CONSTRUCTION BLUEPRINT

Module 9

Life Cycle Assessment

Circular Economy in Construction

24 partners 12 countries

Date of Event

*Author/ **Institute***

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Life Cycle Assessment | Summary

To provide the learner with the basic knowledge of Life Cycle Assessment (LCA), why it matters and the benefits of its use to support sustainable healthy buildings,

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1. Outline the **principles and benefits** of Life Cycle Assessment (LCA) for construction
2. Describe the steps taken at each **life cycle phase** to ensure a circular construction process
3. Identify the **methodology for LCA** and how to apply it in construction projects
4. Identify the **software and tools** available for LCA

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Topic 1 – Introduction to LCA

Topic 2 – LCA and Level(s)

Topic 3 – Building Certifications

1. Introduction to LCA

Building Life Cycle

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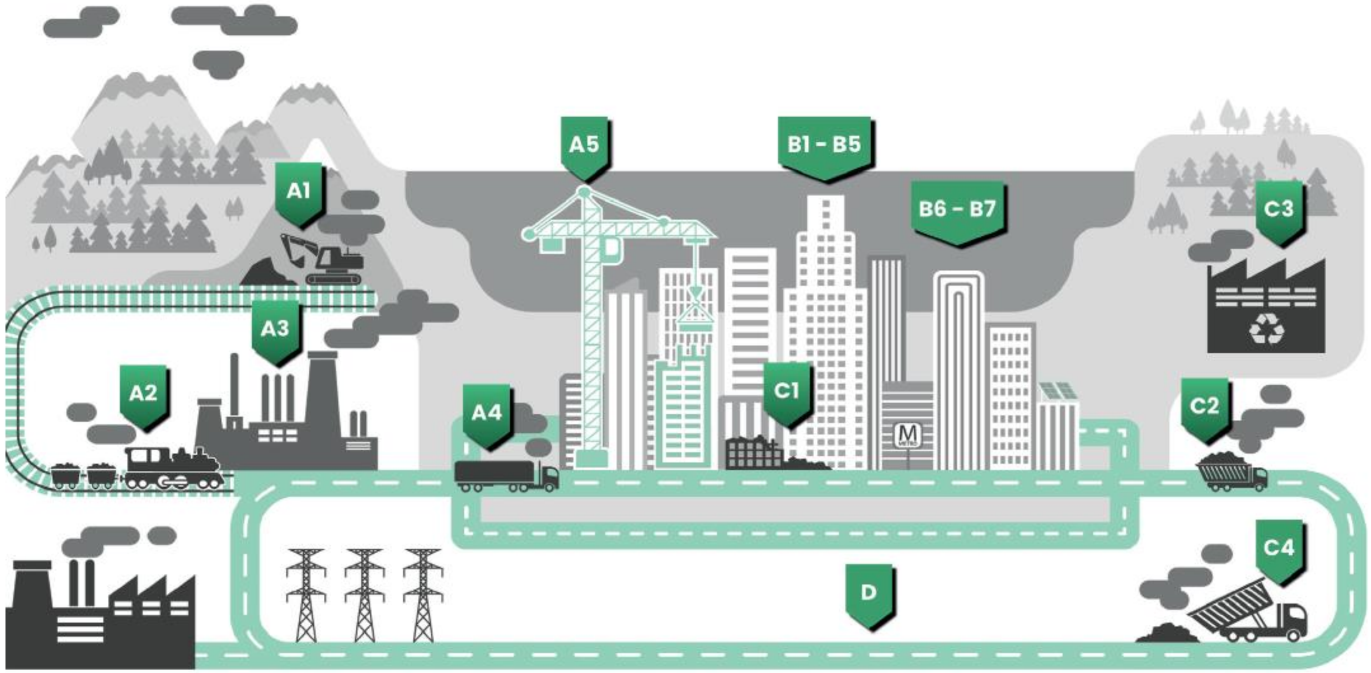
The different periods of a building's life are known as its **life-cycle stages**. They are referred to as **product, construction, use, end-of-life and benefits beyond the system boundary.**

The processes involved in the life-cycle stages of a building releasing gaseous, solid, and liquid emissions into the air, water, or soil can negatively impact the environment and humans.



A1 – A3 Product stage
- A1 Raw material extraction
- A2 Transport to manufacturing site
- A3 Manufacturing

A4 – A5 Construction stage
- A4 Transport to construction site
- A5 Installation / Assembly

B1 – B7 Use stage
- B1 Use
- B2 Maintenance
- B3 Repair
- B4 Replacement
- B5 Refurbishment
- B6 Operational energy use
- B7 Operational water use

C1 – C4 End of life stage
- C1 Deconstruction & demolition
- C2 Transport
- C3 Waste processing
- C4 Disposal

D – Benefits and loads beyond system boundary

Reuse, recovery and/or recycling potentials, expressed as net impacts and benefits

Source: OneClick LCA

“What cannot be measured, cannot be improved”

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- Life Cycle Assessment (LCA) is a methodology that quantitatively analyses and **evaluates the potential environmental impacts of any type of product**, process or service throughout its entire life cycle, or parts of it.

- The environmental impacts of a building, system or construction product can be measured in certain sections of its life cycle, these sections are:

  - **“From the cradle to the door”.** This is the “product stage”, comprising the extraction and processing of raw materials, transport to the factory and manufacturing.
  - **“From cradle to site”:** Comprises the “product stage” plus the “construction stage”.
  - **“From the cradle to the grave”.** It covers the complete life cycle, including demolition and valuation as waste.
  - **“From cradle to cradle”** is the life cycle of the complete product taking into account its reinsertion in the production chain if it is reused or recycled.

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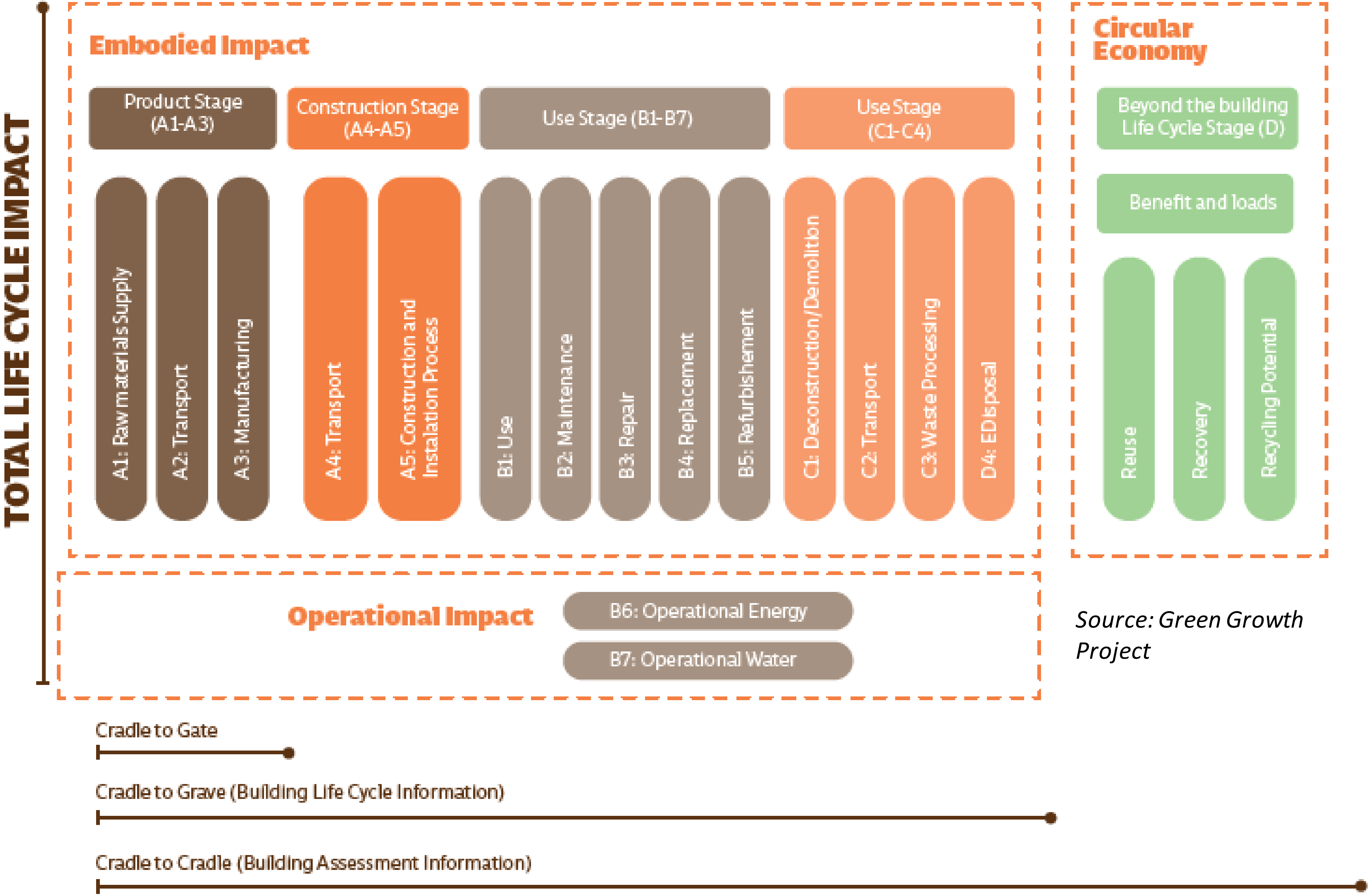

