KPIS FOR CIRCULARITY, LIFE-CYCLE PERFORMANCE AND TECHNICAL AND FUNCTIONAL REQUIREMENTS FOR INBUILT'S PLATFORM

ITeC

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1. Introduction

1.1. INBUILT: Goals and objectives

The INBUILT project seeks to transform the construction industry towards a more sustainable and circular model, in response to the environmental challenges facing the sector, such as high resource consumption and waste generation. Instead of following a traditional linear model of construction, demolition and disposal, the circular approach promotes the reuse, recycling and regeneration of natural products, materials and systems. This involves the integration of circular economy principles, rapid digitalization and industrial solutions, through the massive use of data and tools such as Building Information Modelling (BIM) and Integrated Project Delivery (IPD). These advances are key to optimizing resource efficiency, reducing costs and improving transparency, facilitating the transition towards more sustainable construction.

In this context, INBUILT addresses two key challenges: the high carbon footprint of construction and the limited adoption of innovations. The project drives the decarbonization of the sector and the transition towards circular business models, promoting profitability, job creation and the industrialization of sustainable solutions. Through a digital platform, the design of reusable and recyclable components is optimized, applied both in new constructions and in the renovation of existing buildings. This comprehensive approach seeks to reduce environmental impact, increase resource and energy efficiency, and facilitate compliance with the objectives of the European Green Deal, driving a lasting transformation in the construction sector.

1.2. Monitoring and assessment of impacts

The construction sector has a significant impact on the planet, accounting for 30% of natural resource extraction, 25% of solid waste generation and 40% of greenhouse gas emissions. Therefore, it is essential to consider the environmental impact of future construction solutions.

The importance of developing the 10 innovative design products that integrate local resources and waste of biological, geological/reused and recycled origin with multifunctional designs will be key to meet the different needs of the market.

INBUILT wants to take this research further with the application of a coherent BIM-based workflow to adapt, simplify, optimize, foster and implement a methodology during the design, construction, operation and end-of-life phases of a project.

The objective is to integrate these products into new and/or existing buildings based on different scenarios and to explore the suitability of such products in different contexts.

In order to analyze the environmental, economic, and social impact of the INBUILT project, 5 assessments will be carried out:

- Life cycle assessments and life cycle costs
- Circular assessment
- Social impact assessment
- Hygrothermal and energy performance assessment and monitoring
- Certification of products

This document is where all partners involved in WP5, Monitoring and Impact Assessment, plan how to write these 5 assessments.

The demonstrators subject to the performance assessment will be the three demonstration buildings, but also the components produced for the construction of the building and the innovative products created within INBUILT. Each of the demonstrators in this category will have its own characteristics that must be considered when assessing the impact they have.

In recent years, the urgency of addressing the climate crisis pushes policymakers, companies and researchers to consider the sustainability of the solutions studied. The focus of much research is on the environmental impact of innovative solutions, but for an innovation to be implemented, one cannot forget the economic impact it will have on society and how it will socially affect people's lifestyle, health and well-being. This can be done by assessing the environmental, economic, and social impact each factor will produce.

Comparing results from different outcomes is crucial to truly understand the performance of materials, components, and buildings. To compare products produced with different technologies, in different geographical areas and for different uses, a holistic framework is needed. A structure that defines which indices should be measured, where and how to collect input data and how they should be produced.

Comparable results can only be achieved if they are achieved by respecting some shared guidelines. The assessment that will be carried out at RINBUILT will be tailored to comply with the frameworks, regulations and guidelines established in the market for each sector.

1.3. Outputs expected

INBUILT aims to achieve two major impacts: on the one hand, greater decarbonization of the building stock throughout the entire life cycle and increased resource efficiency, circularity and digital technologies; and on the other hand, greater building performance and quality while preserving the climate and the environment.

Some of the most relevant objectives of the project are:

- *Increased share of bio and* ***geo-sourced materials as well as reused and recycled*** *materials/components in the building sector both new construction and renovation projects fostering low-carbon construction and circular economy*
- ***Reduction of embodied carbon, embodied energy, CO_2 emissions, air and water*** *pollution for both new construction and renovation, over the whole life cycle*
- ***More traceable reduction of the GHG emissions*** *of buildings in design, construction, renovation, operation, and end of life and faster digitalisation*
- ***Increased waste reduction and waste use/reuse***
- ***Increased*** *deployment and faster uptake of* ***bio/geo-sourced-based products*** *and reused or recycled components respecting EU standards and certifications*
- ***Demonstrated hygrothermal and acoustic occupant’s comfort****, improved insulation, and introducing nature into buildings for better indoor air quality*
- ***Decreased energy demands and decreased building related life-cycle costs***

The goal of WP5 “Impact Monitoring and Evaluation” is clear: deliver the INBUILT platform for optimizing the integration of the project’s material and component results and pilot sites WP6, covering the integration of material databases and environmental information (WP4), as well as the final demonstrations of the proposed digital solution, based on a correct methodology built on level(s) indicators.

- *Improve circularity performance based on appropriate methods.*
- *Determine requirements for integrating tools into a circular flow management system.*
- *Develop and deploy a digital ecosystem for accurate and transparent data recording and sharing.*

The project’s digital tools will be populated with demonstrator data to calculate the circularity performance of buildings, components, and materials, as well as their short-term environmental and economic impacts. Simulations using alternative design and usage parameters will allow for estimating long-term impacts based on scenarios regarding materials used, building design, second-life components, and technological uptake. These projections will then be used to study the potential social impacts if circular construction becomes mainstream.

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WP5 aligns with INBUILT's main objective: "To gather calculations of current and future environmental, economic, and social impacts," and its Key Performance Indicators (KPIs), which include Life Cycle Assessments (LCAs), Life Cycle Costing (LCCs), Circularity Assessments, and Scenarios.

- The work in task 5.1 Definition of Resource Assessment Methodology and Platform Services to Enhance Circular Resource Management will produce this deliverable, D5.1 – KPIs for Circularity, Life-Cycle Performance and Technical and Functional Requirements for INBUILT's Platform, and will continue to monitor the work done in WP5 – INBUILT Digital Tool & Urban Mining, as well as in other WPs.

- Task 5.2 – Platform Architecture, Technical and Functional Requirements for Platform Integration is complementary information that will help produce D5.1 – KPIs for Circularity, Life-Cycle Performance, and Technical and Functional Requirements for INBUILT's Platform.

- Task 5.3 – BIM Model According to a Consistent Standard will produce D5.2 – BIM Models for Products and Components & Standard BIM Report.

- Task 5.4 – Integration of LCA & LCC Information to the 3D BIM Model. Integration with BEDEC Database will collect data and standards followed by the different assessments mentioned in this deliverable, in order to integrate all environmental, social, and economic information into digital products and models, producing D5.5 – Platform First Release in Preparation for Monitoring Phases.

- Task 5.5 – Urban Mining Initiatives Tracking will produce D5.3 – Database of Key Stakeholders and Urban Mining Initiatives and D5.4 – Guide for Urban Mining Initiatives Implementation.

- Task 5.6 – Development of the INBUILT Platform and Functionalities will produce D5.6 – Platform Final Release & Guideline for Support Implementation of the Platform.

The purpose of this document is to provide a comprehensive outline of how the various assessments will be produced and later integrated into the platform as digitized final values within the model, to provide a consistent framework and ensure coherence in the economic, environmental, and social results. Respecting these frameworks will provide the opportunity to generate impact results that can be compared with other project outcomes assessed under the same format. Being able to compare results across projects is crucial to understanding the performance of new materials, products, and R&D solutions.

These frameworks must be adhered to in order to help identify the initial data required for each assessment and the calculation methodologies to be used. By streamlining initial information and development processes, it will be possible to determine common information needed for various assessments and identify whether the outputs from one document are needed as inputs for another.

This work aims to ensure the homogeneity and harmonization of the information used within INBUILT. The necessary work for the harmonization of the information and data used in WP5 – INBUILT Digital Tool &

Urban Mining will be carried out in the coming months in Task 5.4 – Integration of LCA & LCC Information to the 3D BIM Model. Integration with BEDEC Database, as explained in Chapter 8 – Conclusions of this document.

The plan outlined in this document will be published in month 15; however, the planned solutions will be updated throughout the project, as it will be necessary to connect with other parts of the project, especially WP4 and WP6. There will be continuous monitoring of the work done in other WPs to ensure that the structure of the assessments can easily integrate information from necessary inputs. The information harmonization work, initiated in this first phase of Task 5.1, will be completed in the second phase, the integration phase, between month 15 and month 38.

The harmonization of environmental information is structured in two phases. The first phase has been developed in **Task 5.1 - Definition of resource assessment methodology and Platform services to enhance circular resource management**. In this phase, the different services/modules to be included in the platform have been defined. As a result, the required tests, methodologies, and final data outputs have been identified. This allows for full traceability of the final values displayed on the platform, whether through tables, digital models, or certificates.

The second phase aims to consolidate this work with real values, ensuring proper monitoring and implementation as planned by the project partners. Once the identified tests are completed, the results at the product level will contribute to integrating environmental data into **BIM models**, which will be carried out in **Task 5.4 - Integration of LCA & LCC information into the 3D BIM model and its connection with the BEDEC database**. Therefore, both the final results and the integration process will be included in **Deliverable D5.2 – BIM models for products and components & standard BIM report**, scheduled for delivery in **Month 30** of the project.

It is not possible to define KPIs, an integration methodology, or a final implementation structure in this deliverable, as **Task 5.1 - Definition of resource assessment methodology and Platform services to enhance circular resource management** and **Task 5.2 - Platform architecture, technical and functional requirements for platform integration** are closely linked to other tasks that have experienced delays or are still in progress.

Therefore, this deliverable aims to establish a **clear work plan**, identifying key tests that, in many cases, align with the project's KPIs. These KPIs will be standardized within the tool to assess the **circularity performance** of buildings, their components, and materials—both from an **environmental perspective** and in terms of their **short-term economic impact**.

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2. Requirements for INBUILT's platform

2.1. INBUILT Platform

The INBUILT project platform aims to address one of the main challenges in the sector. On one hand, it calculates circularity practices at an individual level (energy efficiency, materials, waste, and water) without integrating the different environmental aspects that impact a building's life cycle. On the other hand, it seeks to minimize the lack of detailed information on material characteristics and construction processes, which prevents assessing the impact of potential material reuse or substitution while ensuring the functionality of existing elements during renovation, dismantling, and demolition.

INBUILT will introduce a digital platform for life cycle optimization scenarios, designed to evaluate circularity in the early design stages. This tool will enable designers to view waste as an opportunity to optimize outcomes based on LCA and LCC indicators. Additionally, it will integrate the principles of CE certifications, ensuring that innovative products meet all performance requirements for implementation. This approach links circularity with the life cycle perspective, while ensuring full compatibility with the Level(s) framework.

The INBUILT platform functions as a living ecosystem, not only storing information from Work Packages 2 and 3, but also facilitating decision-making for architects, builders, and investors. It provides essential data on material composition and environmental characteristics, incorporating insights from WP4 and WP6. The following image illustrates the communication flow and collaboration between all project partners.

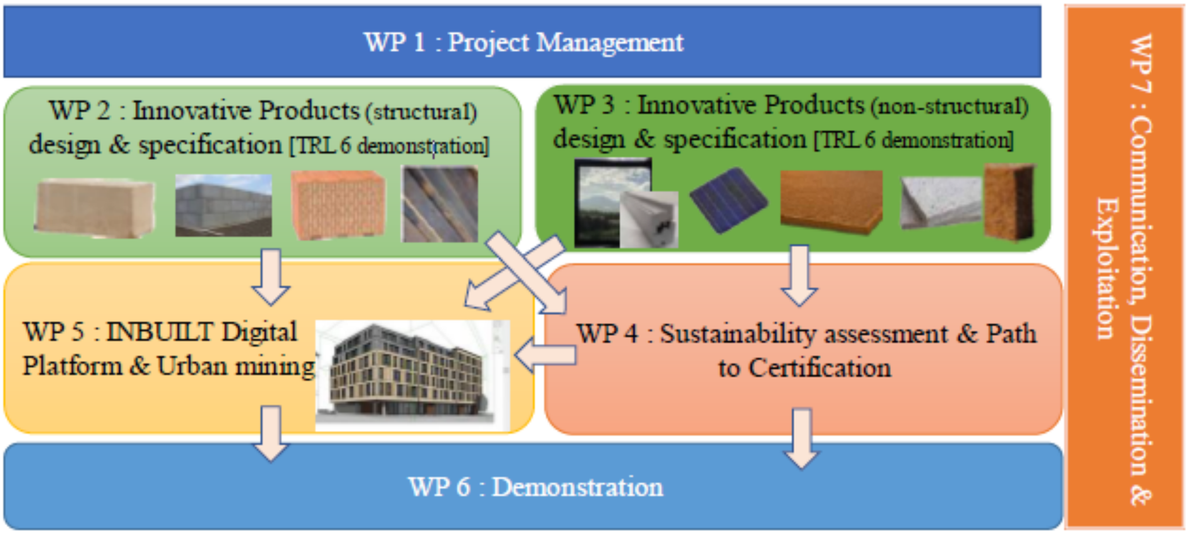

Figure 1 Connection of the project's Work Packages

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2.1.1. Functional Requirements of the Platform

The operation of the platform is designed so that all functionalities offer the user an experience that brings them closer to the digital era and easy access to information, giving special importance to the reliability of the data source. To achieve this, the digitalization of the set of new materials and components from innovative products will be the starting point. These **digital models** will be enriched with **environmental impacts and carbon footprint** information, developing a **6D-BIM model**, meaning a model that includes **sustainability**, **construction, cost, and second-life information for materials.** Recognizing components as a construction section, considering the material's location within the building, and its potential for reuse will be part of following the methodology of the **ECOB standard** and **the European Level(s) framework**. Through the **IFC format** of BIM models, all this information will be visible not only on the Inbuilt platform but also in any tool capable of reading IFC. **The digital models** of innovative products will include **4D** (execution time), **5D** (cost), and **6D** (environmental) information, coming from technical data provided by the manufacturer, manufacturing and market cost obtained from LCC, and environmental data derived from **LCA**.

For **Demo Models 1, 2, and 3**, since they are components and materials that are not part of the project, the **4D-5D-6D information** will be integrated using various tools. The first tool is the **BEDEC database** (Structured Database of Construction Elements), which contains **2,004 environmental data entries**, from manufacturers through **EPDs** (Environmental Product Declarations) and information from Ecoinvent19. The second tool is the **TCQi calculation engine**, used to create the building's LCA following the EN 15978 standard. This tool is validated by the Level(s) framework (JRC, which includes this tool in its software list under Indicator 1.2). The way to group and obtain a **final record of the building** will be through the **materials passport**. The following diagram helps to illustrate and integrate all the aspects mentioned so far.

