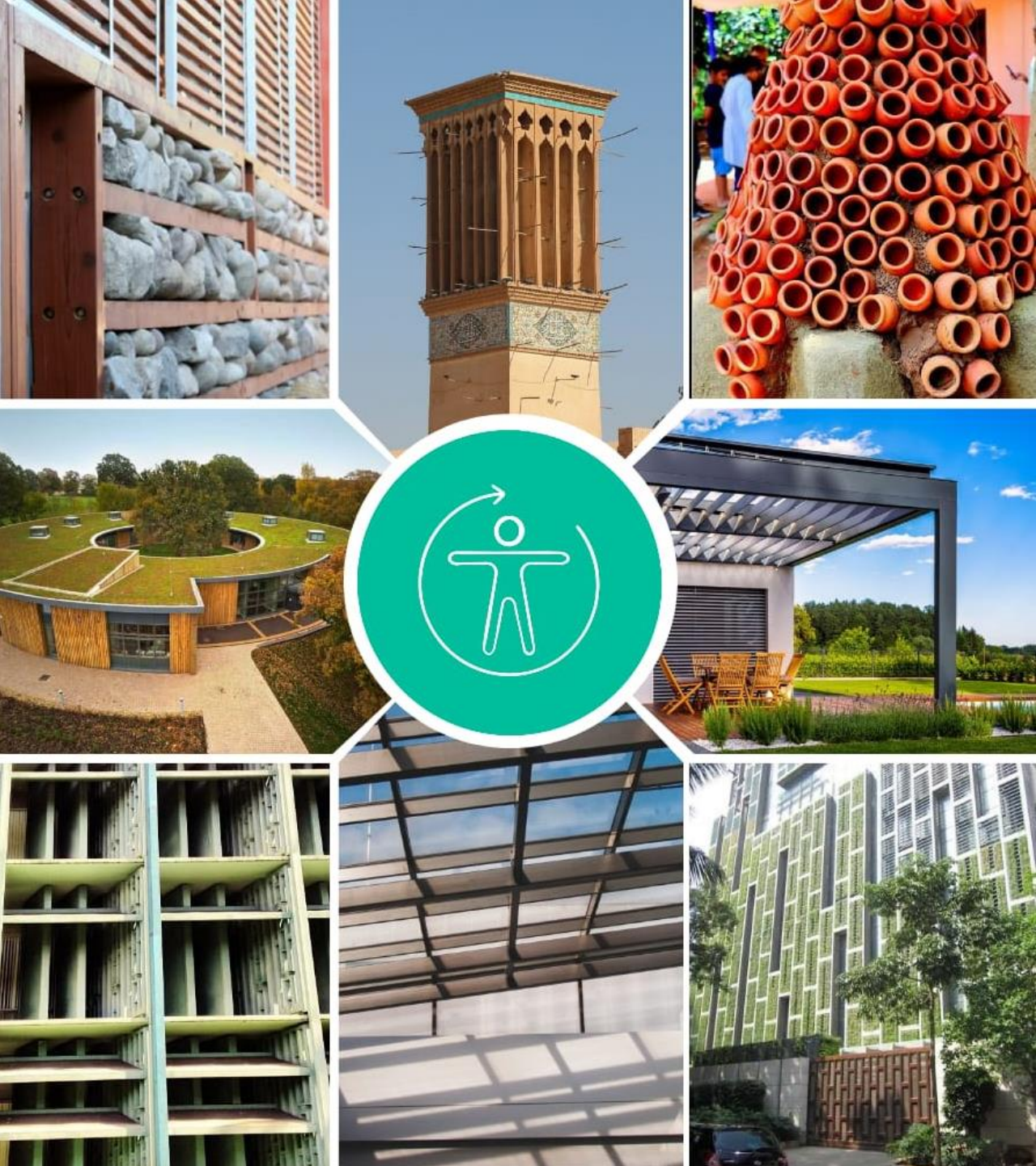


3.1 Concept of Net Zero Carbon Buildings

November 2024



WHAT WILL YOU LEARN?

Climate Change and Carbon Footprint

01

Net Zero Carbon Buildings: Concepts and Approaches

02

Global Net Zero Building Commitments

03

Net Zero Building: Case Examples

04

Climate Change and Carbon Footprint

Emissions and Global Warming



CLIMATE CHANGE AND CARBON

Greenhouse gases

Since the 1800s, greenhouse gases (GHGs) from human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas.

