen, Danish Transport and Construction Agency, 2016

4 LCA ACROSS THE VALUE CHAIN

To create a meaningful LCA of a building, specific input data related to construction products and processes need to be available in a common format and with common calculation rules. Such data need to be consistent and have a cradle-to-grave scope for all input materials and processes. This data can then be used to model the environmental impact of the building for a selected time period. The results of the building assessment need to be interpreted across life cycle stages and impact categories in order to create meaningful insights.

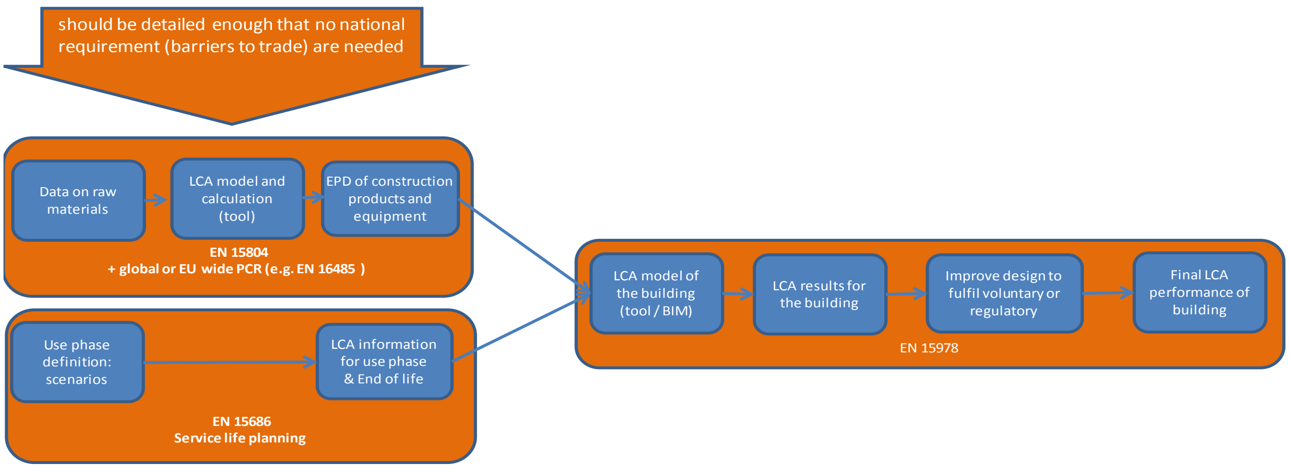


Figure 3. Types of data needed to perform an LCA.

Some additional information on the different actors that will come into contact with LCA are given in Figure 4.

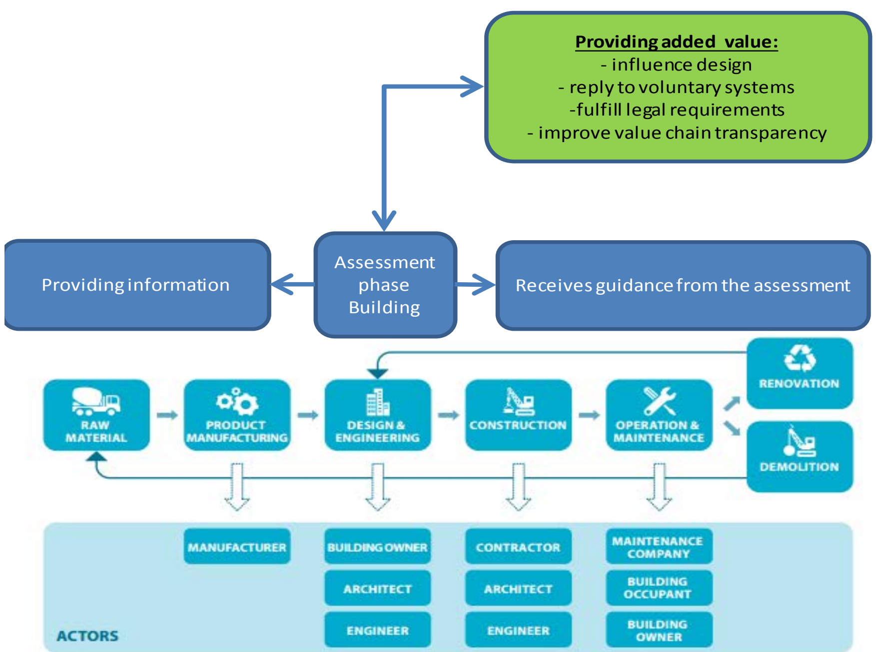


Figure 4. The different actors involved in an LCA.