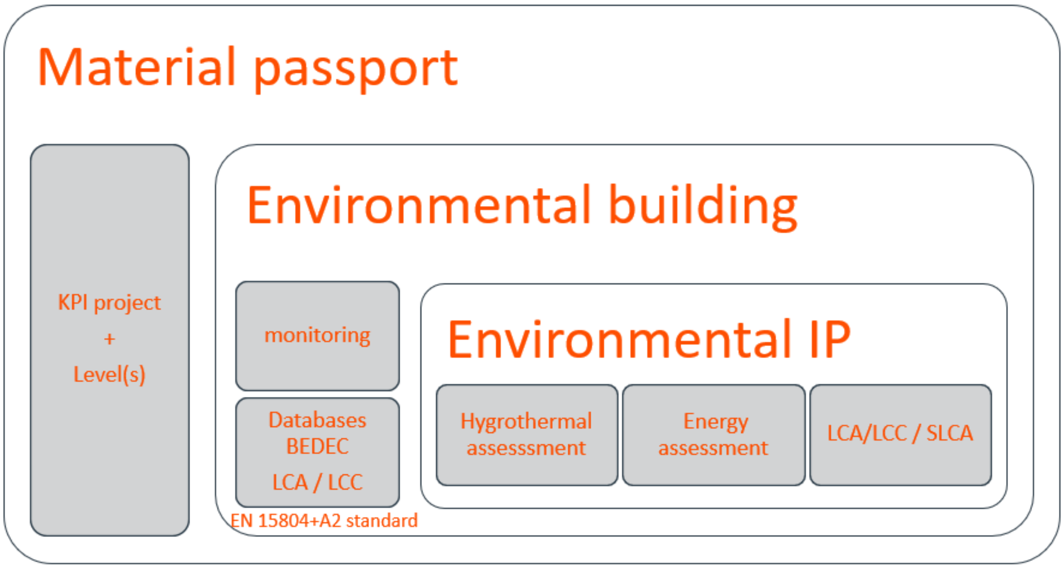

Figure 2 Environmental information classified by levels of work

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The platform will be **web-based**, consisting of **four modules**, each representing a set of actions that, through the workflow, generate **scenarios, reports, technical datasheets, and summaries**. These results are grouped either at the **innovative product level** or at the **building level**.

The platform's main entry point is a map, which allows users to identify, through a locator, whether they are in Demonstrator 1, 2, or 3. Once the demonstrator is selected, the four modules are enabled, along with the option to view the demo in a BIM viewer, allowing users to interact with the different modules while simultaneously visualizing the impact of their actions on the digital model, such as information display, product location, economic impacts, etc. This same tab also presents a summary of the project's most relevant KPIs.

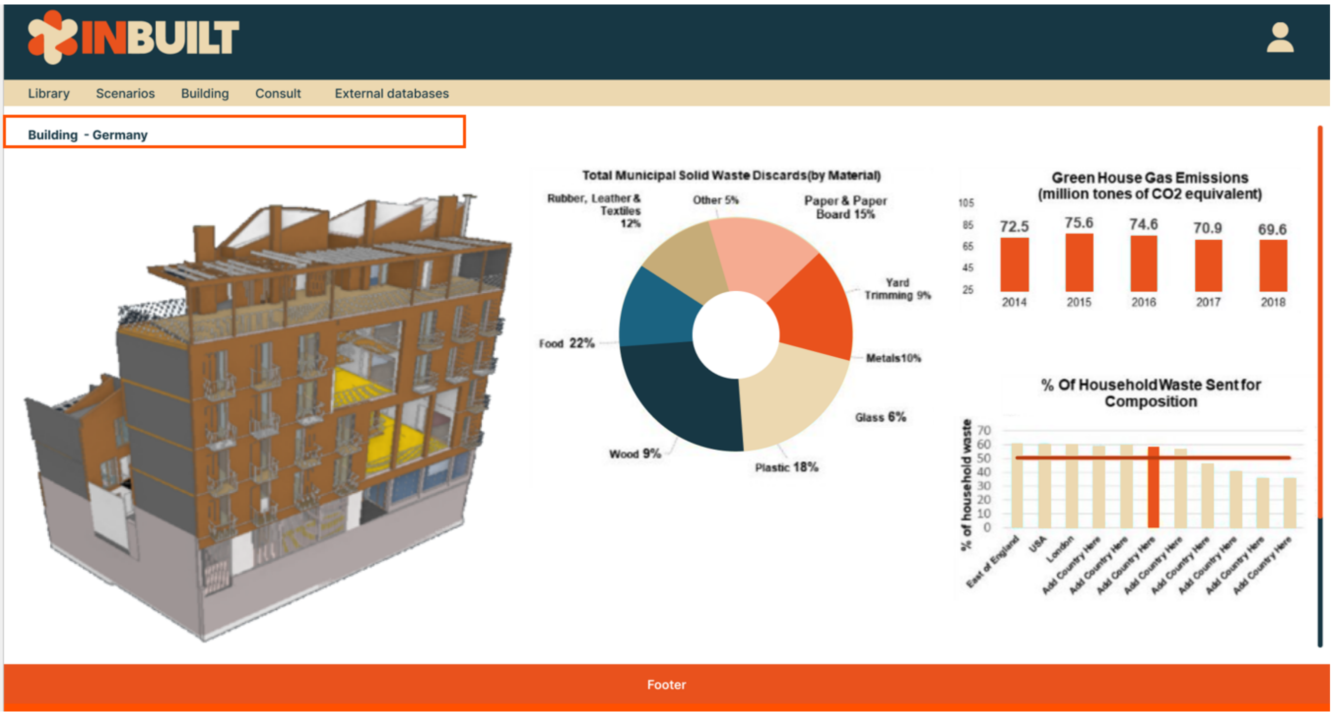
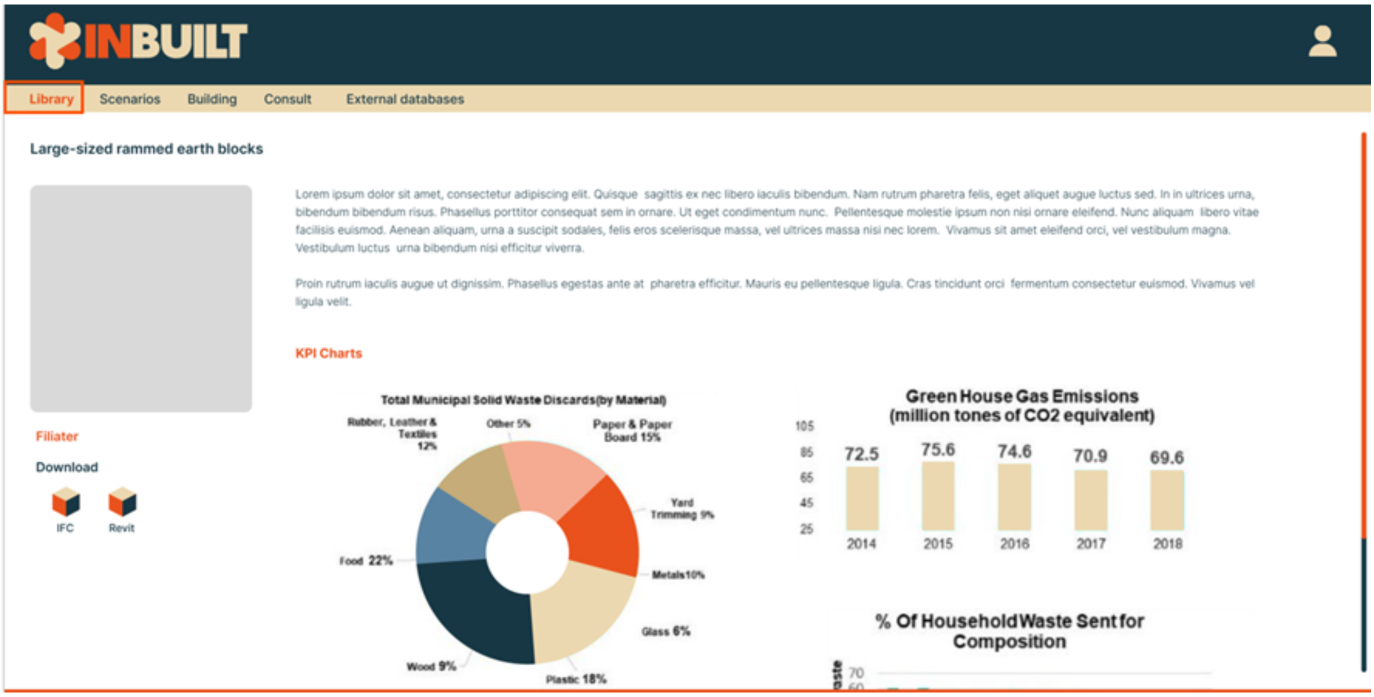


Figure 3 Mockup of the platform - Building homepage

- *Library Module:* Its objective is to display all the innovative products available in the selected demonstrator, obtaining in a detailed and precise manner for each IP, technical product information, mode of use and application. KPI at the product level (CO_2, energy, % recycled content, % raw material, etc.). This information will be shown in graphs and in total. In this same tab, it will be possible to download the IP in RVT and IFC format.



Large-sized rammed earth blocks

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Figure 4 mockup of the platform - Innovative Products Page

- *Scenarios:* The scenarios are designed to give users the freedom to explore different alternatives when using innovative products. The importance of evaluating various scenarios lies in determining that a study on circularity, energy, or emission reduction does not only affect the composition of materials, but also the overall set of materials/constructive solutions in the building. Ultimately, the proper functioning of a building depends on the entire system that makes it up.
  This is why this module of the platform is one of the most important. Through the direct interaction of the user with the project, it will provide optimal and real results about the building's performance based on the composition of innovative products. The scenarios proposed for this environment are finite. The information displayed in each scenario is derived from the various tests, which not only consider technical characteristics, but also take into account the environment and future climate scenarios. For this reason, the combinations of solutions will have a strategy aligned with the results obtained and the location of each IP in the demonstrators, presenting the user with accurate realities from scientific trials.

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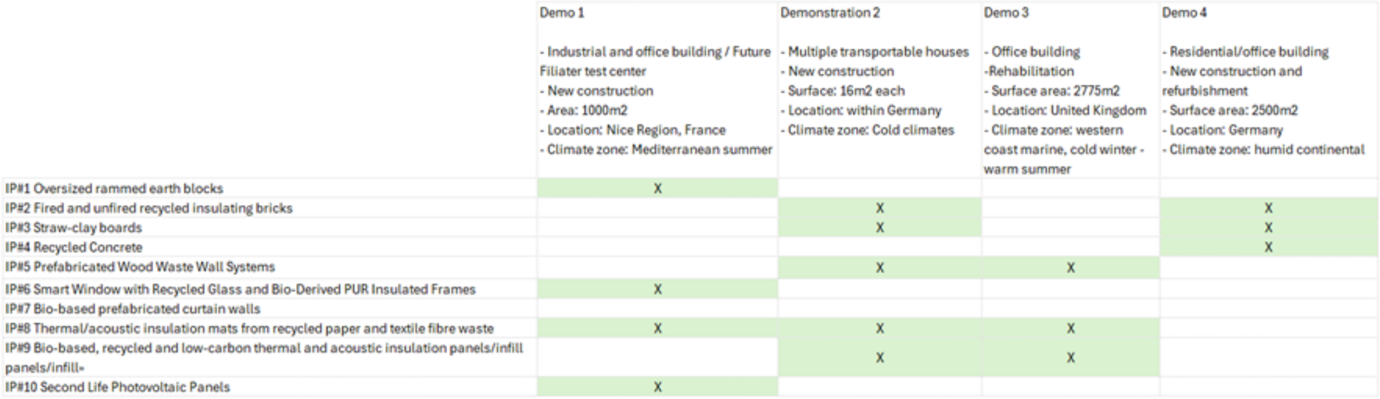
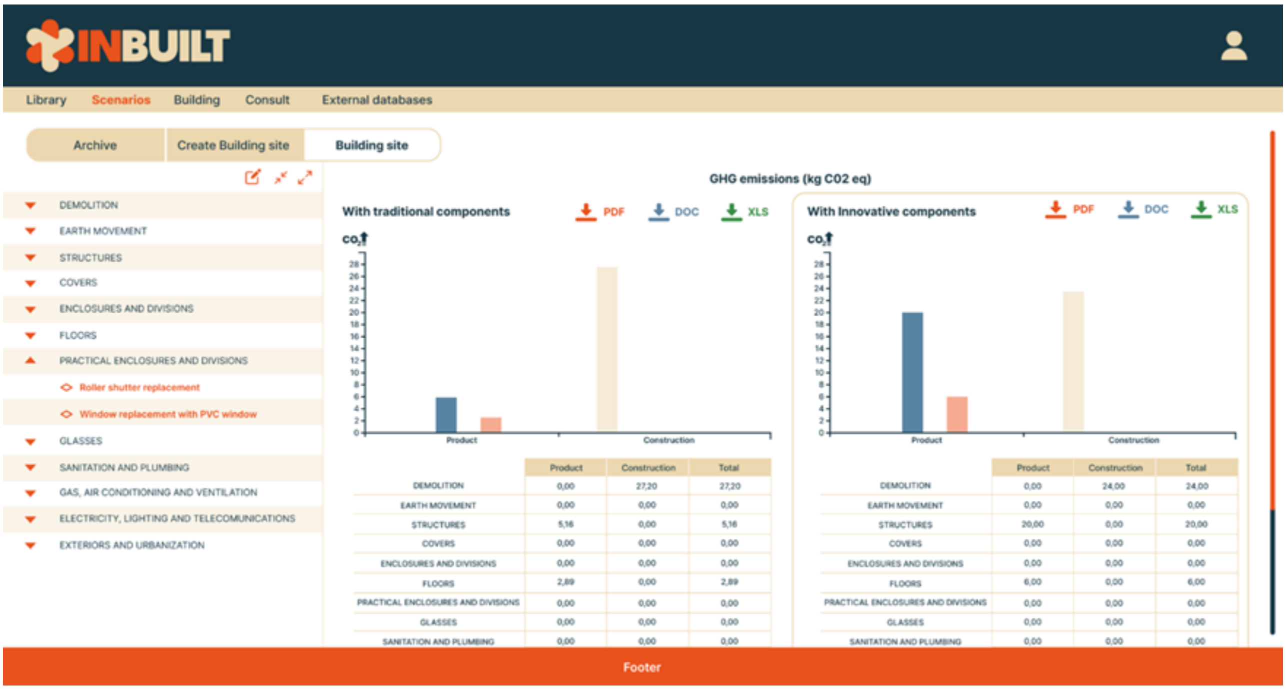


	Demo 1 - Industrial and office building / Future Filiater test center - New construction - Area: 1000m2 - Location: Nice Region, France - Climate zone: Mediterranean summer	Demonstration 2 - Multiple transportable houses - New construction - Surface: 16m2 each - Location: within Germany - Climate zone: Cold climates	Demo 3 - Office building -Rehabilitation - Surface area: 2775m2 - Location: United Kingdom - Climate zone: western coast marine, cold winter - warm summer	Demo 4 - Residential/office building - New construction and refurbishment - Surface area: 2500m2 - Location: Germany - Climate zone: humid continental
IP#1 Oversized rammed earth blocks	X			
IP#2 Fired and unfired recycled insulating bricks		X		X
IP#3 Straw-clay boards		X		X
IP#4 Recycled Concrete				X
IP#5 Prefabricated Wood Waste Wall Systems		X	X	
IP#6 Smart Window with Recycled Glass and Bio-Derived PUR Insulated Frames	X			
IP#7 Bio-based prefabricated curtain walls				
IP#8 Thermal/acoustic insulation mats from recycled paper and textile fibre waste	X	X	X	
IP#9 Bio-based, recycled and low-carbon thermal and acoustic insulation panels/infill panels/infill-		X	X	
IP#10 Second Life Photovoltaic Panels	X			

Figure 5 Participation of each innovative product in the project's demonstrables

Finally, the added value of this module arises from the project's need to demonstrate the potential of an innovative product versus a "traditional" one. For this reason, the comparisons/scenarios are always linked to the creation of the building with the typical construction characteristics of the environment where each of the demonstrators is located (France, Germany, UK), and the challenge is to show the reduction in all the defined parameters, highlighting the competitive advantage of the project in the short, medium, and long term when replacing a traditional element with an innovative one. Each of these scenarios will be defined by ITeC, using the project's own information to indicate the position of each IP in the demonstrators and with the final values obtained from the KPIs.