Key GHGs emitted by human activities are:

- **Carbon dioxide** (CO₂): Primarily from burning fossil fuels. Also, through deforestation, land clearance for agriculture or development, degradation of soils and land management
- **Methane** (CH₄): From agricultural activities, waste management, energy production and use, and biomass burning
- **Nitrous oxide** (N₂O): From agricultural activities, such as fertilizer use, chemical production and fossil fuel combustion
- **Fluorinated gases** (F-gases): From industrial processes, refrigeration, and the use of a variety of consumer products including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF₆)

Global net anthropogenic GHG emissions

65% from CO₂ (fossil fuels and industry)

18% from CH₄

11% from CO₂ (land use, land use change and forestry)

6% from N₂O and fluorinated GHG gases

Source: United States Environmental Protection Agency, 2024

CLIMATE CHANGE AND CARBON

Global warming potential and CO₂ equivalent

- The global warming potential (GWP) allows comparisons of the global warming impacts of different GHGs
- It is a measure of how much energy the emission of 1 ton of a gas will absorb over a given time duration, relative to the emission of 1 ton of carbon dioxide (CO₂)
- The time duration usually used for GWPs is 100 years
- The metric used for measuring GWP of a GHG is CO₂ equivalent (CO₂e)

Global warming potential of greenhouse gases

Greenhouse gases	GWP over 100 years
Carbon dioxide (CO ₂)	1
Methane (CH ₄)	27–29.8
Nitrous Oxide (N ₂ O)	273
Sulfur hexafluoride (SF ₆)	24,300
Perfluorocarbon (PFC)	7,380 – 12,400
Hydrofluorocarbon (HFC)	4.84–14,600

Table source: IPCC, 2021

CARBON EMISSIONS

Global impact of the construction and building industry

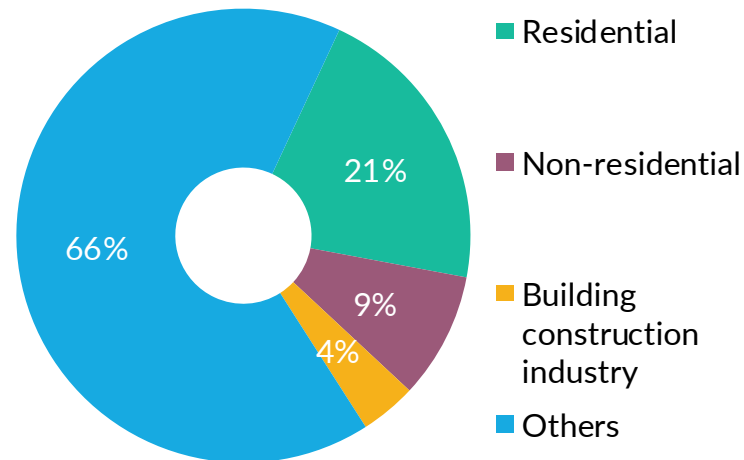
Globally, buildings consume more than 30%–34% of the total energy demand for operational requirements and production of construction materials. In 2022, CO₂ emissions from building operations and construction reached a new high of 37% of total emissions (*Direct emissions are from resources owned and controlled by the user, while indirect emissions are due to generation of purchased electricity*)



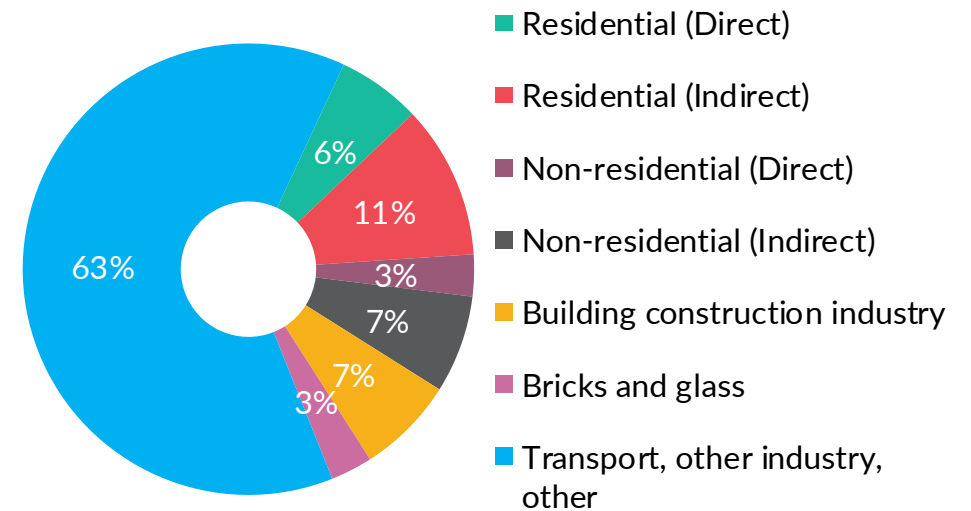
30%–34%
of total energy
consumed by buildings

37%
of total CO₂ emissions

Share of buildings in total final energy consumption (2022)
Energy demand by sector 2022



Share of buildings in global energy and process emissions (2022)
Emissions by sector 2022