5 USING THE RESULTS OF BUILDING LCA CALCULATIONS

5.1 THREE WAYS TO USE THE LCA RESULTS OF A BUILDING

The many ways to use the LCA results of a building are generally grouped into three categories: voluntary use, semi-mandatory use, and mandatory use. Within these different groups the main elements are usually: achieving a certain target value, communicating performance, and improving design.

5.1.1 VOLUNTARY USES OF BUILDING LCA RESULTS

- To reach an appropriate level of excellence in Building Rating Systems (DGNB, BREEAM, LEED, HQE) and to communicate it as a reference case for the market
- To communicate that a building is Responsible and Decarbonised
- To optimise the design (LCA as a part of a larger life cycle approach); some builders and real estate owners do this for their complete portfolio

5.1.2 SEMI-MANDATORY USES OF BUILDING LCA RESULTS

- In the Austrian system through Baubook, subsidies are allowed if an LCA is conducted for a building and a reference target is complied with
- In Germany for some public buildings through a BNB assessment
- In the Netherlands for public buildings.

5.1.3 MANDATORY USES OF BUILDING LCA RESULTS

- In France, the E+/C- is a new scheme for energy consumption and CO_2 impact (currently in a transition phase, it will be mandatory within two years)
- In the Netherlands (tick-the-box and GWP and ADP requirements), although strangely enough these are not applied to all projects
- The environmental ministry of Finland announced that building LCA will become mandatory by law in 2025 at the latest

5.2 EXAMPLES OF THE USE OF LCA OF BUILDINGS IN PRACTICE

5.2.1 IN EU MEMBER STATES

5.2.1.1 France

Environmental Product Declarations (EPDs) are mandatory when an environmental claim is included in any manufacturer's literature. In France, *Fiches de Données Environnementales et Sanitaires* (FDES) are stored in the INIES database and in the BDR (*Base de Données Réglementaires*) database. In the near future, embedded and operational energy, as well as emitted CO_2, will be part of the thermal Building Code (the *énergie carbone* label).

5.2.1.2 Germany

In Germany, Okobaudat is the LCA indicators database utilised for the building LCA tool "eLCA" by the Federal Institute for Research on Building, Urban Affairs and Spatial Development *(Bundesinstituts für Bau-, Stadt- und Raumforschung,* BBSR). The eLCA is then part of the Building Assessment Scheme BNB (*Bewertungssystem Nachhaltiges Bauen*). The BNB is mandatory for federal construction works with a dedicated budget threshold *(verbindliche Anwendung des Bewertungssystem für Bundesbaumaßnahmen*[10]). The Okobaudat database can also be utilised for the DGNB assessment scheme. There is now a direct link between IBU EPDs and Okobaudat to enable the automatic transfer of the EPD results to the Okobaudat. In June 2017, IBU released the "IBU.data" which allows the easy extraction of indicator results for building LCA purposes.

5.2.1.3 The Netherlands

The *Nationale Milieudatabase van Stichting Bouwkwaliteit* (NMD) requires the use of the SBK assessment method version 2.0. The method and database are interconnected as one common framework for manufacturers (data suppliers) and designers/consultants (data users). In addition to product cards, item cards and base profiles, the environmental impact database includes an LCA database of raw materials and background processes, based on Ecoinvent 2.2 and adapted for use in the context of the assessment method (process database). These processes have to be used by creators of EPDs. The assessment method and the NMD are closely connected in order to realise a clear environmental performance calculation for construction and civil engineering works. This system was introduced in the National Building Regulations (Building Decree) in 2012. The calculation of the GWP and ADP of buildings is mandatory but unfortunately not always strictly applied.

5.2.1.4 Belgium

The Belgian database for EPDs has been released mid-2017. The objective is to make EPD indicator results available online so they can be downloaded directly for use in buildings. The building LCA tool is based on the Belgian *Milieugerelateerde Materiaalprestaties van Gebouwelementen* (MMG) method and will be available from Autumn 2017 onwards.

