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TÜRKİYE SUSTAINABLE BUILDINGS NETWORK

THE SUSTAINABLE BUILDINGS E-LEARNING PROGRAM

Module **2**

DECARBONIZATION IN THE BUILDING SECTOR AND THE WHOLE LIFE-CYCLE APPROACH

This module was co-funded by the European Union.
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TÜRKİYE SUSTAINABLE BUILDINGS NETWORK

TÜRKİYE SUSTAINABLE BUILDINGS NETWORK

The Türkiye Sustainable Buildings Network was established as part of the "Türkiye Sustainable Buildings Network Project," which is co-funded by the European Union under the Civil Society Action towards European Green Deal Grant Scheme. The project is coordinated by WRI Türkiye, in partnership with the Zero Energy and Passive House Association (SEPEV) and with the support of the Danish Green Growth Network (DGGN).

The network operates with the aim of supporting climate action in the building and construction sector, promoting green transformation, enhancing the technical knowledge and skills of sector stakeholders, and mainstreaming the concept of sustainable buildings.

As part of this effort, the Sustainable Buildings E-Learning Program has been developed to serve as a comprehensive knowledge resource for all stakeholders in the building sector. The program consists of 10 training modules designed to contribute to the sector's sustainability, energy efficiency, and low-carbon transition goals.

Module 1: **Overview of Sustainable Buildings**

Module 2: **Decarbonization in the Building Sector and the Whole Life-Cycle Approach**

Module 3: **Sustainable Building Materials**

Module 4: **Sustainable Construction and Demolition Practices**

Module 5: **District Heating and Cooling Systems**

Module 6: **Innovative Building Technologies**

Module 7: **Financing Instruments for Sustainable Buildings**

Module 8: **Emissions Trading Systems and the Building Sector**

Module 9: **Energy-Efficient and Passive Building Design**

Module 10: **The European Green Deal and the Building Sector**

For more information about the Türkiye Sustainable Buildings Network and to access other modules, please visit **the link.**

MODULE OBJECTIVES

Decarbonizing buildings, which are responsible for one-third of global carbon emissions, is an effective tool in combating climate change and a prerequisite for climate-resilient construction.

This module aims to provide fundamental knowledge on the causes of carbon emissions in buildings, their calculation, and decarbonization strategies.

By the end of the module, the audience is expected to have an understanding of the following topics:

- The concept of building decarbonization and the role of buildings in carbon emissions
- Building life cycle stages
- Embodied and operational carbon emissions
- Calculation of carbon emissions using the life-cycle assessment (LCA) approach
- Standards used in the life-cycle assessment approach
- Strategies for reducing embodied and operational carbon emissions in buildings
- International and local policies, agreements, and mechanisms related to carbon emissions
- Local and international incentives and regulations for emission reduction

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Section **1**

DECARBONIZATION OF THE BUILDING SECTOR

1.1. Energy Consumption and Carbon Emissions* in the Building Sector

- In **Türkiye**, energy consumption during the operational phase of buildings accounts for **32%** of the total national final energy consumption and approximately **30%** of carbon emissions (excluding building materials) [1] [2].
- **In European Union (EU) countries, 40%** of total energy consumption and **one-third** of energy-related carbon emissions originate from buildings [3].
- **Globally, 34%** of total energy consumption (including energy used for building material production) and **37%** of carbon emissions come from buildings [4].

**Unless otherwise stated, "carbon" refers to multiple greenhouse gases expressed as "carbon dioxide equivalent" (CO_2e).*

1.2. Why is Decarbonization Necessary in the Building Sector?

- With the increasing global population, the building stock and urbanization rate are rapidly growing.
- It is estimated that the global building stock will nearly double in the next 30 years, reaching 460 billion m^2 [7].
- As the building sector accounts **for more than one-third** of global energy consumption and carbon emissions, it is one of the key contributors to global warming and climate change.
- Cities are among the most vulnerable areas to climate change, facing severe impacts such as **floods, droughts, heatwaves, and storms** due to their lack of resilience to these changing conditions.
- To break this cycle, targets have been set to reduce and **ultimately eliminate carbon emissions by 2050,** with the building sector playing a crucial role—particularly in the **EU and Türkiye** [5][6].

1.3. Concept of Decarbonization

“DECARBONIZATION”

It encompasses activities aimed at reducing human-induced carbon emissions (IPCC).

Decarbonization can be achieved through two main approaches:

1. Reducing carbon emissions from the combustion of fossil fuels
2. Capturing and storing existing carbon dioxide in the atmosphere or utilizing it in industrial processes

In buildings, decarbonization is primarily achieved by reducing **direct and indirect** fossil fuel consumption.

The Greenhouse Gas Protocol (GHG) defines direct and indirect carbon emissions as follows:

Scope 1: “Direct Emissions” – Carbon emissions resulting from the direct combustion of fossil fuels such as natural gas, coal, fuel oil, LPG, and LNG in buildings.

Scope 2: “Indirect Emissions” – Carbon emissions associated with electricity consumption in buildings.

Additionally, carbon emissions occur throughout the whole life-cycle of building materials and activities, including raw material extraction, production of building materials, transportation, construction, maintenance, renovation, operation, and demolition of the building.

1.4. Global Decarbonization Targets

European Union (EU)

Fit for 55: Under the European Climate Law, EU countries aim to reduce carbon emissions by **55%** by **2030** compared to 1990 levels.

Net Zero by 2050: The EU targets a climate-neutral economy with **net-zero** greenhouse gas emissions by 2050.

Türkiye

Net Zero by 2053: Under the Paris Agreement, Türkiye has set a target to achieve net-zero carbon emissions by 2053.

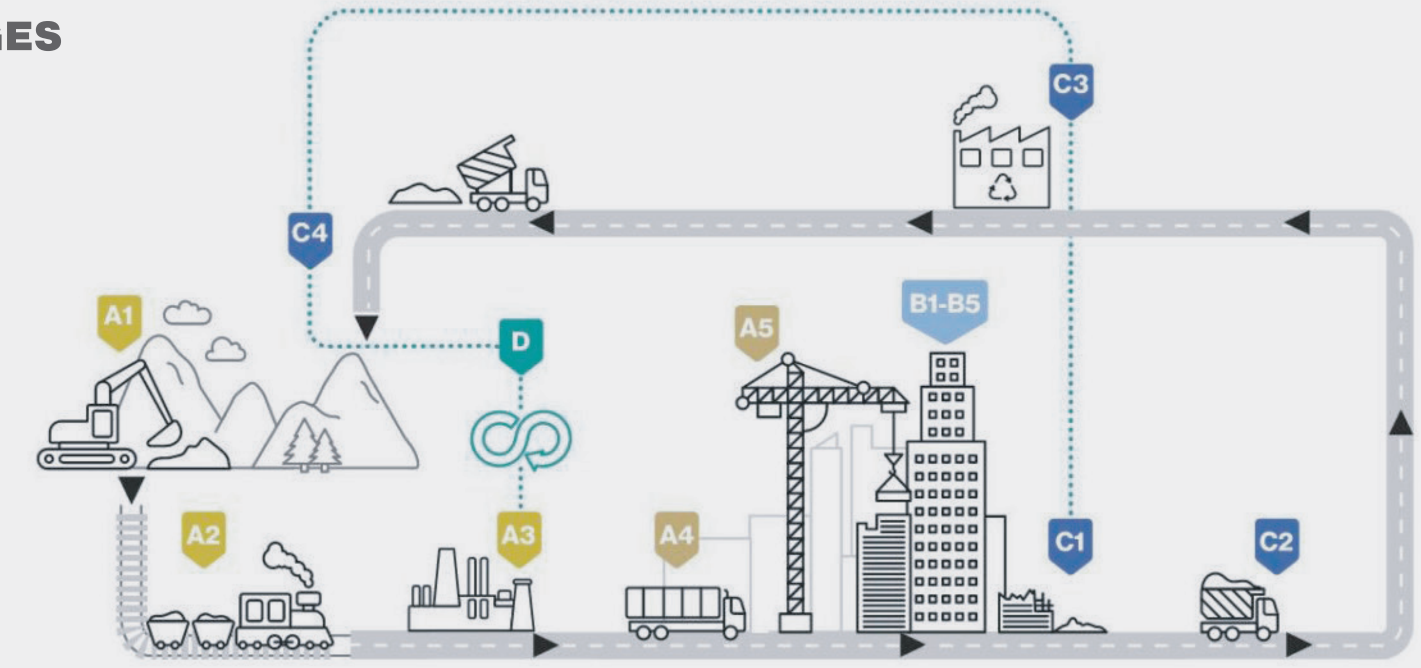
Global

44 countries have legally binding carbon reduction commitments, while 52 countries (including Türkiye) have pledged emission reduction targets through policy documents [8].

1.5. Building Life Cycle Stages

- **The Building Life Cycle** is a concept that encompasses all processes from raw material extraction to demolition or reuse of a building. It is used to assess the environmental, economic, and social impacts of a building.
- **A building's life cycle consists of the following stages:**
  - **Raw Material Supply (A1-A2):** Extraction, processing, and transportation of construction materials.
  - **Production and Manufacturing (A3):** Processing of building materials in factories and their transformation into building components.
  - **Construction and Assembly (A4-A5):** Transportation of materials to the construction site and the building's construction.
  - **Use and Operation (B1-B7):** Energy consumption, maintenance, repair processes, and operational emissions of the building.
  - **Demolition or Reuse (C1-C4, D):** Deconstruction, recycling, or reuse processes at the end of the building's lifespan.
- The Building Life-Cycle Stages are defined in the **EN 15978** standard, which has been in effect in Türkiye as TS EN 15978 since 2012.

LIFE CYCLES STAGES



A1 - A3

PRODUCT
A1 Raw Material Extraction
A2 Transportation to Manufacturing Site
A3 Manufacturing

A4 - A5

CONSTRUCTION
A4 Transportation to Construction Site
A5 Installation/Assembly

B1 - B5

USE
B1 Use
B2 Maintenance
B3 Repair
B4 Replacement
B5 Refurbishment
B6 Operational Energy Use
B7 Operational Water Use

C1 - C4

END OF LIFE
C1 Deconstruction & Demolition
C2 Transport
C3 Waste Processing
C4 Disposal

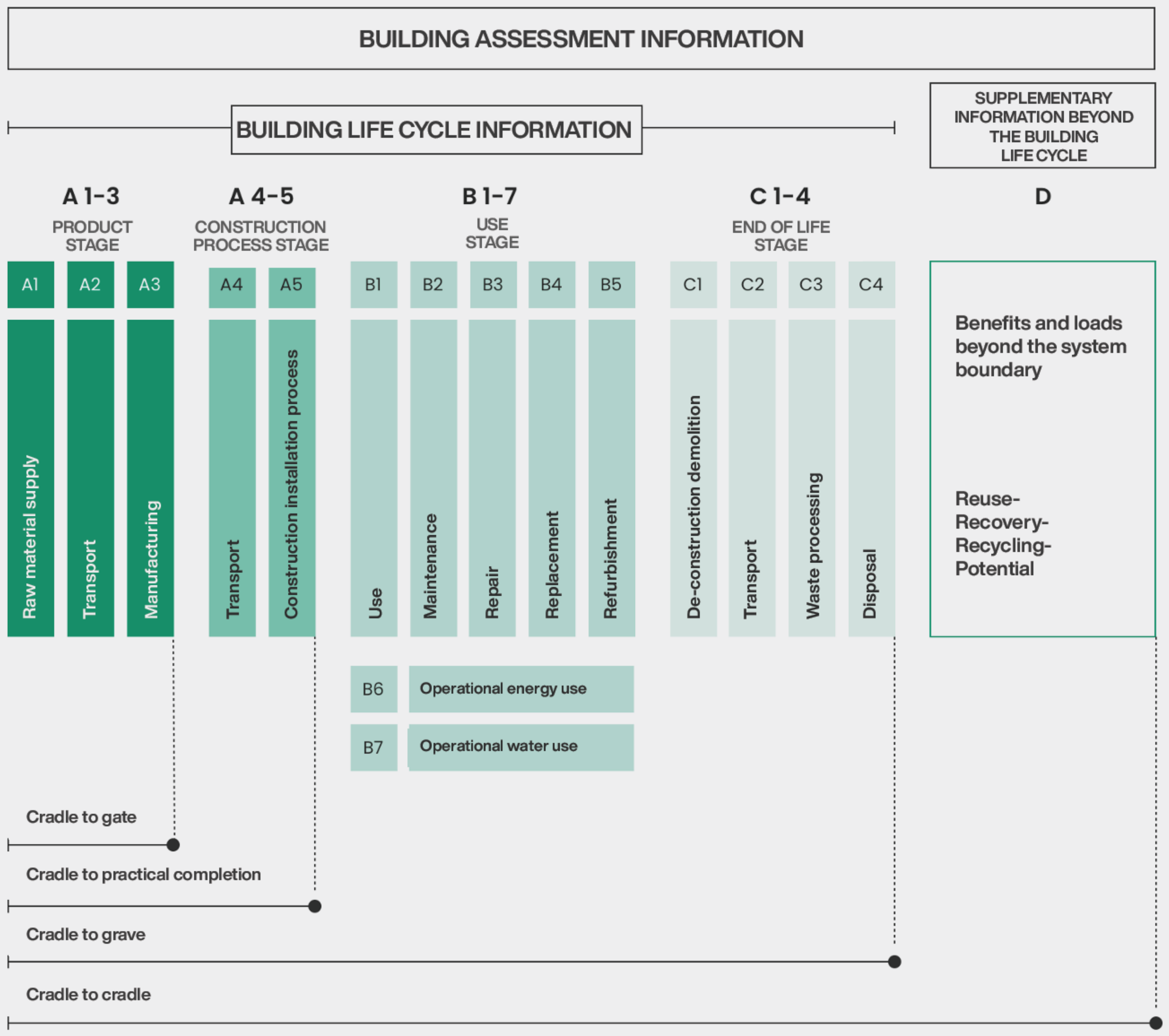
D

REUSE, RECOVERY, RECYCLING POTENTIAL
Counts the benefits (emission reductions) and burdens (emission increases) related to waste disposal after demolition. Module D is consistent with the cradle-to-cradle approach.

Life Cycle Stages Diagram, created by BEYOND (https://www.gobeyondwithus.com).