Source: Green Growth Project

Construction impact

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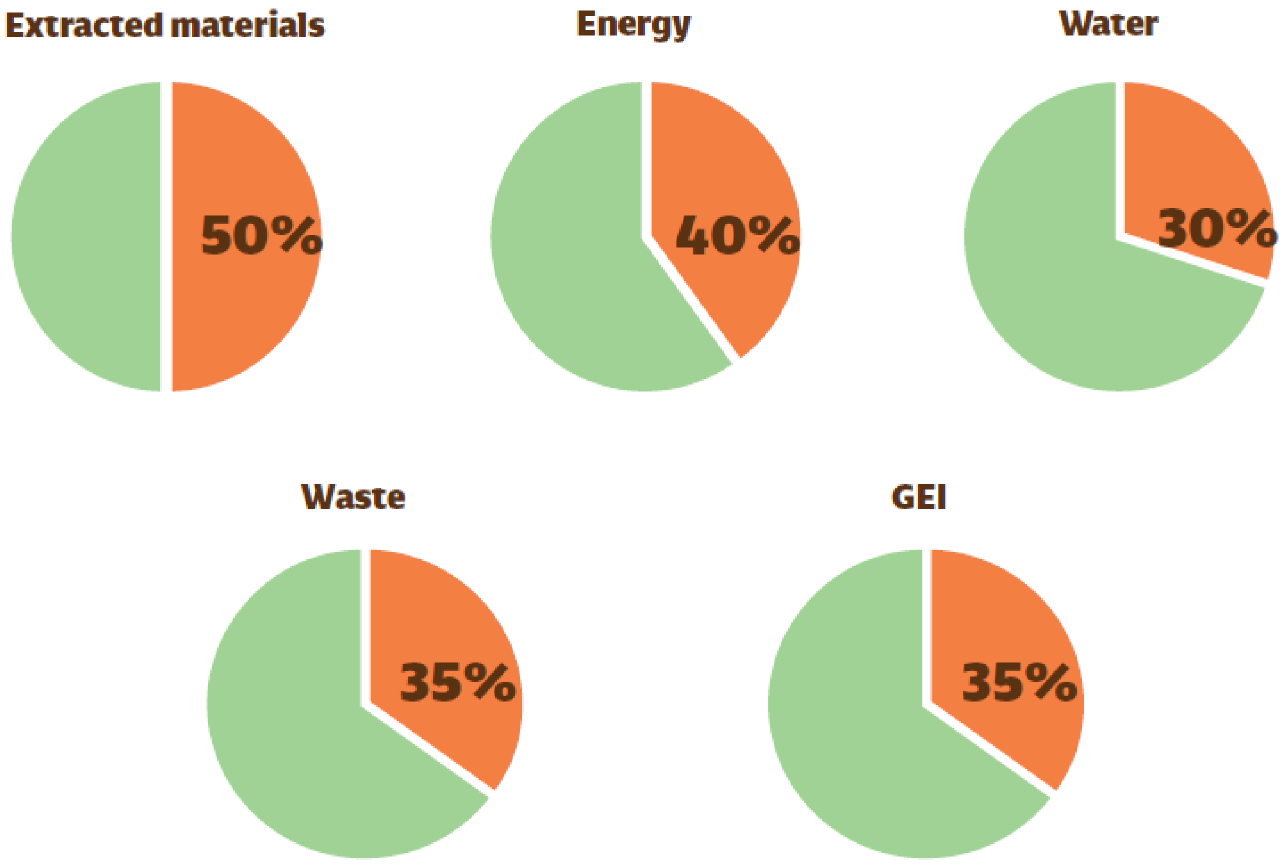
In Europe, in recent years, the data on the impact of the construction sector are as follows:



Impacts of the construction sector in Europe. Data source: Eurostat 2016 data. Green Building Council Spain. 2021. Report on circular economy in building in Spain

Source: Green Growth Project

Benefits of carbon reductions

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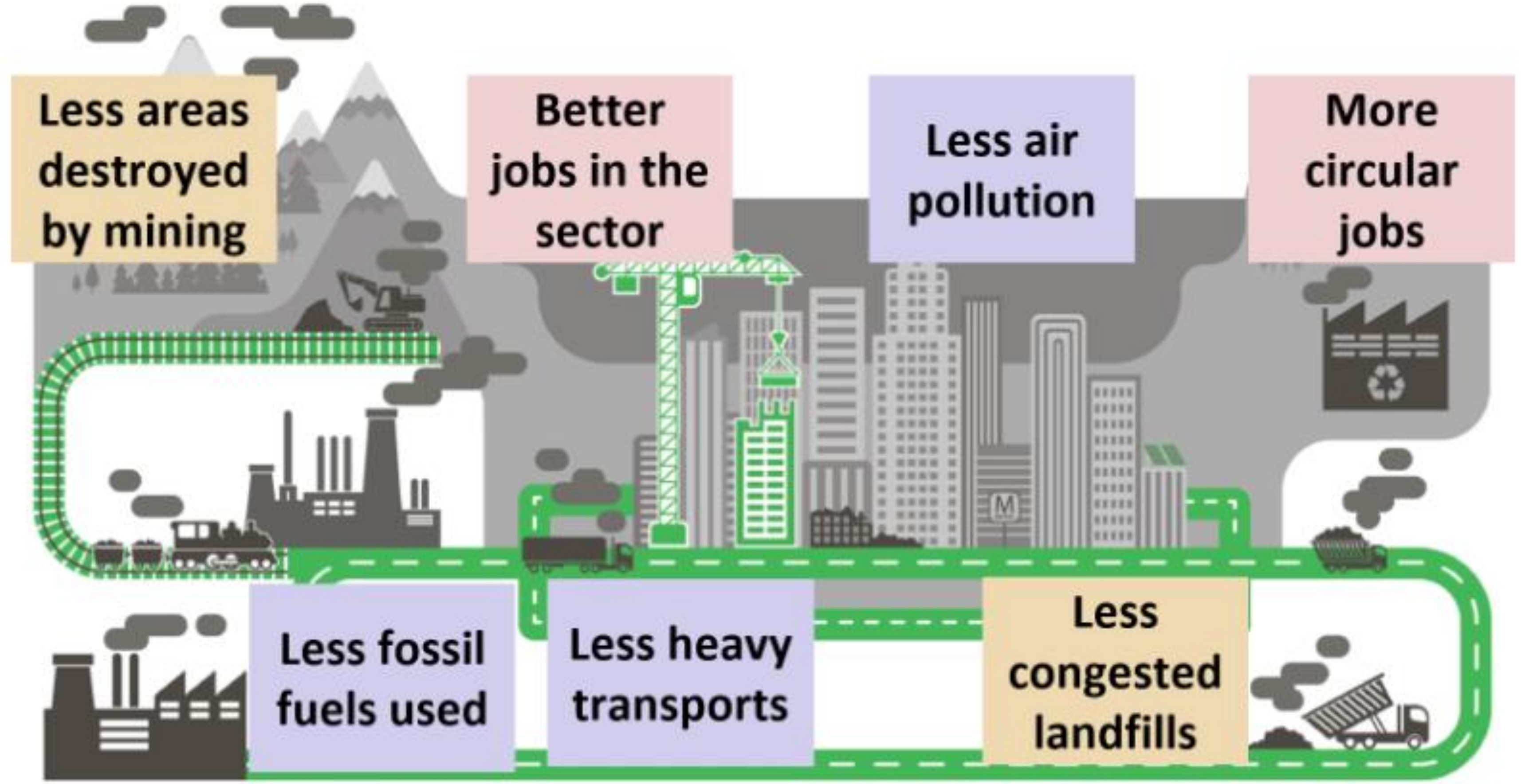

Embodied carbon reductions benefit the broader society in many ways.

How to perform a building LCA

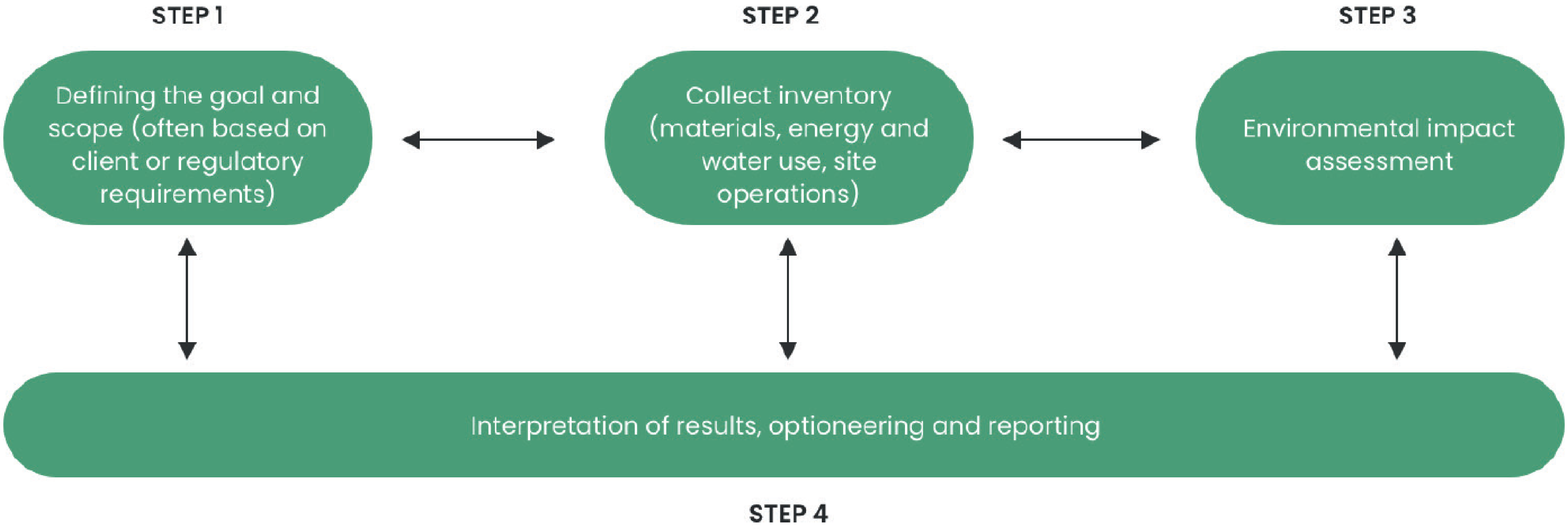

Fig. 7. Steps involved in conducting a building LCA

Source: OneClick LCA

Step 1: Define goal and scope

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Several reasons for conducting a building LCA include **quantifying emissions, achieving certifications, and complying with regulations**.
They often define the goal and scope of the analysis as described below.