With traditional components

	Product	Construction	Total
DEMOLITION	0,00	27,20	27,20
EARTH MOVEMENT	0,00	0,00	0,00
STRUCTURES	5,16	0,00	5,16
COVERS	0,00	0,00	0,00
ENCLOSURES AND DIVISIONS	0,00	0,00	0,00
FLOORS	2,89	0,00	2,89
PRACTICAL ENCLOSURES AND DIVISIONS	0,00	0,00	0,00
GLASSES	0,00	0,00	0,00
SANITATION AND PLUMBING	0,00	0,00	0,00

With Innovative components

	Product	Construction	Total
DEMOLITION	0,00	24,00	24,00
EARTH MOVEMENT	0,00	0,00	0,00
STRUCTURES	20,00	0,00	20,00
COVERS	0,00	0,00	0,00
ENCLOSURES AND DIVISIONS	0,00	0,00	0,00
FLOORS	6,00	0,00	6,00
PRACTICAL ENCLOSURES AND DIVISIONS	0,00	0,00	0,00
GLASSES	0,00	0,00	0,00
SANITATION AND PLUMBING	0,00	0,00	0,00

Figure 6 Mockup of the Platform - Comparative Scenario Results

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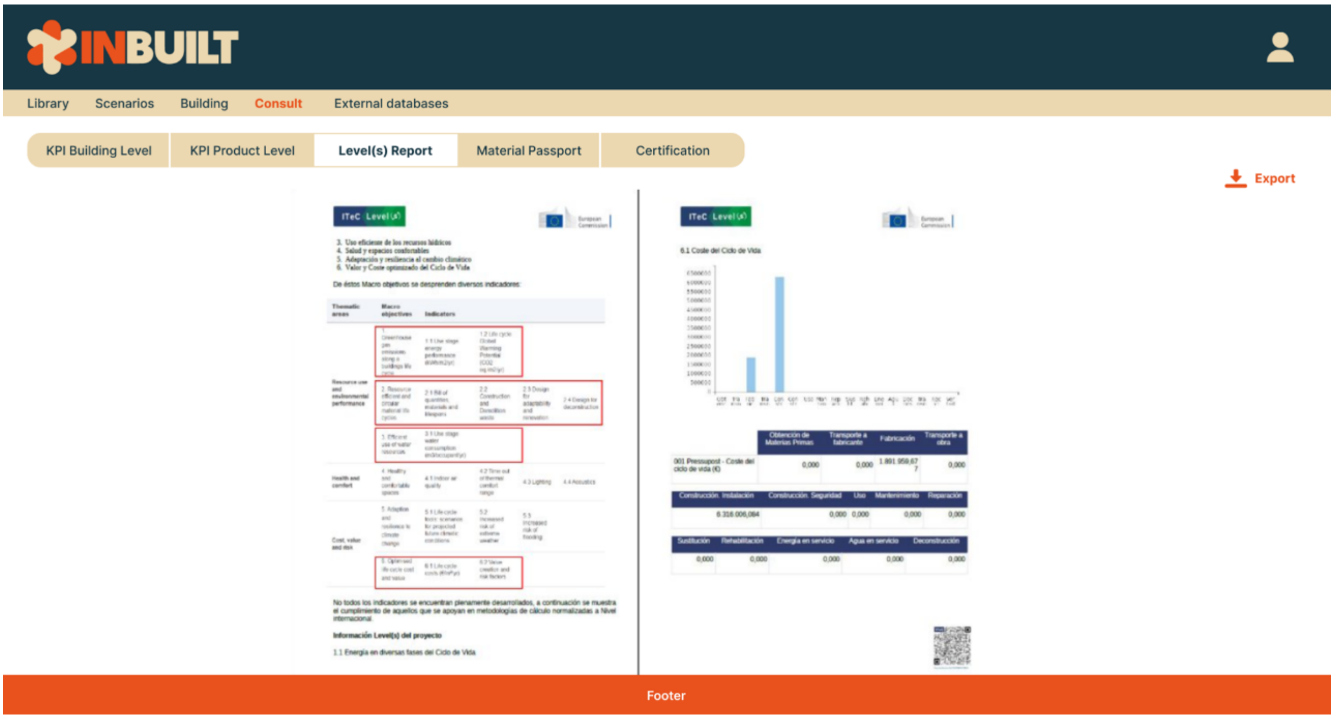
- *Queries:* The queries are the core of the platform; they serve as the module for querying general and total data of the project. It is designed as a technical, environmental, and economic repository. This is the place where end users can go and download reports either at the innovative product level or at the building case study level. The available formats are PDF, DOC, and XLS.



3. Uso eficiente de los recursos hídricos
4. Salud y espacios confortables
5. Adaptación y resiliencia al cambio climático
6. Valor y Coste optimizado del Ciclo de Vida

De éstos Macro objetivos se desprenden diversos indicadores:

No todos los indicadores se encuentran plenamente desarrollados, a continuación se muestra el cumplimiento de aquellos que se apoyan en metodologías de cálculo normalizadas a Nivel internacional.

Información Level(s) del proyecto

1.1 Energía en diversas fases del Ciclo de Vida

6.1 Coste del Ciclo de Vida

Figure 7 Mockup of the platform - available queries, the image depicts the Level(s) report

- *External databases:* This module is designed to offer the user a real-time view of the building's performance, including the location of sensors and the connection with the API that collects the data, reinforcing the values of the usage phase. Another connection of this module is with the EcoPlatform, aimed at facilitating the user's connection with other generic databases that contain information on products and materials with environmental data. This module is targeted at architects and builders committed to the environment, allowing them to access different material and system options that include data obtained through reliable calculation methodologies with competitive environmental values that help to enhance circularity.

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2.2. EU frameworks

To guarantee the replicability of the INBUILT assessments and their validity outside the project competition, it is necessary to analyze the European references in the specific areas of each assessment. Recognized European guidelines, frameworks and programmes are used as a guide to define the requirements of the documents produced within INBUILT, what data to analyze and how to process it, what definitions and units of measurement to use. Adherence to European frameworks ensures that the work carried out within INBUILT can be disseminated throughout the EU and that the results can be compared with other projects and buildings analyzed using the same methods.

The Level(s) framework for assessing the sustainability of buildings is an initiative by the European Commission. Developed by the Directorate-General for Environment, it serves as a common and harmonized tool for evaluating and monitoring building sustainability within the European Union. Introduced in 2017, Level(s) is built upon 16 key indicators and aims to provide a shared methodology for measuring the sustainable performance of buildings. It is widespread in Europe and provides essential guidance on issues ranging from life-cycle studies to circularity assessment, covering the whole environmental impact of buildings.

The Ellen MacArthur Foundation, established in 2010 by British sailor Dame Ellen MacArthur, is a prominent non-profit organization dedicated to advancing the circular economy globally. In collaboration with Arup, a renowned design and engineering firm, the foundation developed the Circular Economy in the Built Environment Toolkit. This toolkit provides practical resources for integrating circular principles into construction projects. Additionally, the foundation partnered with Granta Design to create Circularity Indicators, a methodology focused on measuring and assessing the circularity of products and systems. These partnerships exemplify the foundation's commitment to practical solutions, strategic collaborations, and driving tangible progress towards a more sustainable and circular future.

The Instituto Valenciano de la Edificación's Re10 Tool provides a methodology for analyzing and verifying compliance with qualitative circularity criteria in new construction and refurbishment projects in terms of demolition and adaptability. It also defines a system for assessing the project, so that it can be considered whether the resulting building will meet minimum sustainability requirements in terms of demountability and adaptability.

These frameworks are based on the UNE-ISO 20887:2020 and its 2023 version, which focuses on sustainability in buildings and civil engineering works, with a specific emphasis on design for disassembly and adaptability. The standard establishes principles, requirements, and guidelines to encourage the design of buildings and civil engineering works that can be easily disassembled and adapted throughout their life cycle. The goal is to reduce environmental impacts, improve resource efficiency, and promote circularity in the construction sector. The standard provides a framework for industry practitioners to integrate sustainable practices from the early stages of the design and construction process.

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2.2.1. Level(s)

Level(s) is a framework created to measure the sustainability performance of buildings. It uses common indicators to calculate the required performance according to an established calculation model. This makes it possible to compare both new buildings and major renovation projects. It aims to establish a common language of sustainability for buildings by defining core indicators for the sustainability of office and residential buildings.

The common framework provides a set of indicators and common metrics for measuring the sustainability performance of buildings along their life cycle, assessing the following aspects:

- environmental performance
- health and comfort
- life cycle cost and value
- potential risks to future performance

Level(s) is based on 6 macro-objectives, which describe the strategic priorities that the construction sector must address to contribute to the EU's sustainable development: energy, material use and waste, water, indoor air quality, and the long-term value of goods.

For each of these strategic priorities, it is important that the contribution and performance of individual building projects can be measured. Indicators have therefore been developed that enable the measurement of performance under each macro-objective. The Level(s) common framework consists of 16 core indicators. Each indicator has been selected to measure the performance and contribution of a building towards a specific macro-objective. An overview of the indicators and their units of measurement is provided in the table below (Figure 8).

For each strategic priority, it is essential to measure the performance and impact of individual construction projects. To achieve this, specific indicators have been developed to facilitate the assessment of project performance against overarching objectives. The Level(s) universal framework comprises 16 basic indicators, carefully selected to measure the effectiveness of a building and its contribution to a specific macro-objective. A comprehensive table below provides an overview of these indicators along with their respective units of measurement.

For the purpose of the project, the main focus will be on the indicators of the macro-objective 1 – Greenhouse gas and air pollutant emissions along building’s life cycle, 2 – Resource efficient and circular material life cycles, and 6 – Optimized life cycle cost and value. Each assessment will focus on some specific indicators, LCC will comply with the indicators in Objective 6, the Circular Assessment will focus mainly on the indicators

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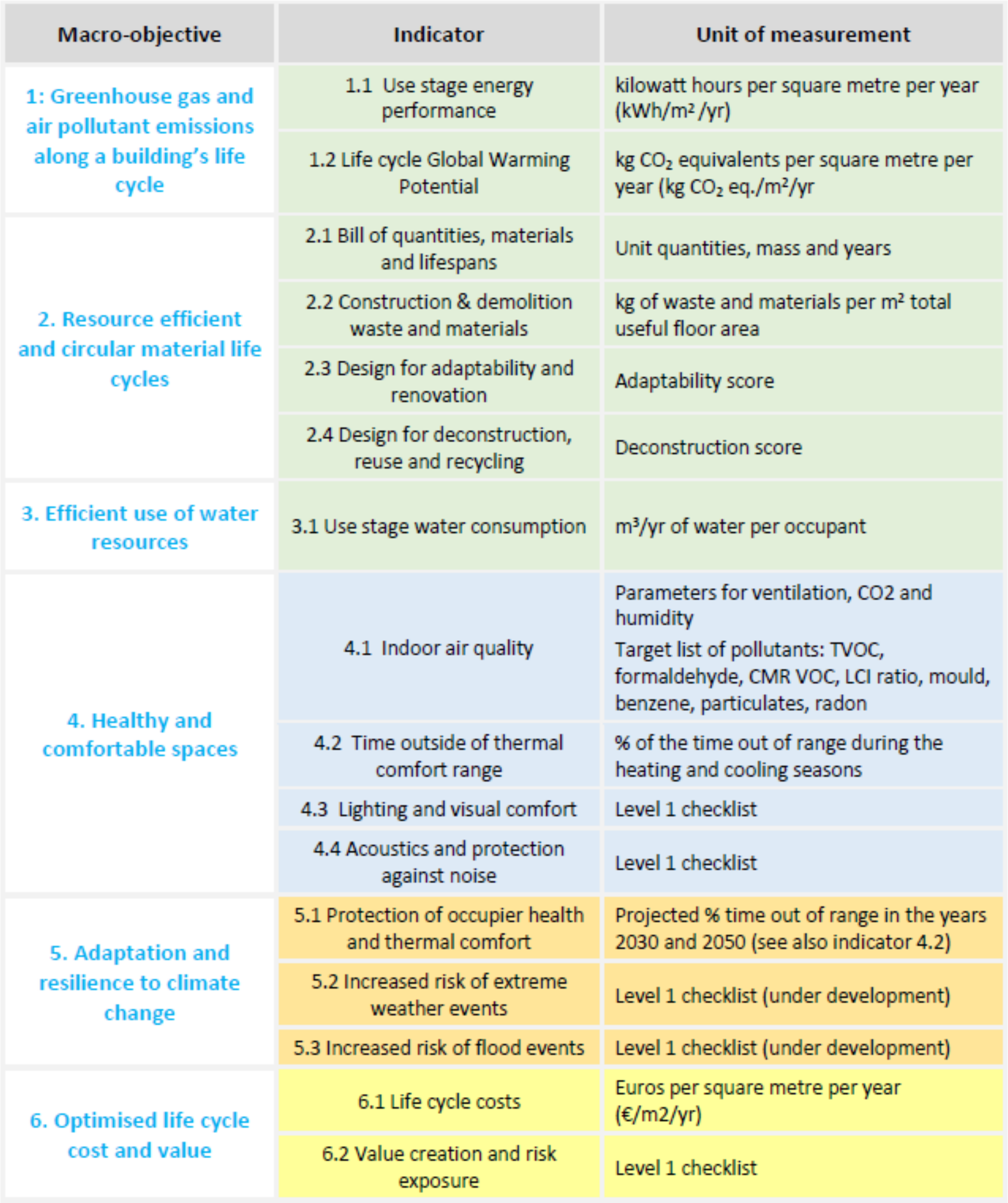
in macro-objective 2. It will be frequent that some Level(s) indicators will be considered in more than one assessment, like the 2.1 Bill of quantities, materials, and lifespans. It is clear that managing the source of the data needed to calculate these indicators is crucial to having the same value for different assessments.