5.2.1.5 Austria

Product-specific LCA data goes into the *Baubook* national database. Then ECOINDEX3 product points are calculated; they are aggregated from global warming potential, primary energy and acidification potential results. With the help of ECO2Soft, all ECOINDEX3 data of building elements are combined, to allow the LCA to be carried out for the whole building. Buildings with low ECOINDEX3 get full credits in certification. Funding for low figures differ slightly in different federal states but can be up to 10% of the total funding amount. Open source tools for calculation are provided in the *Baubook* to encourage building owners to certify and/or request funding.

5.2.2 OVERVIEW OF UPTAKE IN BUILDING RATING SCHEMES

5.2.2.1 DGNB

The DGNB Building Rating System incorporates the LCA approach throughout the majority of calculations in the assessment method. For example, for some criteria it is requested to calculate the life cycle environmental impact of the analysed building and to compare it to the GWP, ODP, POCP, EP etc. of similar buildings (in terms of type and size) with reference values. Points are awarded in a scale for buildings depending on whether they are performing reasonably better or

[10] https://www.bnb-nachhaltigesbauen.de/bewertungssystem.html

much better than the reference cases. In this way, DGNB is also promoting EPDs from operator programs and the comparison of materials to reach an appropriate expected level. DGNB developed an Excel tool which is available for consultants to calculate building LCA and compare it with the mentioned reference cases.

The life cycle cost approach (which is in a way related to building LCA but on the monetary side) is also a relevant, highly weighted criterion in the DGNB assessment.

5.2.2.2 BREEAM

BREEAM recognises and encourages the use of robust and appropriate LCA tools for buildings and consequently the specification of construction materials with a low environmental impact (including embodied carbon) over the full life cycle of the building. Compliance is assessed through the use of an LCA tool that can demonstrate a requested level of quality. In this case, the quality of the tool and the data are of greater significance than the results of the building LCA. BREEAM awards an additional point for the availability of at least five third-party verified EPDs.

5.2.2.3 HQE

ELODIE software, developed by CSTB, allows building LCAs to be calculated with the help of FDES. ELODIE is utilised for HQE assessment (the French Building Rating System). HQE has access to both a tool to calculate LCA of buildings and a database with EPD. This makes it easier to perform an LCA of a building.

In the light of the pilot phase for the new legislation the following tools are approved for testing: ClimaWin, OneClick LCA, ELODIE, novaEQUER, ThermACV.

5.2.2.4 LEED

In addition to requesting 20 EPDs from five different construction product manufacturers to allow additional points, LEED promotes whole-building LCA.

For new constructions, LEED asks for an LCA to be conducted of the project’s structure and enclosure, to demonstrate a minimum of 10% reduction compared with a baseline building, in at least three of the six impact categories, one of which must be global warming potential. No impact category assessed as part of the LCA may increase by more than 5% compared with the baseline building.

5.2.3 EXAMPLES OF COMPANIES ALREADY IMPLEMENTING LCA OF BUILDINGS

5.2.3.1 Skanska

Skanska considers defining and reducing environmental impact as a core differentiator for its business. To enable this, Skanska has developed the Color Palette™ and the Journey to Deep Green™. They incorporate a range of targets from legal compliance to zero/near zero environmental impact, relating to carbon, energy, water and materials. Skanska also developed its own internal decision tool to assess the environmental impact (inspired by LCA) of construction products.

5.2.3.2 B + H Architects

The application of LCA aligns with the core values of B+H Architects. The indicators are frequently used in conversations with their clients to make it easier to discuss the vision, desired outcomes and progress of an LCA project. B+H Architects applies energy, CO_2 (GHG), water and waste life cycle indicators in their design process. Since 2014 they have implemented the database materials and monitoring systems of GIGA[11] across their master specifications and studios. This database is a global cloud-based platform that currently provides (environmental) data on 85,000 materials. The database is an instrument which makes it less time-consuming to collect the necessary data on life cycle indicators.

5.2.3.3 Folkhem

Swedish developer and construction company Folkhem published a complete building LCA EPD cradle-to-grave approach, through the International EPD System program operator. Folkhem's building concept design is based on the strategy "apartment buildings in solid wood above ground". The 10-floor concept building is located in Stockholm. The bottom floor and half of the second floor are below ground and constructed from concrete, while the other floors are above ground and are constructed mainly of solid wood. The functional unit is 1 m² of temperature controlled space (Atemp) of an apartment block. Folkhem uses this EPD as a demonstration project and extrapolates the environmental impact for new projects of similar construction.