Defining goal
The general goal is to measure and reduce a building's environmental impact, but specific goals can be identified based on specific requirements (eg complying with regulations)

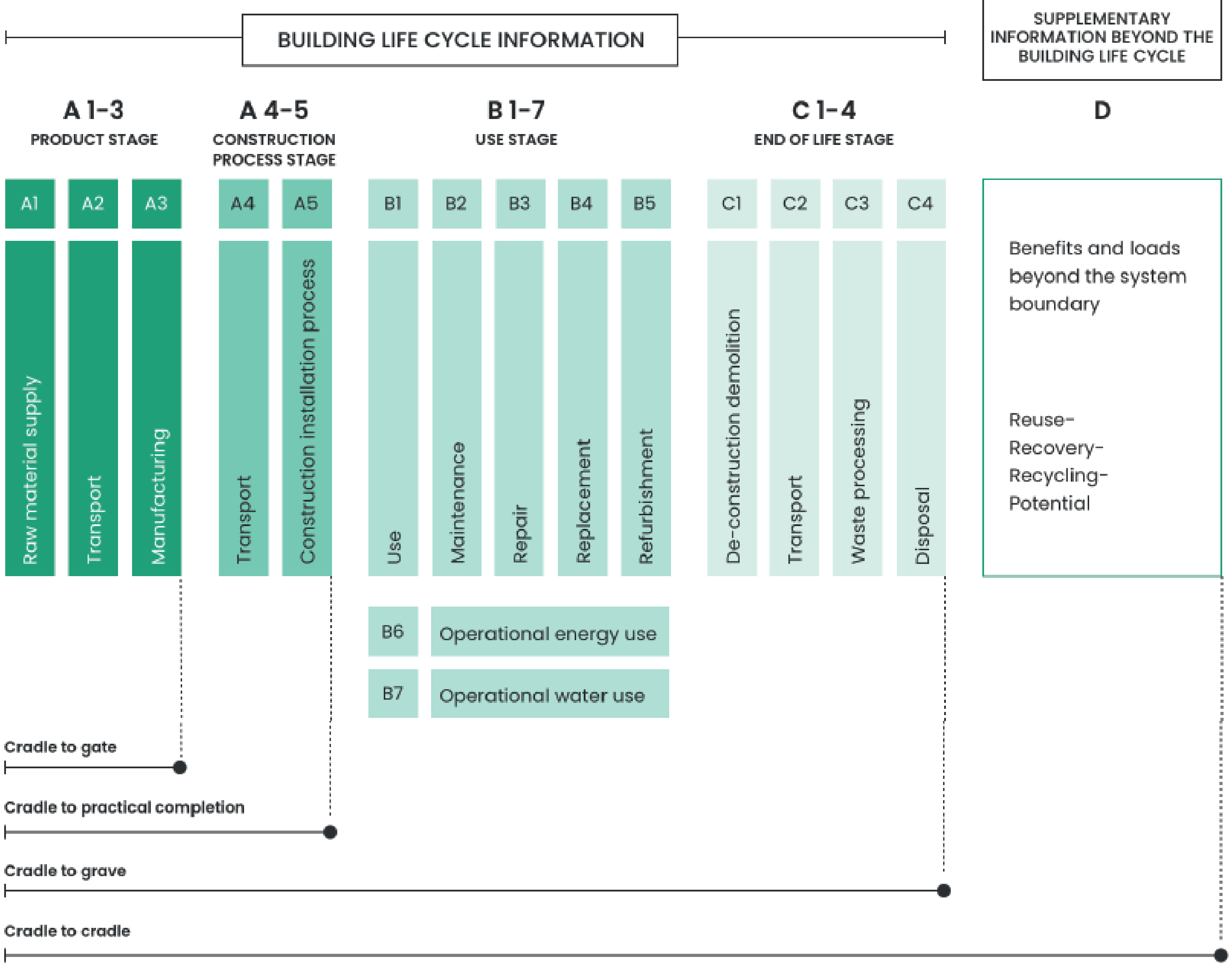
Defining scope
The LCA scope defines the areas to be included or excluded from the LCA analysis, and is usually defined by the overall goal. For example, if the goal does not require the evaluation of whole-life carbon, the extent of the analysis can be limited.

Source: OneClick LCA

Scope

For building LCA, the **life-cycle scope** is specified according to the standardised module designations (A1, A2, A3... Through to D) as defined in EN 15804 and ISO 21930.

Life-cycle scope specified according to the standardised module designations



Source: OneClick LCA

Scope

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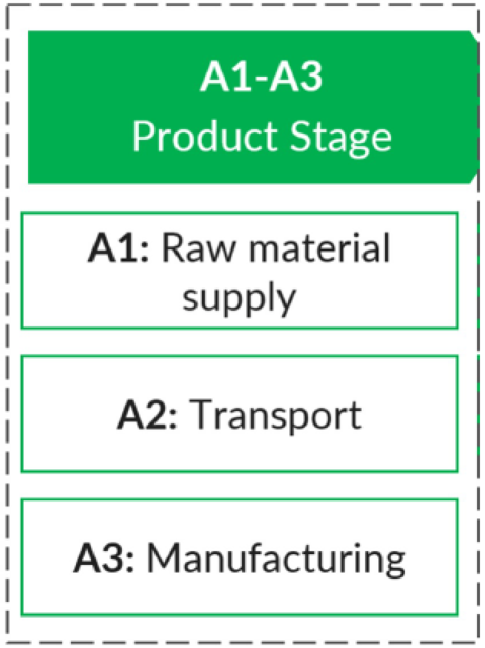
A1-A3 (Product Stage)

Reporting of different life-cycle stages depend on the certification or scheme, A1-A3 is **mandatory in most cases**.

- Calculated by including material quantities which are linked to **EPDs** (explained later in this presentation)



A4 & A5 (Construction process)

Stages A4 & A5 include all impacts and aspects related to any **losses during the construction process stage** (e.g. production, transport, waste processing and the disposal of lost products and materials).

- A4 emissions include the transport to the construction site
- A5 emissions include the installation / assembly of the building

Scope

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B1 – B7 (Use Stage)

Use stage emissions include the use or application of installed products (e.g. refrigerants), maintenance, repair, replacement, refurbishment (often grouped with B4), operational energy usage (heating, services) and operational water use.

C1 – C4 (End of life stage)

End of life stages are emissions which happen after and during the building or asset is demolished. The emissions of these stages depend heavily on how materials are handled during this phase.

D – (Benefits and loads beyond the system boundary)

Module D includes the reuse, recovery and or recycling potentials. Module D allows supplementary information beyond the building lifecycle to be considered and is consistent with a Cradle-to-Cradle (C2C) approach

Step 2: Collect inventory

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The information needed to perform building LCA is known as the life-cycle inventory (LCI).
The inventory can be broadly classified into building **materials and operations.**

Building Materials: Includes information about the type, quantity, lifespan, and life-cycle stage of the building in which the material is used.
This information can be generally obtained from cost plans, drawings, **and BIM models.** Design tools such as Revit, Tekla, Rhino and Grasshopper can be used for material quantities related information.

Building operations: Includes transportation details, material replacements, energy and water consumption, and end-of-life scenarios.
This information can be obtained from designers, contractors, and project owners. The energy consumption can be tracked separately using energy tools such as IES, Design Builder, IDA ICE, etc.

LCA tools, such as One Click LCA, can simplify the inventory collection process by **importing materials**, providing ready-to use scenarios and database. One Click LCA can support integration with **design data from BIM**, IES-VE, Excel and more.

Source: OneClick LCA

LCA Data

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- Once the building information-related queries are filled in, **mapping each material to its respective environmental profile** is the next step.

- This process is simplified by using **LCA data** which contains information about the environmental impacts of each material of interest.

- An **Environmental Product Declaration (EPD)** provides an independently verified summary of the environmental impact of a product throughout its life-cycle, calculated via LCA.

- Single product EPDs are the most common type, but group and industry average EPD are available.
    1. **Single product and manufacturer EPD:** One product and manufacturer.
    2. **Product group EPD:** Average of very similar products, one manufacturer.
    3. **Industry average EPD:** One product and several manufacturers.