The D5.5 Project Impact Assessment will provide a Level(s) report at the end of the project, using the info already elaborated in the previous assessment, respecting the EU framework.



Macro-objective	Indicator	Unit of measurement
1: Greenhouse gas and air pollutant emissions along a building's life cycle	1.1 Use stage energy performance	kilowatt hours per square metre per year (kWh/m² /yr)
	1.2 Life cycle Global Warming Potential	kg CO_2 equivalents per square metre per year (kg CO_2 eq./m²/yr
2. Resource efficient and circular material life cycles	2.1 Bill of quantities, materials and lifespans	Unit quantities, mass and years
	2.2 Construction & demolition waste and materials	kg of waste and materials per m² total useful floor area
	2.3 Design for adaptability and renovation	Adaptability score
	2.4 Design for deconstruction, reuse and recycling	Deconstruction score
3. Efficient use of water resources	3.1 Use stage water consumption	m³/yr of water per occupant
4. Healthy and comfortable spaces	4.1 Indoor air quality	Parameters for ventilation, CO2 and humidity Target list of pollutants: TVOC, formaldehyde, CMR VOC, LCI ratio, mould, benzene, particulates, radon
	4.2 Time outside of thermal comfort range	% of the time out of range during the heating and cooling seasons
	4.3 Lighting and visual comfort	Level 1 checklist
	4.4 Acoustics and protection against noise	Level 1 checklist
5. Adaptation and resilience to climate change	5.1 Protection of occupier health and thermal comfort	Projected % time out of range in the years 2030 and 2050 (see also indicator 4.2)
	5.2 Increased risk of extreme weather events	Level 1 checklist (under development)
	5.3 Increased risk of flood events	Level 1 checklist (under development)
6. Optimised life cycle cost and value	6.1 Life cycle costs	Euros per square metre per year (€/m2/yr)
	6.2 Value creation and risk exposure	Level 1 checklist

Figure 8 Level(s)' Indicators

As the name suggests, the framework is divided into three levels, each relating to a different phase of a building project and with different objectives.

- Level 1. The conceptual design for the building project – the simplest level as it entails early-stage qualitative assessments.
- Level 2. The detailed design and construction performance of the building – an intermediate level as it entails a quantitative assessment.
- Level 3. The as-built and in-use performance of how the building performs after completion and handover to the client – the most advanced level as it entails the monitoring and surveying.

Progression through the levels also means an increase in the accuracy and reliability of the reporting. The higher the level, the closer the reported results will be to providing you with data that reflects the performance of the building as built and in use.

Once the impacts of the building have been measured at different stages of the project, a fundamental part of the Level(s) framework is the ability to compare results between buildings with similar functions.

To ensure a meaningful comparison, it is essential that the indicators provide guidance on how they should be evaluated.

How comparability is supported by using Level(s):

- Use of the common units of measurement

- Completion of the Level(s) building description

- Use of the cited reference standards and methods

- The required reporting on key parameters, assumptions, and data quality, in order to ensure transparency

- The rules stipulated that are specific to Level(s) and which: fix key parameters, provide default data, and define calculation assumptions

The Level(s) common framework takes a whole life cycle approach to the sustainability of buildings. To fully support this approach, the core indicators of macro-objectives 1, 2, and 3 are complemented by a holistic assessment of a building's environmental impact - a full Life Cycle Assessment (LCA) of a building. By making a LCA, the environmental impacts associated with a building can be quantified and the most significant areas – commonly referred to as "hot spots" – can be identified and used as the starting point for improving performance

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2.2.2. Ellen MacArthur Foundation

The Ellen MacArthur Foundation, established in 2010 by British sailor Dame Ellen MacArthur, is a globally renowned non-profit organization dedicated to accelerating the transition to a circular economy. The foundation's mission is to inspire and drive the adoption of circular economic principles across industries and sectors worldwide. It has gained widespread recognition across Europe and from the European Community for its pioneering advocacy, strategic partnerships with major entities, educational initiatives, and development of practical tools like the Circularity Indicators project, in partnership with Granta Design, and the Circular Economy in the Built Environment Toolkit, in partnership with Arup.

The Circular Indicators project was developed by the Ellen MacArthur Foundation in partnership with Granta Design. The project was co-funded by the European Union's LIFE financial instrument. The aim is to provide indicators for assessing the circularity of products and companies. It offers tools and indicators to guide companies towards greater circularity, helping them to make informed decisions on the trade-offs between circularity and economic, environmental, and social objectives related to product design and material sourcing.

The project has focused on quantifying the restoration of material flows and the development of a Material Circularity Indicator (MCI). Other considerations (e.g. toxicity, scarcity, and energy) are included as complementary indicators. The indicators have been developed on a product and company level. The Circularity Indicators methodology also contains a section giving guidance to help estimate the profitability of circular economy business initiatives.

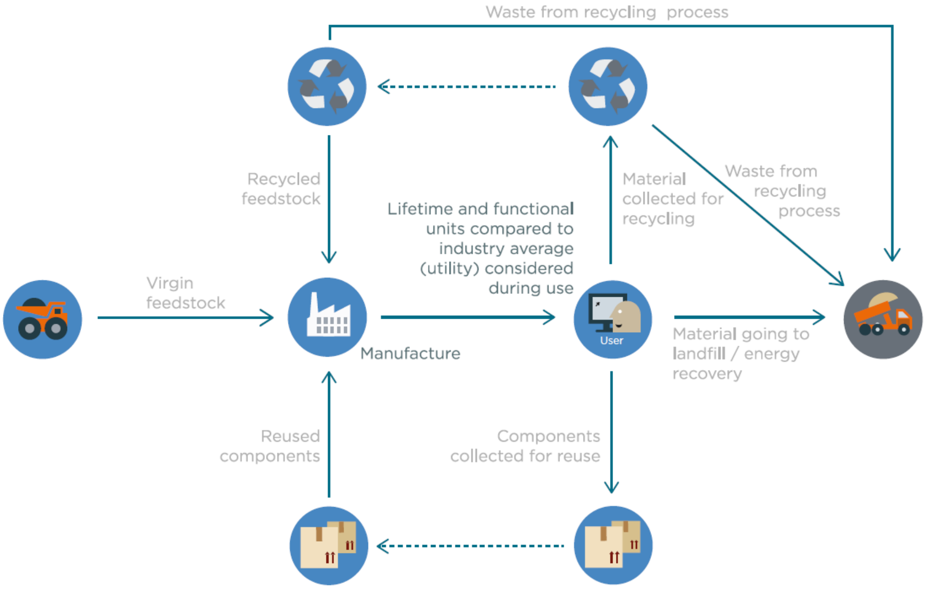

Figure 9 Material flows considered to arrive at the Material Circularity Indicator of a product

It considers inputs from several sources:

- Inputs in the production process: How much input is coming from virgin and recycled materials and reused components?
- Utility during use phase: How long and intensely is the product used compared to an industry average product of similar type? This considers increased durability of products but also repair/maintenance and shared consumption business models.
- Destination after use: How much material goes into landfill (or energy recovery), how much is collected for recycling, which components are collected for reuse?
- Efficiency of recycling: How efficient are the recycling processes used to produce recycled input and to recycle material after use?
- A detailed bill of materials for the product is needed to compute the MCI, listing the above data for all its components and materials.

Considering these inputs plus some complementary risks and impact indicators, the MCI calculations give a value between 0 and 1 to a product or to a company, with higher values indicating higher circularity.

2.2.3. RE10 tool

The RE10 Tool developed by the Instituto Valenciano de la Edificación (IVE) is a tool that analyses and verifies compliance with sustainability criteria in new construction and building renovation projects, with a focus on disassembly and adaptability.

The main goal of RE10 is to assess how well a building project aligns with sustainability criteria, particularly in terms of the ability to disassemble and adapt building elements. It is based on the ISO 20887:2020 standard, which establishes principles for evaluating the disassembly and adaptability of products.

The analysis considers various criteria, including:

- Disassembly: It evaluates how easily building elements can be disassembled without damage
- Adaptability: It examines the building’s capacity to adapt to new uses or needs over time

The RE10 Tool provides a methodology for assessing sustainability levels in terms of disassembly and adaptability. It can be used for both new construction and renovation projects, making it a valuable resource

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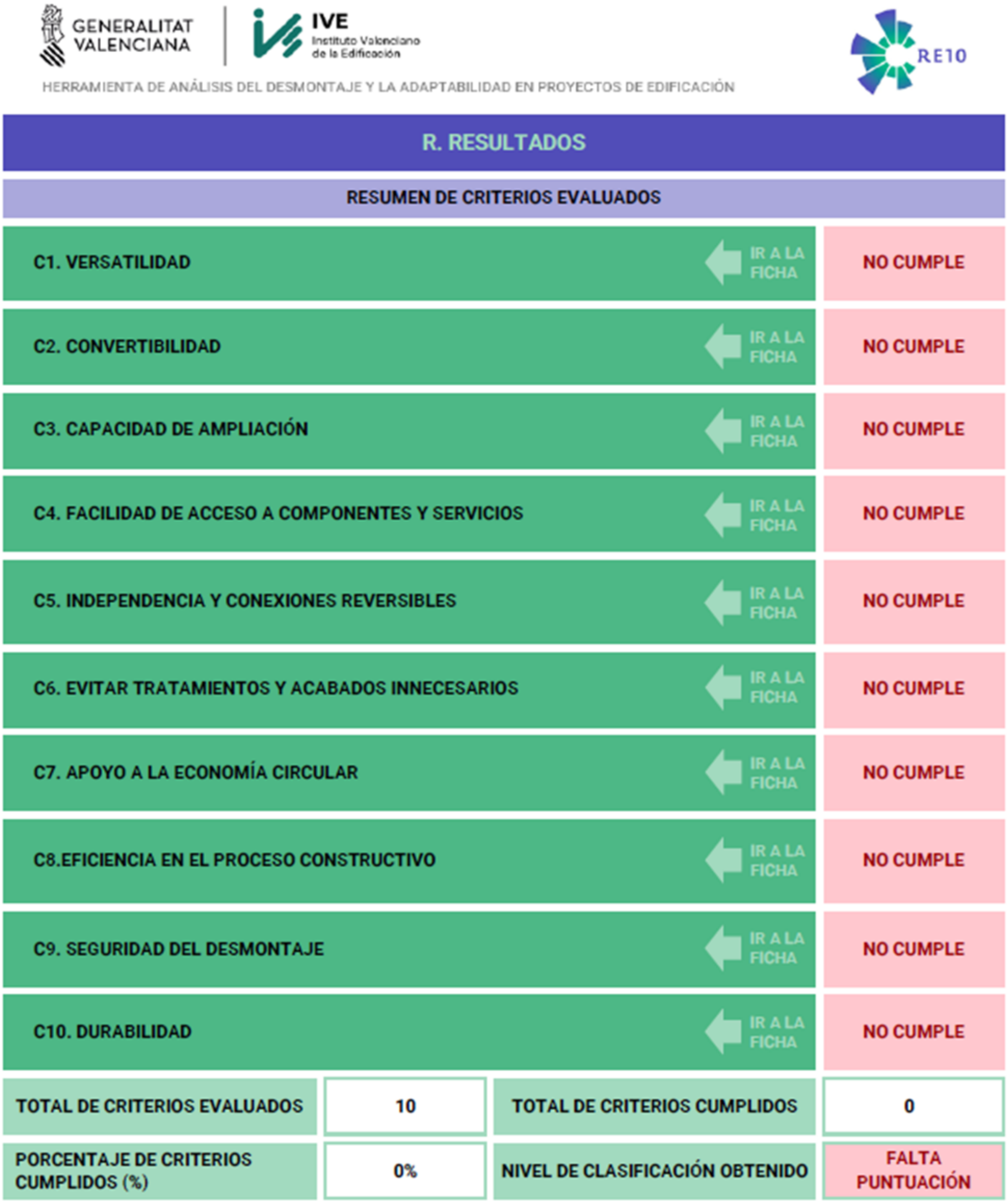
for architects, engineers, and building professionals to evaluate and enhance the sustainability of building projects and verifying if the project could apply to the EU Next Generation funding.



HERRAMIENTA DE ANÁLISIS DEL DESMONTAJE Y LA ADAPTABILIDAD EN PROYECTOS DE EDIFICACIÓN

R. RESULTADOS

RESUMEN DE CRITERIOS EVALUADOS

C1. VERSATILIDAD	IR A LA FICHA	**NO CUMPLE**
C2. CONVERTIBILIDAD	IR A LA FICHA	**NO CUMPLE**
C3. CAPACIDAD DE AMPLIACIÓN	IR A LA FICHA	**NO CUMPLE**
C4. FACILIDAD DE ACCESO A COMPONENTES Y SERVICIOS	IR A LA FICHA	**NO CUMPLE**
C5. INDEPENDENCIA Y CONEXIONES REVERSIBLES	IR A LA FICHA	**NO CUMPLE**
C6. EVITAR TRATAMIENTOS Y ACABADOS INNECESARIOS	IR A LA FICHA	**NO CUMPLE**
C7. APOYO A LA ECONOMÍA CIRCULAR	IR A LA FICHA	**NO CUMPLE**
C8.EFICIENCIA EN EL PROCESO CONSTRUCTIVO	IR A LA FICHA	**NO CUMPLE**
C9. SEGURIDAD DEL DESMONTAJE	IR A LA FICHA	**NO CUMPLE**
C10. DURABILIDAD	IR A LA FICHA	**NO CUMPLE**

TOTAL DE CRITERIOS EVALUADOS	**10**	**TOTAL DE CRITERIOS CUMPLIDOS**	**0**
PORCENTAJE DE CRITERIOS CUMPLIDOS (%)	**0%**	**NIVEL DE CLASIFICACIÓN OBTENIDO**	**FALTA PUNTUACIÓN**

Figure 10 Table of results and evaluation criteria of R10 Tool

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2.2.4. S-LCA guidelines by UNEP

The Guidelines for Social Life Cycle Assessment (S-LCA) of Products, developed by the United Nations Environment Programme (UNEP), provide a roadmap and a body of knowledge for stakeholders engaged in assessing the social and socio-economic impacts of product life cycles. These guidelines cover the entire life cycle of products, from the extraction of natural resources to final disposal.

