Habitat for Humanity® | Empty Spaces to Homes

Developing Life Cycle Assessment Carbon Footprint Methodology and Establishing Key Performance Indicators Aligned with EU Taxonomy

Review Report of Existing Methodologies and Requirements Related to Life-Cycle Assessment Carbon Footprint Related to Construction Sector

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ENOVA
CONSULTANTS AND ENGINEERS
INSPIRED BY THE FUTURE

Contents

List of Abbreviations

BREEAM	Building Research Establishment Environmental Assessment Method
BSI	British Standards Institute
CEN	European Committee for Standardisation
CFP	Carbon Footprint of Product
DGNB	Deutsche Gesellschaft fur Nachhaltiges Bauen
EC	European Commission
EBRD	European Bank for Reconstruction and Development
EE	Energy Efficiency
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
EPD	Environmental Product Declaration
ESTHer	Empty Spaces to Homes
EU	European Union
GDP	Gross Domestic Product
GET	Green Economy Transition
GHG	Greenhouse Gases
GPP	Green Public Procurement
GWP	Global Warming Potential
HQE	Haute Qualite Environnementale
IFI	International Financial Institution
ISO	International Organisation for Standardisation
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
UN	United Nations
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

1 Introduction

Project Context. The Empty Spaces to Homes (**ESTHer or the "Project"**) is an innovative initiative launched in January 2024, designed **to tackle the urgent housing challenges in Hungary, Poland, Croatia, and Great Britain**. Funded by the Laudes Foundation and led by Habitat for Humanity International (the "Client"), in collaboration with Habitat for Humanity Great Britain and Habitat for Humanity Poland, **the Project seeks to repurpose vacant and underutilised spaces to create affordable, sustainable housing**. By reusing existing structures, ESTHer reduces carbon emissions and offers a progressive solution to both the housing crisis and environmental sustainability.

In many European countries, particularly in the target regions of this Project, housing affordability remains a significant issue. Systemic inequalities, underinvestment, and limited social housing options are widening the gap between housing supply and demand. The shortage is exacerbated by energy-inefficient housing, which contributes to energy poverty, especially affecting vulnerable groups. Research shows that up to 12% of housing in these areas is vacant, with many properties owned by local governments. The Project aims to transform these vacant spaces into affordable, carbon-neutral homes, addressing housing exclusion and inequalities. It focuses on providing sustainable living solutions for vulnerable groups, including young adults, the elderly, and those affected by homelessness, while also improving energy efficiency (EE) and reducing the environmental impact by reusing embodied carbon in construction.

The Project consists of several key components: research, financial model development, demonstration builds, stakeholder engagement, and policy advocacy. Research will involve creating baseline housing reports and analysing financial and governance models to better understand the landscape of vacant properties in selected cities. Demonstration builds will showcase the potential of transforming empty spaces into affordable housing units, directly addressing homelessness and overcrowding while reducing energy poverty. A strong focus on stakeholder engagement will ensure alignment among policymakers, sector players, and communities, supporting the successful implementation of these solutions.

Policy advocacy will play a central role in influencing housing policy at the local, national, and EU levels, with a focus on supporting social rental agencies and improving affordable housing governance. By addressing both housing affordability and environmental sustainability, ESTHer offers a dual approach that not only tackles the immediate housing crisis but also creates long-term, resilient housing solutions.

The Assignment. The Client has engaged Enova (the "Consultant") **to develop a comprehensive methodology for assessing and mitigating CO_{2e} emissions throughout the entire renovation process of repurposed buildings** (the "**Assignment**"). The primary objective is to provide the Client with the necessary information, analysis, and recommendations to comprehensively assess, structure, and approve Project implementation.

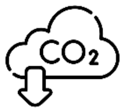
About this Report. As part of the Assignment, the Consultant conducted a thorough **review of existing Life Cycle Assessment (LCA) carbon footprint methodologies relevant to building reconstruction** to identify the most suitable approaches. This process involved an extensive literature review of peer-reviewed journals, industry reports, and recognised guidelines, with a particular focus on LCA tools and databases designed specifically for construction, renovation, and material reuse in building projects.

The chapters below present the findings of the Consultant's review conducted during the inception phase of the Project; referencing various standards, tools, and frameworks, including European Union (EU) and International Organisation for Standardisation (ISO) requirements, EU Green Public Procurement criteria, the GHG Protocol, as well as International Financial Institution (IFIs) guidelines and methodologies, to identify the most applicable approaches for the Project.

2 Existing Methodologies and Requirements Related to LCA Carbon Footprint

2.1 Background – Key Carbon Footprint Categories

The carbon footprint of a building is typically assessed in two main categories:



embodied carbon

Embodied carbon refers to the total greenhouse gases (GHG) emissions from producing, transporting, constructing, and disposing of materials and products over their entire life cycle. This includes emissions from extracting raw materials, manufacturing, assembly, distribution, and eventual decommissioning or recycling. In essence, it encompasses all emissions before a product or building is operational.

operational carbon

Operational carbon refers to emissions generated during the active use of a building or product. This includes energy consumed for heating, cooling, lighting, appliances, and machinery, and the associated emissions from electricity or fuel use throughout its life.

These categories, embodied and operational carbon, measure the total carbon impact of a building or product. While operational carbon covers ongoing energy use, embodied carbon often accounts for a significant portion of total emissions, especially in construction. Addressing and reducing both is crucial for mitigating climate change.