5.2.3.4 Bouygues

Bouygues is a major construction company based in France and operating through Europe. It has developed its Polygreen database of construction products to help them select the best products for dedicated purposes based on six criteria: technical data, production site, environmental impact, sanitary impact, environmental labels and public price. The Bouygues teams are trained in the LCA methodology and are familiar with current environmental issues. They use Polygreen to select construction product alternatives with lower environmental and sanitary impact.

5.3 ADVANTAGES OF LCA OF BUILDINGS

5.3.1 REGIONALISATION OF POLICY OBJECTIVES

Regionalisation of policy objectives is not the final aim of requesting a building LCA for all new construction or retrofit projects. Local authorities should analyse what is the best level of implementation to diffuse the concept, to reach the appropriate stakeholders and to comply with local sustainability targets.

LCA is a tool that can be used for a wide variety of policy objectives:

- Allow subsidies for retrofitting or new construction
- Select between demolition or retrofitting
- Authorise construction permits following the calculated environmental impacts.

5.3.2 POSSIBILITY TO SPLIT BETWEEN MANDATORY AND ADDITIONAL REGIONAL INDICATORS OR IMPACT CATEGORIES

5.3.2.1 Mandatory (GWP and Energy)

Global Warming Potential (GWP) is one of the relevant indicators for building LCA that should always be part of the assessment. Related to this impact is the energy consumption as embodied energy and operational energy, which should always be clearly reported. Core indicators are under development by the European Commission for sustainable building assessment; currently under the spotlight in the context of the circular economy are water scarcity and resources consumption.

[11] www.gigabase.org

5.3.2.2 Additional regional indicators (out of the CEN/TC350 basket)

Additional regional indicators could be added following regional priorities but should always allow an adequate level playing field. Building LCA indicators should never be based on private labels (cradle-to-cradle etc.) but should rely on science and comply with norms EN 15978 and EN 15804.

5.4 LIMITATIONS OF THE USE OF LCA OF BUILDINGS

5.4.1 LIMITED SCOPE

The LCA of buildings is fit for environmental impacts that can be assessed by adding them up over the life cycle. This means that all health- and comfort-related issues are normally not part of the LCA of buildings. Those environmental impacts which have a location-dependent impact in function of the emissions should be assessed with additional care.

5.4.2 LIMITS TO MODELLING

LCA of buildings is based on modelling, as the number of different environmental impacts that should be measured throughout the value chain is too high. The advantage of modelling is that it gives the opportunity to assess something which is not measurable. The limitation of modelling is that it is based on certain assumptions which inevitably create some uncertainties. These uncertainties need to be taken qualitatively into account when assessing the results of the model.

5.5 CONCLUSIONS

Despite the examples above, we see that the uptake of the LCA methodology as an assessment tool at the building level currently stays marginal. The many initiatives show that the LCA of buildings will be part of the future assessment of the environmental impacts of buildings. In order to use this methodology more easily, there should be as soon as possible a big leap forward in its uptake, as this will trigger the availability of tools for a reasonable budget. The driver for increased uptake should come from regulation which will ideally include benchmarks. It is only through such regulation that a larger part of the market will be incentivised to use LCA.

6 CALCULATING THE LCA OF BUILDINGS: POSSIBILITY TO USE IT TOOLS

Calculating the LCA of a building is very similar to the cost calculation of the building.

If environmental assessment is already included in the beginning of the building design the whole design process will be guided from an environmental perspective. In such a case, minimisation of impact will more easily be obtained at lower effort and cost.

The competitiveness of the European building sector will be increased from both the environmental and the cost point of view.

6.1 WHY IT TOOLS ARE NEEDED

A building LCA needs to use a large amount of data coming from different products/processes used in different stages. The modular approach (typical for the currently used EN15978 standard) included in the LCA method facilitates the management of this large amount of data. Nowadays, any building performance is calculated using IT tools (stability, thermal, acoustic, IAQ etc.); LCA for buildings will not be an exception.

Ideally, LCA for buildings (for all characteristics) should be as close as possible to the tool that calculates the costs and Bill of Materials (BoM) of the building and can thus share the overwhelming majority of collected data with these tools.

If environmental data from building products and processes are available in a digital format, a building environmental assessment only needs the BoM (quantity of products), processes (maintenance, repair etc.) and scenario's on end-of-life and transport. This building information is also needed for life cycle cost calculations, so no extensive additional work or calculation time is needed, on the precondition that a life cycle costing calculation has been done.