The S-LCA aims to assess and report on the impacts and benefits related to social aspects throughout a product's life cycle. It goes beyond environmental considerations to include social dimensions. The guidelines offer a robust technical framework for conducting S-LCA. They provide guidance on data collection, impact assessment, and reporting. Stakeholders can use this methodology to evaluate social responsibility when assessing goods and services. The Social assessment considers various aspects, such as labor conditions, human rights, health and safety, community well-being, and socio-economic factors. It helps identify potential hotspots and areas for improvement.

The S-LCA can complement environmental life cycle assessments (LCA) and economic assessments. Integrating social aspects into decision-making processes enhances overall sustainability. These guidelines serve as a valuable resource for practitioners, policymakers, and organizations striving for more socially responsible and sustainable product development and consumption.

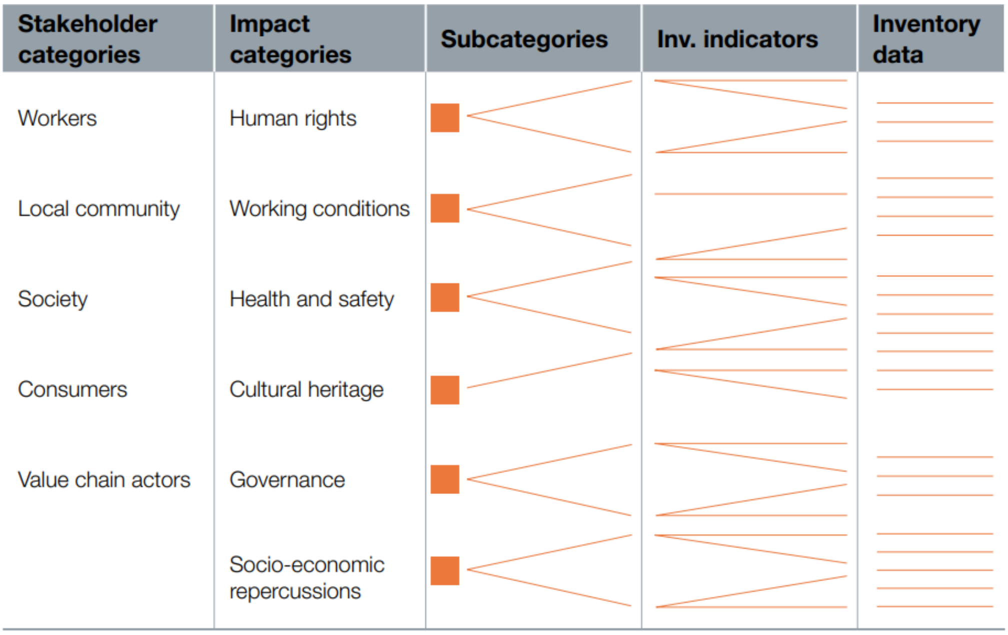

Figure 11 Assessment system from categories to unit of measurement

Within approaches to sustainable consumption and production, a strong role is played by methods for assessing and reporting the contributions from organizations and their products. Public planning and other strategic decisions are also increasingly assessed from a sustainable development perspective. Social aspects can be assessed through a variety of tools. A social dimension can be included as part of the sustainability assessment or can be handled specifically. The social assessment toolbox is composed of families of tools that serve different goals. The different families may include: analytical tools, procedural and management tools, monitoring tools, reporting tools and communication tools. The diversity of terminology, the current slight nuances and the variety of disciplines involved in social assessment make it hard to present a comprehensive picture. Economics, sociology, geography, anthropology, psychology, administration (strategy, management), agronomy, forestry, and health sciences have all contributed to the elaboration of a plethora of social assessment tools.

In INBUILT, the ISO 14075 will be used for the assessment of Social impact trough "Pathway Approach": characterization models representing causal-effect chain, describes impact pathways linking quantitative inventory items, such as child labor, to damage categories. The social impact is defined as hours worked by employees with a certain risk, level of a certain risk indicator per process product in monetary terms (EUR) within the considered boundaries, further represented as medium risk hours equivalent (mrheq).

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3. LCA & LCC

3.1. Description

Life cycle assessments (LCA) and simplified life cycle costing (LCC) of the Innovative Products make up Task 4.3 on the INBUILT project, running from Month 6 (M6) to Month 12 (M33) of the project. This task is led by the University of Bath with five additional institutions conducting LCA for the products. The distribution of the LCAs among the institutions was provided in Table 14 in Deliverable 4.1. The task also overlaps with Task 4.4 which produces social life cycle assessments (SLCA) for the products. Together, the three assessment types (SLCA, LCC and LCA) form a holistic assessment of the product's sustainability.

Task 4.3 focuses on the environmental (LCA) and economic (LCC) impact assessments at a product scale and will be discussed in this section. SLCA is discussed in Section 5 of this report.

3.1.1. State of the art

Life cycle assessment is a method to calculate the impacts of a product or service over its lifecycle, from raw material extraction to the end of life and disposal. The relevant standards relating to LCA and LCC have been outlined in D4.1 titled, "Report on Suitable Standards and Guidelines for Certification and Sustainability Analysis", and can be summarised as follows:

- *ISO 14040/44 – International Standards providing principles and frameworks for conducting LCA*
- *EN 15978 – Specific LCA methodology for calculating the environmental performance of building*
- *EN 15804 – Core Product Category Rules (PCR) for producing Environmental Product Declarations (EPD) for construction products*
- *Complementary Product Category Rules (c-PCR) – produced by EPD programme to provide consistency and comparability of construction products.*

3.1.2. Strengths and weaknesses

Some of the key challenges relating to LCA and LCC are:

- ***Data availability** – this is a particular problem for new and novel materials where supply chain data is not available*
- ***Data gaps –** incomplete data capture of manufacturing processes, transportation etc.*
- ***Lack of transparency –** results are often presented as single values for life cycle impact assessments (LCIA) with little detail on assumptions made in the LCA modelling. Also, uncertainty and data quality assessments for LCA studies are rare*

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- ***Lack of harmonization and comparability*** *– different standards and sustainable product certifications are available but have underlying differences in LCA methods leading to challenges when making comparisons. Even LCA results conducted to the same international standards can also significantly lack in harmonization.*
- ***Inconsistent methodology***

However, recent updates to international standards and the development of new product category rules (PCRs) have helped to address some harmonization concerns, particularly with regards to the comparison of EPD and PEF results. Task 4.3 will include peer-review stages where the LCA work can be checked for consistency in methods and assumptions.

3.2. Partner's methodology

In Task 4.3, we will conduct life cycle assessment of Innovative Products in accordance with EN 15804:A2, by selecting and using an appropriate c-PCR if available, for each type of product within INBUILT. The choice of c-PCR will depend on the type of product and will be decided by the LCA practitioners with agreement from the product manufacturer.

As the Innovative Products are at various stages of product development, they may not all be able to fully meet the requirements for publishing an EPD, and EPD production also has costs beyond those covered by INBUILT. As per the original proposal, we therefore will not publish EPDs within the project (unless manufacturers wish to do so themselves), but to follow all the appropriate LCA rules so that the results are in the form of EPD results. Alongside this, we will make clear if and how an LCA deviates from the relevant PCR, so that manufacturers know what else will be required in order to produce an Environmental Product Declaration when their products are ready for the mass market.

Importantly, the LCA standards are aligned to allow for product scale LCA results (i.e., EPDs to EN 15804:A2) to be used as an input for building level LCAs using EN 15978. For the INBUILT platform, building level LCAs will be calculated to EN 15978 and therefore the Task 4.3 LCA results for the innovation products can be easily integrated into the building scale calculations.

3.2.1. Inputs required

An overview of the steps involved in an LCA were provided in D4.1 and involve engagement and collaboration between the product manufacturer and the LCA practitioner. The key inputs for the task are listed below:

1. ***From partners:***
    a. *Data collection templates were provided in D4.1 from ISO 14044 and were sent to all project partners during the proposal stage*

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  b. *A flow chart or similar, outlining each stage of the manufacturing process for the relevant product*
  c. *Product characteristics established through testing*

2. ***From tools:***
  a. *Life cycle inventory (LCI) and life cycle costing (LCC) databases, among other sources, to capture processes in the background system*

3.2.2. Outputs obtained

Task 4.3 will produce deliverables in the form of:

1. *Final task 4.3 deliverable report containing a summary of the LCA results for the innovative products*
2. *A mock EPD to illustrate how results could be published as ecolabels by manufacturers when the products are ready for the market*
3. *Scientific publications and dissemination activities.*

The LCA will contain the life cycle impact assessment (LCIA) results for the EN15804:A2 indicators for the relevant life cycle modules. Where possible, the LCA results will represent the mandatory life cycle modules according to EN15804:A2 which are product (A1-3), end-of-life (C1-4) and benefits and loads beyond the system boundary (D), Figure 12. LCIA results are presented in a tabular format by module and life cycle indicators (Figure 13). The LCIA results and LCI indicators will be provided and can assist with the calculation of circularity-related KPIs. The LCI categories, as listed in EN15804:A2 (Table 6, 7 and 8), are:

- *Use of secondary material*
- *Renewable and non-renewable secondary fuels*
- *Materials for recycling*
- *Materials for energy recovery*
- *Exported energy (electricity, heat)*
- *Recovered energy*
- *Use of renewable and non-renewable primary energy resources used as raw materials*
- *Use of renewable and non-renewable primary energy excluding renewable primary energy resources used as raw materials*
- *Total use of renewable and non-renewable primary energy resources*
- *Use of net freshwater*
- *Hazardous and non-hazardous waste disposed*
- *Intermediate and low-level radioactive waste disposed*
- *High-level radioactive waste disposed*
- *Biogenic carbon content in product and in accompanying packaging*

The LCA results will be provided for the following core and additional impact categories listed in Table C.1 and C.2 of EN 15804:A2 are as follows:

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- *Climate change – total, fossil, biogenic and land use and land use change (LULUC)*
- *Ozone Depletion*
- *Acidification*
- *Eutrophication – aquatic freshwater, aquatic marine and terrestrial*
- *Photochemical ozone formation*
- *Depletion of abiotic resources – minerals and metals and fossil fuels*
- *Water use*
- *Particulate matter emissions*
- *Ionizing radiation, human health*
- *Ecotoxicity (freshwater)*
- *Human toxicity – cancer effects and non-cancer effects*
- *Land use related impacts / soil quality*

It is important to note that the climate change impact category results are split into four categories of Global Warming Potential (GWP): total, fossil, biogenic, and LULUC. For reporting purposes, it is often recommended to provide fossil, biogenic, and LULUC results separately (Figure 13).