Strategies for Reducing Embodied Carbon. Reducing embodied carbon is crucial for minimising the environmental impact of construction activities and achieving sustainability goals. The following strategies and measures provide a framework for addressing this challenge:

Table 1: Strategies for reducing embodied carbon

Strategy	Measures
Using low-carbon materials	Prioritisation of **sustainable materials** with lower carbon footprints, such as timber and bamboo, which serve as sustainable alternatives to concrete and steel.
	Incorporation of **recycled or repurposed materials**, such as recycled steel, glass, or plastic, which significantly lower embodied carbon compared to newly produced materials.
	Considering that traditional concrete production is a major source of embodied carbon, alternative **low-carbon concrete materials** like geopolymer concrete should be considered to substantially reduce emissions.
Optimisation of materials use	Employment of **advanced structural design techniques**, such as parametric design, to minimise material requirements, particularly for concrete and steel in frames and foundations.
	Adoption of **prefabricated or modular construction methods**, which inherently reduce material waste and energy consumption during production.
	Local sourcing of materials to minimise transportation-related emissions.
Consideration of whole life cycle (cradle-to-cradle)	Evaluation of the **entire life cycle of materials and products**, from extraction (cradle) to end-of-life (cradle-to-cradle).
	Selection of **products designed for easy disassembly and recycling**, to encourage lower embodied carbon over time.
Enhancing lifespan and durability	Utilisation of **durable materials** with longer life cycles.
	Selection of **materials that require minimal maintenance**, further reducing embodied carbon over time.

Strategies for Reducing Operational Carbon. The following strategies and measures are considered to minimise energy consumption and emissions during a building's life cycle:

Table 2: Strategies for reducing operational carbon

Strategy	Measures
EE improvements	**Improvement of insulation and air sealing** to reduce energy consumption for heating and cooling.
	Installation of energy-efficient windows, such as double or triple glazing, to enhance thermal performance.
	Usage of **energy-efficient lighting systems** (e.g., LEDs) and appliances to reduce electricity consumption.
	Incorporation of **passive design principles** to naturally regulate temperature through features like shading, ventilation, and green roofs.
Renewable energy utilisation	**Installation of renewable energy systems**, such as solar panels or small wind turbines, to reduce reliance on grid electricity.
	Utilisation of electric heat pumps for heating and cooling, which can be powered by renewable electricity.
	Connection to district heating systems powered by renewable energy or waste heat for enhanced efficiency.
	Purchase of **renewable energy credits or source electricity from green grids** to offset emissions.
Smart systems and automation	Usage of **real-time energy optimisation tools**, such as smart meters and automated controls, to improve EE.
	Installation of systems like **heat recovery ventilators** to capture and reuse wasted energy.

Integrated Approaches. For comprehensive and sustainable outcomes, operational carbon reduction should be integrated with embodied carbon strategies:

- Whole-life carbon assessment: Consideration of LCA tools to evaluate the total carbon impact of buildings and materials.
- Net-zero carbon buildings: Design of buildings to balance emissions through renewable energy generation or carbon sequestration.
- Circular economy principles: Implementation of reuse, refurbishment, and recycling practices to minimise the carbon impact associated with production and demolition.

Reducing both embodied and operational carbon is crucial for achieving significant emission reductions. A key reference in this effort is **PAS 2080:2023 Carbon Management in Buildings and Infrastructure**, which offers a comprehensive framework for consistent carbon management. This guideline emphasizes critical processes such as target setting, opportunity identification, and collaborative decarbonisation, ensuring a structured approach to carbon reduction. While PAS 2080 provides guidance on managing carbon, detailed methodologies for GHG quantification, assessment, and data gathering are addressed in other standards and specifications, as outlined in the subsequent sub-chapters.

This Project includes strategies/measures aimed at reducing both embodied and operational carbon. Developing a methodology/tool to quantify these reductions is an integral part of this Assignment.

2.2 General – Carbon Footprint Calculation Methodologies Based on LCA

GHGs can be emitted or removed throughout the life cycle of a product – covering stages such as raw material acquisition, design, production, transportation, use, and end-of-life treatment. Quantifying the carbon footprint of product (CFP) is crucial for understanding its climate impact and taking measures to enhance GHG removals and reduce emissions across the product's life cycle.

Carbon Footprint of Product (CFP). Carbon footprint calculation is a methodology used to measure, manage, and communicate the GHG emissions associated with goods and services. While rooted LCA principles, it specifically focuses on evaluating the Global Warming Potential (GWP).

Current **CFP calculation methodologies** are grouped into two categories:

Table 3: CFP categories

Category	Methodologies	
Single-issue methodologies covering only emissions and impacts related to climate change	**ISO 14067:2018**	**The international reference standard for conducting CFP, derived from ISO LCA standards.**
	PAS 2050	Developed by the British Standards Institute (BSI) in 2008 and revised in 2011, it was the first widely used carbon footprint standard.
	GHG Protocol Product Standard (2011)	Developed by World Resources Institute (WRI)/ World Business Council for Sustainable Development (WBCSD), this methodology aligns with PAS 2050 but includes requirements for public reporting.
Broader-scope methodologies covering environmental issues beyond climate change	**ISO 21930:2017**	The international reference standard providing environmental product declaration (EPD) guidelines for buildings and construction products, enhancing transparency in sustainability efforts.
	Product Environmental Footprint	EU-recommended LCA approach, requiring 16 impact categories. Recent proposals emphasize climate change as a key indicator for CFP.
	BP X30-323-0	Developed by the French government, it includes multiple environmental impacts, with optional climate change reporting.
	EN 15804	European standard for construction products, addressing several environmental indicators, including climate change.
	EN 15978	**European standard addressing environmental performance of buildings over their life cycle.**
	ASTM E2921-16	American Society for Testing and Materials developed LCA guidance for building and construction projects, including reconstruction activities.

All methodologies are grounded in **ISO 14040** and **ISO 14044**, which outline principles and frameworks for LCA. They also align with Intergovernmental Panel on Climate Change reports to ensure consistency. Despite some differences, developers (e.g., ISO, BSI, EC, WRI/WBCSD) have worked to harmonise their approaches.

Moreover, all methodologies provide requirements for addressing crucial factors for CFP calculations, such as: land-use changes, biogenic carbon emissions and uptake, soil carbon stock, green electricity use, and carbon offsetting.