Source: OneClick LCA

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GENERAL INFORMATION

MANUFACTURER INFORMATION

Manufacturer	Rearden Steel
Address	Philadelphia, Pennsylvania, United States
Contact details	John Galt john.galt@reardensteel.com
Website	www.reardensteel.com

PRODUCT IDENTIFICATION

Product name	Rearden Metal
Product number / reference	RM-001
Place(s) of	Philadeplhia, PA, United States

EPDs of construction products may not be comparable if they do not comply with EN 15804 and if they are not compared in a building context.

EPD program operator	Program operator name here
EPD standards	This EPD is in accordance with EN 15804+A2 and ISO 14025 standards.
Product category rules	The CEN standard EN 15804+A2 serves as the core PCR. Program operator PCR here.
EPD author	Bionova Ltd, Suvilahdenkatu 10 B, 00500 Helsinki, Finland
EPD verification	Independent verification of this EPD and data, according to ISO 14025: ☐ Internal certification ☒ External verification
EPD verifier	Werner Verifier
EPD number	00001
ECO Platform nr.	-

ADDITIONAL ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	D
Particulate matter	Incidence	3.16E-06	2.86E-07	1.40E-07	3.59E-06	3.54E-07	MND	MND	4.10E-07	2.26E-07	2.14E-06	8.76E-06	-1.02E-06
Ionizing radiation, human health	kBq U235e	3.66E+00	3.09E-01	2.10E+00	6.07E+00	3.92E-01	MND	MND	9.99E-02	2.44E-01	1.51E-01	6.33E-02	-1.20E+00
Eco-toxicity (freshwater)	CTUe	1.77E+01	2.10E+00	2.03E-01	2.01E+01	2.74E+00	MND	MND	1.20E-01	1.70E+00	1.82E-01	8.80E-02	-2.14E+00
Human toxicity, cancer effects	CTUh	8.81E-08	1.22E-09	1.11E-09	9.04E-08	1.54E-09	MND	MND	4.29E-10	9.59E-10	6.43E-10	1.96E-10	-5.48E-08
Human toxicity, non-cancer effects	CTUh	2.21E-06	7.09E-08	7.74E-08	2.36E-06	9.76E-08	MND	MND	6.96E-09	6.07E-08	1.26E-08	7.45E-09	-8.45E-07
Land use related impacts/soil quality	-	8.20E+02	6.48E+01	1.56E+00	8.86E+02	8.19E+01	MND	MND	3.41E-01	5.08E+01	5.15E-01	9.79E+00	-3.58E+01

EN 15804+A2 disclaimer for Ionizing radiation, human health. This impact category deals mainly with the eventual impact of low dose ionizing radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionizing radiation from the soil, from radon and from some construction materials is also not measured by this indicator.

ENVIRONMENTAL IMPACTS - TRACI 2.1

Impact category	Unit	A1	A2	A3	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	D
Global warming potential	kg CO2e	9.42E+01	3.88E+00	2.74E+00	1.01E+02	4.92E+00	MND	MND	1.58E+00	3.06E+00	2.39E+00	4.95E-01	-1.22E+01
Ozone depletion	kg CFC11e	4.32E-06	9.51E-07	5.60E-07	5.83E-06	1.21E-06	MND	MND	3.64E-07	7.51E-07	5.51E-07	2.21E-07	-1.02E-06
Photochemical smog formation	kg O3e	2.73E-01	7.49E-03	8.51E-03	2.89E-01	9.51E-03	MND	MND	2.22E-03	5.91E-03	3.36E-03	2.00E-03	-4.52E-02
Acidification	kg SO2e	1.73E-01	3.87E-03	4.42E-03	1.82E-01	4.66E-03	MND	MND	9.87E-04	2.89E-03	1.46E-03	7.40E-04	-5.90E-02
Eutrophication	kg Ne	3.35E+00	7.58E-02	1.50E-01	3.58E+00	9.75E-02	MND	MND	2.24E-02	6.06E-02	3.38E-02	2.90E-02	-5.41E-01
Depletion of non-renewable energy	MJ	3.97E+01	8.52E+00	4.54E+00	5.27E+01	1.08E+01	MND	MND	3.25E+00	6.72E+00	4.92E+00	2.65E+00	-9.02E+00

Left: Sample EPD generated with One Click LCA EPD generator

LCA Data

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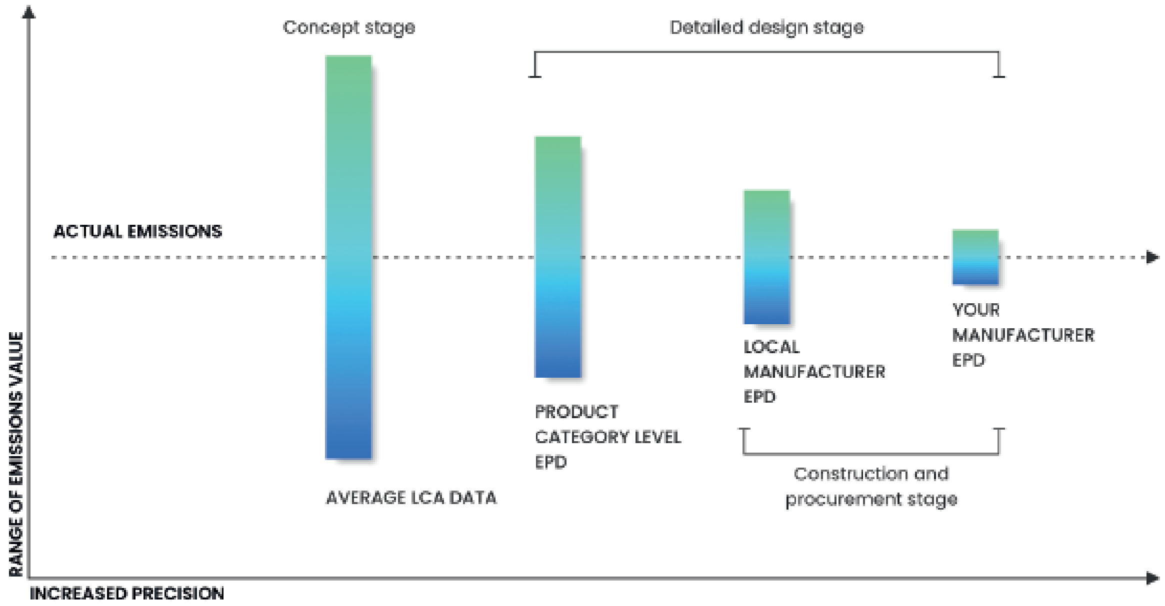
When selecting building material data for LCA calculations, the principle is always to choose the most appropriate and highest accuracy option.
Data should be used in the following **order of priority:**

1. EPD of the product from the specific manufacturer, if available.
2. Technically similar product data from a local manufacturer if the manufacturer is not confirmed yet.
3. Product category level EPD or LCA.
4. Average LCA data for the product in question (same product from different manufacturers)



Source: OneClick LCA

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Where do I find LCA Data?

- LCA data can be obtained from EPD program publishers or a **building LCA database (such as One Click LCA)**.

- It is essential to have an accurate and robust database to get accurate results and identify the best material alternatives. For example, during the design phase, it helps to compare the environmental performance of building materials before finalizing the design.

To view some EPDs..

SCAN ME

https://www.epdhub.com

Source: OneClick LCA

LCA Data for different project stages

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- Individual products of any building material type have significant variations in environmental performance, which is reflected in their EPDs.
- Generic data represents average environmental performance for all products within that category.
- During the concept design phase it is best to use generic data, rather than a specific single product EPD, to avoid making design decisions based on the performance of a single product that may not be representative.
- EPD data can be used when you are ready to buy the material from a specific supplier. For example, the level of detail required for the construction material steel increases as the project progresses.

Source: OneClick LCA

The use of data depends on the stage of the project .