1.5. Building Life Cycle Stages

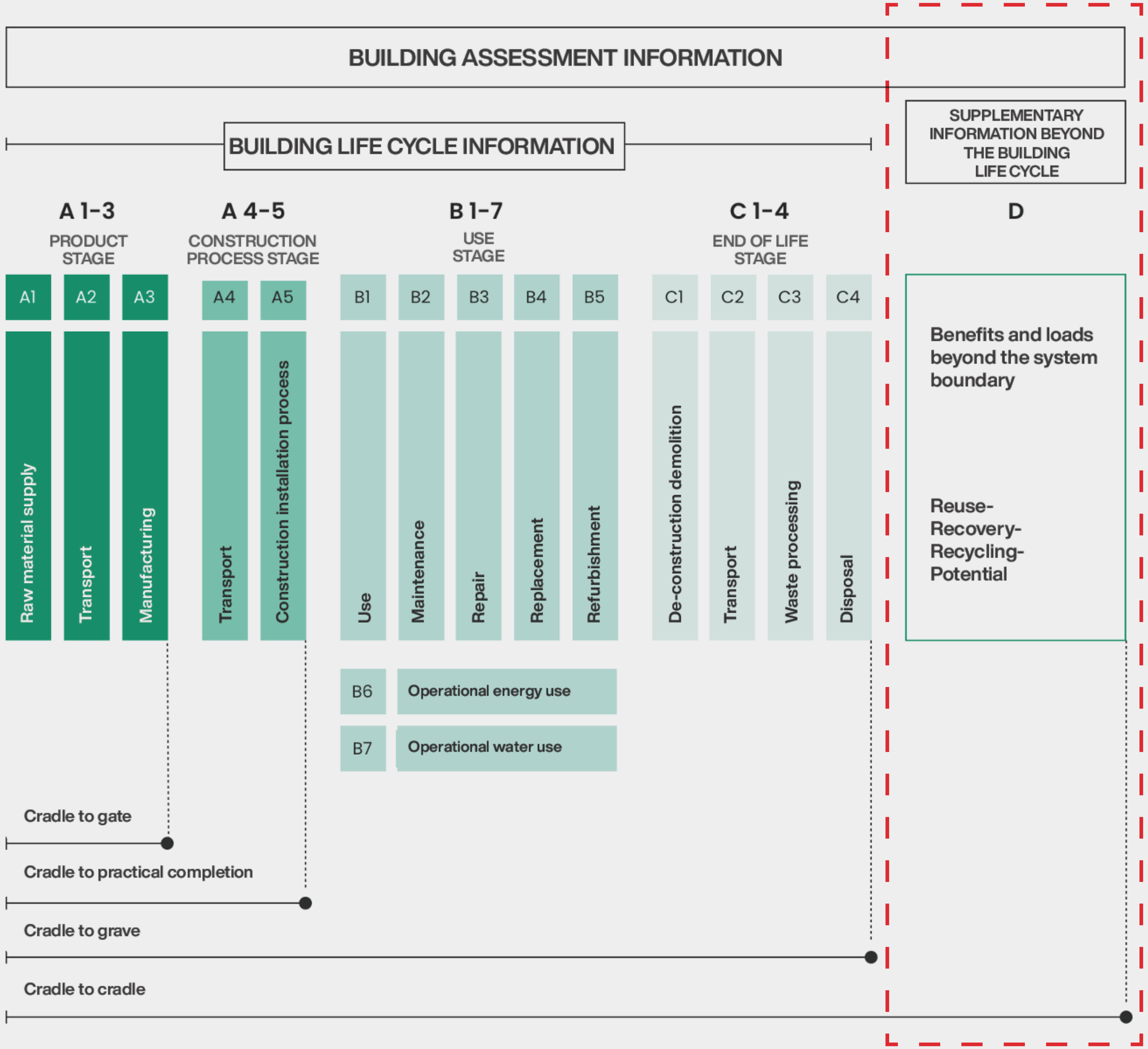
- **A1:** Raw material extraction and processing, processing of secondary material inputs *(e.g., recycling processes)*
- **A2:** Transportation of raw materials to the manufacturer
- **A3:** Production of material/product
- **A4:** Transportation of material/product to the construction site
- **A5:** Construction activities *(excavation, foundation laying, building construction, disposal of construction waste)*
- **B1:** Direct emissions during building use
- **B2:** Maintenance
- **B3:** Repair
- **B4:** Replacement
- **B5:** Refurbishment
- **B6:** Operational energy use in the building
- **B7:** Operational water use in the building
- **C1:** Demolition of the building
- **C2:** Transportation of demolition waste
- **C3:** Processing of demolition waste (recycling)
- **C4:** Disposal of non-recyclable or non-reusable waste



1.5. Building Life Cycle Stages

D: Benefits and burdens outside the system boundary

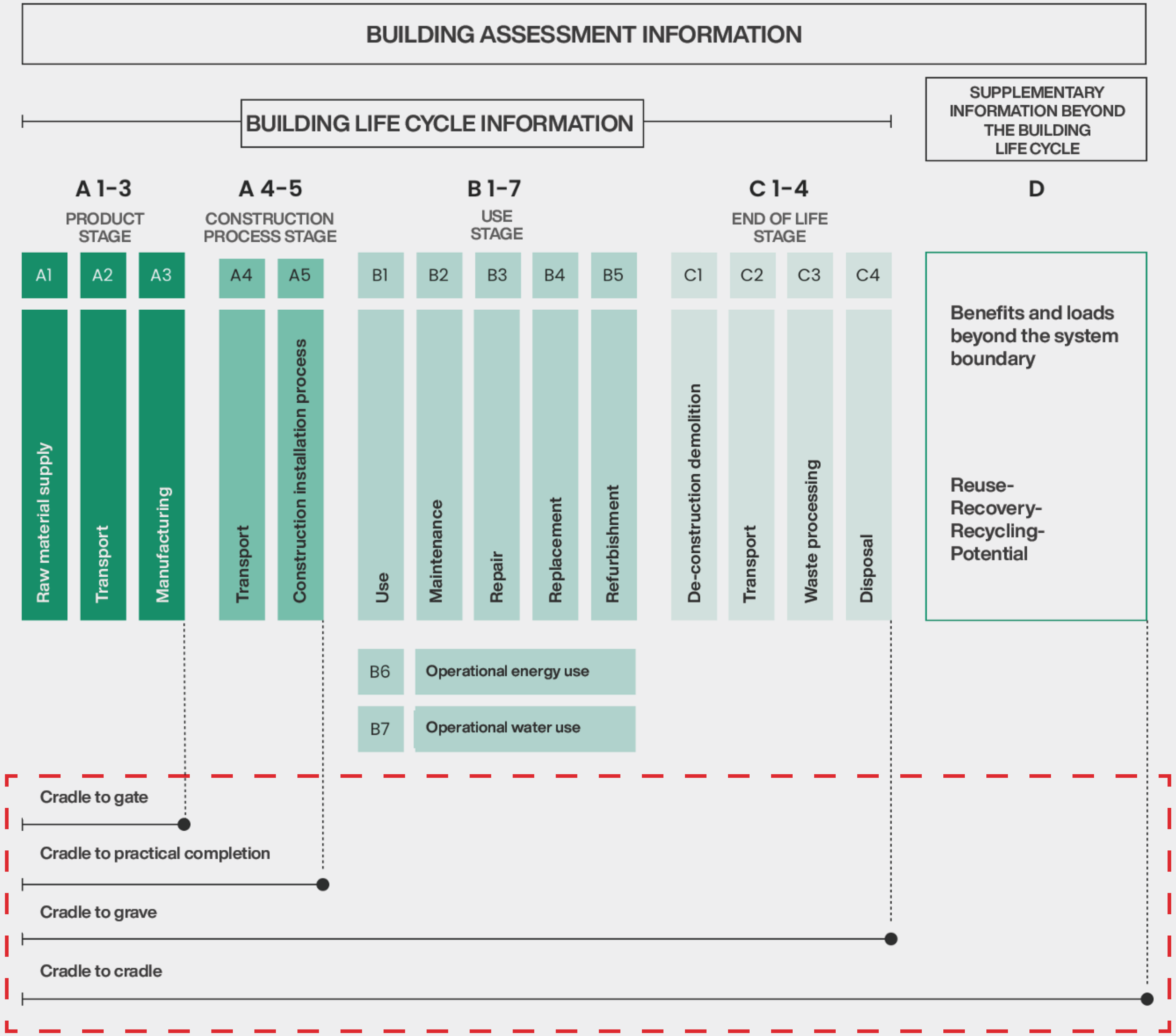
- Reuse, recovery, recycling potential
- Module D, reduced emissions *(benefits)* associated with avoided primary material production or avoided energy production. *(Prevention of potential carbon emissions outside the system boundary by including materials for reuse. For example, the reuse of aluminum window frames obtained from building demolition in a different building or application avoids the consumption of materials and energy, and reduces carbon emissions, providing a benefit outside the system boundary.)*
- The module, which is linked to Circular Economy



1.5. Building Life Cycle Stages

The building life cycle stages are named according to the processes they cover as follows:

Cradle to Gate The process from raw material extraction to the factory gate	A1-A3
Cradle to Practical Completion The process from raw material extraction to the end of the construction stage	A1-A5
Cradle to Grave The process from raw material extraction to the final disposal of building demolition waste	A1-C4
Cradle to Cradle A circular process from raw material extraction to the recycling/reuse of demolition waste	A1-D



1.6. Building Life Cycle and Circular Economy Concept

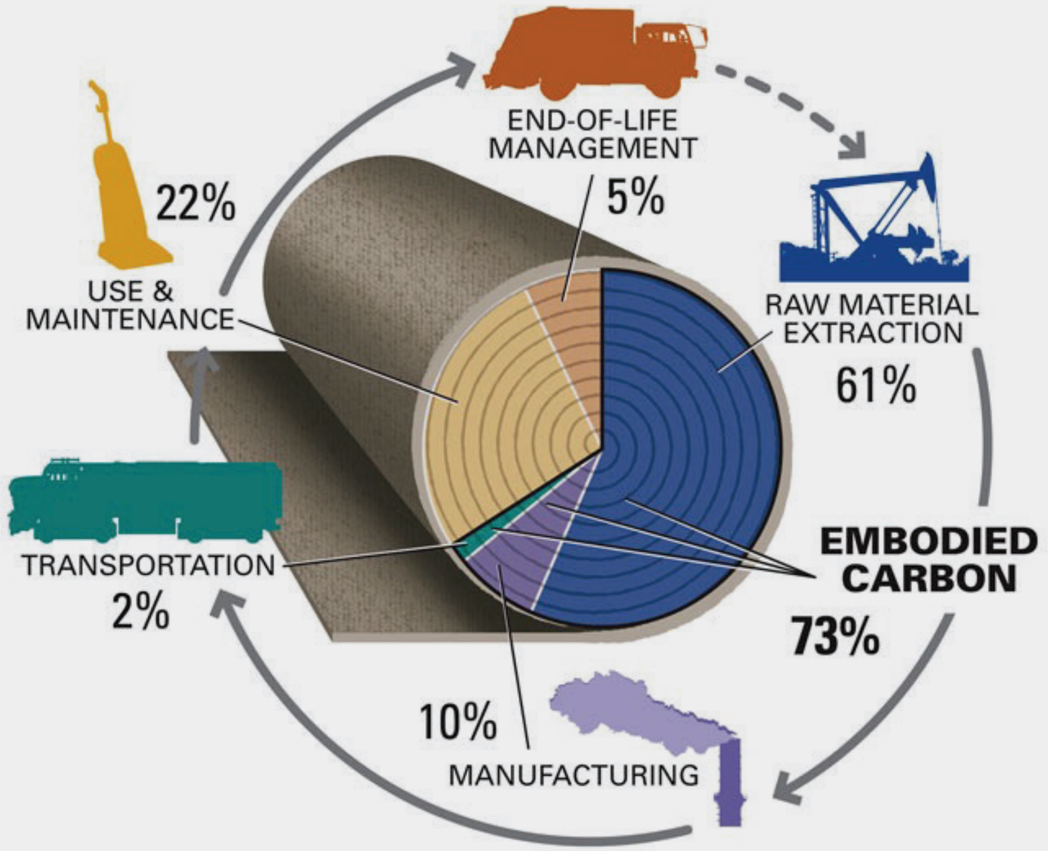
- **Circular economy** is an innovative economic model that aims to minimize waste materials and maximize resource efficiency. Unlike the **traditional** linear model that follows the "take, make, dispose" sequence, the circular economy is based on three main principles:
  - Waste materials are reintroduced into the reuse processes through recycling or repurposing.
  - Products and materials are kept in use for as long as possible.
  - The renewal *(regeneration)* of natural resources is ensured *(e.g., by extending the use of products, the opening of new mining sites can be prevented, raw material usage is reduced, and natural resources are allowed to regenerate)*.
- This model creates a more sustainable and resilient system by encouraging the reuse, recycling, and recovery of materials throughout all stages of a product's life cycle.
- In the building life cycle, the "**Cradle to Cradle**" (A1-D) carbon reduction approach supports the principles of **circular economy**.
- In the circular economy model, existing buildings will act as material suppliers for future buildings.