To correctly use LCA to improve the design (it makes no sense to wait until all the information on the building is available), the requirements play a role, as it's not possible to wait until the end of the project to see if the requirements have been fulfilled.

IT tools allow building information to be integrated in or transferred between tools in order to perform specific calculations even at the earliest stages of building design.

Making an LCA calculation of a building is not something futuristic. It is already current practice (for a limited amount of buildings) in many EU countries. It is interesting to note that this is usually on the basis of a dedicated IT tool in order to make the LCA calculation easier, as this requires a large amount of data. The additional advantage of an IT tool is that it provides the possibility to recalculate the LCA of the building, without too much additional burden, if the design of the building is changed.

6.2 IT TOOLS ALREADY IN EXISTENCE

France: Elodie allows all EN 15804 environmental impact calculations using FDES (= EPD) as input data. Calculations are performed on all impacts which are part of EN15978. There is a direct, electronic link between Elodie and the French database INIES.

Spain: Some cost IT tools such as CYPE and TCQ2000 are able to calculate the GWP and embedded energy for the construction phase, and include in their database the information for each product/material. These tools share the BoM calculated for cost purposes to "automatically" obtain the environmental impacts for the construction phase.

Germany: Okobaudat is integrated in the building LCA tool "eLCA" by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). The eLCA is then part of the Building Assessment Scheme BNB (*Bewertungssystem Nachhaltiges Bauen*).

Elsewhere in Europe: The BRE Group in the UK is promoting the use of the IMPAC tool to carry out building LCA. LEED is promoting the use of Tally. Baubook in Austria is promoting Eco2soft.

Elsewhere in the world: Some dynamic energy building simulation tools such as DesignBuilder (using the Energy+ engine) include for each product material the information on GWP and embodied energy as required data. The tool can then calculate not only the GWP and primary energy for the operational phase (it's one of the goals of this software) but also the embedded CO_2 and primary energy for the construction phase. In Finland, the Bionova company is also selling a complete solution from product level LCA to building LCA: "one click LCA".

6.3 FUTURE DEVELOPMENTS

Today only a few tools can calculate all environmental impacts and many of them can only perform calculations for the most relevant impacts. This is due to limited data availability or a "political" choice of the IT developers to concentrate on only some impact categories. However, all categories could fairly easily be integrated into IT tools.

Most of the current IT tools are focused on the construction phase because there is a lack of information from environmental profiles on building processes (maintenance, repair, refurbishment etc.). All life cycle stages should be taken into account.

Access to environmental profiles of products and processes should be improved using digital formats. The INDATA project could be a good way to facilitate this access and implement LCA for buildings.

There is a need for communication between architecture tools (CAD systems) and EPD databases to make LCA of buildings. This is very similar to all the issues encountered during cost calculations (identifying the economic cost for a product/system is not too different from identifying the environmental cost). This approach is not bi-directional.

6.4 FUTURE INTEGRATION IN BIM PRINCIPLES

Building Information Modelling (BIM) is the medium/long term opportunity to integrate in a single tool all building information coming from the building itself (geometry, building elements etc.) and the information coming from products/processes (product performances etc.). This will enable a multidirectional tool evaluating the building performance (cost, thermal, acoustical, LCA etc.) and allowing interaction between different possible choices to have correct and well justified solutions.

Interactivity will make it possible to fully use LCA of buildings to improve the design of the building without losing building performance or unnecessarily increasing costs.

6.5 INTEGRATION WITH OTHER ARCHITECTURE TOOLS

Currently, too many of the available LCA tools are not connected with other architecture tools. This creates too much additional burden for the architect and could create a bad first impression of LCA calculation of buildings.

7 THE NEED FOR GOOD DATA AND COST EFFICIENCY

7.1 TYPES OF DATA NEEDED

The types of data needed for the calculation of the LCA of a building were presented earlier in this document in Figure 3. These data are now further detailed.

7.1.1 EPD OF PRODUCTS AND EQUIPMENT

Many EPDs for products and materials already exist and are publicly available. Less information is available for equipment and components for building installations (plumbing, electricity, HVAC, etc.). For example, PEP Eco-Passeport has been recognised for a few years in France as filling this gap. As figure 5 illustrates, many EPDs are available on the market and will only increase in availability.