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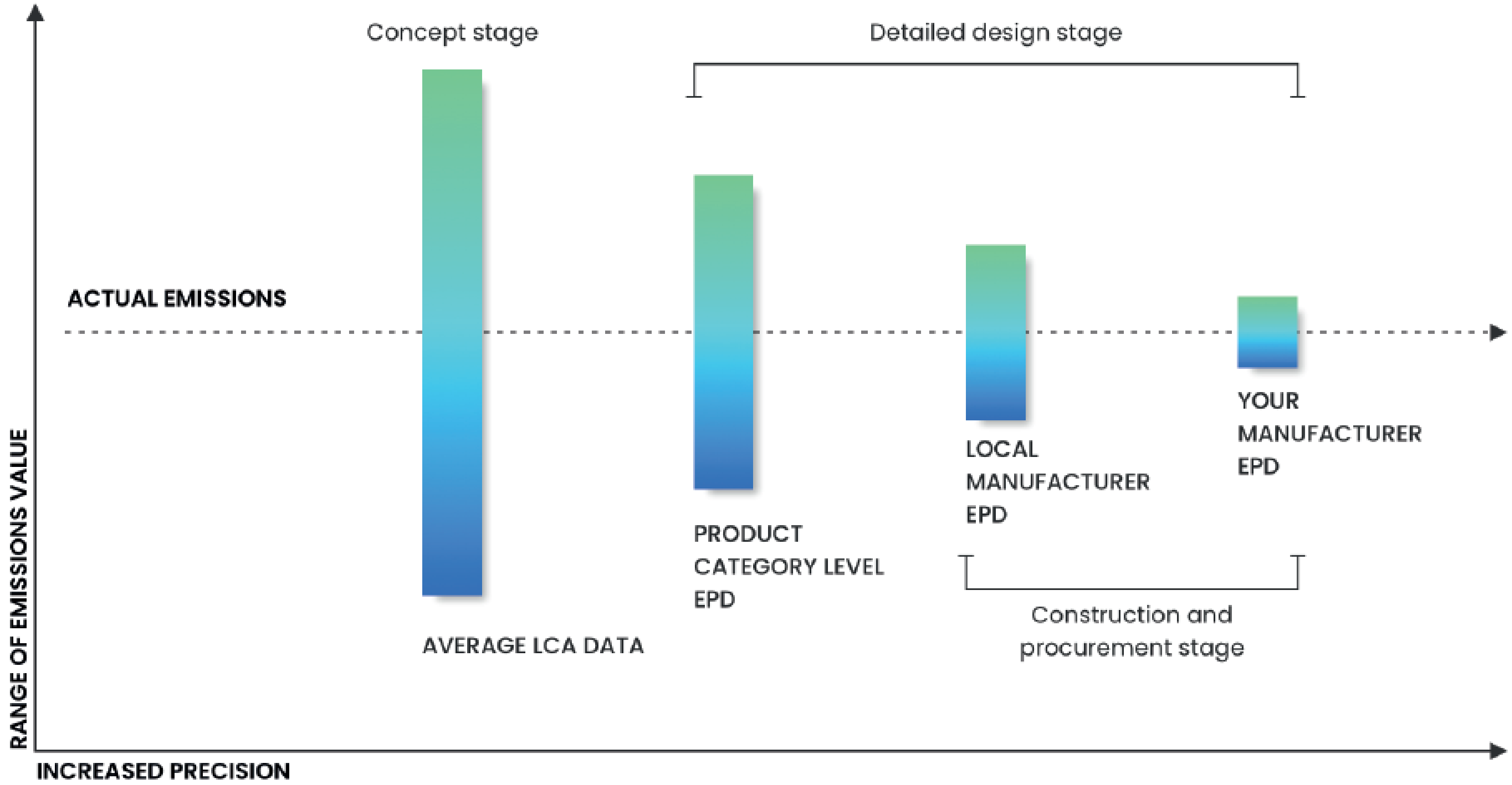

E.g. The level of detail required for the construction material steel increases as the project progresses

Source: OneClick LCA

Carbon reduction potential at each stage

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LCA performed early in the design process results in the highest carbon reductions and lowest costs.

As the project progresses, the ability to reduce carbon decreases drastically.

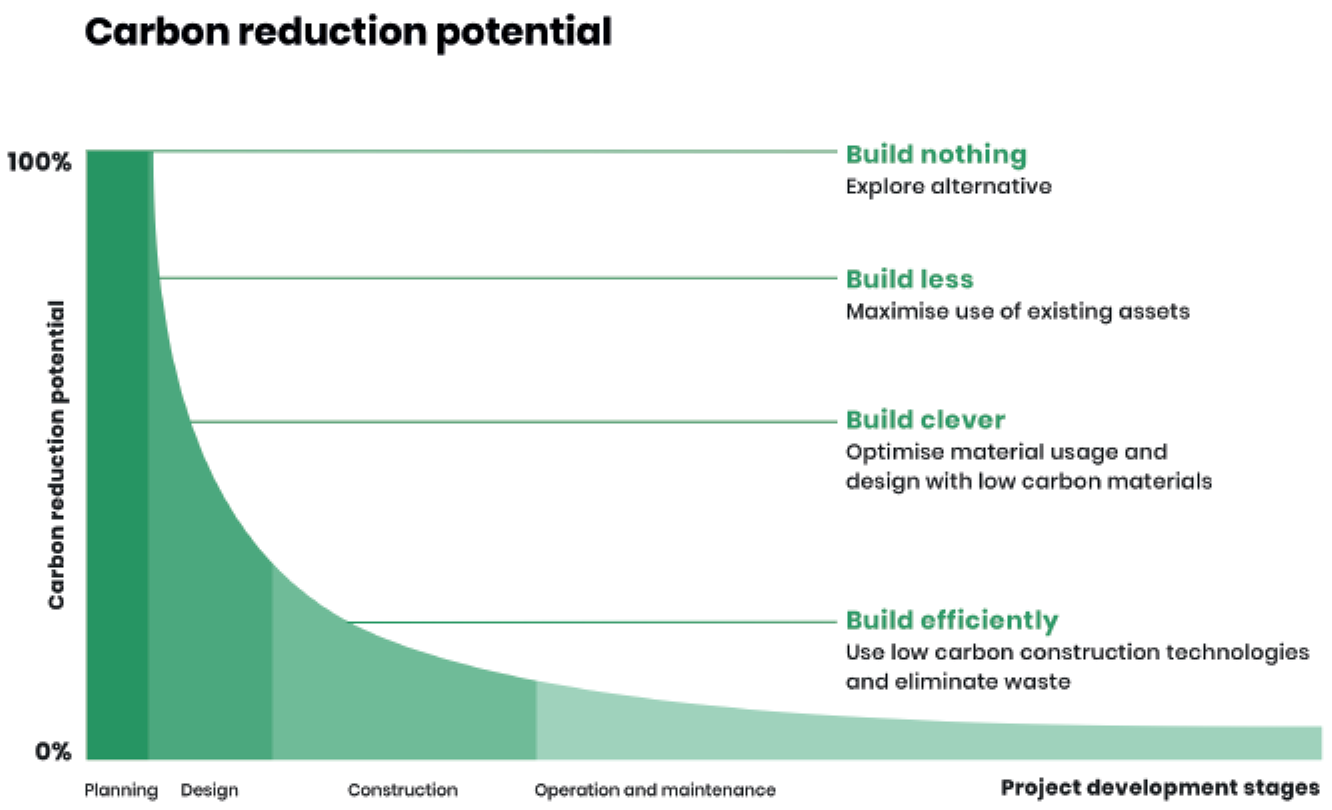

Fig 6. Opportunities to reduce embodied carbon reduces as the project progresses (Decarbonizing construction, 2021, WBCSD)

Source: OneClick LCA

Step 3: Impact Assessment

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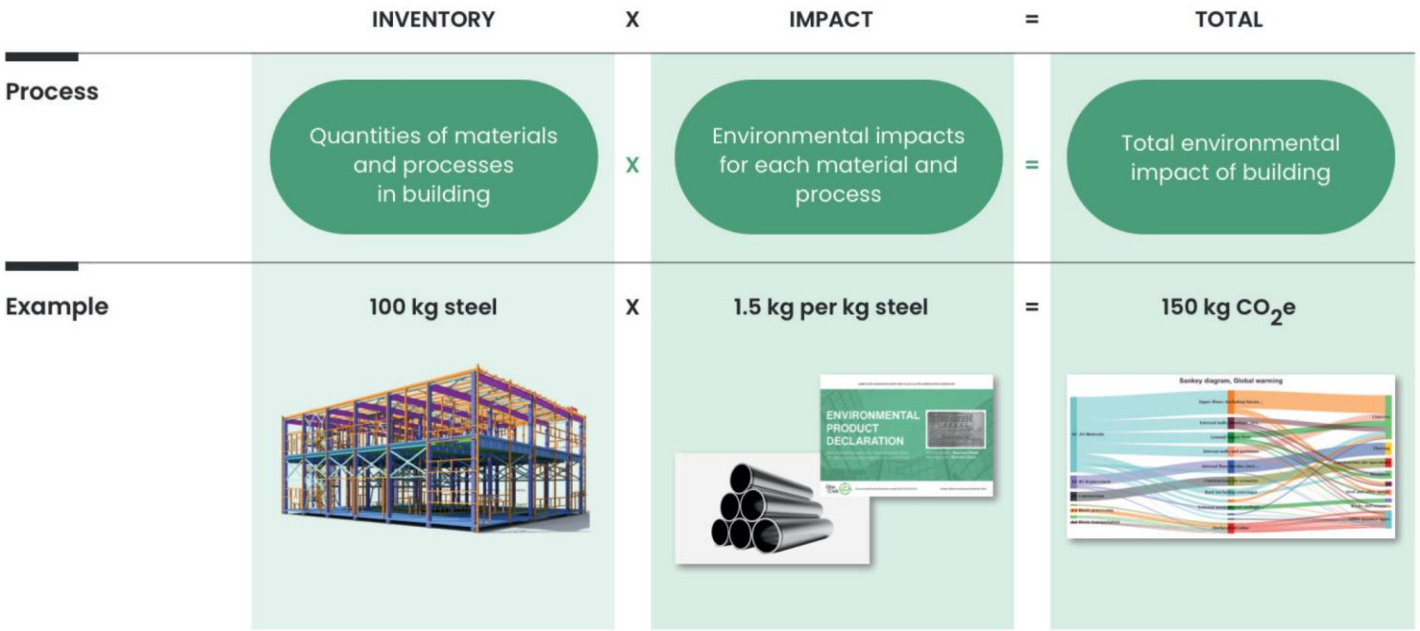
- The overall environmental impact of a building is calculated by performing an Impact assessment.
- The results are expressed as impact categories based on the scope of the LCA.
- For example, the **Level(s)** assessment requires a reporting of GWP, AP, EP, ODP, POCP, and biogenic carbon.