1.7. Carbon Emissions in the Building Life Cycle

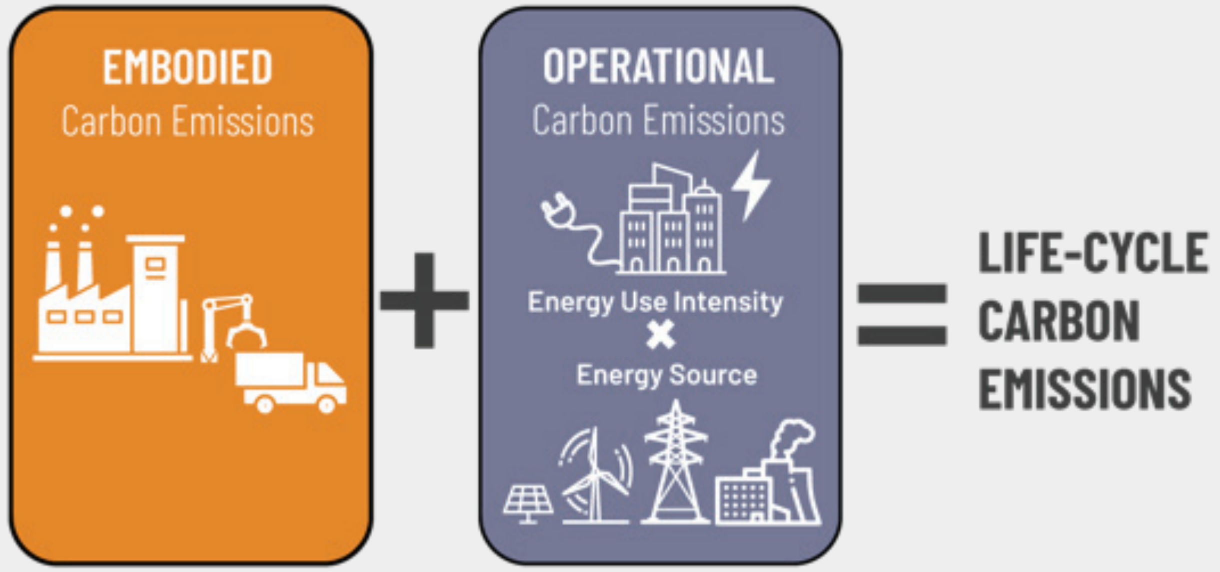
- Buildings contribute to carbon emissions throughout their entire life cycle, starting from raw material extraction.
- A significant portion of these emissions arises from the energy consumption during the building's operational phase *(B6 stage) (e.g., heating, cooling, ventilation, cooking, hot water preparation, electrical equipment usage, lighting)*.
- In addition, buildings generate carbon emissions throughout their life cycle due to material usage, as well as construction, maintenance, repair, renovation, demolition, and recycling activities.
- The carbon emissions over the entire building life cycle are classified as "**Embodied Carbon**" and "**Operational Carbon**".

1.8. Embodied Carbon vs. Operational Carbon

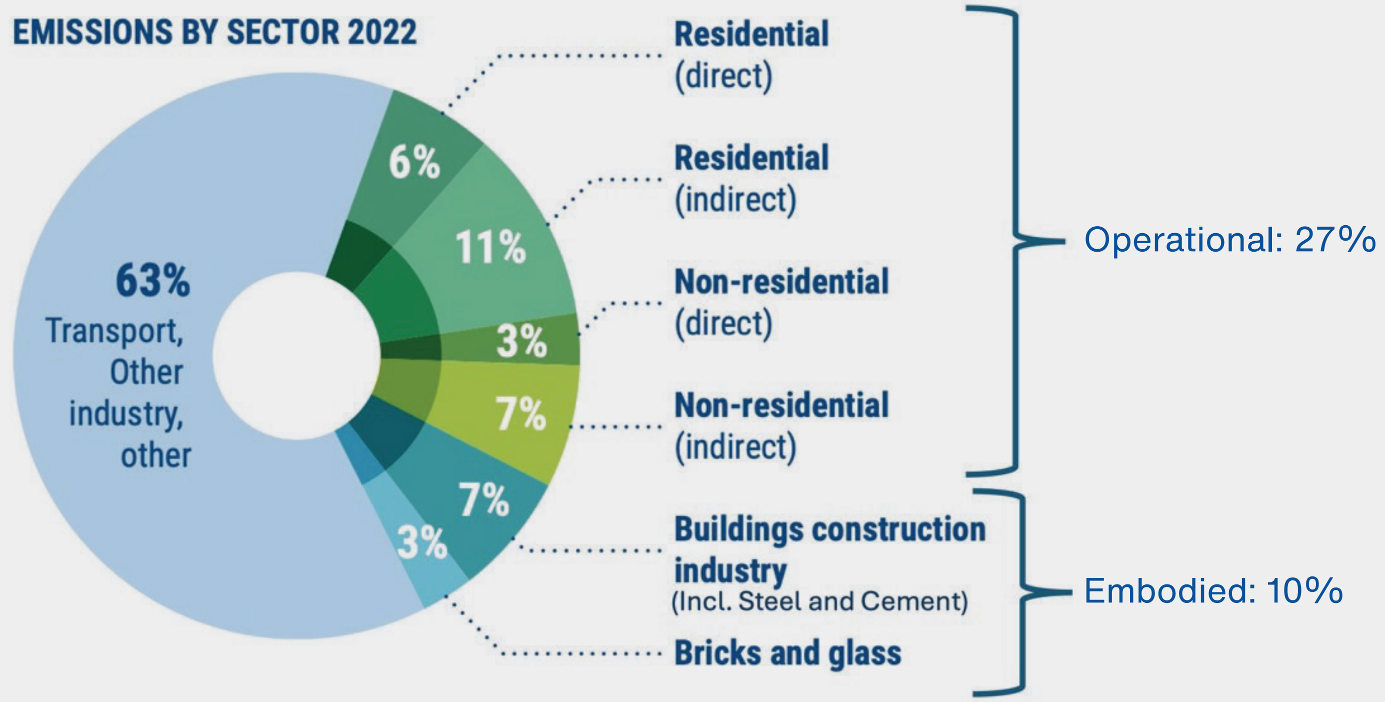
- **Embodied carbon** refers to the greenhouse gas emissions resulting from the production, transportation, installation, maintenance, and disposal of building and infrastructure materials. [9]
- **Operational carbon,** refers to emissions associated with the energy used to operate a building, including heating, hot water, cooling, ventilation, lighting systems, equipment, and elevators, as well as emissions linked to water supply and wastewater treatment. [10]
- In 2022, global carbon emissions were composed of **27%** operational emissions and **10%** embodied emissions.



Reference: Building Green



Reference: Magwood et al. 2021



Reference: UNEP 2023 Global Status Report for Buildings and Construction

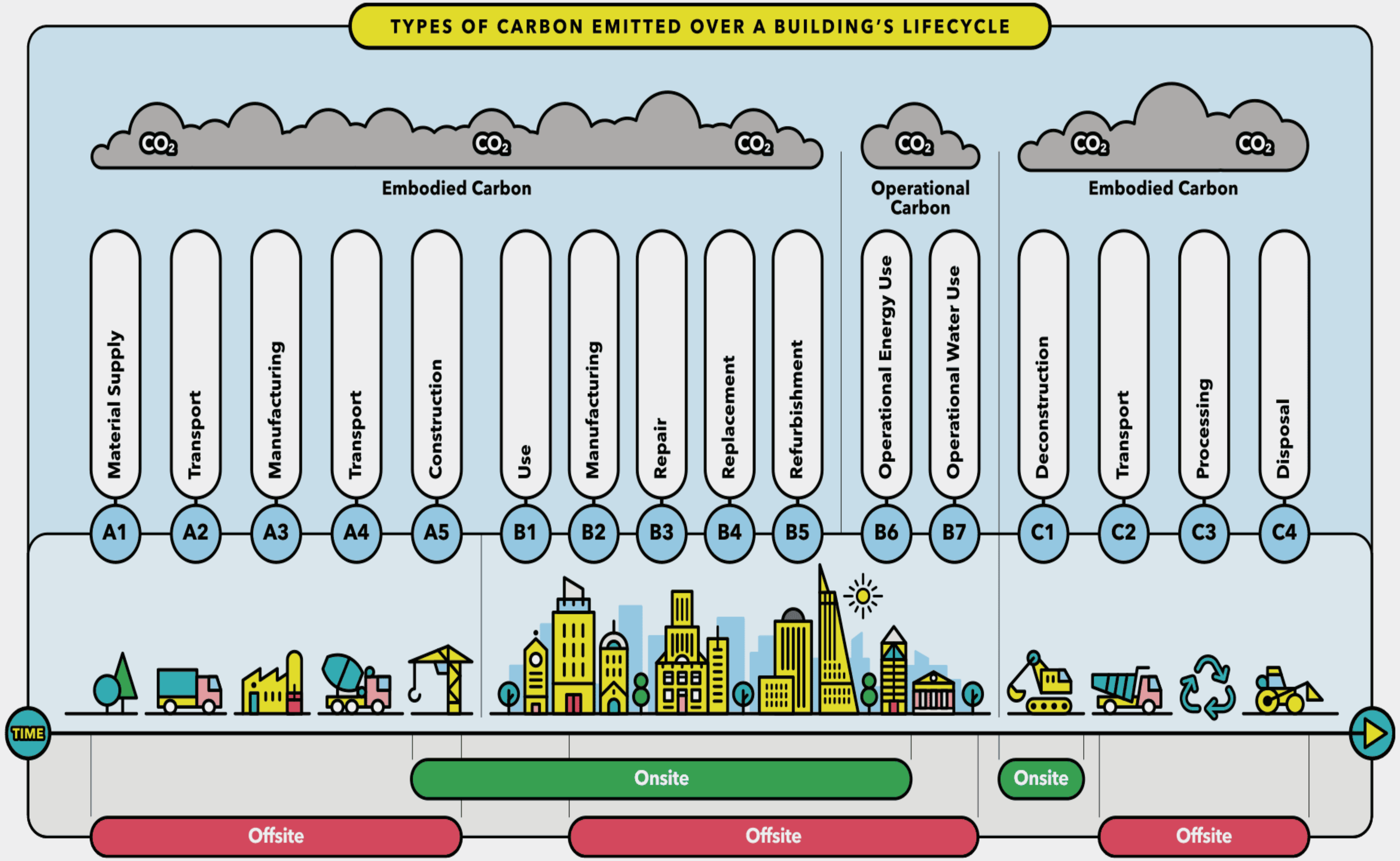
1.8. Embodied Carbon vs. Operational Carbon

Embodied carbon emissions occur during the following life cycle stages:

- **A1-A5:** Material production and construction process
- **B1-B5:** Building use process
- **C1-C4:** Demolition and waste processing/disposal

Operational carbon emissions occur during the following life cycle stages:

- **B6:** Operational energy use
- **B7:** Operational water use



Reference: UK Green Building Council

1.9. Embodied Carbon Emissions

Embodied carbon emissions occur in three phases of the building life cycle:

Upfront Carbon Emissions

These emissions are associated with the production of materials and devices used in the building, as well as the construction process. These emissions are released into the atmosphere before the building is even operational.
For example, emissions related to the extraction of raw materials, production, and transportation of construction

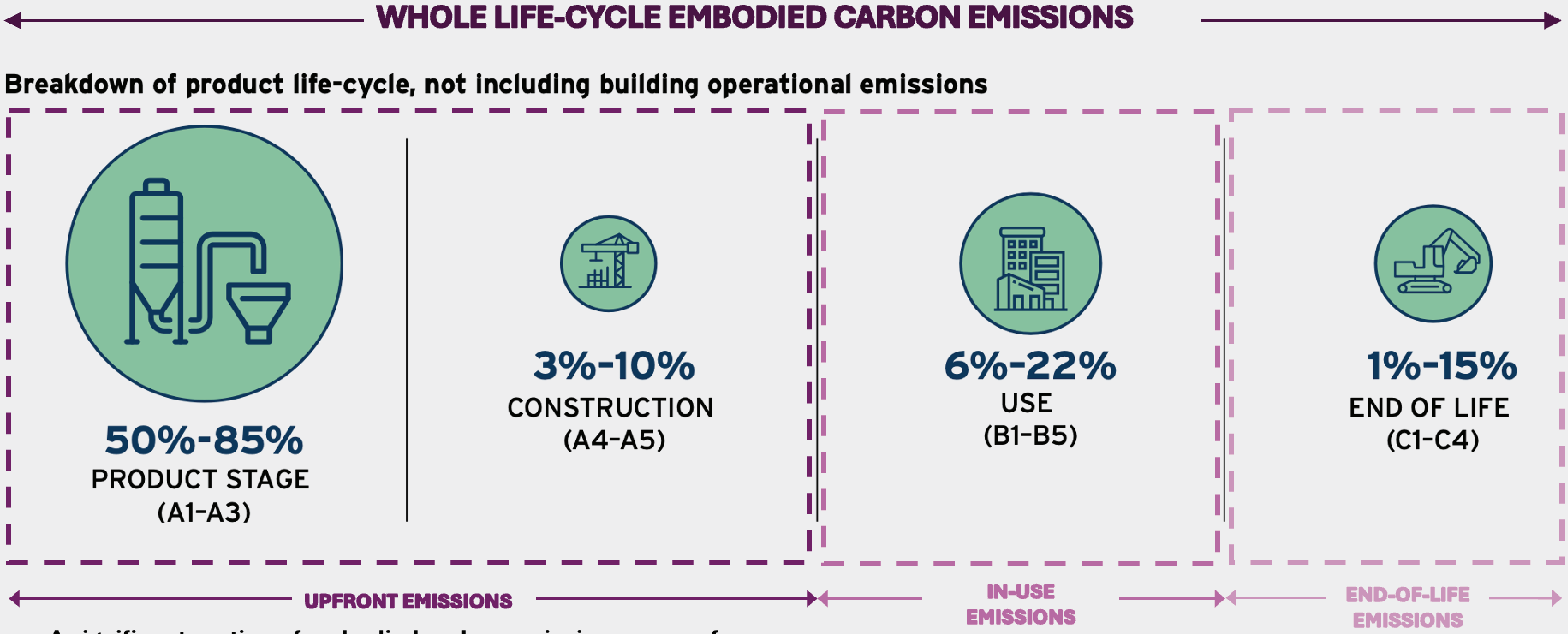
In-Use Carbon Emissions

These emissions are associated with the materials and processes that occur during the building's use, maintenance, repair, replacement, and renovation.
For instance, emissions from materials used in the building during its life, emissions from material replacements, emissions from maintenance processes like cleaning and exterior painting, etc.

End-of-life Carbon Emissions

These emissions are related to the demolition, transportation from the site, waste processing, and disposal stages that occur after the building's usage.

1.9. Embodied Carbon Emissions



A significant portion of embodied carbon emissions comes from Upfront Emissions.