The selection of methodology depends on the product's context and applicable regulations. **ISO 14067 is often a default methodology** due to its international recognition and adaptability. Its results can be expanded into broader LCA studies compliant with ISO 14040-44.

2.3 International and European Standards

2.3.1 International Standards

ISO addresses sustainability in buildings through *ISO/TC 59 Buildings and Civil Engineering Works*, and its subcommittee *SC 17 Sustainability in Buildings and Civil Engineering Works*. The following ISO standards are applied for LCA assessments in (re)construction activities:

Table 4: ISO/TC 59/SC 17 standards

Reference	Title
ISO/TS 12720:2024	Sustainability in buildings and civil engineering works — Guidelines on the application of the general principles in ISO 15392
ISO 15392:2019	**Sustainability in buildings and civil engineering works — General principles**
ISO 16745-1:2017	Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication
ISO 16745-2:2017	Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 2: Verification
ISO 20887:2020	Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance

Reference	Title
ISO 21678:2020	Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements and guidelines
ISO 21928-2:2023	Sustainability in buildings and civil engineering works — Sustainability indicators — Part 2: Framework for the development of indicators for civil engineering works
ISO 21929-1:2011	Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings
ISO 21930:2017	Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services
ISO 21931-1:2022	Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 1: Buildings
ISO 21931-2:2019	Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: Civil engineering works
ISO/TR 21932:2013	Sustainability in buildings and civil engineering works — A review of terminology
ISO 22057:2022	Sustainability in buildings and civil engineering works — Data templates for the use of EPDs for construction products in building information modelling

Other standards under ISO/TC 59/SC 17 include frameworks for assessing environmental, social, and economic performance of construction works, guidelines on terminology, and methods for sustainability assessment, such as:

- ISO 59000 series: focuses on circular economy principles.
- ISO 37101: provides a management system framework for sustainable development in communities.
- ISO 50001: supports energy management systems for improved EE.
- ISO 17742: guides energy savings calculations for regions and cities, considering sectors like industry, transport, and households.

2.3.2 European Standards

The European Committee for Standardisation (CEN) plays a significant role in developing sustainability standards for construction works. *CEN/TC 350 – Sustainability of Construction Works* focuses on horizontal standardised methods for assessing sustainability in the context of the UN Sustainable Development Goals and the circular economy. CEN/TC 350 includes:

- methodologies for environmental, social, and economic performance assessments,
- rules for EPDs, and
- facilitates the transition to a climate-neutral, resource-efficient construction sector.

The following CEN standards are applied for LCA assessments in (re)construction activities:

Table 5: CEN/TC 350 Published Standards

Reference	Title
EN 17472:2022	Sustainability of construction works – Sustainability assessment of civil engineering works - Calculation methods
EN 15942:2021	Sustainability of construction works – Environmental product declarations - Communication format business-to-business
EN 16309:2014 +A1:2014	Sustainability of construction works – Assessment of social performance of buildings - Calculation methodology
EN ISO 22057:2022	Sustainability in buildings and civil engineering works – Data templates for the use of EPDs for construction products in building information modelling(ISO 22057:2022)
EN 15941:2024	Sustainability of construction works – Data quality for environmental assessment of products and construction work - Selection and use of data

Reference	Title
EN 15804:2012+ A2:2019/ AC:2021	Sustainability of construction works – EPDs - Core rules for the product category of construction products
EN 17680:2023	Sustainability of construction works – Evaluation of the potential for sustainable refurbishment of buildings
EN 15643:2021	Sustainability of construction works – Framework for assessment of buildings and civil engineering works
CEN/TR 16970:2016	Sustainability of construction works - Guidance for the implementation of EN 15804
CEN/TR 17005:2016	Sustainability of construction works – Additional environmental impact categories and indicators - Background information and possibilities - Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings
EN 17672:2022	Sustainability of construction works – Environmental product declarations - Horisontal rules for business-to-consumer communication
EN 15804:2012 +A2:2019	Sustainability of construction works – Environmental product declarations - Core rules for the product category of construction products
EN 16627:2015	Sustainability of construction works – Assessment of economic performance of buildings - Calculation methods
EN 15978:2011	**Sustainability of construction works – Assessment of environmental performance of buildings - Calculation method**

Moreover, *CEN/TC 371 Energy Performance of Buildings* ensures alignment of energy performance standards across Europe.

2.4 European Green Building Standards

European Green Building certifications, including BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), DGNB (Deutsche Gesellschaft fur Nachhaltiges Bauen), and HQE (Haute Qualite Environnementale), evaluate the environmental performance of buildings, considering the carbon footprint of materials as part of their criteria. Achieving any of these certifications requires meeting a set of sustainability requirements closely tied to LCA assessments, as outlined below.

BREEAM. One of the most widely used certification systems in Europe and globally, BREEAM assesses sustainability across several categories, including materials and energy:

- Materials impact: credits are awarded for minimising the environmental impact of materials used in construction, including their embodied carbon.
- LCA: The carbon footprint of products is assessed over their entire life cycle, not just during the construction phase.
- Sustainable products: BREEAM promotes the use of low-carbon, sustainable materials, awarding points for products with certified environmental standards (e.g., EPDs).

LEED. A globally recognised green building certification – LEED, incorporates the carbon footprint of materials into its criteria, as follows:

- Materials and resources credit: LEED awards credits for reducing material-related environmental impacts, emphasizing locally sourced materials to reduce transportation-related emissions and promoting products with lower embodied carbon.
- Life cycle impact reduction: LEED's materials and resources credit encourages LCA to understand the full environmental impact of products, including carbon emissions.
- EPDs: Materials with EPDs demonstrating their carbon footprint and other environmental impacts can earn additional LEED points.