Impact assessment is carried out by **multiplying the life-cycle inventory (LCI) with the appropriate impacts for each material or process** during the life-cycle impact assessment step.
The environmental profile of the inventory is obtained from the respective EPDs or generic data.



Left: Example of impact assessment calculations

LCA tools such as One Click LCA can fully **automate the calculation of impacts** from building materials, scenarios and can **give results by life-cycle stage and building component**.

Summary: Simplified steps for how LCA is performed

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After the scope is defined…

1. Find out the details of the type of building, life cycle (60 years) and size, as well as geometry (optional)
2. Collect the material information.
3. Import details from models, cost plans, Carbon Designer or add manually per material layer or constructions.
4. Add energy use (SBEM, SAPs), water use (water calculations for BC or BREEAM), construction site operations (actual data or scenarios), repair in % and withdrawals
5. Check the results, do optioneering, complete report

Visualising building LCA

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- By performing a building LCA, you can identify and analyse the environmental **impacts distributed across life-cycle stage, materials, and structural elements**.
- Once the environmental impacts and hotspots have been identified, you can optimise your designs and make informed decisions to lower the impacts of your project.
- To understand how this works in practice, we will look at the results of an example building LCA project carried out according to the EN 15978 standard using One Click LCA software.

Source: OneClick LCA

Impacts from life cycle stages

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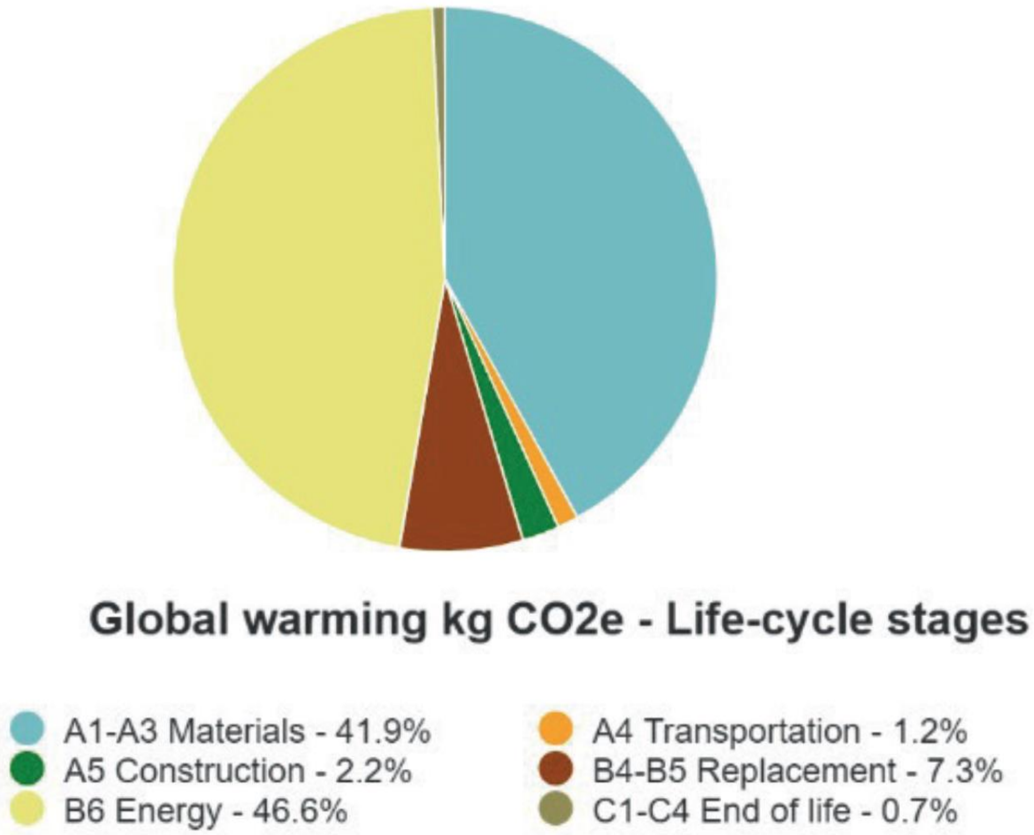
- This chart illustrates an example of how Global Warming Potential (GWP) is distributed among the different life-cycle stages of a building.

- The results imply that efforts must be focused on the product stage of the building to reduce the GWP.

Other environmental impacts measured per life-cycle stage are shown on the following slides.

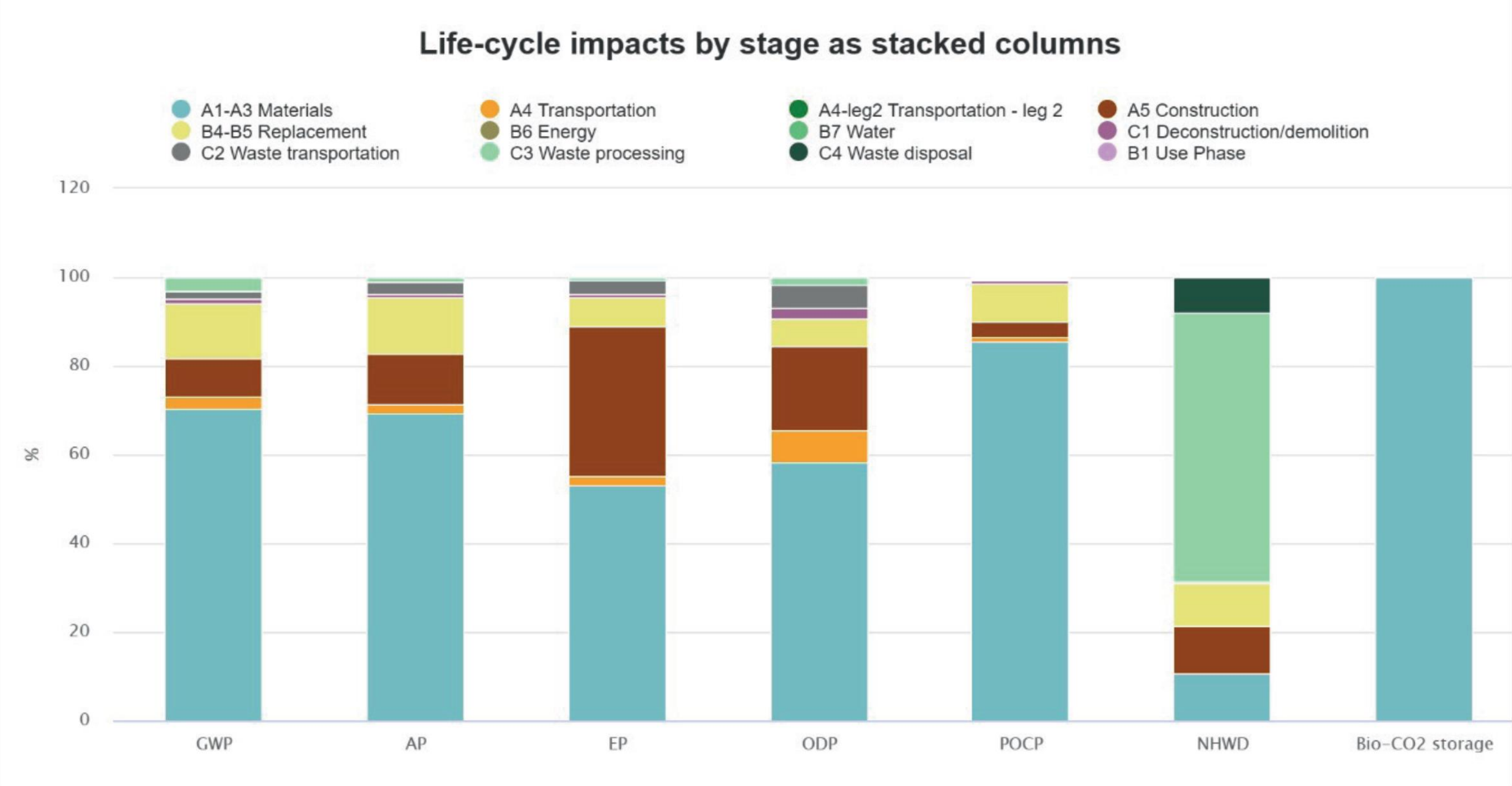
Construction materials (product stage) contribute to most of the impacts irrespective of the environmental impact category.