Reference: Driving Action on Embodied Carbon in Buildings, RMI and U.S. Green Building Council (USGBC), 2023 (Adapted)

1.10. Operational Carbon Emissions

Operational carbon emissions occur only during the building's use phase (B6-B7):

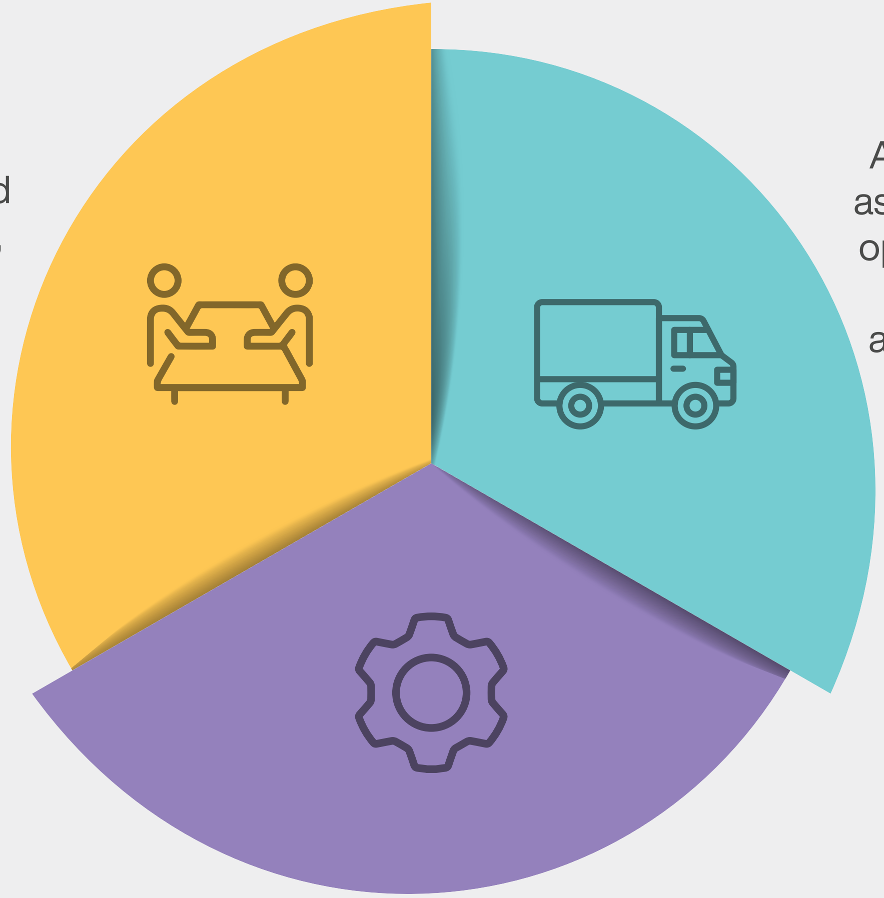
1. **Emissions from Operational Energy Use:** These emissions result from the energy consumption of integrated building systems and equipment, including heating, cooling, ventilation, hot water preparation, humidification/dehumidification, lighting systems, power systems, elevators, escalators, communication systems, security systems, and building automation systems. [11] Non-integrated equipment such as plug loads, household appliances, and computers may optionally be included in carbon assessments.
2. **Emissions from Operational Water Use:** These emissions arise from the operation of water systems within the building, including water heating and distribution, greywater and blackwater treatment systems, and rainwater reuse systems.

1.11. Scope 1, 2, and 3 Emissions & Embodied-Operational Carbon

According to the Greenhouse Gas Protocol standards, Scope 1, 2, and 3 emissions are defined as follows:

Scope 1

Direct emissions from fuel combustion in assets owned or controlled by a company, such as buildings, vehicles, and equipment.



Scope 3

All other indirect emissions associated with a company's operations and supply chain that fall outside Scope 1 and 2 boundaries. Scope 3 emissions typically represent the largest share of a company's total carbon emissions.

Scope 2

Indirect emissions from the purchase and use of electricity, steam, heating, and cooling in a company's buildings and production processes.

While Scope 1, 2, and 3 emissions show similarities with embodied and operational carbon emissions, they represent fundamentally different concepts

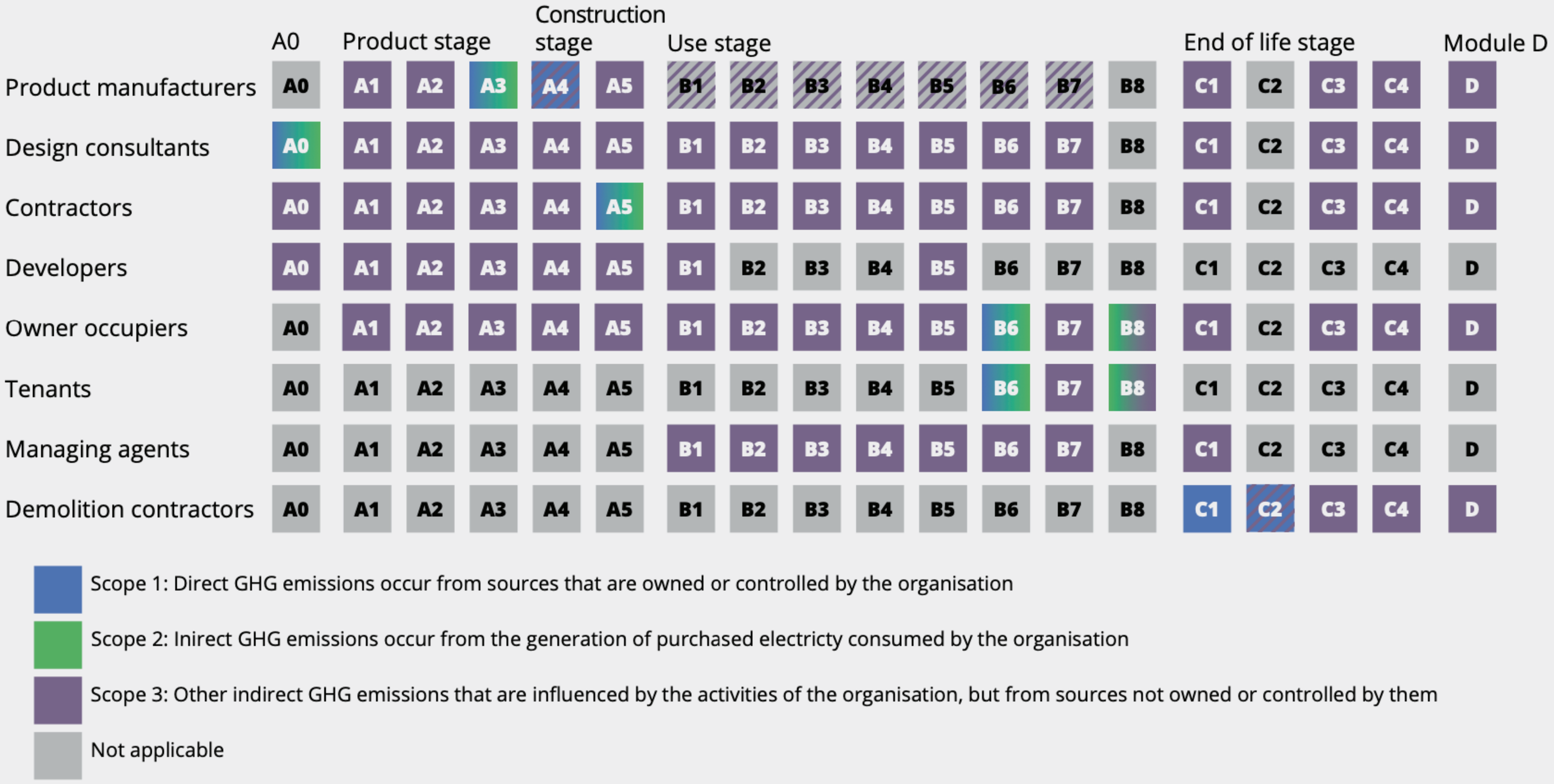
Scope 1, 2, and 3 emissions account for a company's direct and indirect emissions. Embodied and operational carbon emissions relate to the emissions associated with a building's material usage and operations.

Embodied and operational carbon emissions can contribute to a company's Scope 1, 2, and 3 emissions.

1.11. Scope 1, 2, and 3 Emissions & Embodied-Operational Carbon

The embodied and operational carbon emissions of a building can be classified as Scope 1, 2, or 3 depending on the relationship of the stakeholder reporting carbon emissions with the product.

For example, the carbon emissions from the concrete used in the construction phase (A5) of a building undergoing a life-cycle carbon assessment fall under Scope 3 for the concrete manufacturer, while they are classified as Scope 1 and 2 for the contractor using the concrete in the building's construction.



Reference: RICS Professional Standard, Whole life carbon assessment for the built environment & Construction LCA Ltd.

1.12. Key Strategies for Reducing Embodied Carbon

Strategies for reducing embodied carbon in the building life cycle can be categorized under three main approaches:

1. Reducing carbon emissions associated with building materials (**RESET**: Reduce, Reuse, Sequester)
   - *Reduce:* Minimizing material use
   - *Reuse:* Reusing materials and buildings
   - *Sequester:* Using materials with high carbon sequestration potential
   - Decarbonizing building materials **(Module 3: Sustainable Building Materials)**
2. Preferring local materials to reduce emissions from transportation
3. Reducing carbon emissions in construction and demolition activities **(Module 4: Sustainable Construction and Demolition Practices)**

Detailed strategies for reducing embodied carbon are explained in **Section 4**.

1.13. Key Strategies for Reducing Operational Carbon

Strategies for reducing operational carbon in the building life cycle can be categorized under three main approaches:

1. **Minimizing building energy demand** through passive design strategies (Energy-efficient façade design, building orientation for optimal solar exposure, shading, airtightness, prevention of thermal bridges, maximizing daylight utilization, natural ventilation, etc. **(Module 9: Energy-Efficient and Passive Building Design)**

2. Meeting building energy demand with **efficient systems:**

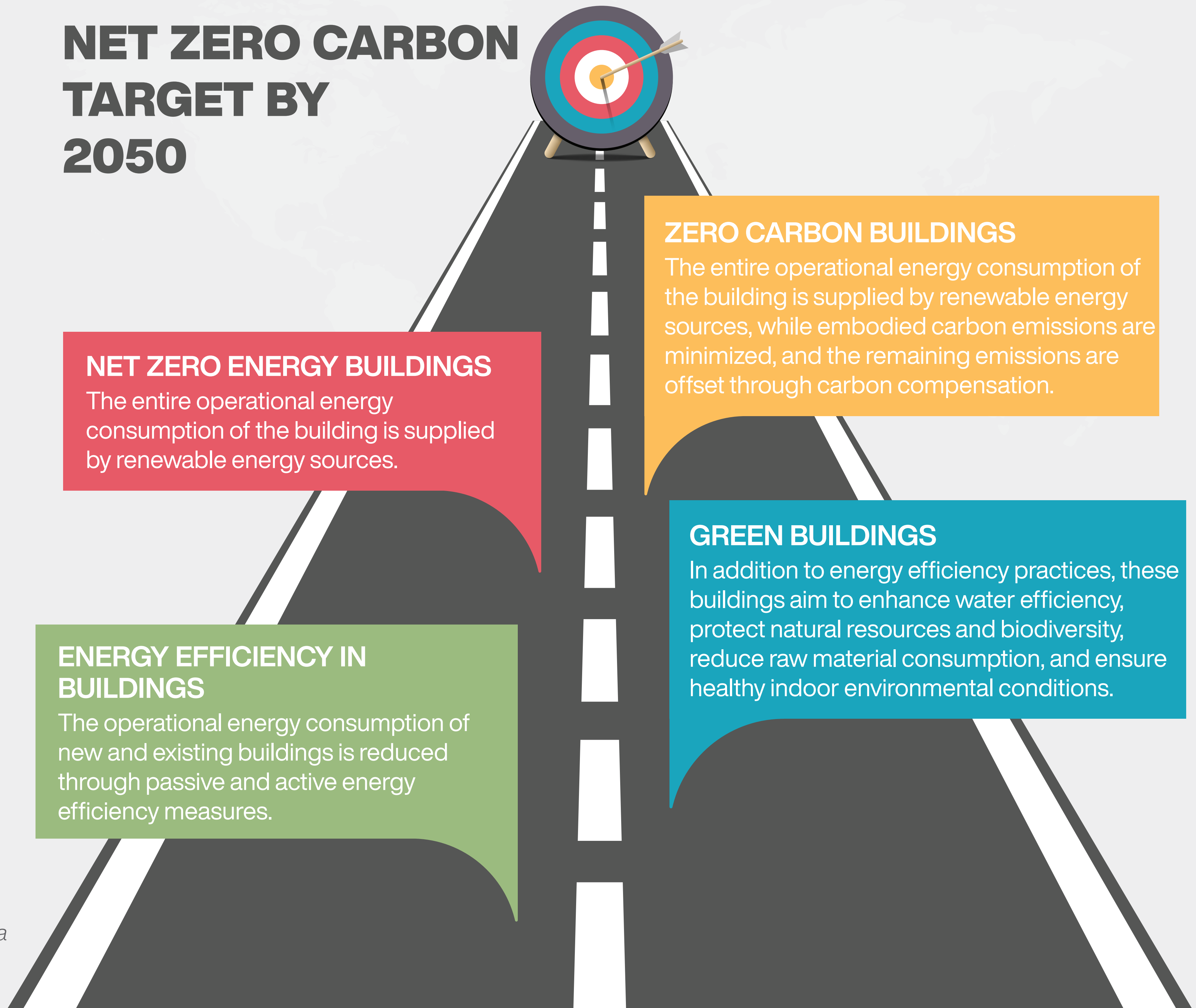
- Using high-efficiency mechanical and electrical equipment (Efficient heating, cooling, and ventilation systems, proper sizing of equipment [avoiding downsizing or oversizing],high-efficiency lighting fixtures, etc.)
- Optimizing energy efficiency through software applications (Building automation control systems, energy monitoring, smart building technologies, etc.)

3. Meeting building energy demand through **renewable energy sources** (Solar energy, wind energy, biomass energy, geothermal heating systems, etc.)

Detailed strategies for reducing operational carbon are explained in **Section 4**.

1.14. Building Classifications in the Decarbonization Target

- **Green Building:** These are structures that prioritize environmental sensitivity, ecological preservation, and resource efficiency throughout their entire life-cycle—from land use planning and design to construction, operation, maintenance, renovation, and demolition. Additionally, they provide healthy indoor environmental conditions for occupants.
- **Net Zero Energy Building:** These buildings meet their annual operational energy needs through on-site renewable energy systems [15]. The definition of a net zero energy building may vary by country. Some guidelines (e.g., the EU Energy Performance of Buildings Directive, LEED Zero Energy, etc.) also recognize off-site renewable energy generation, renewable energy credits, and green power purchases as acceptable means to offset operational energy consumption.
- **Zero Carbon Building:** These buildings have exceptionally high energy efficiency, meet their remaining energy demand through on-site renewable sources or renewable energy plants, and minimize operational and embodied carbon emissions throughout their life-cycle. Any unavoidable emissions are offset through carbon compensation measures [16].



Reference: Alarnova

Section **2**

LIFE-CYCLE CARBON APPROACH

2.1. Life-Cycle Assessment for Buildings

The embodied and operational carbon emissions, along with other environmental impacts caused by a building throughout its entire lifespan, are calculated using the life-cycle assessment approach.