DGNB. The German sustainability certification, DGNB, places significant emphasis on environmental impacts, including carbon emissions:

- Material use: DGNB evaluates the carbon footprint of building materials and promotes low-carbon products, encouraging the use of materials with EPDs.
- Life cycle considerations: LCA are central to DGNB's evaluation, factoring in embodied carbon for a comprehensive environmental performance assessment.
- Carbon footprint of construction: DGNB tracks construction-related carbon emissions and supports reduction measures, such as using energy-efficient construction processes and low-carbon materials.

HQE. The French certification system, HQE, integrates carbon footprint analysis in its approach to sustainability:

- Materials and resources: HQE emphasizes the use of materials with reduced environmental impacts, assessed using life cycle approaches.
- EE and carbon reduction: HQE promotes energy-efficient building practices to minimise operational carbon emissions while encouraging reductions in embodied carbon through thoughtful material selection.

2.5 Level(s) – European Framework for Sustainable Buildings

Level(s) is a tool designed to assess and report the sustainability performance of buildings, providing an overview for the building transformation process. It is closely aligned with the EU sustainability initiatives and is grounded in the principles of circularity. Level(s) is structured around six macro-objectives that cover key sustainability aspects across a building's life cycle:

1. GHG and air pollutant emissions,
2. resource-efficient and circular material life cycles,
3. efficient use of water resources,
4. healthy and comfortable spaces,
5. adaptation and resilience to climate change, and
6. optimised life cycle cost and value.

These objectives are tracked using 16 indicators, which help align a building's performance with EU policy goals, such as EE, material use, waste management, water conservation, indoor air quality, and climate resilience. The indicators most relevant to this Assignment are listed below, while all Level(s) indicators are provided in Chapter 3.3:

Table 6: Level(s) indicators most relevant to this Assignment

Topic	Indicator	Description
GHG and air pollutant emissions across the building's life cycle	**Use stage energy performance ($kWh/m^2/yr$)**	This indicator measures the energy consumption during the use phase, reported in $kWh/m^2/yr$ of primary energy, in line with national or regional methods. It can be broken down by renewable and non-renewable energy use, as well as "self-used" versus "balance" energy, the latter accounting for energy exported from the building site[1].
	Life cycle GWP (CO_2 eq./m^2/yr)	This indicator tracks emissions throughout the building's life cycle, from raw material extraction to deconstruction. It accounts for both embodied carbon (from materials and construction processes) and operational carbon (from energy use during the building's operation). The results are reported by fossil GWP, biogenic GWP, and land use

[1] RANEA PALMA, A., GONZALEZ TORRES, M., PEREZ ARRIBAS, Z. and DONATELLO, S., Background report for the revision of EU Green Public Procurement criteria for Buildings, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/3484975, JRC138891

Topic	Indicator	Description
		change GWP, across the building life cycle modules defined in EN 15978.
Resource-efficient and circular material life cycles	**Bill of quantities, materials, and lifespans**	The Bill of Quantities is a critical tool used during design and construction for cost assessments and LCAs. It serves as a foundation for other indicators, such as: *construction & demolition waste and materials*, and *life cycle GWP*[2].
	Construction & demolition waste and materials	This indicator encourages professionals to plan for the reuse and recovery of materials by segregating waste during construction, renovation, and demolition. It highlights the environmental and financial costs of material waste, which can be minimised through practices like re-selling excess materials or prefabricating custom-sized components[3].
	Design for adaptability and renovation	This indicator focuses on designing buildings to be adaptable and flexible, thereby extending their useful life. It aligns with the concept of design for adaptability, which aims to accommodate changing occupier needs and market demands. While this approach may conflict with traditional business models, it supports a longer building lifespan and improves property value[4].
	Design for deconstruction, reuse, and recycling	This indicator supports designers and architects in considering how materials can be recovered at the building's end of life. By embedding circular principles in design, such as planning for the separation and recycling of materials, the embodied life cycle impact and resource consumption of the construction sector can be reduced[5].
Efficient use of water resources	**Use stage water consumption (m^3/occupant/yr)**	This indicator focuses the efficiency of water use within a building (consumption of water by building occupants, which may include water used for drinking, cooking, cleaning, sanitation, and other domestic or building-related purposes) during its operational phase.

Level(s) is not a certification scheme, and it does not include built-in benchmarks. Instead, it provides a shared reference point for the building sector to assess and monitor building performance. However, many certification providers are integrating Level(s) indicators into their performance criteria, contributing to consistent assessment methods, reporting, and data comparison across projects and countries.

2.6 EU Directives

Several EU Directives relate to the LCA of buildings and, consequently, GHG emissions. The most relevant ones are summarised in the table below:

Table 7: EU Directives related to the LCA of buildings

Directive	Description
2024/1275/EU Energy Performance of Buildings Directive (EPBD)	The EPBD is a key legislative instrument for enhancing and monitoring the energy performance of the EU's building stock. It promotes the transition towards zero-emission buildings, emphasizing very low energy demand and minimal operational GHG emissions. The EPBD also encourages a lifecycle approach to emissions, starting with new constructions and extending to renovations, while advocating for resource efficiency, circularity, and reduced GWP.
2023/1791/EU Energy Efficiency Directive (EED)	The EED focuses on reducing overall energy consumption by improving EE. Key provisions include: ○ A legally binding target to reduce EU final energy consumption by 11.7% by 2030, relative to 2020 levels. ○ Gradually increasing annual energy savings, with the goal of reaching 1.9% annual savings by 2028.

[2] „LEVEL(S): Putting circularity into practice", Available at: https://op.europa.eu/en/publication-detail/-/publication/ea438090-cf14-11eb-ac72-01aa75ed71a1/language-en
[3] Ibid.
[4] Ibid.
[5] Ibid.