Source: OneClick LCA

Distribution of environmental impacts across different life-cycle stages

Co-funded by the Erasmus+ Programme of the European Union



Source: OneClick LCA

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Impacts from building materials

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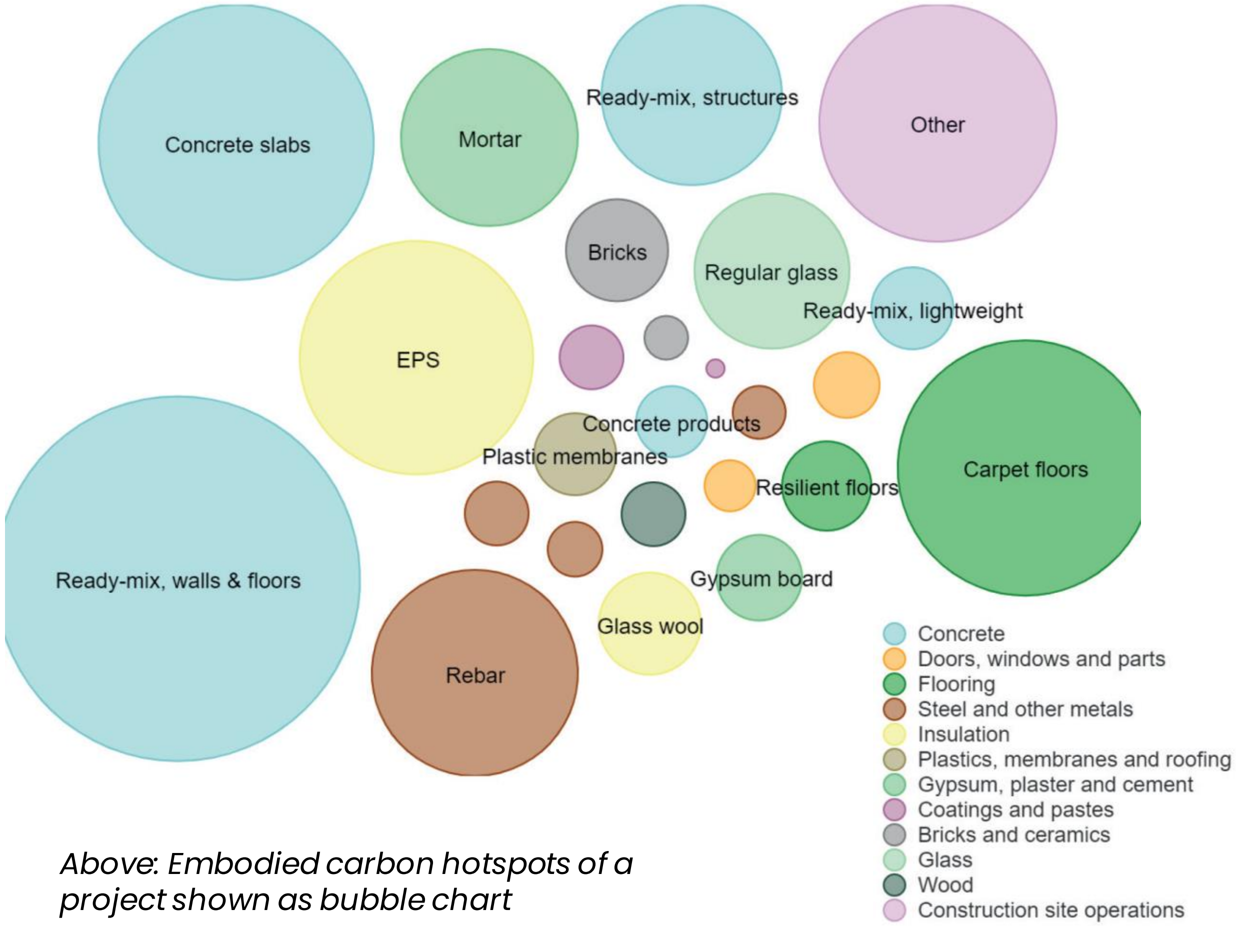
- Building materials are significant sources of emissions.
- Carbon emissions released before using a building (**upfront carbon**) are of great concern as they are irrevocably released before construction.
- Building LCA results can show which materials have high environmental impact



Above: Embodied carbon hotspots of a project shown as bubble chart

Source: OneClick LCA

Design Alternatives

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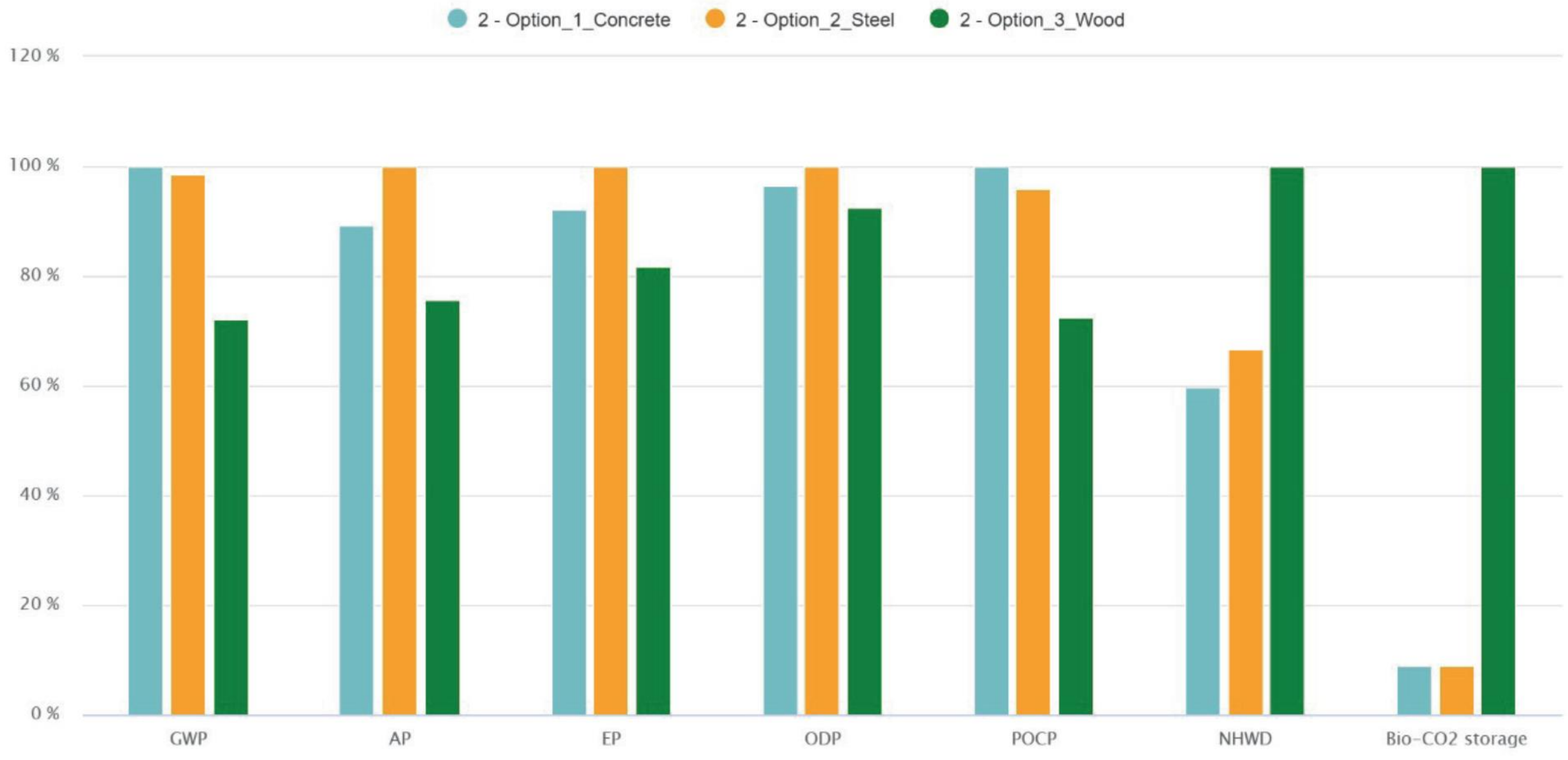
- Comparing the **impacts of different design alternatives** is helpful for decision-making.
- For example, the same building constructed with concrete, steel, or wood will differ in environmental impact, as shown below

Design optioneering can help in reducing emissions



Source: OneClick LCA

Standards governing building LCA

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- Building LCA is performed according to international standards **(ISO 14040, 14044, or EN 15978).**
- These standards (below) ensure transparency and consistency, meaning that the results obtained from an LCA are robust and widely respected.

Cornerstone standards	Construction works specific standards	EPD standards
ISO 14040 (fundamentals for LCA)	EN 15978 – LCA standard for construction projects (European standard, basis for all EU regulations)	ISO 14025 – cornerstone standard for all kinds of EPDs
ISO 14044 (fundamentals for LCA)	ISO 21929-1 and ISO 21931-1 (less used LCA standards)	EN 15804 (EPD data) and EN 15942 (EPD format) (European standard, basis for all EU regulations) ISO 21930

Source: OneClick LCA

Conclusion

- The adoption of LCA by the construction sector, came as a result of increasing awareness of the environmental impact of buildings and followed a backlash against greenwashing and vague eco-labelling.

- In short, performing a building LCA is **the only reliable way to evaluate the sustainability of a building**.

Image source: Blue North

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2. LCA and Level(s)

Introduction to Level(s)

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- Level(s) is a common framework for sustainable buildings across Europe.

- **It is an assessment and reporting tool for sustainability performance of buildings,** firmly based on circularity.

- As we respond to the Paris Agreement's demand that the building and construction sector **decarbonise by 2050**, Level(s) supports the essential **assessment over the full lifecycle** through design, construction, use, and end of life.

- Building upon the objectives of both the EU Green Deal and the EU Circular Economy Action Plan, Level(s) supports the efforts of the building sector **in improving energy and material efficiency**, thereby reducing overall carbon emissions

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Introduction to Level(s)

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- Level(s) uses core sustainability indicators to measure carbon, materials, water, health, comfort and climate change impacts throughout a building's full life cycle.

- It is a flexible solution for identifying sustainability hotspots and for future-proofing a project or portfolio.

- By using Level(s) you are contributing to EU policy goals to strengthen the sustainability of Europe's buildings, which are responsible for:

  - 1/2 of all extracted materials
  - 1/2 of total energy consumption
  - 1/3 of water consumption
  - 1/3 of waste generation.

- Level(s) is open source and freely available to all

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Introduction to Level(s)

- International sustainability certification tools are aligning their schemes to Level(s), ensuring common EU policy objectives are integrated.