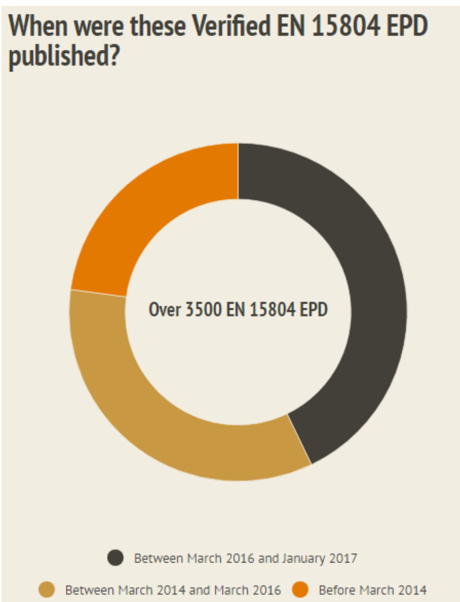


Figure 5. Availability of EDPs[12].

7.1.2 INSTALLATION DATA AND TRANSPORT TO CONSTRUCTION SITE

A lot of installation information is not readily available, although that does not mean it may be neglected.

7.1.3 MAINTENANCE AND REPLACEMENT DATA

This information is specific to the building and is currently not readily available. It covers a large scope of activities (cleaning, specific maintenance, technical maintenance, replacement, etc.). Again, just because it's not readily available does not meant that it may be neglected.

[12] https://constructionlca.wordpress.com/2017/02/27/updated-epd-infographic-for-2017/

7.1.4 USE STAGE

Usually scenarios are available to model the use stage. The service life scenario in building LCA is generally 50 or 60 years life time.

7.1.5 END-OF-LIFE

There is a need to work on some scenarios. It should not be too difficult to imagine end-of-life scenarios. This information could be used at a product level; there is no need to make it building specific.

7.2 SOME CHALLENGES

7.2.1 COST OF THE DATA FOR PRODUCT MANUFACTURERS

Cost of the calculation (LCA to EPB)

If the LCA analysis is being performed by an external consultant, costs vary according to the complexity of the product/system, the consultant's experience, the country, and the options being considered (data collection, support for third-party verification, etc.). For example, the typical cost for an LCA analysis and a few EPDs in the Czech Republic could vary between 3000 and 12000 EUR.

For an internally performed LCA analysis, the cost is linked to two parameters: the cost of the LCA tool, and the internal time spent on the analysis. For example, the table below indicates costs for the main tools on the market as perceived by our industry first half of 2017[13]:

Price of a basic initial license (without annual fee or maintenance)	Gabi	Simapro	Team 5.2
Cost (EUR)	9 000	9 500 to 12 500	3 000
Source	Internal proposal	EVEA website	Brochure

Cost of the secondary data

These costs are also variable depending on the level of detail of the data needed. The table below gives examples of available databases for the secondary data on the market as perceived by our industry first half of 2017[14]:

Price of a basic license	Gabi database	Ecoinvent	DEAM	ELCD database
Cost (EUR)	Basic database included in Gabi: x thousand EUR for each additional database	3800	Included in Team	Free
Source	Internal proposal	Website	Brochure	Website

It is worth pointing out that the final cost can be higher if a new data collection is necessary, or if an LCA is needed for secondary data (whether new or old). In these cases, the cost can approach that to make LCA for EPD.

[13] These costs can evolve over time. The objective of integrating costs in this document is to give an indicative order of magnitude as it is currently perceived by our industry and not to provide data to make comparative assessments.
[14] These costs can evolve over time. The objective of integrating costs in this document is to give an indicative order of magnitude as it is currently perceived by our industry and not to provide data to make comparative assessments.

Cost of third-party verification

These costs are divided into two parts:

- Cost of verifier: This is linked to the number of days the verifier needs to verify the LCA, the LCA report, one EPD and make a verification report. For one EPD, typically the number of days is three or four, with the cost being 2000 to 4000 EUR. After this, the cost per EPD can be reduced as the number of EPDs to verify increases.

- Cost of program operator: This varies per program operator and country. For example, in France the cost per EPD is 200 EUR (which decreases with the number of EPDs to register). For Environdec the cost for one EPD is 1500 EUR.