Directive	Description
	○ Requiring contracting authorities to prioritise high energy-efficiency products, services, and buildings and to disclose information on life cycle GWP, use of low-carbon materials, and circularity, particularly for buildings >2,000 m^2 in floor area. ○ Advancing EE in district heating and cooling systems.
2008/98/EC Waste Framework Directive	This Directive directly influences the carbon footprint of buildings through: ○ Construction waste reduction by promoting waste minimisation strategies to reduce landfill waste and carbon emissions linked to disposal. ○ Circular economy in construction by encouraging the reuse and recycling of building materials, reducing carbon emissions from manufacturing and transport. ○ Sustainable building practices by fostering policies that advocate for low-carbon materials and designing buildings for easy deconstruction and material recovery. ○ Carbon savings from recycling by supporting the recovery of valuable materials from demolition debris, thus reducing emissions associated with manufacturing new materials.
2012/27/EU Energy Efficiency of Buildings Directive	This Directive promotes EE within the building sector, which is a major consumer of energy. Key points include: ○ Establishing minimum energy performance standards for buildings and promoting energy performance certificates for both residential and commercial properties. ○ Encouraging the renovation of existing buildings to improve EE, particularly in regions with inefficient building stocks. ○ Requiring Member States to develop long-term renovation strategies for their building stocks, with a focus on cost-effective deep renovations that significantly reduce energy consumption.
2009/125/EC Directive on Ecodesign of Energy-related Products	This Directive establishes a framework for improving the environmental performance of energy-related products, focusing on EE. Its objectives are: ○ Reducing energy consumption and GHG emissions by improving the design of energy-related products such as appliances, lighting, and industrial equipment. ○ Setting mandatory performance criteria for products, addressing their entire lifecycle from production to disposal. ○ Providing clear environmental performance information to support informed purchasing decisions. ○ Promoting ongoing innovation by regularly updating ecodesign requirements based on market evolution and technical advancements.

Moreover, the **Building Renovation Wave Initiative**, part of the **EU's Green Deal**, aims to significantly improve the energy performance of buildings by 2030. Its goals include:

- Renovating millions of buildings to enhance EE, thereby reducing energy waste and emissions.
- Accelerating renovation projects to make buildings more environmentally friendly, with a particular focus on reducing carbon footprints.

2.7 EU Green Public Procurement Criteria for Construction

Green Public Procurement (GPP) focuses on purchasing goods and services based on environmental criteria to reduce carbon emissions and environmental harm throughout their lifecycle. Public procurement accounts for 15% of global GHG emissions, with construction and transport sectors each contributing 12% of procurement-related emissions. In the EU, public purchasing represents 15% of GDP, making it a powerful tool for influencing markets and driving decarbonisation in high-impact sectors like construction[6].

[6] https://www.sei.org/wp-content/uploads/2023/02/green-public-procurement-eu.pdf

The construction industry is responsible for nearly half of Europe's energy and material consumption, one-third of water use, waste generation, and GHG emissions. Sustainable investments in buildings and systems can significantly reduce these impacts while promoting innovation in green technologies.

The EU's 2014 Public Procurement Directive outlines principles for including sustainability in procurement processes[7], but implementation varies across Member States, leading to inconsistent standards and enforcement. To address this, the European Commission introduced GPP criteria for construction in 2016 and revised them in 2020 to align with the European Green Deal's climate neutrality goals. It should be noted that the process of revising the criteria has incorporated two new themes that are crucial for the sustainability of buildings: vulnerability and resilience to climate hazards, and biodiversity[8].

2.8 IFIs Guidelines

International Financial Institutions (IFIs), including major development banks like the European Bank for Reconstruction and Development (EBRD), World Bank, and others, collaborate through the International Financial Institutions Technical Working Group to harmonise GHG emissions accounting at the project level. This collaboration aims to improve the consistency, transparency, and comparability of climate investment assessments, particularly in light of the Paris Agreement's focus on robust climate action and emissions reporting.

A harmonised approach to GHG emissions accounting enables standardised methodologies[9], improving trust and efficiency in estimating and comparing emissions impacts across projects. Key elements for consistent GHG estimation include:

- Methodological choices and assumptions, including assessment boundaries.
- Reporting absolute and relative emissions disaggregated by scope.
- Metrics like emissions intensity or pre-project emissions for project comparisons.

Standards such as the GHG Protocol, ISO standards, and the EU Emissions Trading Scheme guide these estimations. However, many existing standards focus on GHG inventory rather than LCA, which is essential for comprehensive evaluation of building renovations.

The EBRD's Green Economy Transition (GET) initiative exemplifies IFIs' commitment to low-carbon development by prioritising investments in renewable energy, EE, and sustainable infrastructure. Under GET, projects are assessed for their ability to reduce emissions or avoid carbon footprint increases through cleaner technologies and sustainable practices.

Environmental and social due diligence by IFIs often includes calculating life cycle emissions for building projects, focusing on reducing carbon impacts through energy-efficient renovations, renewable energy integration, and sustainable design. These efforts align with international best practices and support the transition to climate-resilient and resource-efficient economies.

[7] Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC Text with EEA relevance, EU Commission, available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014L0024

[8] RANEA PALMA, A., GONZALEZ TORRES, M., PEREZ ARRIBAS, Z. and DONATELLO, S., Background report for the revision of EU Green Public Procurement criteria for Buildings, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/3484975, JRC138891.

[9] IFI TWG AHG-003: Guideline for a Harmonised Approach to GHG Accounting, ver. 02.0, June 2021

3 EU Taxonomy Requirements and Alignment with LCA

3.1 Overview of the EU Taxonomy for Sustainable Activities

The EU Taxonomy is a classification system designed **to identify environmentally sustainable economic activities**, supporting the European Green Deal's objectives. It provides a framework to help companies and investors make informed decisions on sustainable investments by defining activities that contribute to environmental objectives without causing significant harm to others.

To qualify as environmentally sustainable under the EU Taxonomy, an activity must:

- substantially contribute to at least one of the six defined environmental objectives
- do no significant harm to any of the other objectives
- comply with minimum safeguards
- meet applicable technical screening criteria.