European Commission

JRC TECHNICAL REPORTS

Level(s) – A common EU framework of core sustainability indicators for office and residential buildings

Parts 1 and 2: Introduction to Level(s) and how it works (Draft Beta v1.0)

Nicholas Dodd, Mauro Cordella, Marzia Traverso, Shane Donatello (Unit B5)

August 2017

Beta version

How does Level(s) work?

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- Level(s) is based on six **macro-objectives.** These can be tracked through sixteen **indicators.**

- The **six macro-objectives** address key sustainability aspects over the building life cycle.

- The sustainability **indicators** within each macro-objective describe how the building performance can be aligned with the strategic EU policy objectives in areas such as energy, material use and waste, water, indoor air quality and resilience to climate change. The following slides will explain what each entails.

Source: EU Academy

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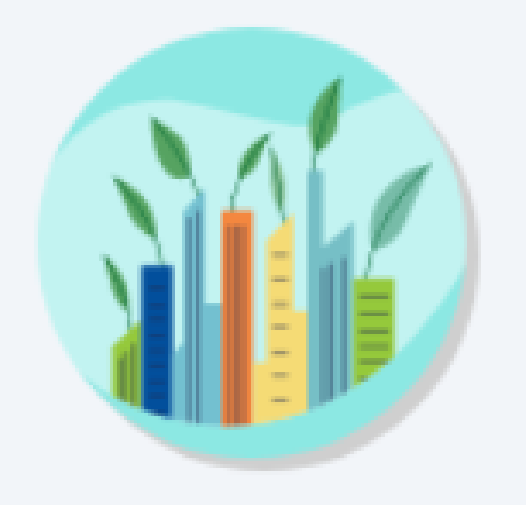
Macro Objective 1: Greenhouse gas emissions along a building's life-cycle

Intention: to minimise whole life cycle carbon emissions, taking into account both energy consumption during the use stage of the building and embodied energy in building materials and construction products.

Indicators:

1.1 Use stage energy performance.

1.2 Life cycle Global Warming Potential.



Source: EU Academy

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<u>Macro Objective 2:</u> Resource efficient and circular material life cycles

<u>Intention:</u> to optimise the building design to support lean and circular product and material flows, including:

- Quantification of construction products and materials used.
- Planning, estimation and monitoring of circular outcomes for construction and demolition waste generated.
- Assessment and scoring of the adaptability of building designs.
- Assessment and scoring of the potential for deconstruction in building designs as opposed to demolition.

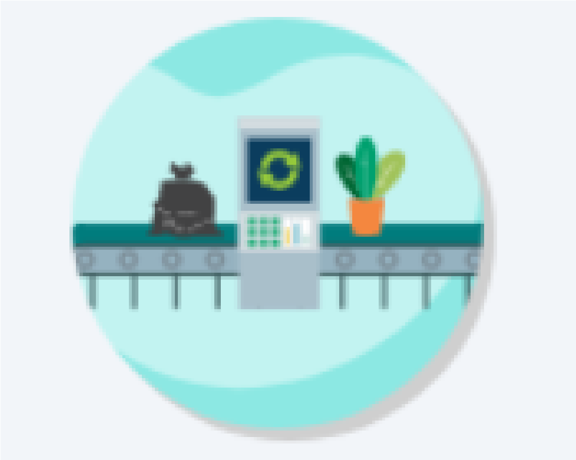
<u>Indicators</u>:

2.1 Bill of quantities, materials, and lifespans.

2.2 Construction & demolition waste and materials.

2.3 Design for adaptability and renovation.

2.4 Design for deconstruction.



Source: EU Academy

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Macro Objective 3. Efficient use of water resources

Intention: to use water efficiently, particularly in areas with identified long-term or projected water stress.

Indicator:

3.1 Use stage water consumption.

Source: *EU Academy*

TUS
Technological University of the Shannon: Midlands Midwest
Ollscoil Teicneolaíochta na Sionainne: Lár Tíre Iarthar Láir

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Macro Objective 4. Healthy and comfortable spaces

Intention: to create building spaces that are comfortable, attractive, and productive. This includes four aspects regarding the quality of the indoor environment:

- The quality of indoor air for specific parameters and pollutants.
- The degree of thermal comfort.
- The quality of artificial and natural light and associated visual comfort.
- The capacity of the building fabric to provide a comfortable acoustic environment for its occupants.

Indicators:

4.1 Indoor air quality.
4.2 Time outside of thermal comfort range.
4.3 Lighting and visual comfort.
4.4 Acoustics and protection against noise.

Source: EU Academy

5. Adaptation and resilience to climate change

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Macro Objective 5. Adaptation and resilience to climate change

Intention: to futureproof building performance:

- Adapt to future climate changes that will impact thermal comfort.
- Make the building more resilient and resistant to extreme weather events (including flooding: fluvial, pluvial and coastal).
- Improve the building design to reduce the chances of pluvial/fluvial flood events in the local and downstream area (i.e. incorporating sustainable drainage features).

Indicators:

5.1 Protection of occupier health and thermal comfort.

5.2 Increased risk of extreme weather events.

5.3 Sustainable drainage.

Source: EU Academy

6. Optimised life cycle cost and value

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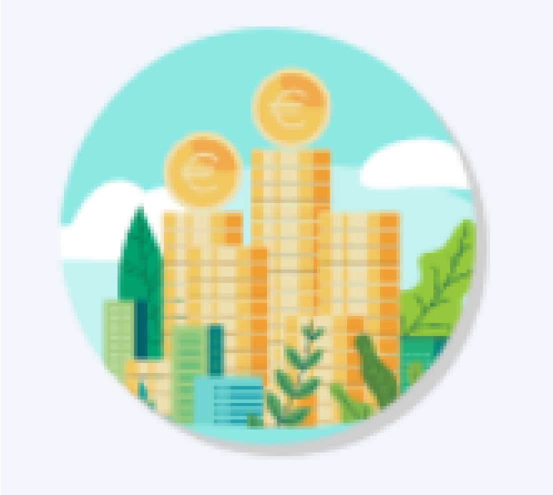
Macro Objective 6. Optimised life cycle cost and value

Intention: to gain a long term view of the whole-life costs and market value of more sustainable buildings, including:

- Life cycle costs (construction, operation, maintenance, refurbishment, and disposal).
- Encourage the integration of sustainability aspects into market value assessment and risk rating processes and ensure that this is done in as informed and transparent a way as possible.



Indicators:

6.1 Life cycle costs.

6.2 Value creation and risk exposure.

Source: EU Academy

Establish a Level(s) project plan

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To set up a project and use the Level(s) common framework, you must establish a **Level(s) project plan.**

- Once you have selected the macro-objectives and indicators to address, you next decide at which 'level' the project performance will be assessed.

- A design team could use different levels for the different indicators, use one or several levels for each indicator to follow the development of performance throughout the project.

- The more levels that can be addressed, the more complete the picture of the project's sustainability performance.

Source: EU Academy

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Learn more about Level(s)!

EU Level(s) User manuals:

- **User Manual 1** - introduction guide to Level(s). It provides detailed information on who Level(s) is for and how to use it.
- **User Manual 2** shows you how to set up a project according to the Level(s) methodology.

- All the user manuals and accompanying Level(s) documentation are available to download on the Level(s) website

For more courses on Level(s)..

- EU Level(s) academy
- Level(s) Building Sustainability Performance - Irish Green Building Council (igbc.ie)

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2. Certification

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By far, the most common goal for the use of building LCA is **decarbonizing the construction sector and ensuring competitiveness in an increasingly carbon-aware market**.

With the growing focus on sustainability, investors, end-users, and tenants are increasingly looking for ways to assess and reduce the lifetime environmental impact of their projects. **Conducting a building LCA demonstrates a commitment to measuring and reducing the environmental impact of construction projects.** It also provides sound market advantages for actors across the supply chain.

Depending on your role within the construction supply chain – investor, designer, engineer, or consultant – the business drivers for performing LCAs may vary.

Business case for LCA

Achieve certification

A building LCA can contribute toward achieving BREEAM, LEED, HQE, E+C- or other green building certifications.

Its results must be tailored to the relevant scheme, including life-cycle stages, impact indicators, benchmarking, and more.

List of green building certifications

Certifications	Requirements
BREEAM International (Similar to BREEAM Sweden, Norway and Spain) BREEAM	Perform a high-quality whole building LCA analysis.
LEED	Complete a whole building LCA. Additional credits are awarded based on the demonstrated impact reductions and by incorporating building reuse and/or salvage materials into the project's scope of work.
DGNB DE, DGNB International and DK DGNB	Perform a whole building LCA and demonstrate impact reductions.
Energie Carbone	Undertake a whole life-cycle assessment for the building permit and post construction. The assessment accounts for materials, construction site, energy, and water impacts. The results are then benchmarked against carbon level thresholds.
Level(s) Level(s)	Measure GHG across a building's life cycle, demonstrate resource-efficient and circular material life-cycles, optimize life-cycle cost and value.

LCA for green certification

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The scope can be restricted to meet the requirements (of certifications or regulations), as shown below:

Scope	Cradle-to-gate	Cradle-to-grave	Cradle-to-cradle
Life-cycle stages	A1-A3	A1-C4	A1-D
Examples	Product LCA	LEED	BREEAM, RICS, GLA

Source: OneClick LCA

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QUIZ!

Thank You

Insert Organiser Logo Here
For illustrative purposes only delete this shape from final presentation

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