7.2.2 REPRESENTATIVENESS AND RELIABILITY OF THE DATA

If done correctly, third-party verification solves this issue. The market will automatically be motivated to improve the representativeness and reliability of data. In the Netherlands, a penalty is issued for each EPD which is not representative of the market.

7.3 SOME SOLUTIONS

7.3.1 REAL HARMONISATION

The current EPD system is strongly related to national markets. This is mainly due to program operators and specific national legislation. This creates a burden for the industry and could be seen as a barrier to trade.

Below, we give first an overview of the various elements that could/should be harmonised, followed by an overview of the various "associations and groups" in which we are to finally give a strategy on how to obtain this harmonisation.

Various elements to harmonise

The majority of construction product manufacturers are requesting harmonisation of EPDs. However, there is no single harmonisation process. The only way to obtain harmonisation is to combine partial solutions to harmonise parts of the elements. The following elements need harmonisation:

The calculation methodology (and indicators): mainly EN15804 and PEF

- This should be solved through the new mandate of the EC for CEN/TC350

- The mandate will not solve all the issues of harmonisation between PEF and EN15804

- The mandate and discussion to review the standard should be done in such a way that limits room for interpretation by Member States and program operators

- A product-specific PCR EU level (TC 88) should be developed for all product categories and should allow the elimination of program operators' PCRs.

The use of databases with background data

- This is currently a requirement from the program operator or from the public authorities (in most cases)
- The harmonisation solution is to leave the choice on which database to use
- This can only be done if requirements can be set for the quality of the data
- This could also be solved by having a common database for the most frequent processes (energy, transport, etc.). This should require someone to manage such a free database and that it becomes in practice the only or the mandatory database to use for these processes. The PEF implementation is helping the creation of a common database for supporting studies by the central purchasing of datasets by the European Commission (ELCD?).

The format/content of the EPD

- The formats are currently different from one program operator to another. This complicates the comparability of the EPD and is a barrier to the use of EPD in other countries
- Different templates are also occurring because different PCRs (part A general and Part B product focussed) are developed by each program operator. PEFCRs and a product-specific PCR EU level (TC 88) should help to reach consensus.

The additional requested information

- This additional information can be requested by the program operator, the public authorities or the Building Assessment Scheme
- The additional information is currently merged with the rest of the "mandatory" EPD. This makes it very difficult to work with a core part of the EPD. This core part of EPD and the additional information in annexes should become the rule in Europe.

The language of the EPD

- For example, Okobaudat (Germany) only accepts an EPD in German, while INIES is requesting FDES in French.

7.3.2 SMART USE OF TOOLS TO GENERATE THE INFORMATION TO DECLARE

A package of smart tools is needed to:

- Model and calculate
- Collect primary and secondary data
- Make EPD/reports
- Facilitate third-party verification.

7.3.3 LOWERING THE COST OF VERIFICATION WITHOUT LOWERING ITS ADDED VALUE (PROBABLY THROUGH A COST APPROACH)

There is the possibility to verify sets of products and verify tools, for example via a parametric approach. In addition, sharing LCA models, scenarios and secondary data sets at sectorial level could lower cost.

7.4 SOME SPECIFICITIES FOR SMES

7.4.1 THEIR CHALLENGES

Data

- Relevant data, for example supply chain data, raw materials, chemicals and potential waste
- Preparation of data
- System for handling data

Cost

- Cost of calculation
- Cost of the secondary data
- Cost of third-party verification
- Cost for platforms – yearly fee and amounts

Knowledge

- There can be limited in-house knowledge of the whole LCA process
- Networking is necessary among program holders, to help the choice of relevant programs, program platforms etc.

7.4.2 EXISTING AND UPCOMING SOLUTIONS

There is a need to share the cost, for example of modelling and third-party verification, instead of sharing all the results, although questions remain as to how this could be done in practise in regard to:

- IT tools
- Need for mutual recognition between program holders/platforms without extra cost
- LCA is regulatory driven instead of market driven -> limits for reasonable cost?

Other

- Consider quality verification of data on top of technical verification?

7.5 THE ROLE OF SIMPLIFICATION

If a parallel is made with energy efficiency calculations where both simplified calculations exist (e.g. EPC calculations) and more correct full-fledged calculations (e.g. dynamic calculations), there is a clear need for the LCA community to have some further reflections on the potential role and benefits of simplification. Even more than in the energy efficiency calculations, simplification in LCA can lead to wrong assessments if not done carefully.