The **six environmental objectives** outlined in the EU Taxonomy are:

- climate change mitigation,
- climate change adaptation,
- sustainable use and protection of water and marine resources,
- transition to a circular economy,
- pollution prevention and control,
- protection and restoration of biodiversity and ecosystems.

The EU Taxonomy is not a mandatory list of investments or a rating system for the "greenness" of companies. Instead, it is a dynamic, technology-neutral tool that evolves with advancements in policy and technology. It aims to facilitate the transition of polluting sectors, promote transparency through disclosure requirements, and avoid misclassification of non-listed activities as inherently polluting.

3.2 Relevance of Carbon Footprint in EU Taxonomy for Construction Sector

The EU Taxonomy emphasizes **the importance of carbon footprint reduction in the construction sector** as part of its broader objectives to promote environmentally sustainable economic activities. Renovating existing buildings is a key focus area, as it directly addresses climate change mitigation, adaptation, and the transition to a circular economy. The Taxonomy establishes clear criteria to ensure that renovation activities align with its principles and contribute to reducing GHG emissions across the lifecycle of buildings.

Contribution to Climate Change Mitigation. Renovation activities contribute to climate change mitigation by:

- Meeting national requirements for major renovations or **achieving at least a 30% reduction in primary energy demand**.
- **Encouraging EE improvements**, which reduce operational emissions.
- **Retaining and reusing embodied carbon** through the preservation of existing structures and materials, thereby minimising emissions from new material production.

Contribution to Climate Change Adaptation. Carbon footprint considerations are integral to adaptation measures, as they influence the selection of materials and solutions to reduce physical climate risks. Best practices and climate risk assessments guide the integration of adaptation measures that enhance resilience without increasing emissions.

Transition to a Circular Economy. The Taxonomy supports the circular economy by emphasizing waste minimisation, material reuse, and recycling. Renovation projects are required to:

- **Reuse or recycle at least 70%** of non-hazardous construction and demolition waste.
- **Design for adaptability and deconstruction**, reducing lifecycle emissions.
- **Calculate and disclose the GWP of renovation works**, ensuring transparency and accountability.

Ensuring "Do No Significant Harm" Compliance. Renovation activities must comply with "do no significant harm" criteria to other environmental objectives, including:

- Sustainable water use: Ensuring **water-efficient installations**.
- Pollution prevention: **Using low-emission building materials** and controlling dust, noise, and pollutants during construction.
- Hazardous substances: **Avoiding or strictly regulating materials that pose risks to health and the environment**, such as formaldehyde and persistent organic pollutants.

Alignment with Minimum Safeguards. Renovation projects must align with international standards, including the Organisation for Economic Co-operation and Development Guidelines for Multinational Enterprises and the United Nations Guiding Principles on Business and Human Rights, ensuring ethical and responsible business practices throughout the lifecycle of construction activities.

3.3 Key Performance Indicators in the EU Taxonomy and their Alignment with LCA

The EU Taxonomy emphasizes sustainable construction practices by integrating the **Level(s) European framework**, which provides a standardised methodology for assessing and reporting sustainability performance in building projects. Reconstruction projects, in particular, can benefit from the 16 **key performance indicators (KPIs)** outlined in the Level(s) framework, as presented in Table 8 below. These indicators align closely with the LCA principles, ensuring a comprehensive evaluation of environmental impacts throughout a building's life cycle.

Table 8: Carbon footprint KPIs Aligned with the EU Taxonomy

Macro-objective	Indicators
GHG emissions along a building's life cycle	Use stage energy performance (kWh/m^2/yr)
	Life cycle GWP (CO_{2eq}./m^2/yr)
Resource efficient and circular material life cycles	Bill of quantities, materials, and lifespans
	Construction & demolition waste and materials
	Design for adaptability and renovation
	Design for deconstruction, reuse, and recycling

Macro-objective	Indicators
Efficient use of water resources	Use stage water consumption (m^3/occupant/yr)
Healthy and comfortable spaces	Indoor air quality
	Time outside of thermal comfort range
	Lighting and visual comfort
	Acoustics and protection against noise
Adaptation and resilience to climate change	Protection of occupier health and thermal comfort
	Increased risk of extreme weather
	Sustainable drainage
Optimised life cycle cost and value	Life cycle costs (€/m^2/yr)
	Value creation and risk factors

4 Conclusions and Next Steps

4.1 Key Findings from the Review

Calculating the carbon footprints of buildings is a vital component of sustainable building practices, aimed at reducing the environmental impact of the built environment and mitigating climate change. This practice is deeply embedded in the EU acquis and supported by various European and ISO standards and requirements, as well as IFI guidelines, which provide detailed methodologies for assessing the environmental impact of buildings, including their carbon emissions.

While some standards, such as **ISO 14067**, adopt a general approach applicable to any product, standards tailored specifically to buildings and the (re)construction sector are more relevant in this context. Key standards for this Assignment include:

- **ISO 15392:2019 – Sustainability of Construction Works**
  This standard outlines principles for sustainability in (re)construction activities, including strategies for carbon footprint calculation.
  It provides guidance on measuring carbon emissions throughout a building's life cycle, from material production and energy usage during operation to eventual demolition.
- **EN 15978:2011 – Sustainability of Construction Works: Assessment of Environmental Performance of Buildings**
  This standard applies a comprehensive LCA approach to evaluate the environmental performance of buildings, including carbon emissions.
  It encompasses a building's entire life cycle, addressing embodied carbon, operational carbon, and end-of-life impacts, such as deconstruction and waste management.
  EN 15978 offers a detailed methodology for calculating the carbon footprint, ensuring all life cycle phases are considered.