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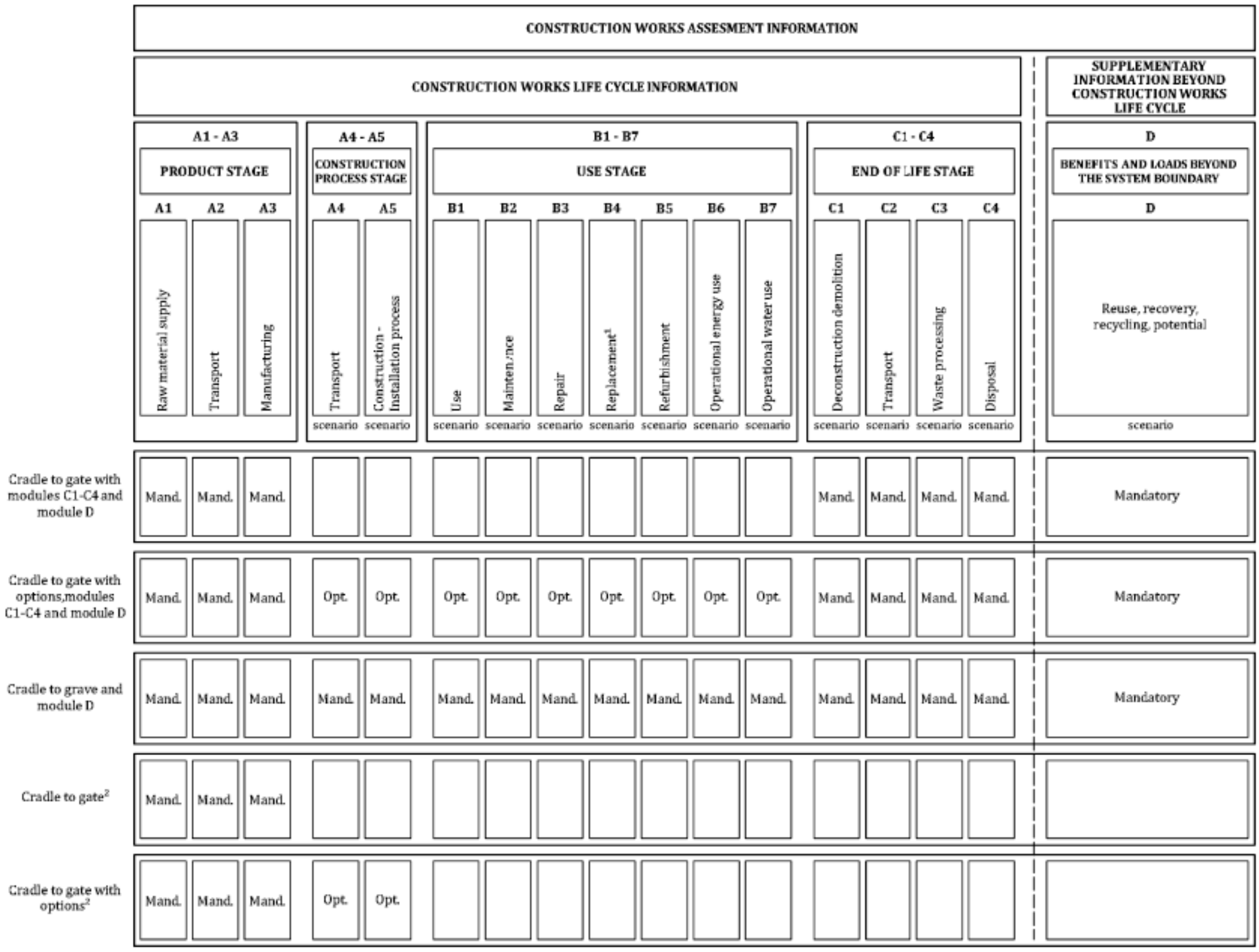
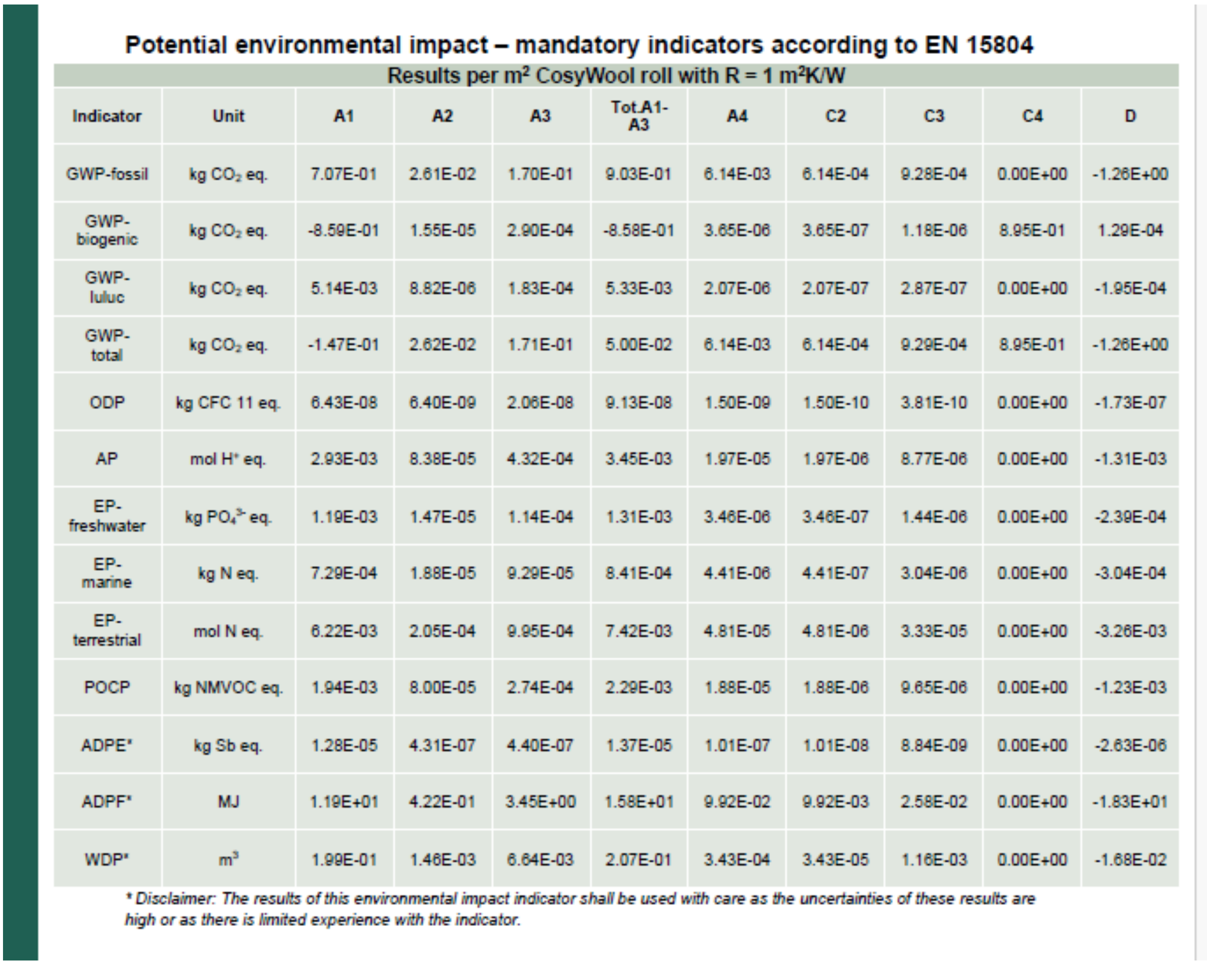


	CONSTRUCTION WORKS ASSESMENT INFORMATION																
	CONSTRUCTION WORKS LIFE CYCLE INFORMATION																SUPPLEMENTARY INFORMATION BEYOND CONSTRUCTION WORKS LIFE CYCLE
	A1 - A3			A4 - A5		B1 - B7							C1 - C4				D
	PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Raw material supply	Transport	Manufacturing	Transport	Construction - Installation process	Use	Maintenance	Repair	Replacement[1]	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling, potential
				scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario
Cradle to gate with modules C1-C4 and module D	Mand.	Mand.	Mand.										Mand.	Mand.	Mand.	Mand.	Mandatory
Cradle to gate with options,modules C1-C4 and module D	Mand.	Mand.	Mand.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Mand.	Mand.	Mand.	Mand.	Mandatory
Cradle to grave and module D	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mandatory
Cradle to gate[2]	Mand.	Mand.	Mand.														
Cradle to gate with options[2]	Mand.	Mand.	Mand.	Opt.	Opt.												

Figure 12 "Types of EPD with respect to life cycle stages covered and life cycle stages and modules for the construction works” EN 15804:A2

The results will be provided in a tabular format for easy integration into the INBUILT platform as part of work package 5. An example LCIA results table from an EPD has been provided in Figure 12.



Potential environmental impact – mandatory indicators according to EN 15804

Results per m² CosyWool roll with R = 1 m²K/W

Indicator	Unit	A1	A2	A3	Tot.A1-A3	A4	C2	C3	C4	D
GWP-fossil	kg CO_2 eq.	7.07E-01	2.61E-02	1.70E-01	9.03E-01	6.14E-03	6.14E-04	9.28E-04	0.00E+00	-1.26E+00
GWP-biogenic	kg CO_2 eq.	-8.59E-01	1.55E-05	2.90E-04	-8.58E-01	3.65E-06	3.65E-07	1.18E-06	8.95E-01	1.29E-04
GWP-luluc	kg CO_2 eq.	5.14E-03	8.82E-06	1.83E-04	5.33E-03	2.07E-06	2.07E-07	2.87E-07	0.00E+00	-1.95E-04
GWP-total	kg CO_2 eq.	-1.47E-01	2.62E-02	1.71E-01	5.00E-02	6.14E-03	6.14E-04	9.29E-04	8.95E-01	-1.26E+00
ODP	kg CFC 11 eq.	6.43E-08	6.40E-09	2.06E-08	9.13E-08	1.50E-09	1.50E-10	3.81E-10	0.00E+00	-1.73E-07
AP	mol H^+ eq.	2.93E-03	8.38E-05	4.32E-04	3.45E-03	1.97E-05	1.97E-06	8.77E-06	0.00E+00	-1.31E-03
EP-freshwater	kg PO_4^{3-} eq.	1.19E-03	1.47E-05	1.14E-04	1.31E-03	3.46E-06	3.46E-07	1.44E-06	0.00E+00	-2.39E-04
EP-marine	kg N eq.	7.29E-04	1.88E-05	9.29E-05	8.41E-04	4.41E-06	4.41E-07	3.04E-06	0.00E+00	-3.04E-04
EP-terrestrial	mol N eq.	6.22E-03	2.05E-04	9.95E-04	7.42E-03	4.81E-05	4.81E-06	3.33E-05	0.00E+00	-3.26E-03
POCP	kg NMVOC eq.	1.94E-03	8.00E-05	2.74E-04	2.29E-03	1.88E-05	1.88E-06	9.65E-06	0.00E+00	-1.23E-03
ADPE*	kg Sb eq.	1.28E-05	4.31E-07	4.40E-07	1.37E-05	1.01E-07	1.01E-08	8.84E-09	0.00E+00	-2.63E-06
ADPF*	MJ	1.19E+01	4.22E-01	3.45E+00	1.58E+01	9.92E-02	9.92E-03	2.58E-02	0.00E+00	-1.83E+01
WDP*	m^3	1.99E-01	1.46E-03	6.64E-03	2.07E-01	3.43E-04	3.43E-05	1.16E-03	0.00E+00	-1.68E-02

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

Figure 13 Example LCIA results as presented in an EPD - ThermaFleece EPD

4. Circularity Assessment

4.1. Description

The assessment of circularity is necessary because it highlights the limitations of the planet, such as the predicted scarcity of virgin resources and the large accumulation and need to manage the waste generated in the different sectors of activity, as well as the modification of the environment resulting from this resource extraction and waste disposal.

The concept of circularity means closing the cycle of the 3 resource streams as much as possible: materials-waste, energy, and water, as shown in figure 14. Within the construction sector, it means minimizing the extraction of virgin materials, including fossil fuels, and avoiding the generation of waste either in the construction and subsequent use stage or in the final demolition of the building, as shown in Figure 15.

This is achieved using renewable materials/resources, the continuous reuse or recycling of these materials and resources (waste, water, energy) within the production chain of a building, the design of construction solutions that enable final disassembly and separation into independent materials for recycling or reuse, extending the useful life of the product whenever possible, and the correct management of waste. This concept is opposed to the current linear "take–make–waste" economy.

According to Circle Economy, the world was only 8.6% circular in 2021[i]. This is just one of the indicators that have been proposed to measure the progress of the circular economy.

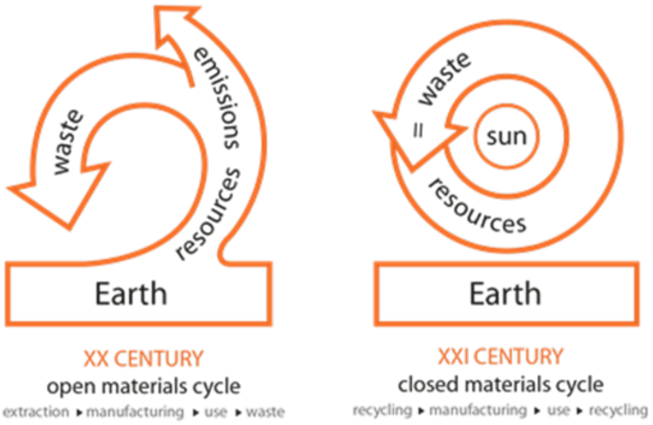


Figure 14 Open and Closed loop (circular) of resources. Source: Societat Orgànica

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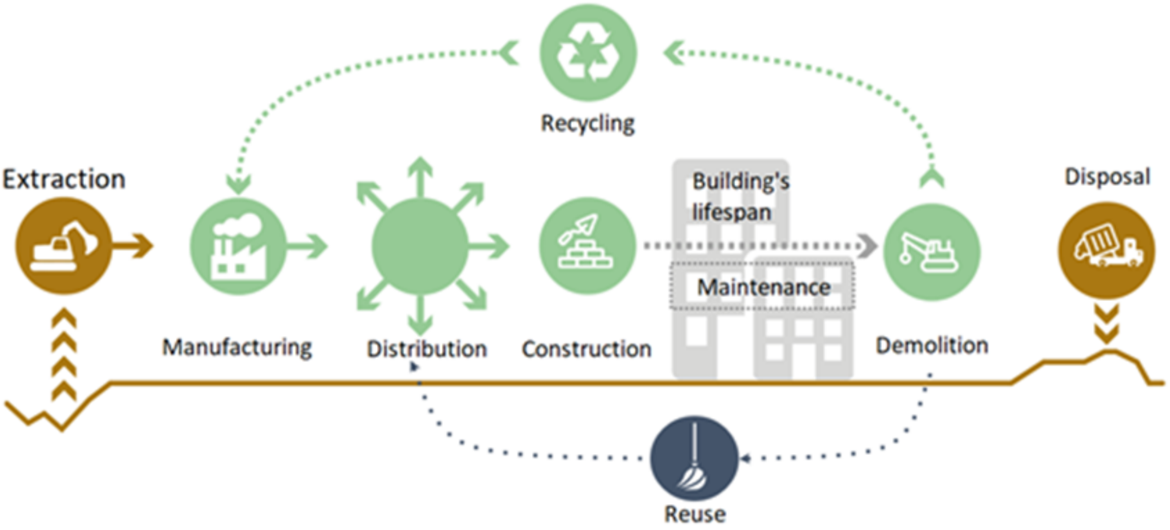

Figure 15 Stages of lifecycle of a building to close the loop (green and blue stages). Source: Societat Orgànica

The circular assessment developed in this case will focus on the material and waste stream, the water resource will be discarded from this analysis and the energy flow will be included in the LCA assessment as they are not the object of the experiments sought in this project.

There are several ways to assess environmentally a building, and besides Circular Assessment, the LCA (Life Cycle Assessment) and the LCC (Life Cycle Costing) are two of them which are directly related through various indicators. However, there are currently no harmonized definitions of what a circularity analysis is meaning a unique methodology, global indicator, or tool since it must cover different stages of life cycle and future scenarios difficult to define.

The need for a more circular economy has been translated into European directives that are replicated in national regulations. Change is difficult within the construction sector. There are concerns within the European Commission (EC), international regulations and other standards regarding the Circular Economy and CDW. In this sense, the EC presented an ambitious Circular Economy Package, this comprises updated legislative suggestions on waste management, aiming to encourage Europe's shift towards a circular economy. The goal is to enhance global competitiveness, promote sustainable economic expansion, and create employment opportunities.

The difficulties are partial since there is currently no harmonized and holistic European framework on circularity between EU countries or even in public administration like certificates schemes of circularity, different approaches to the assessment of circularity, public regulation, lack of long-term statistic's, etc. What do exist are frameworks from recognized institutions or projects such as the Ellen MacArthur Foundation, Circle Economy or BUS Go-Circular, or tools, developed to identify part of this analysis at different levels of project development, such as the Circular Economy in the Built Environment developed by Arup and Ellen

MacArthur Foundation for strategic decisions in the early stages of the project, RE10 Tool for the analysis of disassembly and adaptability in the retrofitting of residential buildings developed by Instituto Valenciano de la Edificación (IVE), the COAC questionnaires adapting the Do No Harm to the Environment (DNHS) principle or the Material Circular Indicator developed by Ellen MacArthur Foundation. Based on these references and others identified in the State of Art of the project, together with the experience of the consortium partners and external stakeholders, a list of indicators has been defined to define the circularity concept in this project, and which is intended to be a replicable methodology for the building sector. This evaluation is explained in section 4.2. of this document.