- **Life-cycle assessment (LCA)** is a systematic method for evaluating the environmental impacts of a product, process, or service throughout its life-cycle, from raw material extraction to final disposal.
- For buildings, LCA analyzes the environmental impacts of all phases, from pre-construction and construction to operation and end-of-life processes.
- Building life-cycle assessment is based on international standards (e.g., **ISO 14040, ISO 14044**) and serves as a crucial tool for sustainable design, energy efficiency, and the development of low-carbon solutions.
- LCA should be integrated into project planning and cost estimation during the **early design phase**, developed in collaboration with the broader project team, and updated as the project progresses.
- LCA can be conducted at any stage of a project; however, general information is used during early design phases, and as the design evolves, more specific data is incorporated to refine the carbon assessment for more accurate results.
- By supporting decision-making during the design, procurement, construction, and operational phases, LCA ensures the lowest possible carbon impact across all stages of a building's life-cycle.

2.1. Life-Cycle Assessment for Buildings

Scope

Building life-cycle assessment (LCA) aims to systematically and comprehensively evaluate the environmental impacts of a structure. This process encompasses the entire life-cycle of the building.

Product Stage A1-A3	**Construction Stage** A4-A5	**Use Stage** B1-B7	**End-of-Life Stage** C1-C4	**Beyond Building Lifecycle** D
1. Raw material extraction and processing 2. Material production and transportation	1. Transportation of materials to the construction site 2. Energy and water consumption during construction	1. Repair, replacement, renovation, maintenance, and operation of the building 2. Energy and water consumption	1. Demolition or deconstruction at the end of the building’s service life 2. Waste transportation, recycling, or disposal	1. Environmental benefits from recycling or energy recovery within the circular economy framework
Example: Production processes of construction materials such as cement, steel, and wood.	**Example:** Fuel consumption of construction equipment.	**Example:** Heating, cooling, lighting, and water usage.	**Example:** Recycling of concrete waste.	**Example:** Using waste materials as raw materials in new products.

2.1. Life-Cycle Assessment for Buildings

The following **key metrics** are used to assess the major environmental impacts of a building, including its carbon emissions:

- **Global Warming Potential (GWP)** (kg CO_2 equivalent)
- **Stratospheric Ozone Depletion Potential (ODP)** (kg CFC-11 equivalent)
- **Acidification Potential (AP)** of soil and water resources (kg SO_2 equivalent)
- **Eutrophication Potential (EP)** (kg PO_4^3 equivalent)
- **Photochemical Ozone Creation Potential (POCP)** in the troposphere (kg Ethene equivalent)
- **Non-Renewable Primary Energy Input** (MJ, net calorific value)
- **Renewable Primary Energy Input** (MJ, net calorific value)
- **Embodied Carbon:** Carbon emissions resulting from material production, transportation, construction, and waste throughout the building's life cycle (kg CO_2e/m^2 or total kg CO_2e).
- **Operational Carbon:** Carbon emissions generated from energy consumption during the building's operational phase (kg CO_2e/year).
- **Life-Cycle Carbon Emissions:** The total carbon emissions over the building's entire life cycle, including both embodied and operational carbon (kg CO_2e).
- **Energy Use Intensity (EUI):** The ratio of the building's energy consumption to its total floor area (kWh/m^2/year).

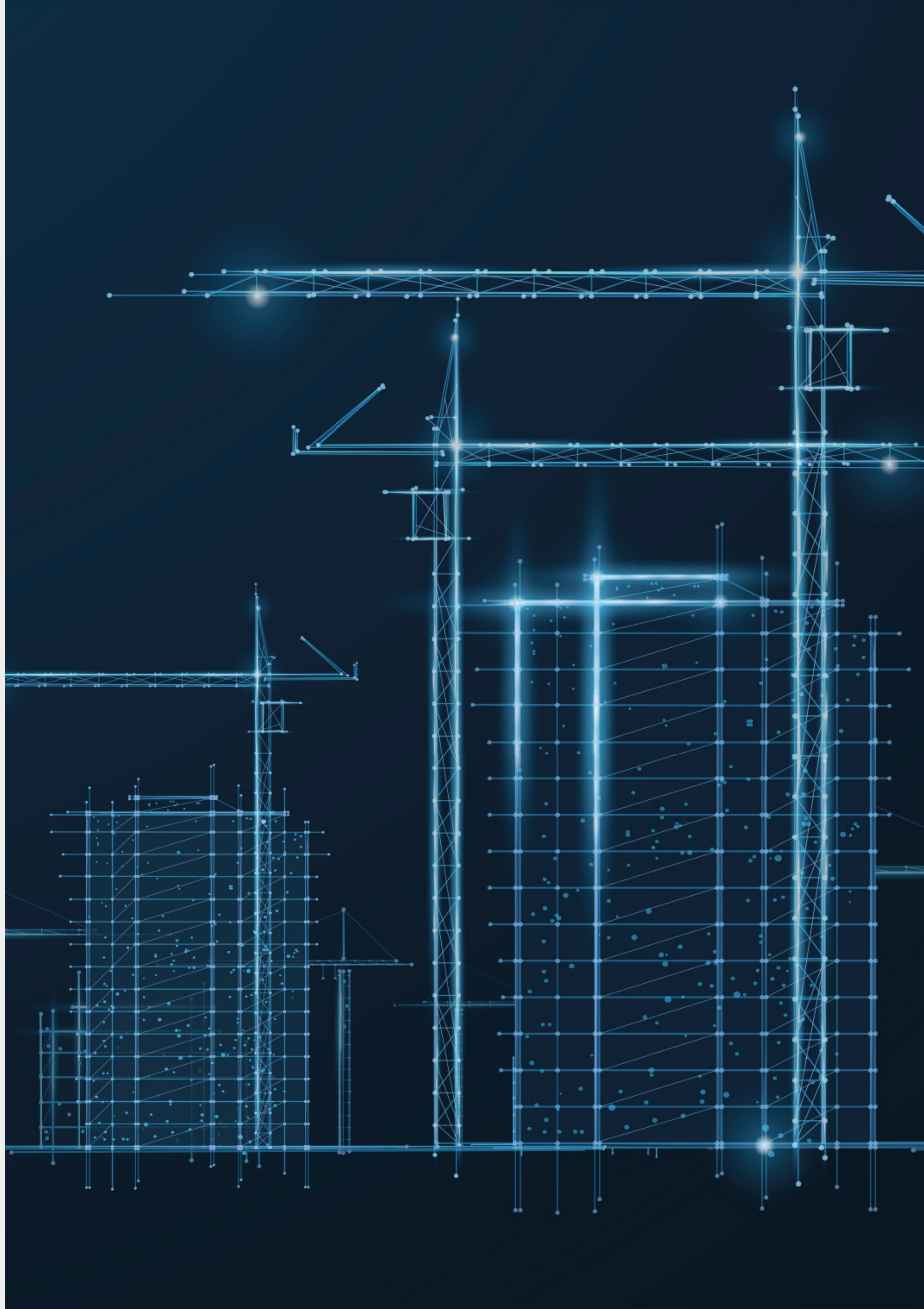
2.2. The Importance of Data in Life-Cycle Assessment

A reliable life-cycle assessment (LCA) study ensures the accuracy and reliability of results through the use of accurate, up-to-date, and locally relevant data.

1. **Accurate and Up-to-Date Data:** The data should be current, high-quality, and suitable for the local conditions of the building being analyzed. Missing or outdated data may lead to incorrect or misleading results.
2. **Data Compatible with Local Conditions:** Data related to material production, transportation, and energy usage should be aligned with local geographic conditions and practices. This ensures that the results are more reliable and applicable.
3. **Data Validation:** The reliability of the data can be enhanced through an independent validation process. The source, validity, and methodology of the data sets used in the LCA study should always be specified.

Building Information Modeling (BIM) plays a critical role in life-cycle assessment.

- **BIM:**
  - Creates digital representations of buildings or infrastructure projects.
  - Collects critical data such as material consumption, energy use, and carbon emissions throughout the building's life cycle.
- **Integration with LCA:**
  - BIM data can be integrated into LCA software to automatically calculate the carbon footprint.
  - Enables the direct use of material and energy data across the entire life cycle.
- **Advantages:**
  - Provides precision and speed in data collection.
  - Guides the application of carbon reduction strategies starting from the design phase.
  - Optimizes material consumption and energy use.



2.3. Standards Used in Life-Cycle Assessment

The building life-cycle assessment (LCA) methodology, scope, and guidelines are regulated by the following international standards:

- **ISO 14040:** Environmental Management – Life Cycle Assessment – Principles and Framework
- **ISO 14044:** Environmental Management – Life Cycle Assessment – Requirements and Guidelines
- **EN 15978:** Sustainability of Construction Works – Assessment of Environmental Performance of Buildings – Calculation Method
- **ISO 21931-1:** 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

2.3. Standards Used in Life-Cycle Assessment

ISO 14040 Environmental Management – Life Cycle Assessment – Principles and Framework	**ISO 14044** Environmental Management – Life Cycle Assessment – Requirements and Guidelines
Scope: Defines the general framework of life cycle assessment, including goal and scope definition, inventory analysis, impact assessment, and interpretation of results [17].	**Scope:** Defines the technical requirements and methods based on ISO 14040 [18]. Includes rules for data collection, analysis, and reporting.
Importance: ▪ Establishes the foundation for life cycle assessment. ▪ Has a broad application across all sectors.	**Importance:** ▪ Establishes the foundation for life cycle assessment. ▪ Has a broad application across all sectors.
EN 15978 Sustainability of Construction Works – Assessment of Environmental Performance of Buildings – Calculation Method	**ISO 21931-1** 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
Scope: Specifies the standards for evaluating the environmental performance of buildings throughout their life cycle. Includes environmental impacts such as carbon, energy, and water from product phase to end of life [19].	**Scope:** Provides a general framework for assessing the environmental performance of structures, with a focus on construction sector-specific applications [20].
Importance: ▪ Widely used for building projects in Europe. ▪ Provides a strategic framework for carbon reduction and energy efficiency.	**Importance:** ▪ Ensures international alignment and supports sustainable design principles.

2.4. Commonly Used Life-Cycle Assessment Software

Life-cycle assessment (LCA) for buildings is carried out using various software tools. These software tools play a crucial role in obtaining **accurate and reliable** results in LCA analyses. Some of the commonly used software tools for building life cycle assessment include:

- SimaPro
- Sphera LCA for Experts (GaBi)
- One Click LCA
- OpenLCA
- eTool
- Athena Impact Estimator
- Tally (Revit plugin)
- The Level(s) CAT

2.4. Commonly Used Life-Cycle Assessment Software

SimaPro	Sphera LCA for Experts (GaBi)
Usage Area: Applied in various sectors, particularly for product life-cycle analysis and environmental performance assessment of buildings **Features:** ▪ Extensive database (such as Ecoinvent, Agri-footprint) ▪ Detailed carbon and energy calculations ▪ Suitable for supply chain analysis **Official Web Site:** https://simapro.com	**Usage Area:** LCA studies for products, processes, and building systems **Features:** ▪ Customizable modules for building projects ▪ Comprehensive databases and standard compliance ▪ Comparative analysis and scenario studies **Official Web Site:** https://sphera.com
One Click LCA	**OpenLCA**
Usage Area: Carbon footprint calculation and environmental performance reporting for buildings **Features:** ▪ Carbon analysis for construction materials and energy use ▪ Compliance with EN 15978 and ISO 14040/14044 standards ▪ User-friendly interface, compatibility with building certifications (LEED, BREEAM) **Official Web Site:** https://www.oneclicklca.com	**Usage Area:** Open-source LCA software, suitable for academic and commercial use. **Features:** ▪ Free and open-source ▪ Compatible with various databases for data integration (such as Ecoinvent, ELCD) ▪ Large user community and support materials **Official Web Site:** https://www.openlca.org

2.4. Commonly Used Life-Cycle Assessment Software

eTool

Usage Area: Life-cycle carbon assessment and environmental impact optimization for building projects

Features:

- Analysis suitable for green building certifications (LEED, Green Star)
- Analysis of carbon and energy data throughout the life cycle
- Simple interface and cloud-based access

Official Web Site: https://cerclos.com

Athena Impact Estimator

Usage Area: Life-cycle analysis for North American building projects.

Features:

- Regional database for building materials
- Evaluation of energy, water consumption, and carbon emissions
- Easy use in architectural design and engineering projects

Official Web Site: https://calculatelca.com

Tally (Revit® eklentisi)

Usage Area: Integration of life cycle analysis with Building Information Modeling (BIM)

Features:

- Analysis suitable for green building certifications (LEED)
- Allows comparative analysis of various design options with different environmental impacts using LCA data during the design phase

Official Web Site: https://choosetally.com

The Level(s) CAT

Usage Area: Life-cycle assessment for building projects participating in the European Union's "The Level(s) – European Framework for Sustainable Buildings" program.

Features:

- User-friendly interface designed with SMEs and micro-enterprises in mind
- Simple and quick tool to calculate and compare results across different projects
- Free to use

Official Web Site: https://environment.ec.europa.eu/

Section **3**

STRATEGIES FOR REDUCING LIFE-CYCLE CARBON EMISSIONS

3.1. Strategies for Reducing Embodied Carbon in Building Materials

In reducing the embodied carbon emissions caused by building materials, the Avoid (A) - Shift (S) - Improve (I) approach;

A – Avoid:

Reduce waste, use less material, extend the lifespan of materials, and increase recyclability.

S – Shift:

Change material preferences. Transition to natural building materials.