EN 15978 is highly technical and focuses on quantitative assessments of environmental impacts through LCA, providing precise measurement methodologies. ISO 15392, on the other hand, offers a broader, qualitative framework for sustainability, emphasizing principles and strategies without delving into specific measurement methods.

These standards collectively support the (re)construction sector's shift towards more sustainable practices by offering robust frameworks for assessing and minimising the carbon impact of buildings. As such, they will serve as the foundation for conducting the LCA within this Assignment.

4.2 Recommendations for Developing LCA Carbon Footprint Methodology for the Project

For the carbon footprint assessment of building reconstruction, **EN 15978:2011 is the most suitable standard due to its comprehensive and holistic methodology**. By considering all life cycle stages, as presented in Figure 1, this standard ensures a complete evaluation of environmental impacts while avoiding double counting of emissions.

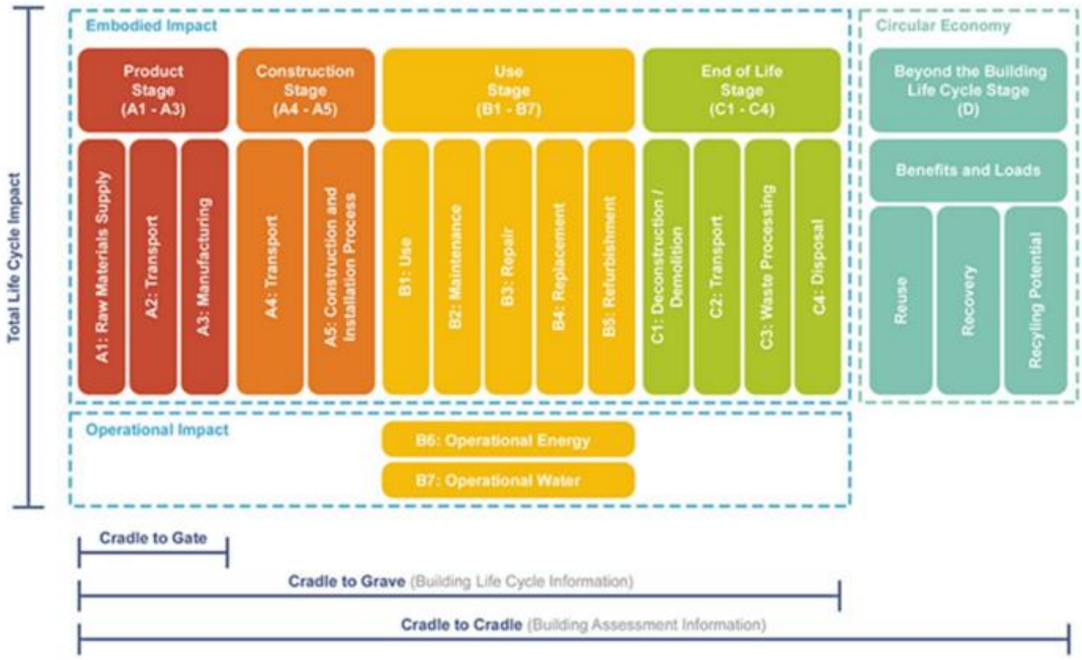


Figure 1: Different stages of the building life assessment

The proposed methodology for this Assignment involves operationalising the LCA approach through a tailored **excel-based tool** designed **to encompass all life cycle stages** outlined in Figure 1. This tool will integrate inputs and perform calculations for each stage of the building's life cycle, including raw material extraction and supply, transportation, manufacturing and construction activities, operational energy use and maintenance, and eventual demolition, ensuring a comprehensive and user-friendly framework for assessing carbon emissions.

Key considerations include:

- ensuring **compliance with EN 15978's requirements**,
- providing **user-friendly interfaces for data input and interpretation**,
- calculating Assignment-relevant **Level(s) indicators**, and,
- enabling **scenario analyses** to explore the impacts of different design, material, and operational choices.

The Excel tool will serve as a comprehensive and user-friendly platform designed to facilitate the consistent application of LCA principles across various stages of building (re)construction activities. It will enable detailed quantification and analysis of GHG emissions and their associated impacts. By capturing data on energy use, material flows, and waste generation, the tool will provide stakeholders with actionable insights to support sustainable decision-making and align with climate impact reduction goals.

Key features of the excel tool are:

1. **Stage-by-stage assessment framework**:
   - The tool will be structured to align with the building life cycle stages outlined in EN 15978, encompassing modules A (product and construction stage), B (use stage), C (end-of-life stage), and D (benefits and loads beyond the system boundary).
   - Each stage will include detailed input fields to capture essential parameters, such as energy consumption, raw materials, transportation details, and waste management data. The required input data and the corresponding output data, derived from these inputs, are presented in Table 9 below.

2. **GHG emissions calculation**:
   - The tool will integrate emission factor libraries for various materials, energy sources, and transportation modes to calculate the associated GHG emissions (CO_2, CH_4, N_2O) for each activity.
   - Customisation options will allow users to input location-specific or project-specific emission factors, ensuring accurate and relevant results.
3. **Comprehensive input and output mapping**:
   - Inputs and outputs for each life cycle stage, such as energy, materials, water, and waste, will be clearly defined and tracked, enabling a holistic view of environmental impacts.
   - Outputs such as GHG emissions, waste generated, and potential by-products will be automatically calculated, streamlining the analysis process.
4. **Focus on climate change impact category**:
   - While the tool can be expanded to include multiple environmental impact categories, this assignment will prioritise the climate change impact category.
   - The results will focus on GHG emissions and potential removals, facilitating a targeted approach to reducing carbon footprints.
5. **Decision-support mechanism**:
   - By presenting detailed emissions data, the tool will support informed decision-making regarding material selection, construction methods, and transportation logistics.
   - Comparative analysis features will enable users to evaluate multiple scenarios and identify options with the lowest environmental impact.
6. **Procurement and compliance support**:
   - The tool will assist in the procurement of products and materials by providing clear, quantifiable data on their environmental performance, ensuring compliance with GPP criteria.