4.2. Methodology for the assessment

For the assessment of circularity, we do not propose a single indicator that makes it possible to evaluate the greater or lesser circularity of a building. We agree that it would be an impossible task to give exclusive importance to a single aspect or indicator in this case, as in LCA we don't only measure kgCO$_2$ eq. without paying attention to the rest of the impact indicators.

Based on the different existing frameworks and tools analyzed and on the own experience of partners of the consortium in the environmental consultancy of architectural projects, we propose instead a series of indicators that will be able to demonstrate circularity in wider spectrum and along the stages of the life cycle. Adaptability will be included as an indicator of circularity as well. Once we have obtained all the indicators that we consider that represents the circularity of a building considering various circular strategies, we will intend to group the indicators by categories and suggest a weighting between them that gives different weight to each one. Ultimately, three summary indicators will be proposed to make the effort to combine the circular potential in each stage of life cycle, according to proposed weightings. These indicators will be compared with Ellen MacArthur's circularity indicator (MCI), trying to provide extra information to this factor. The process explained above will also be carried out at the product level, adapting the indicators that are appropriate for this level.

Some of these indicators, such as the potential for disassembly, will be difficult to calculate if it is not done on a specific building and if it is not analyzed where it is placed within the building and within which system. Therefore, it will be difficult to establish a form of calculation that does not involve the use of actual building assumptions so as not to incur unrealistic future assumptions. For example, an element may be designed to be dismantled for maintenance, replacement, or end of life but, if it is finally placed behind a building system that does not allow access to its dismantling or a wet construction layer, this element will end up being non removable. It will have a potential for demountability but it will not be in accordance with the final design result of the solution. Therefore, such future hypotheses will be useful if a concrete analysis of the construction solution is carried out within the building; it will not make sense to associate a factor to the product alone. These and other questions will arise during the analysis and methodological solutions will be provided on how to calculate or measure them.

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This analysis aims to provide harmonization in the method of conducting circularity assessments, an increase in the amount of data monitored on real buildings, a methodology on the creation of assessment scenarios and, therefore, some final recommendations for the implementation of these analyses in future policies or public tenders. Moreover, trying to demonstrate that circularity, if thought from the beginning and in conjunction with the value chain, should not always translate into higher upfront costs.

One of the evaluation frameworks we rely on is necessarily LEVEL(s), together with other references of recognized entities such as Ellen MacArthur & Arup or the national tool (mainly for adaptability and quality inputs) of Valencian Institute of Edification (IVE), among others reviewed. Based on this research, we have defined the outputs that we will calculate as well as the necessary inputs to reach them and the sources that allow us to obtain them, always under European regulations or recognized standards in the sector. If feasible, the results obtained will be translated into graphics and communication understandable by different users with different levels of expertise to overcome these knowledge barriers and foster awareness and interest.

The list of inputs required to develop the circularity assessment is shown below:

- *Positions in the building (qualitative):* This input is related to the geometric information that can be taken from the BIM model, with reference to the family (exterior or interior façade, pavement, fundings, etc.) to identify the system.
- *Year of colocation (year):* the year of installation or construction of the product/material is needed to get an idea of the material condition, the standard that was covered in that year and discover the durability of the product. Source: Material Passport.
- *Composition of the product, per material (% of material per kg of product):* The source will be the Digital Product Passports. This input is important to discover if there is a pure material or mixed and the type of union: dry, binders, adhesives, sealants, etc. The next step will be to investigate the actual existence of technology to separate the product into pure materials to enable recycling.
- *Recycled content of each Product/material (% of recycled content in the total mass):* Its usual source is the Digital Product Passport, Material Passport or databases with sector data. In this case, this recycled content will be measured during the production of the materials inside the consortium. For the external materials, suppliers will be asked to provide us with the recycled content documentation.
- *Origin and suppliers of the materials (qualitative):* Qualitative indicator that will contain the information about where the material comes from (including if it comes from another building) and which is its supplier/s. This information is comprehended in the Material Passport.
- *Ease of separation of product components:* Possibility and methods of separation (qualitative) + quantity of pure material that can be separated with respect to the total mixed material (kg/kg).
- *Building sites on going of consortium partners (locations):* The idea is to find sites & industries for reusing elements from CDW and the excess of materials fabricated. The first step is to find sites of the consortium partners (COM, INC, HOL), if not possible, external stakeholders will be consulted for developers contact.

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- *Life Cycle Global Warming Potential:* LCA will be provided inside the consortium by ITEC in the unit of kg CO_2 equivalents per square meter per year (kg CO_2 eq./m^2/year).
- *Bill of quantities, materials (units and kg/m^2):* This information is comprehended in the Digital Product Passport.
- *Construction & Demolition waste quantity (kg/m^2):* From BIM model of the Digital Twin, we will monitor demos real data of the kg of each type of waste per m^2 constructed floor area. Comparison with LEVEL(s) statistics data in 2.2 Construction and demolition waste.
- *Architecture: Detailed constructive solutions & plans:* From BIM model
- *Maintenance for each material:* Quantity of materials incorporated for maintenance of a product and each frequency. It is supposed that Digital Twin will enable us to get this input.
- *Hypothetical materials durability - service life (years)*: Its usual sources are RCP from EPD, specific manufacturer info included in Digital Product Passport. The directly output related is Cost per service life = (Initial cost + Maintenance costs + Replacement costs) / Estimated service life.

4.2.1. Output obtained

Below is the list of outputs that will emerge from the development of the required circularity assessment. All these outputs will be compared with a baseline building with conventional solutions to check the improvement of the constructed demo within the project. In addition, these results will be calculated for each stage of the building's life cycle (if applicable) and then summed up to obtain the final result.

- *Quantity of solutions in the building with circularity potential (dismountability):* % kg /kg.
- *Quantity of inert/ hazardous waste:* % kg/m^2.
- *Quantity of materials that close the loop (recycled content or renewable):* % kg/m^2.
- *Quantity of recyclability (different quality of waste, different recyclability):* % kg/m^2 of recyclability and % kg/m^2 of under-recycling. It is useful because it relates waste and its circularity potential.
- *Materials with valorization potential (qualitative):* materials developed within the project and found in CDW sites that have the possibility of being separated into pure materials or components and have actual value chain to recycle or reuse. Generalization with other products on the market.
- *Qualitative data of adaptability/deconstruction from R10 tool:* Qualitative indicator which will be weighted.
- *Quantity of adaptability:* % m^2 of its total construction surface. This indicator checks the percentage of buildings that can be adapted.
- *MCI (material circular indicator)*: It is a factor developed by Ellen MacArthur Foundation and it will be considered to validate it.
- *Cost per service life:* (Initial cost + Maintenance costs + Replacement costs) / Estimated service life-(euro/year m2). It brings the economic aspect of circularity.

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5. Social impact assessment

5.1. Description

The Social Life Cycle Assessment (SLCA) forms a critical component of Task 4.4 within the INBUILT project, spanning from Month 12 (M12) to Month 36 (M36). Led by ESK with contributions from all consortium partners, this task integrates a comprehensive Life Cycle Sustainability Assessment (LCSA) by combining results from environmental (LCA), economic (LCC), and social (SLCA) impact assessments. This holistic approach ensures a robust evaluation of the implemented solutions within each INBUILT pilot, addressing sustainability across its three dimensions.

By aligning environmental, economic, and social assessments, Task 4.4 identifies potential trade-offs among these dimensions. The outcomes are geared towards summarizing the SLCA of the 12 innovative products (IPs) developed in the project and complementing dissemination and exploitation activities. The ultimate goal is to support sustainable product policies, showcase successful application stories, and provide actionable insights at both macro (EU-28) and sectoral scales.

The SLCA methodology focuses on impacts across four key stakeholder groups:

1. ***Workers***: *Ensuring health and safety, fair wages, reasonable working hours, freedom from discrimination, and elimination of forced labor.*
2. ***Building Occupants***: *Evaluating functionality, usability, health and comfort, and accessibility of the solutions.*
3. ***Local Communities***: *Addressing health and safety concerns, accessibility, and fostering local employment opportunities.*
4. ***Society***: *Supporting technological development and promoting public commitment to sustainability issues.*

Two functional units—**per person·year** and **per m^2·year**—will standardize interpretation and comparability across analyses. To further enhance sustainability insights, circularity potential will be explored through scenario analyses, comparing alternative end-of-life treatments. Sensitivity analyses will also provide deeper understanding of the influence of critical factors, such as user behavior and electricity mix, on the overall results.

This assessment aims to demonstrate significant advancements in:

- ***High-quality recycling*** *at the end-of-life stage of products.*
- ***Reduction in greenhouse gas emissions (t CO_2-eq)*** *and ambient air pollution.*

- ***Substantial reduction of embodied energy****, without compromising energy efficiency and user comfort.*

By addressing these objectives, the assessment of the social impacts aligns with the broader goals of the INBUILT project, supporting sustainable innovations while balancing environmental, social, and economic considerations.

5.1.1. State of the art

Social Life Cycle Assessment (SLCA) is an evolving methodology designed to evaluate the social and sociological impacts of products across their entire lifecycle, from raw material extraction to end-of-life disposal. Its development has been shaped by growing awareness of sustainability's social dimension, complementing the environmental (LCA), and economic (LCC) pillars of life cycle assessment.

5.1.1.1. Current Practices in SLCA

SLCA is guided by established frameworks and tools:

- ***UNEP Guidelines (2020)****: Provide a comprehensive framework for conducting SLCA, emphasizing the need for transparency, stakeholder inclusivity, and comparability.*
- ***Handbook for Product Social Impact Assessment (2018)****: Offers practical guidance on measuring and reporting social impacts, particularly within corporate and industrial contexts.*
- ***SimaPro and Social Hotspot Database (SHDB)****: Widely used tools that allow for a systematic and data-driven approach to identifying social "hotspots" across a product's lifecycle.*

5.1.1.2. Advancements in Methodologies

Recent advancements have enhanced SLCA's rigor and relevance:

- ***Integration with LCSA****: Combining SLCA with LCA and LCC allows for a holistic sustainability assessment, identifying trade-offs and synergies between social, environmental, and economic dimensions.*
- ***Dual-Method Approaches****: The use of top-down (impact pathway) and bottom-up (reference scale) methodologies enables both quantitative and qualitative assessments, providing a comprehensive view of social impacts.*
- ***Standardized Indicators****: Stakeholder-specific indicators, such as health and safety, labor rights, and accessibility, improve consistency and comparability across studies.*

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5.1.1.3. Challenges in SLCA

Despite these advancements, SLCA faces notable challenges:

- ***Data Gaps***: *Social data, particularly at the lifecycle stage level, is often incomplete or unavailable, affecting the accuracy of assessments.*
- ***Lack of Harmonization***: *Variability in indicator selection and assessment methodologies complicates comparability across studies.*
- ***Complexity of Social Metrics***: *Quantifying social impacts such as cultural preservation or public commitment to sustainability remains a methodological hurdle.*

5.1.1.4. Relevance to the INBUILT Project

The INBUILT project builds on the state of the art by:

1. ***Leveraging Dual-Method Approaches***: *Using top-down and bottom-up methodologies to provide robust, stakeholder-focused assessments for 10 innovative products.*
2. ***Focusing on Circularity***: *Introducing scenario analyses to investigate circularity potential and alternative end-of-life treatments, aligned with the EU's sustainability goals.*
3. ***Addressing Trade-Offs***: *Integrating SLCA with LCA and LCC to identify and address potential conflicts between environmental, social, and economic objectives.*
4. ***Enhancing Stakeholder Engagement***: *Collecting primary data through customized questionnaires to ensure assessments reflect real-world conditions and stakeholder perspectives.*

By aligning with current best practices while addressing existing challenges, the SLCA methodology in the INBUILT project exemplifies a forward-looking approach to sustainability assessment, supporting product innovation and sustainable policy development.

5.1.2. Strengths and weaknesses

5.1.2.1. Strengths

- ***Holistic Approach***: *Combines environmental (LCA), economic (LCC), and social (SLCA) assessments, ensuring a comprehensive understanding of sustainability across all dimensions.*
- ***Stakeholder Focus***: *Addresses impacts on diverse stakeholder groups, including workers, building occupants, local communities, and society.*
- ***Standardized Functional Units***: *The use of per person·year and per m²·year ensures clear interpretation and comparability of results across pilots and products.*

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- ***Circularity Potential****: Scenario analyses investigate end-of-life recycling alternatives, highlighting pathways for achieving high-quality recycling and reduced embodied energy.*
- ***Advanced Tools and Frameworks****: Utilizes SimaPro and the Social Hotspot Database (SHDB) alongside internationally recognized guidelines (e.g., UNEP 2020, Roundtable for Product Social Metrics 2018).*
- ***Sensitivity Analysis****: Provides insights into the influence of critical parameters (e.g., user behavior, electricity mix), offering actionable recommendations for optimization.*

5.1.2.2. Weaknesses

- ***Data Availability****: Dependence on high-quality, granular lifecycle data from all project partners and stakeholders can pose challenges.*
- ***Complexity of Integration****: Combining LCA, LCC, and SLCA requires significant coordination and expertise to ensure consistency and avoid trade-offs.*
- ***Quantifying Social Impacts****: Some social aspects, such as cultural preservation or social justice, are inherently qualitative, making quantification challenging.*
- ***Resource Intensity****: SLCA, particularly in combination with LCA and LCC, demands significant time, expertise, and computational resources.*

5.2. Partner's methodology

5.2.1. Input(s) required and Output(s) obtained

Inputs Required

1. ***From Partners****:*
    a. *Lifecycle data for the 12 innovative products, including material sourcing, production, usage, and end-of-life stages.*
    b. *Policies and practices related to labor rights, working conditions, and health and safety.*
    c. *Stakeholder-specific data, such as local community impact assessments and user feedback.*
    d. *Environmental (LCA) and economic (LCC) results from Task 4.3 for integration into LCSA.*
2. ***From Tools****:*
    a. ***SimaPro Software****: To perform top-down social hotspot analyses.*
    b. ***Social Hotspot Database (SHDB)****: To identify potential social risks and "hotspots".*
    c. ***Customized Questionnaires****: To collect stakeholder-specific data for bottom-up analysis.*

Outputs Obtained

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1. ***Top-Down Analysis****:*
    a. *Identification of social "hotspots" across lifecycle stages, highlighting areas of high-risk impacts.*
    b. *Quantified insights into stakeholder-specific social challenges.*
2. ***Bottom-Up Analysis****:*
    a. *Social performance assessments using performance reference points (e.g., semi-quantitative 0-5 scales).*
    b. *Stakeholder engagement reports capturing input from workers, local communities, and building occupants.*
3. ***Final Deliverables****:*
    a. ***Comprehensive SLCA Report****: Summarizing methodologies, results, and trade-offs across environmental, economic, and social dimensions.*
4. ***Impact Demonstrations****:*
    a. *High-quality recycling pathways and reduced GHG emissions (t CO_2-eq).*
    b. *Substantial reduction in embodied energy without compromises in comfort and usability.*
    c. *Success stories showcasing scalable applications of sustainable practices.*

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6. Hygrothermal and energy performance assessment and monitoring

6.1. Description

The hygrothermal and energy performance assessment focuses on evaluating and optimizing the performance of innovative building elements developed within the INBUILT project, relying on both numerical and experimental approaches. The assessment combines numerical modeling and simulation techniques to address both hygrothermal performance and energy efficiency across multiple scales, which is the core of Task 4.5.