I – Improve:

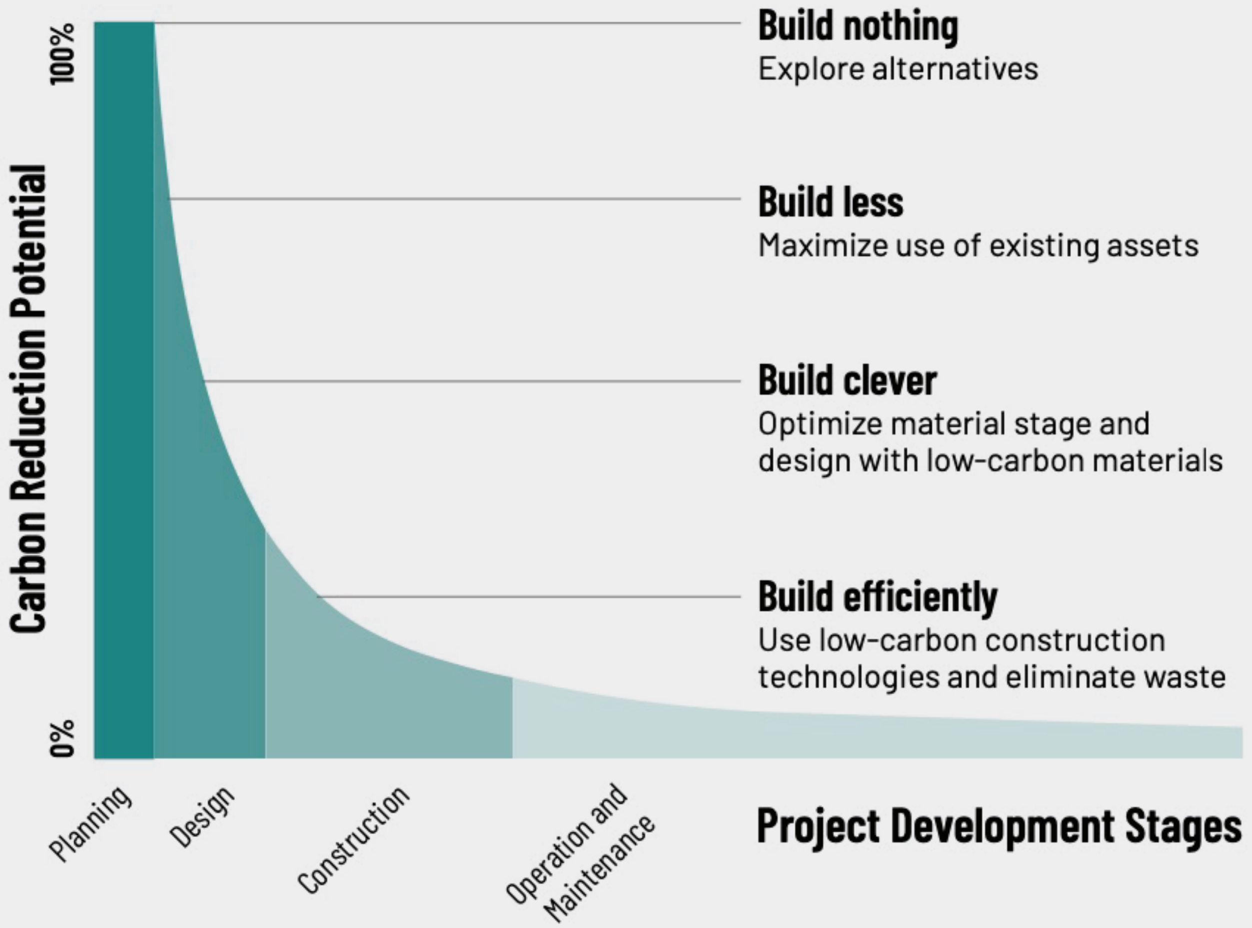
Decarbonize carbon-intensive building materials and production processes.

Reference: United Nations Environment Programme (2023). Building Materials and the Climate: Constructing a New Future. Nairobi

3.2. Strategy-1: Avoid

Opportunities for circular design, recycling, and reuse exist at every stage of a building's life cycle.

- By establishing a circular material economy that prioritizes reuse and recycling, raw material consumption and waste generation can be reduced.
- The greatest potential for reducing and preventing embodied carbon emerges during early planning and design phases.
- Building life cycle carbon assessment should be integrated into the design process from the project planning stage.
- Some strategies to reduce material use and waste generation in buildings include:
  - Adaptive reuse and preservation of existing buildings to extend their lifespan
  - Prioritizing lightweight structures that use fewer materials and designing for longevity in new construction
  - Designing for deconstruction with modular and demountable building approaches
  - Reusing secondary materials, such as scrap and construction by-products
  - Prioritizing selective dismantling over demolition to support the recovery of building components and materials
  - Recycling materials (should be considered a last resort due to potential quality degradation)



Reference: United Nations Environment Programme (2023). Building Materials and the Climate: Constructing a New Future. Nairobi

Reference: United Nations Environment Programme (2023). Building Materials and the Climate: Constructing a New Future. Nairobi

3.3. Strategy-2: Shift

Transitioning from resource-intensive traditional building materials to renewable alternatives is a key carbon reduction strategy. However, sustainable resource management and biodiversity conservation must not be overlooked in this transition. Some natural alternatives to conventional building materials include:

- Production of wood and lumber through sustainable forestry practices
- Utilization of rapidly renewable biological materials in construction *(e.g., bamboo, corn, flaxseed, hemp, mycelium, sugarcane bagasse, etc.)*
- Repurposing by-products from agriculture and forestry for material production *(e.g., non-timber lignocellulosic materials for insulation, flooring, and building textiles)*
- Incorporating living biomass into building design *(e.g., green roofs, green walls)*

3.4. Strategy-3: Improve

The embodied carbon emissions of commonly used carbon-intensive building materials can be reduced through innovative production and material technologies.

- Reducing the clinker-to-cement ratio in cement production, increasing the share of alternative binders, transitioning to electric kilns powered by renewable energy, and enhancing concrete through carbon capture and utilization during production
- Transitioning from blast furnace-based primary steel production to direct reduced iron (DRI) technology, utilizing electric arc furnaces powered by renewable energy, and improving steel recycling efficiency
- Enhancing collection, sorting, and mechanical and chemical recycling processes for plastics, as well as standardizing polymer compositions to facilitate recycling
- Decarbonizing glass production and ensuring the recycling of window glass
- Decarbonizing the electricity grid to reduce emissions in energy-intensive aluminum production, where electricity is the primary energy source

3.5. Reducing Embodied Carbon – Case Study "Stadium 974"

Doha, Qatar

- Indoor area: 137,000 m²
- Year of construction: 2021
- Building type: Steel
- Built for the 2022 FIFA World Cup, Stadium 974 is the world's first fully demountable stadium and a leading example of the **Design for Disassembly** *(DfD)* approach.
- The stadium was developed as an innovative concept that can be easily dismantled, reassembled as multiple smaller stadiums, or relocated entirely to a different location.
- The structure consists of a steel frame, resembling a high-rack warehouse divided into different sections.
- This frame is designed with a modular beam and column system and special pin connections that allow for easy disassembly and reassembly.
- Shipping containers placed within the structural frame create the stadium's enclosed spaces.
- Once dismantled, the entire structural frame can be transported to another location using standard shipping containers.
- The modular design, reduced material use and waste, and the ability to repurpose building components at the end of their lifespan significantly contribute to reducing the stadium's embodied carbon emissions.

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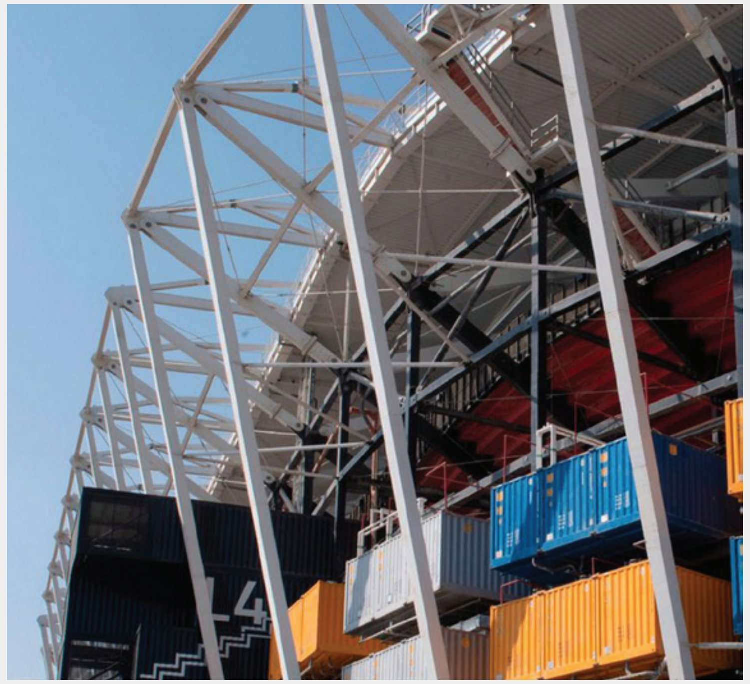
Fenwick Iribarren Architects



Fenwick Iribarren Architects

3.6. Reducing Embodied Carbon – Case Study “Dalston Works”

London, UK

- Indoor area: 14,280 m^2
- Year of construction: 2017
- Building type: Timber
- Dalston Works is a 10-story residential building with 121 units, making it one of the world’s largest cross-laminated timber (CLT) structures.
- The use of CLT significantly reduced the building’s embodied carbon emissions, both in material production and on-site energy consumption.
- Dalston Works **weighs approximately one-fifth** of a concrete building of the same size.
- During construction, all CLT components, including floors, walls, staircases, and shafts, were prefabricated, resulting in an **80% reduction in waste**.
- The use of CLT accelerated the construction process, **reducing the overall construction time by approximately eight months** compared to traditional materials, thereby further minimizing embodied emissions associated with construction activities.

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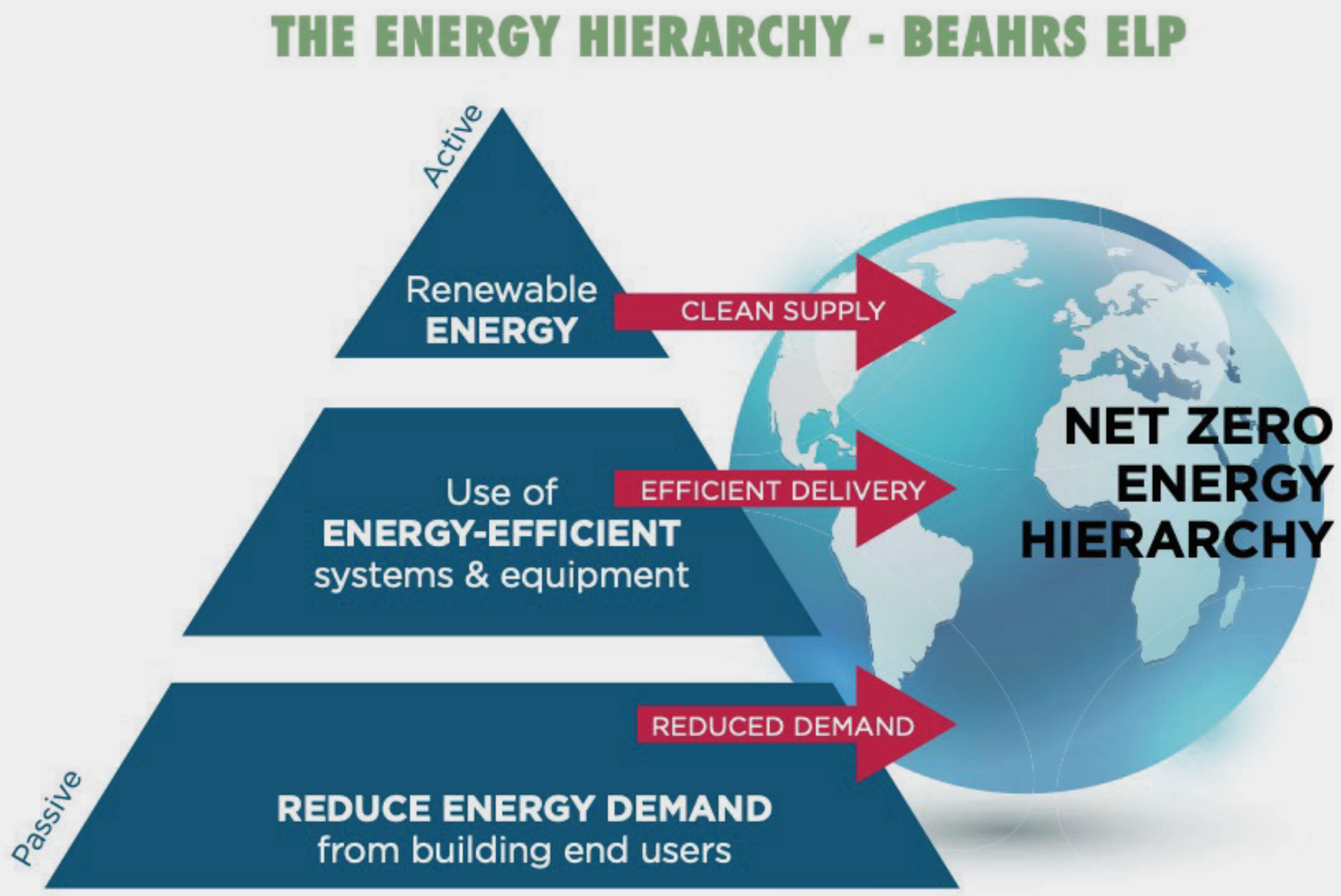
3.7. Strategies for Reducing Operational Carbon

Some key strategies to reduce operational carbon emissions in a building's B6 and B7 life-cycle stages include:

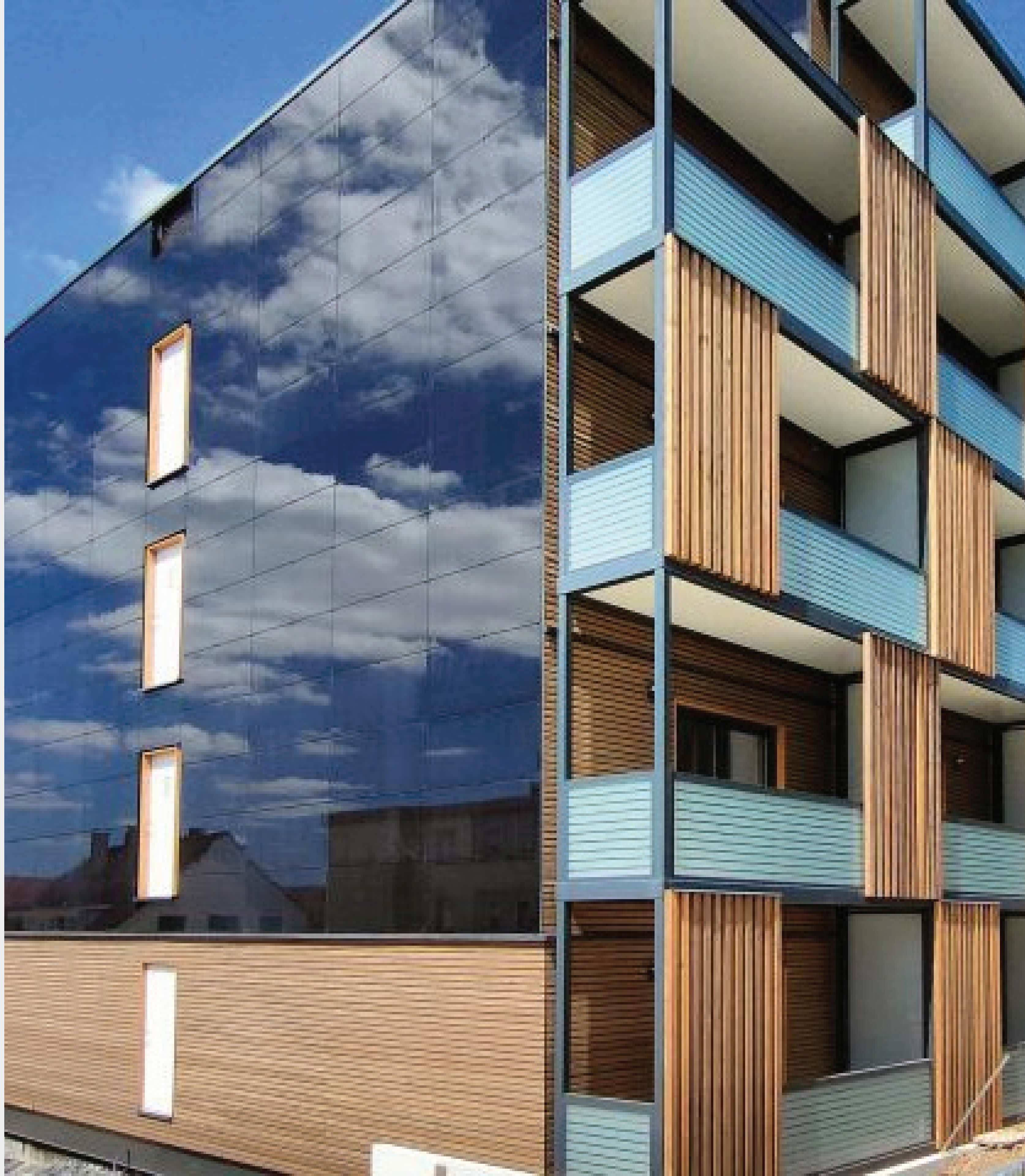
- To minimize the heating and cooling energy demand of the building, it should be positioned to maximize solar exposure and natural ventilation potential while ensuring an **energy-efficient façade design**. Key design elements include insulation of walls, floors, and roofs, thermal performance of windows and frames, façade airtightness, prevention of thermal bridging, and the use of shading elements. **(Module 9: Energy-Efficient and Passive Building Design, and Module 6: Innovative Building Technologies.)**
- During the early design phase, **building energy modeling** should be conducted to identify the most efficient heating, cooling, and ventilation (HVAC) equipment and their **optimal capacities** based on the selected design conditions. Operating HVAC systems at underloaded or overloaded capacities reduces efficiency and increases energy consumption.
- The availability of renewable energy sources in the building's location should be assessed. **On-site renewable energy generation should be prioritized to meet the building's energy demand.** Examples include photovoltaic (PV) panels on roofs and parking structures, building-integrated PV systems, wind turbines, and geothermal systems. **(Module 6: Innovative Building Technologies.)**



Reference: Getting to Zero- A Guide to Developing Net Zero Carbon Buildings in South Africa

3.7. Strategies for Reducing Operational Carbon

- The carbon emissions associated with the building's electricity consumption can be reduced through the use of off-site renewable energy generation or by purchasing green energy.
- The use of fossil fuels (such as natural gas, fuel oil, LPG, and LNG) within the building should be minimized or completely eliminated. Where renewable energy sources are available, full building electrification should be prioritized.
- Energy monitoring and automation systems should be implemented to enable continuous tracking of energy consumption, ensure HVAC systems operate under optimal conditions, facilitate early fault detection, and support preventive maintenance practices, thereby maximizing energy efficiency.
- IoT-based smart building applications should be leveraged to optimize not only the energy efficiency of building systems but also occupant behavior, preferences, and comfort conditions, ensuring the most efficient operational scenarios.
- The building should maximize the use of alternative water sources, such as rainwater harvesting, greywater treatment systems, blackwater (wastewater) treatment systems, and the reuse of condensate water from air conditioning units, etc..



3.8. Reducing Operational Carbon – Case Study “CIC Zero Carbon Park”

Hong Kong, China

- Indoor Area: 3,300 m^2
- Year of Construction: 2012
- The CIC Zero Carbon Park project achieves net zero operational carbon emissions.
- **To reduce operational carbon emissions**, passive strategies have been prioritized **in the building design**.
  - Building orientation that maximizes the use of natural ventilation and daylight
  - Shading with light shelves
  - Daylight chimneys
  - High-performance glass façade system
  - Wind catchers on the roof *(natural ventilation shafts)*
  - Highly insulated roof, PV panels, and green roof applications
  - The CIC Zero Carbon Park project provides **20% energy efficiency** compared to standard buildings through passive measures.

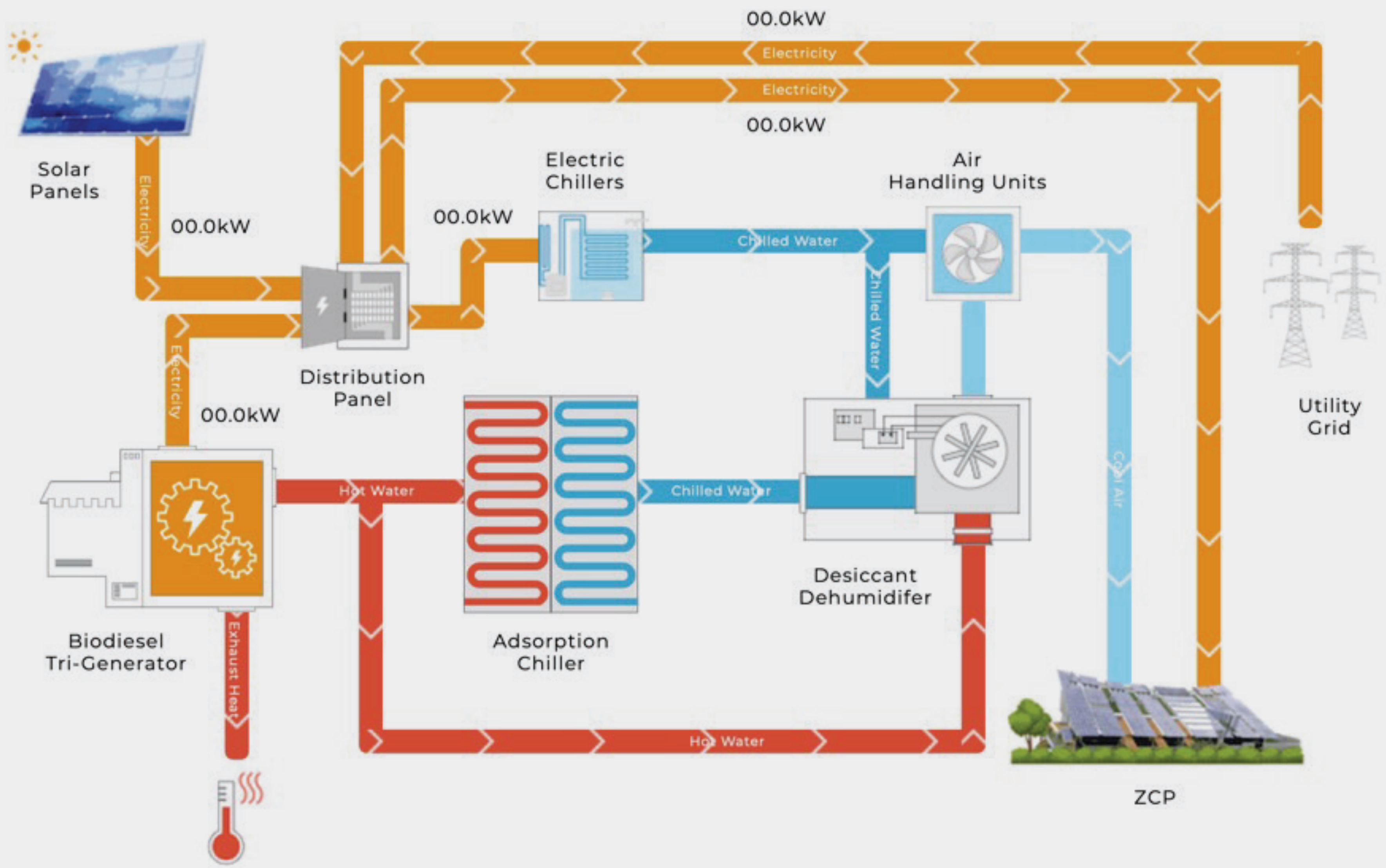
Reference: Construction Industry Council

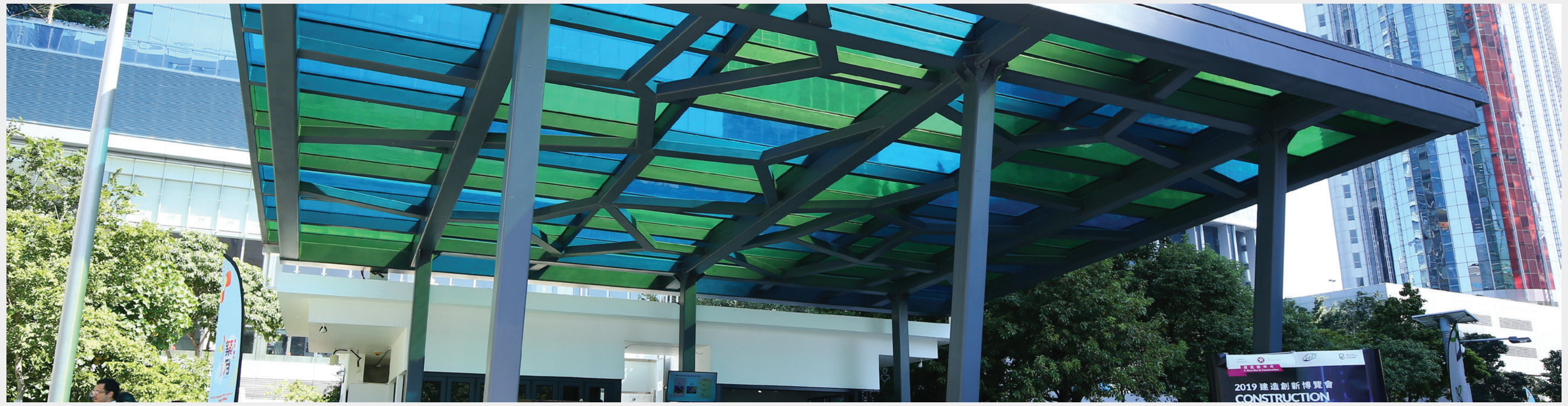
Reference: Construction Industry Council

3.8. Reducing Operational Carbon – Case Study "CIC Zero Carbon Park"

In the building where energy needs are reduced through passive strategies, high-efficiency electrical and mechanical systems have been utilized to ensure the required comfort conditioning:

- Electric energy is obtained from a **tri-generation system powered by biodiesel** produced from waste oils, and hot and cold water for space climate control is obtained from the waste heat of the system.
- The use of energy-efficient mechanical systems, such as high-volume low-speed fans and high-temperature cooling systems, combined with smart control applications, has **reduced the building's energy demand by 25%**.
- The building produces more energy than it requires **(net positive energy)** through **photovoltaic solar energy** systems installed on the roof and entrance canopy.
- As an innovative application, **energy-generating (regenerative) elevator** systems and **air-purifying nano-film coated photovoltaic panels** have been employed in the building.
- Rainwater collected from the roof and hard surfaces is **naturally treated in an artificial pond** for use in landscape irrigation. Additionally, low-water consumption lavatory faucets, toilets, showerheads, and waterless urinals help reduce operational carbon emissions associated with the building's water consumption.





Reference: Construction Industry Council [14]

3.9. Reducing Life-Cycle Carbon Through Carbon Offsetting

- **Carbon offsetting** refers to a tradable credit that represents each metric ton of carbon emissions (CO_2e - carbon dioxide equivalent greenhouse gas) that has been prevented or reduced and can be used for both direct and indirect emissions.
- In cases where a building cannot generate all of its energy from renewable sources and draws energy from natural gas or electrical grids, it is necessary for the building to engage in carbon offsetting corresponding to the energy it consumes from the grid to be verified as net zero operational carbon.
- Similarly, the embodied carbon emissions associated with the entire life cycle of the building can also be neutralized through carbon offsetting.
- Carbon offsetting is not a long-term solution for achieving net zero carbon buildings. **It should be noted that carbon offsetting should be the last resort in life cycle carbon reduction efforts.** Priority should always be given to practices that reduce embodied and operational carbon.

3.10. Life-Cycle Carbon Approach – Case Study: Bergen City Hall

Denmark

- Indoor Area: 11,000 m²
- Year of Construction: 1974
- Following the detection of corrosion in the structural elements of Bergen City Hall, **the rehabilitation or demolition and reconstruction of the building** was considered.
- During the initial phase of the project, a **life-cycle carbon assessment** was conducted for both alternatives, evaluating material options, carbon emissions, and construction costs.
- As a result of the assessment, it was decided to **renovate** the city hall due to its potential to **produce 40% lower carbon emissions.**
- The rehabilitation of Bergen City Hall, completed in 2022, achieved a **60% reduction** in carbon emissions compared to new construction.
- As part of the renovation, the building's facade was restored, and structural reinforcement was implemented. Concrete rehabilitation was carried out for all facade columns, extending the building's lifespan by an additional **50 years.**

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Section **4**

POLICIES, INCENTIVES, TARGETS, AND OBLIGATIONS RELATED TO DECARBONIZATION

4.1. Policy Environment for Decarbonization

International Agreements

1. United Nations Framework Convention on Climate Change (UNFCCC) (1994)	2. Kyoto Protocol (1997)	3. Paris Agreement (2015)
Goal: To encourage Parties to reduce greenhouse gas emissions, cooperate on research and technology, and protect greenhouse gas sinks (e.g., forests, oceans, lakes). **Principle:** The Convention is based on the principle of **"common but differentiated responsibilities and respective capabilities,"** taking into account the development priorities and specific conditions of countries for the reduction of greenhouse gas emissions. **Instruments:** Kyoto Protocol (by 2020) and Paris Agreement (after 2020).	**Goal:** To ensure and promote the reduction of greenhouse gas emissions by industrialized and transitioning market economy countries. **Commitments:** ▪ Mandatory carbon reduction targets for Parties. ▪ Flexibility mechanisms: Emissions Trading (IET), Clean Development Mechanism (CDM), Joint Implementation (JI). The Kyoto Protocol was the first international agreement to set quantified emission reduction targets for Annex I Parties. Türkiye became a Party to the Kyoto Protocol on **August 26, 2009.**	**Goal:** To ensure that global temperature increases are kept well below 2°C above pre-industrial levels (preferably to limit the increase to 1.5°C). **Commitments:** ▪ Countries' Nationally Determined Contributions (NDCs). ▪ Targets for reducing carbon emissions. It mandates all countries to establish legally binding carbon reduction strategies. Unlike the Kyoto Protocol, there are no punitive measures. Türkiye ratified the Paris Agreement on **October 7, 2021**, becoming a Party to the Agreement.