The following breakdown outlines the key stages of the building life cycle, as defined by EN 15978, along with their respective inputs and outputs. For this Assignment, the primary focus is on the climate change impact category, particularly GHG emissions and removals.

Table 9: Lifecycle stages of buildings: inputs and outputs

Stage	Inputs	Outputs
A1: Product Stage (Raw Material Supply)	○ raw materials (e.g., concrete, steel, wood, etc) ○ energy (for extraction and processing), ○ water (for material production) ○ transport (for moving materials to manufacturing sites)	○ GHG emissions (CO_2, N_2O, CH_4) ○ waste (solid waste from material extraction and processing) ○ by-products (e.g., secondary materials, if any) ○ water usage (wastewater from production processes)
A2: Product Stage (Transport)	○ energy (for transportation; typically fuel for trucks, ships, trains, etc) ○ transport vehicles (e.g., trucks, ships, etc) ○ water (if transport requires water-based methods)	○ GHG emissions (CO_2, N_2O)
A3: Product Stage (Manufacturing)	○ energy (energy used in the manufacturing process, such as electricity, fuel, etc) ○ raw materials (inputs for the fabrication of products) ○ water (for cooling, processing, or cleaning) ○ labour (human resources)	○ GHG emissions (CO_2, N_2O, CH_4) ○ waste (production scrap, packaging waste, etc) ○ by-products (e.g., secondary materials that may be reused or recycled)
	○ construction materials and components (e.g., concrete, steel, wood, insulation materials, etc)	○ total energy required for transporting the materials

Stage	Inputs	Outputs
A4: Transport of Building Materials to the Construction Site	○ distance of the materials source to the construction site (e.g., manufacturing plant or raw material supplier) ○ transport modes – the type of transportation used (e.g., road, rail, sea, air) ○ total amount of materials being transported ○ type of fuel used in transport	○ GHG emissions generated from the transport process ○ waste generated during transport ○ including packaging waste or other by-products from the transportation process
A5: Construction Process On-Site	○ materials used for building the structure (e.g., concrete, steel, timber, insulation, etc) ○ machinery used during the construction process (e.g., cranes, excavators, mixers, etc.) ○ human resources (labour) required to perform construction tasks on-site ○ energy used for various construction processes (e.g., electrical energy for machinery, heating, and lighting; fuel for construction vehicles and equipment), ○ water used for mixing concrete ○ construction processes, and possibly other resources (e.g., cooling agents, temporary shelters, etc)	○ energy consumption during construction – includes all forms of energy used (electricity, fuel, etc.) to carry out the construction activities ○ GHG emissions produced from fuel combustion in equipment and machinery, energy use, and other activities on-site ○ waste generated during the construction process (e.g., excess materials packaging, and construction debris) which may require disposal or recycling
B1: Use Stage (Building in Use)	○ energy (electricity, heating, cooling, water, etc.) ○ water (for sanitation, usage, irrigation, etc.) ○ materials (for maintenance and repair) ○ labour (for maintenance activities) ○ services (e.g., energy supply, waste management, etc.)	○ GHG emissions from building energy use ○ waste (e.g., wastewater, packaging, etc.) ○ resource consumption (e.g., water, energy, materials) ○ heat (if the building is heated)
B2: Use Stage (Maintenance)	○ energy (for maintenance operations, machinery, etc.) ○ materials (for repairs, renewals, or refurbishment) ○ labour (for maintenance work)	○ GHG emissions (from energy consumption and maintenance activities) ○ waste (e.g., old materials, packaging, consumables)
B3: Use Stage (Repair)	○ energy (for tools and machinery used for repairs) ○ materials (for repairing or replacing damaged parts of the building) ○ labour (for repair work)	○ GHG emissions (due to the energy required for repairs and disposal of damaged materials) ○ waste (removed and replaced components) ○ potentially hazardous waste (if repair requires the handling of hazardous materials)
B4: Use Stage (Replacement)	○ energy (for replacing building components or systems) ○ materials (for replacement parts, new systems) ○ labour (for installation and system replacement)	○ emissions (from energy used in replacement activities) ○ waste (removed and replaced components) ○ by-products (secondary materials from new systems)
C1: End-of-Life Stage (Deconstruction)	○ energy (for tools and equipment used in demolition or deconstruction) ○ labour (for disassembly and removal work)	○ waste (e.g., construction waste, debris, recyclable materials, etc.) ○ GHG emissions (from transportation and mechanical equipment) ○ by-products (potential for recycling or reuse materials)
	○ energy (fuel used for transportation of materials to recycle or disposal facilities)	○ GHG emissions (from fuel consumption during transportation)

Stage	Inputs	Outputs
C2: End-of-Life Stage (Transport)	○ transport vehicles (for moving construction waste or recyclable materials)	○ waste (remaining un-recyclable materials)
C3: End-of-Life Stage (Waste Processing)	○ energy (for processing construction waste or recycling materials) ○ water (for waste treatment and processing) ○ materials (used in recycling and treatment processes)	○ emissions (from waste treatment processes) ○ by-products (such as recycled materials or compost) ○ waste (non-recyclable waste) ○ water (if treatment requires water discharge)
C4: End-of-Life Stage (Disposal)	○ energy (for disposal operations like landfilling or incineration) ○ materials (for landfill or disposal) ○ labour (for waste handling)	○ GHG emissions (from incineration or decomposition in landfills) ○ waste (e.g., non-recyclable waste, leachates from landfills) ○ resource consumption (for landfilling or disposal services)
D: Benefits and Loads Beyond the System Boundary	○ secondary materials (e.g., recycled materials reused in new construction) ○ energy (used to recycle or reuse materials)	○ environmental benefits (such as avoided impacts of virgin material extraction) ○ waste reduction (through reuse or recycling)