Simplification could include the following principles:

- Availability of generic data for certain products (with a penalty)
- Availability of generic construction elements (with a penalty)
- Default scenarios for end-of-life calculations
- Default values for other parameters (e.g. transport distances)

It is key that these simplifications are made in such a way that they don't hamper the incentives to provide product-specific information.

For the optimisation of design it could well be that in a first stage a simplified calculation is made which is then refined for the hot spots.

7.6 WEIGHTING AND SINGLE SCORES AS PART OF THE SIMPLIFICATION

A part of the added value of LCA as a methodology comes from the fact that it assesses different impact categories. The downside of these different impact categories is that when making comparisons the conclusions can be different between the different impact categories.

This means that when assessing the results of the LCA calculation, some weighting is necessary between the different impact categories. This weighting can be done on the basis of a provided weighting set between the indicators or can be done on the basis of the judgement of the person assessing the results.

For transparency and consistency reasons it seems interesting that a weighting method would be provided. However, when results are provided publicly this should always be done for all the impact categories in parallel to the weighted results.

Note: In the mandate for the amendment of the TC350 standards, CEN has been requested to integrate a weighting system within the standards.

8 THE NEED FOR TRAINING AND POSITIVE COMMUNICATION

In general, the LCA community has not been very effective in its communication to other stakeholders concerning the principle of LCA calculations at the building level. This communication needs in the coming period to focus on training and on positive messages.

8.1 THE NEED FOR DIFFERENTIATED TRAINING

Many stakeholders along the value chain seem afraid of starting to use LCA of buildings as a tool. There seems to be a real need for training of the various stakeholders in the value chain. Every type of stakeholder needs to be trained in function of the way he or she will be in contact with LCA of buildings. Only a very limited number of them will be in contact with the modelling part of the LCA, which is by far the most complex part. In countries where there is already some uptake of the methodology of LCA at the building level, experience shows us that training is not too difficult to organise in a meaningful way if it is well targeted to the specific needs of the stakeholder.

As LCA of buildings is based on modelling, it is intrinsically accompanied by a certain level of uncertainty. In the curricula of current students, the management of uncertainty starts to be part of the courses. For other stakeholders in the value chain this is probably something that needs some attention.

A staged approach with different complexity levels for the LCA of buildings should be, if necessary, designed in order to facilitate the training of stakeholders.

8.2 THE NEED FOR POSITIVE COMMUNICATION

Most of the communication about LCA of buildings is currently done by the LCA practitioners and the LCA experts. Those communicate, naturally, on the challenges which are still in front of us. It is the duty of the community which supports LCA principles to communicate proactively and positively on how LCA of buildings is already practiced today for quite a number of buildings. Special attention should be given to communicate on the added value of LCA of buildings for the different stakeholders in the construction value chain.

8.3 THE NEED FOR INTEGRATION OF LCA OF BUILDINGS IN UNIVERSITY CURRICULA

The upcoming generation of architects and engineers should be trained during their studies on the LCA of buildings.

9 CONCLUSION: NEXT STEPS TO FURTHER IMPLEMENTATION

Most elements to calculate the LCA of a building are currently available. The added value of the LCA of a building, in the perspective of achieving sustainable development goals, is high, because it is a tool to improve the design of buildings.

The current situation is that the use of LCA of buildings is still marginal. Important steps towards further implementation are:

- The need to better explain across the whole building value chain the benefit of doing LCA of buildings, in order to close the gap with lack of political and market awareness.
- The further need for harmonisation in the way data are delivered and the tools for calculation are set up
- The further need for incentives (France, Austria, etc.) to make an LCA calculation of the building and to optimise it in order to lower its environmental impact over the life cycle
- The need for more guidance and vision on how LCA of buildings can be implemented in practice.

Eurima believes that the mainstreaming of LCA of buildings, if implemented in a correct way, gradually supported by a regulatory framework, will lower the environmental impact of the construction industry.

Owing to the large amount of information that needs to be processed, the implementation of LCA of buildings will only be possible if it takes place in a digitalised environment. Some existing tools already make this approach possible. However, to mainstream it, Eurima believes that the following challenges need to be addressed and solved in the coming years:

- Harmonisation of methodologies, IT formats, declarations, third-party verification
- Information providers need to work with tools for LCA calculations instead of providing PDFs with EPD information
- The Building Information Modelling (BIM) format needs to be accepted as the de facto communication format.