At the system and facade scale, the work examines heat and moisture transfer characteristics in complete wall sections, including elements combined from prior development. Key performance indicators, such as heat flux, surface temperature, relative humidity, and mold growth risk, are analyzed under various climatic conditions and construction techniques.

At the building scale, the focus shifts to the energy demands and thermal comfort impacts of these innovative systems when applied to new and existing structures. Overheating risks during summer and overall comfort levels are assessed, while optimization algorithms are employed to enhance performance based on energy efficiency and comfort criteria for diverse building typologies and climates.

The hygrothermal and energy performance will also be assessed under real conditions at four demonstration sites through long term monitoring, which forms the core of Task 6.3.

These assessments aim to demonstrate the expected outcomes KPI#10 and KPI#12:

- *Expected Energy demand reduction*
- *Expected Indoor hygrothermal comfort enhancement*

A multi-step and multi-scale approach will be used: the models at wall and building scale will be validated and calibrated against measured data. In parallel, the models will be used to run simulations on baseline scenarios (building without INBUILTs developed solutions). The comparison of energy consumption and hygrothermal comfort with and without INBUILTs innovative products will allow us to quantify the gains compared to the reference case.

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6.2. Partner's methodology

The aim of Task 4.5 is to assess and enhance the performance of INBUILT's innovative building products at both façade and building scales.

1. *Façade scale:* Using WUFI software, we will perform numerical simulations of heat and moisture transfer to evaluate critical parameters, including heat flux, surface temperature of inner walls, relative humidity, mould growth potential, and other relevant indicators. This analysis will be conducted for various climate conditions and construction techniques to identify optimal performance.
2. *Building scale:* At the building level, we will employ simulation tools WUFI or EnergyPlus to analyze energy demands and thermal comfort across different climates and building typologies. This will allow us to understand the broader impacts of INBUILT solutions in diverse real-world contexts.

This dual-scale approach provides a thorough evaluation of the hygrothermal, energy, and comfort performance of INBUILT solutions. By utilizing the two simulation tools, we can pinpoint ideal configurations, proactively address potential risks, and optimize the real-world applicability of these innovative building elements. In addition, these simulated results will be calibrated and validated against the data collected at wall scale testings (T4.6) and from Task 6.3 monitoring (T6.4).

Then, task 6.3 will focus on the installation of sensors, data collection, and storage at four demonstration sites. The monitoring will include:

1. *Global energy metering:* To assess overall energy usage and efficiency.
2. *Local sensors:* These will include heat flux meters, wall and air temperature sensors, window opening detections, occupant presence sensors, and HVAC system monitoring to provide detailed insights into building performance.

This comprehensive monitoring approach will support data-driven optimization, ensuring that INBUILT solutions deliver on their performance goals in real building conditions.

Demo 1: New building performance evaluation

To evaluate the performance of innovative products incorporated into the newly built office building, intended to be the headquarter of Filiater, the following equipment will be installed during the construction stage:

Indoor environmental sensors:

- *Air temperature and relative humidity in each zone*
- *CO_2 sensors in offices, showroom, meeting room, and laboratory*

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- *Motion sensors in offices, showroom, meeting room, and laboratory*

Outdoor environmental sensors:

- *Air temperature and relative humidity (from weather station)*
- *Solar radiation (if possible)*

Wall sensors:

- *Heat fluxmeter on the interior face of the wall*
- *Surface temperature with thermocouples*
- *Temperature and relative humidity embedded inside the wall (2-3 depths)*
- *Temperature and relative humidity at the interface between layers inside the wall*

Window sensors:

- *Frame temperature with thermocouples*
- *Opening state (open/closed)*
- *Shading state (if possible)*

Other type of sensors:

- *Energy metering (depending on the system chosen)*
- *Power metering at the output of PV panels*
- *Blower door measurement*
- *IR thermography*

Demo 2: Tiny houses performance evaluation

- *Relative Humidity & Temperature sensors in the room*
- *Relative Humidity & Temperature sensors in the stud walls*
- *Relative Humidity & Temperature sensors in the wall*
- *Heat Flux sensors in wall surface inside (North side)*
- *Temperature sensors accompanying/next to the Heat Flux sensors*
- *Energy measuring devices (heater, light, PC etc) in the power distribution box*
- *Material moisture measurement in the timber studs in the stud walls*
- *Global energy metering*
- *Air permeability (blower door test)*

Demo 3: Pre- and post- retrofit building performance evaluation

To undertake the pre-retrofit measurements, the University of Bath will deploy the following equipment:

- *1 x Heat Flux sensor*
- *2 x temperature sensors adjacent to the Heat Flux sensor on the internal face and at a corresponding location on the external wall face*
- *1 x (battery powered) Data logger*

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To undertake the post-retrofit evaluation, the University of Bath will deploy the following equipment:

- *1 x Heat Flux sensor – for in-situ U-value measurement*
- *2 x temperature sensors adjacent to the Heat Flux sensor on the internal face and at a corresponding location on the external wall face*
- *1 x CO_2 sensor in the main workshop space – for IAQ evaluation*
- *1 x RH and Temperature sensor in the main workshop space – for IAQ evaluation*
- *1 x 'clamp-on' AC current clamp (at main Consumer Unit or spur to micro-factory workshop) – for monitoring of electrical energy use (kW & kWh, monitored at least half-hourly)*
- *Up to 3 'clamp-on' AC current clamps for installed HVAC, To Be Confirmed as retrofit plans evolve - – for monitoring of electrical energy use (kW & kWh, monitored at least half-hourly) of key electrical HVAC equipment e.g. lighting circuit, hot water heating, electric space heating etc.*
- *2 x in-line flow meters for main hot and cold-water pipework – for monitoring total hot and cold-water usage.*
- *Externally, air temperature, relative humidity, and global solar radiation will be recorded.*

In addition to sensor deployment, the team will aim to conduction additional Post-Occupancy Evaluation (POE) e.g. interviews and, if the space can be practically enclosed, 'blower door' testing to determine zone air permeability.

6.2.1. Inputs required and Outputs obtained for hygrothermal and energy performance assessment

Inputs required:

1. ***From INBUILT product manufacturers:***
   - *Product geometry*
   - *Product thermal properties*
   - *Product moisture transport properties*
2. ***From Demo-side leaders:***
   - *Building geometry and layout*
   - *Envelope construction and materials*
   - *Thermal properties*
   - *Internal loads*
   - *HVAC systems*
   - *External weather data*
   - *Building use and occupancy profiles*

Outputs obtained:

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1. ***Heat and moisture transfer analysis***
    a. *Heat flux profiles*
    b. *Temperature distribution across different layers of building envelope*
    c. *Moisture transport and accumulation in building envelope*
    d. *Mould growth risk index*
2. ***Energy demand analysis***
    a. *Heating and cooling load profiles*
    b. *Energy consumption*
    c. *Energy efficiency gains from INBUILT solutions*
3. ***Thermal comfort analysis***
    a. *Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD)*
    b. *Overheating risk during summer*
4. ***Optimization algorithms***
5. ***Final Deliverables:***
    a. *Report on Hygrothermal simulation results, analysis, and recommendations for optimized design*
    b. *Results analysis and design recommendations based on the global approach numerical modelling*

6.2.2. Inputs required and Outputs obtained for monitoring

Inputs Required:

1. ***Sensor configuration and specifications***
    a. *Global energy metering*
    b. *Local sensors*
    c. *HVAC system monitoring*
2. ***Monitoring system setup and communication protocols***
3. ***Specific inputs for each demo-site***
    a. *Building characteristics and layout*
    b. *Climate and environmental data*

Output obtained:

1. ***Real-time monitoring dashboards***

Final deliverable: Report on data analysis - Demo Site 1, Demo Site 2, and Demo Site 3

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7. Certification of products

7.1. Description

This part of the report describes the possibilities for future certification of the newly developed materials and systems concerning technical performance of products. Main goal is to estimate time necessary for certification at European level in order to gain a CE-marking based on the Construction Products Regulation CPR (EU No. 305/2011).

7.1.1. State of the art

The Construction Products Regulation (CPR) requires all construction products covered by harmonized European Standards (hEN) to have a declaration of performance (DoP) produced and to be CE marked. Additionally, products not covered by a hEN (including innovative products), but which have successfully achieved a European Technical Assessment (ETA) must also carry the CE mark. This is a legal requirement and applies to manufacturers, importers, or distributors of affected construction products placed on the market in Europe. Construction products covered by the regulation cannot be legally sold in Europe if they do not comply, even if the product is an established one.

Suitable standards, technical rules and guidelines (EADs on European level) for the developed products and designs have been identified and reported in Deliverable D4.1. Main factors which influence time needed for fully certified products are following:

- Status of the technical specification (harmonized European product standards, European Assessment Documents),
- System of conformity assessment (AVCP-System),
- Required tests (specified test time, availability of testing facility),
- Level required for the certification of construction product (product, kit).

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7.1.2. Strengths and weaknesses

IP No.	Estimated time for a fully certified product (based on Grant Agreement)	Comment (USTUTT)
IP#1	6 - 12 months after project	For non-standard techniques such as IP#1, an ATEx (Avis Technique d'Expérimentation) is required. Estimated time is realistic if the national technical assessment body already has experience with similar products.
IP#2	12-24 months after project	Both IP#2 products will be certified with German National technical assessment (Zulassung). These products are new on German market but standards for typical masonry units can be mostly applied. The estimated time is well estimated.
IP#3	6-8 months after project	There are no similar products on the market but standards for individual layers of IP#3 exist. Certification time of max. 8 months is reasonable because this product is declared with less characteristics than typical building products. Moreover, there are no long-term tests.
IP#4	12-24 months after project	There are some comparable products on German market as IP#4 but containing less recycled materials. Product must be certified with German National technical assessment (Zulassung) in order to fulfill estimated certification time.
IP#5	12-24 months after project	There are product standards for similar products as IP#5. If traceability and testing methods for recycled materials are well established, estimated certification time is realistic.
IP#6	June 2025	The estimated time is possible to reach if developed product is market ready by the end of March 2025. Certification is based on European standards.
IP#7	12-24 months after project	Certification is based on the European standard but there are some big scale tests required for the certification. The estimated time is realistic.

IP#8	3-6 month after achieving TRL8	The estimated time is possible to reach if available EADs are applicable without modifications.
IP#9	6-8 months after project	There are no standards for IP#9. If the producer starts the application process for the certification during project time, they will reach the estimated time.
IP#10	12 months before the end of the project	The estimated time is well defined. The producer of P#10 is very active in standardization work of such products.

8. Conclusions

This deliverable outlines all the actions to be developed within the project to achieve, through a comprehensive approach, the transformation of the construction sector towards a more sustainable, efficient, and digitalized model. Through the collaborative work of the various consortium partners, key performance indicators (KPIs) have been defined to assess circularity, life cycle performance, and the technical and functional requirements of the digital platform. These KPIs will allow for an objective measurement of the environmental, economic, and social impact of the innovative solutions developed within the project framework.

Throughout the development of this report, various fundamental aspects influencing the transition towards a circular economy have been addressed. The importance of integrating bio-based, geological, recycled, and reused materials has been consistently highlighted, positioning these elements as a key strategy for reducing the carbon footprint and improving the environmental performance of buildings. Additionally, the role of digitalization has been emphasized, particularly through Building Information Modeling (BIM) and resource management tools, which help optimize design, construction, and maintenance processes.

One of the main challenges of this deliverable has been structuring a standardized methodology for environmental impact assessment, based on recognized European methodologies such as the Level(s) framework, UNEP's S-LCA guidelines, and the RE10 Tool. The harmonization of criteria and the collection of standardized data will enable valid comparisons between different products and construction solutions, facilitating decision-making based on reliable and transparent information. Another key aspect of the project has been the assessment of material and construction system circularity, which has made it possible to define strategies to enhance the reuse and recyclability of components throughout their life cycle. Using the Level(s) framework as a reference, particularly macro-objective two, specific indicators have been established to quantify the circularity of each proposed solution, integrating all relevant information into a material passport.

From a social perspective, the impact analysis will assess the influence of innovative solutions on building occupants' quality of life, local community well-being, and working conditions within the supply chain. Using the S-LCA methodology and collecting data through surveys and specialized databases, the social impact has been identified as one of the most relevant indicators among the innovative products developed within INBUILT.

Hygrothermal and energy performance has also been a key pillar of the project, addressed through both numerical modeling and real-world evaluations in demonstration buildings. Through simulations and real-world measurements, the effects of innovative solutions on energy demand, thermal efficiency, and occupant comfort have been determined. This approach will validate the proposed strategies and improve

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their implementation in future applications, supported by the different scenarios available within the platform.

Finally, the product certification process has been analyzed in detail to facilitate the future commercialization of the innovative solutions. This work aims to emphasize transparency regarding the specific requirements for each type of material and the estimated timelines for obtaining certifications such as the CE marking. This aspect will not only facilitate the market introduction of solutions that meet the technical and sustainability standards required in the European Union but also reinforce the commitment to visibility for products composed of non-virgin raw materials, ensuring their performance.

In conclusion, this work aims to lay the foundation for a structural transformation of the construction sector, providing advanced digital tools, standardized methodologies, and scientific knowledge applicable to the implementation of circular economy strategies. The proper integration of the defined KPIs, along with the implementation of the digital platform, will enable architects, designers, builders, and other stakeholders to make informed decisions that contribute to the sustainability and efficiency of the sector in the short, medium, and long term. The next steps of the project will include the validation of methodologies in real-world scenarios, integration with external databases, and the optimization of information flow within the platform, ensuring its applicability and scalability at the European level.

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[i] Circle Economy. (2020). The Circularity Gap Report 2020

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