4.1. Policy Environment for Decarbonization

European Union (EU) (European Green Deal)	**United States (US)** (Inflation Reduction Act - IRA)
Goal: To make Europe the world's first climate-neutral continent by 2050, with net greenhouse gas emissions reduced to zero in line with the Paris Agreement. **Scope:** Promoting low-carbon and sustainable practices in sectors such as energy, construction, transportation, agriculture, and industry. **Significance:** Aims to prevent carbon leakage with regulatory tools like the Carbon Border Adjustment Mechanism (CBAM) and promote global decarbonization efforts. Encourages carbon reduction practices across all sectors, including the building sector.	**Goal:** To increase investments in clean energy projects and green technologies. **Scope:** Incentives for renewable energy, energy efficiency, and carbon capture technologies. **Significance:** Represents the largest investment in addressing climate change in U.S. history. The Act aims to reduce U.S. greenhouse gas emissions by 40% below 2005 levels by 2030.

4.1. Policy Environment for Decarbonization

National Policies

- Türkiye ratified the Paris Agreement, which was adopted at the 21st Conference of the Parties (COP 21) of the United Nations Framework Convention on Climate Change (UNFCCC) and signed on April 22, 2016, on **October 7, 2021**, thus becoming a party to the agreement.
- The Government of the Republic of Türkiye has published an updated First **Nationally Determined Contribution (NDC)** as of 2023 within the context of the Paris Agreement.
- In the contribution, it confirms that it will reduce greenhouse gas emissions by **41%** by 2030 (to **695 Mt CO_2 equivalent**) compared to the reference scenario specified in the First Nationally Determined Contribution, which considers the year 2012 as the reference year. Türkiye's updated First Nationally Determined Contribution encompasses the entire economy and includes evaluations of comprehensive mitigation and adaptation actions, as well as implementation tools. Türkiye aims to reach peak emissions by no later than 2038.

4.2. Green Building Standards and Decarbonization

Green building standards aim to minimize carbon emissions from buildings through energy efficiency, water conservation, sustainable material use, and reducing environmental impacts. These standards serve as a crucial tool for lowering the carbon footprint of buildings and achieving **decarbonization** targets. Some of the widely used green building standards today include [27]:

Standard / Certification	Type	Governing Organization
BREEAM	Green building rating and certification system through on-site independent third-party verification	BRE Global
LEED	Green building rating and certification system through independent third-party verification	U.S. Green Building Council (USGBC)
Living Building Challenge	Performance-based standard and certification program	International Living Future Institute
Passive House	Performance-based passive building standard	International Passive House Association (iPHA)
DGNB System	Performance-based standard and certification program	Deutsche Gesellschaft für Nachhaltiges Bauen
CASBEE	Building assessment tool	JSBC (Japan Sustainable Building Consortium)
EDGE	Standard and certification system for residential and commercial buildings	International Finance Corporation (IFC), a member of the World Bank Group
YES-TR ***(Green Certificate for Buildings and Settlements)***	A national green building certification system specifically designed to evaluate and promote building projects in Türkiye	Republic of Türkiye Ministry of Environment, Urbanization, and Climate Change

4.3. Decarbonization Incentives

Decarbonization incentives are financial, regulatory, and technical support mechanisms aimed at reducing carbon emissions and promoting the green economy. These incentives are categorized under Global Incentives, National Incentives, and Private Sector & International Funds.

Global Decarbonization Incentives

1. Carbon Pricing Mechanisms

- **Carbon Tax:** Through a carbon tax, governments impose a fee on greenhouse gas emissions from entities within the scope of regulation, providing a financial incentive to reduce emissions. Under a carbon tax scheme, the government sets the emission price (tax rate).
- **Emissions Trading Systems (ETS):** In an emissions trading system (ETS), governments establish a cap on the total amount of greenhouse gas emissions allowed for regulated entities. These entities must submit emission allowances (or “allocations”) to cover their emissions for a compliance period. Each emission allowance represents the right to emit a specific amount of emissions (typically 1 tCO_2e) and can be traded between regulated entities or, in some cases, with other market participants. For more details, see **Module 8: Emissions Trading Systems (ETS) and the Building Sector.**
- **Carbon Credits:** Under the carbon crediting mechanism, tradable credits (1 tCO_2e/credit) are generated through voluntary emission reduction activities. Demand for these credits may come from compliance instruments (ETSs or carbon taxes that allow offsets), countries seeking to meet their Nationally Determined Contribution (NDC) targets under the UNFCCC, voluntary offsetting, or results-based climate finance (RBCF).

2. Renewable Energy Incentives:

- To boost investments in renewable energy production, governments provide subsidies, low-interest loans, and tax incentives.
- **Example:** Under the Inflation Reduction Act, the U.S. has allocated $400 billion for clean energy investments [29].

3. Clean Transportation Incentives:

- Incentives for electric vehicles (EVs) include purchase subsidies, support for charging infrastructure, restrictions or bans on fossil fuel-powered vehicles, and emission regulations.
- **Example:** Norway offers tax exemptions to encourage EV purchases and aims to phase out new fossil fuel vehicle sales by 2025.

4.3. Decarbonization Incentives

National Decarbonization Incentives

1. Renewable Energy Resources Support Mechanism (YEKDEM) [31]

- YEKDEM provides various incentives such as price guarantees and tax reductions for electricity generation from renewable energy sources. The mechanism aims to increase renewable energy production and reduce carbon emissions associated with energy generation. Under YEKDEM, facilities generating electricity from wind, solar, geothermal, biomass, and hydroelectric energy sources receive government support for a specified period. YEKDEM has been in effect since 2011.

2. Energy Efficiency Incentives [32]

- The Republic of Türkiye Ministry of Energy and Natural Resources provides financial support for energy efficiency investments in all sectors through grant programs such as the Efficiency Increasing Project (VAP) and the Energy and Carbon Reduction (EKA) programs.

3. Green Building Grant Incentives [33]

- The Republic of Türkiye Ministry of Trade has included the LEED green building certification in its Market Entry Documents program, which facilitates access to foreign markets and promotes exports. If a company's building obtains LEED certification and gains an advantage in international market entry or exports, the company can benefit from the Market Entry Grant Support. The Ministry covers 50% of the LEED certification costs.

4. Investment Incentives [34]

- Decarbonization-focused investments such as energy efficiency, green transformation in industry, waste recycling, circular economy practices, and energy production from waste heat benefit from investment incentives under the 5th Region (priority investments) of the Republic of Türkiye Ministry of Industry and Technology. These incentives include tax exemptions, tax reductions, social security premium (SGK) discounts, land allocation, interest support, and more.

4.3. Decarbonization Incentives

Private Sector and International Funds

1. Green Bonds

- One of the key financial instruments used to support decarbonization projects is green bonds. These bonds are issued by governments or corporations to finance environmentally friendly projects, such as renewable energy initiatives, sustainability efforts, energy efficiency improvements, forestry, and greenhouse gas emission reduction projects. Green bonds can be issued and managed by governments, international organizations, the private sector, and civil society organizations. They are exclusively allocated to projects that contribute to nature conservation, climate action, sustainability, and environmental protection [35].
- In 2023, global green bond issuance reached $1.073 trillion. In the first half of 2024, green bond issuance totaled $636 billion, and it is expected to exceed $1 trillion by the end of the year [36].

2. Green Climate Fund

- The Green Climate Fund (GCF) is a climate finance mechanism established under the United Nations Framework Convention on Climate Change (UNFCCC). Recognized as the world's largest climate fund, the GCF aims to support developing countries in climate adaptation and mitigation efforts.
- As of December 2023, the GCF manages a portfolio of $13.5 billion, with total co-financing reaching $51.9 billion [37].

4.4. Embodied Carbon Policies

Embodied Carbon Policies and Mechanisms

1. Carbon Border Adjustment Mechanism

- **Objective:** Developed by the European Union, this mechanism aims to price the embodied carbon content of imported goods, thereby preventing carbon leakage and protecting domestic producers.
- **Carbon leakage** occurs when the production of carbon-intensive goods shifts from EU countries—where stringent environmental regulations apply—to nations with more lenient climate policies, leading to an overall increase in global emissions [38].
- Through the **CBAM** mechanism, it will be ensured that a charge is paid for the embodied carbon emissions generated during the production of certain goods imported into the EU, confirming that the carbon price of imports is equivalent to the carbon price of domestic production and preventing the undermining of the EU's climate targets. CBAM is designed to be compliant with World Trade Organization (WTO) rules.
- CBAM entered into force on October 1, 2023, and will remain in a transition phase until the end of 2025. During this period, it applies to imports of cement, iron and steel, aluminum, fertilizers, electricity, and hydrogen. By 2026, CBAM is expected to be fully implemented, expanding its scope to include all products covered under the EU Emissions Trading System (EU ETS).
- Beyond reducing carbon emissions within EU borders, CBAM also aims to drive global climate action. Countries exporting carbon-intensive goods to the EU will be incentivized to develop their own carbon pricing policies and take steps to reduce emissions in order to avoid the additional costs imposed by the mechanism.

4.4. Embodied Carbon Policies

Embodied Carbon Policies and Mechanisms

2. Environmental Product Declarations (EPD)

Environmental Product Declarations are key tools for monitoring and reducing embodied carbon emissions, as they provide comprehensive information on the environmental impacts of products throughout their production processes. EPDs for building materials are prepared in accordance with the following standards:

- **ISO 14025** - Environmental labels and declarations – Type III environmental declarations – Principles and procedures (TS ISO 14025)
- **ISO 14040** - Environmental management – Life cycle assessment – Principles and framework (TS EN ISO 14040)
- **ISO 14044** - Environmental management – Life cycle assessment – Requirements and guidelines (TS EN ISO 14044)
- **ISO 14067** - Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification (TS EN ISO 14067)
- **ISO 21930** - Sustainability in buildings and civil engineering works – Core rules for environmental declarations of construction products and services (TS ISO 21930)
- **EN 15804** - Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (TS EN 15804+A2)

3. Carbon Footprint Reporting Standards

- **Greenhouse Gas Protocol:** A global framework for conducting life-cycle analyses and reporting carbon emissions for companies, countries, and cities.

4.5. Case Study: State-Led Decarbonization Initiatives

Iceland's Carbon Capture and Storage (CCS) Initiative	Interreg VI B North-West Europe (NWE) Programme (2021-2027)
▪ The Icelandic government supports the development of innovative carbon capture technologies to reduce fossil fuel-related carbon emissions. ▪ The **CarbFix** project ensures the injection of carbon dioxide into basalt rocks, allowing it to mineralize and be permanently stored within two years. ▪ The CarbFix method is currently used to capture and store **one-third of the 40,000 tons of CO_2** emitted annually by geothermal power plants. Additionally, the process enables the safe underground storage of two-thirds of the emitted hydrogen sulfide. By significantly reducing atmospheric CO_2 emissions, CarbFix serves as a global model for effective decarbonization. [39]	▪ Approved by the European Commission on August 24, 2022, the Interreg VI B North-West Europe (NWE) Programme (2021-2027) promotes a **green, smart, and fair transition to support balanced development and enhance the resilience** of all regions to better respond to current and future challenges. ▪ The Interreg NWE Programme assists regions in their **transition to energy and circular economy** by implementing and adopting international and local solutions to contribute to the **conservation of natural resources** and the development of nature-based solutions against **climate change.** [40]

4.5. Case Study: State-Led Decarbonization Initiatives

The Netherlands – Pricing Embodied Carbon Emissions in Buildings	Austria – Housing Subsidies and Funds

▪ Since 2013, new residential and office buildings exceeding 100 m² have been required to present their embodied emissions through a life-cycle assessment. The calculation method used converts the life cycle assessment categories into a shadow price expressed in euros.
▪ All impacts are converted into a single monetary value and divided by the building's floor area and the length of the assessment period (50 years for office buildings and 75 years for residential buildings).
▪ In 2018, this regulation was revised to set a mandatory upper limit on environmental impact at **€1.00** per square meter per year for buildings.
▪ This regulation is the first of its kind in the world. [41]
	▪ Austrian states provide various subsidies to building owners who declare the embodied carbon emissions of their buildings using a building life-cycle assessment (LCA) approach.
	▪ These subsidies vary by state and include some of the following:
	  ▪ Grant support (based on the building's local green building certification, Ökoindex 3 performance)
	  ▪ Long-term, low-interest loans (35 years, 1.75% rate, and a maximum of 110 m² for residential properties)
	  ▪ Cash support for sustainable building materials (per m² of material) [42]

4.5. Case Study: State-Led Decarbonization Initiatives

Denmark
▪ Denmark's decarbonization success is partly due to the ban on regular landfills that promote large-scale incineration processes. The electricity and heat energy produced by large furnaces is supplied to district heating facilities, which provide heating and hot water to numerous buildings.
Finland
▪ Thanks to significant investments and incentives in heat pumps, the country has substantially reduced fossil fuel consumption, ensuring that 15% of the heating energy (annual 10 TWh) for residential and commercial buildings comes from water, air, and ground-source heat pumps.
Japan
▪ In 2017, Japan became the first country in the world to develop a comprehensive hydrogen strategy, aiming to reduce emissions by 46% by 2030 and achieve carbon neutrality by 2050. ▪ Today, pioneering cities like Kobe are utilizing hydrogen technology to generate heat and electricity for sports centers, trains, and hospitals.

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