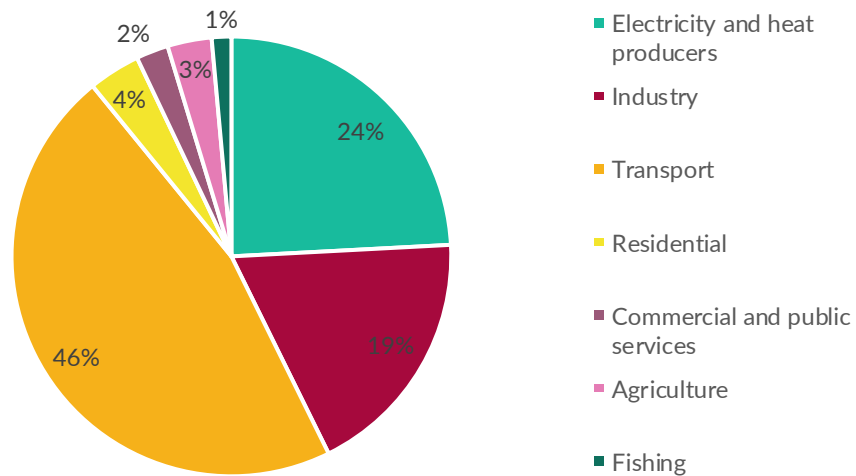


Sources: International Energy Agency, 2023a; United Nations Environment Programme, 2024

EMISSIONS AND ELECTRICITY CONSUMPTION

Cambodia

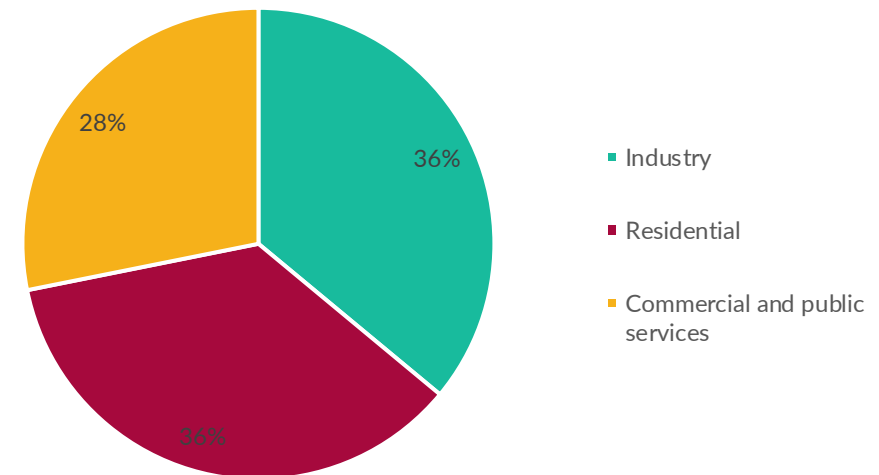
Emissions by sector, 2022



Largest sources of emissions:

- Transport = 46%
- Electricity and heat producers = 24%

Electricity consumption by sector, 2022



Largest consumers:

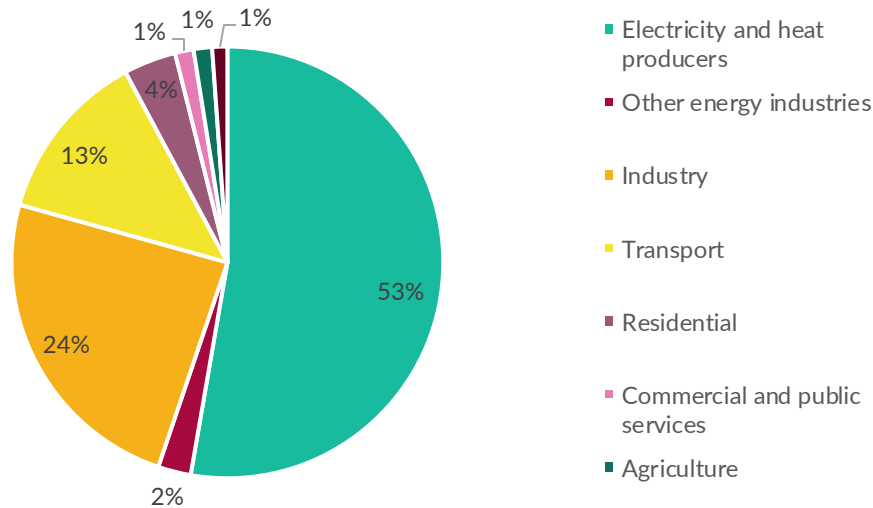
- Industry = 36%
- Residential = 36%

Source: <https://www.iea.org/countries/cambodia>

EMISSIONS AND ELECTRICITY CONSUMPTION

India

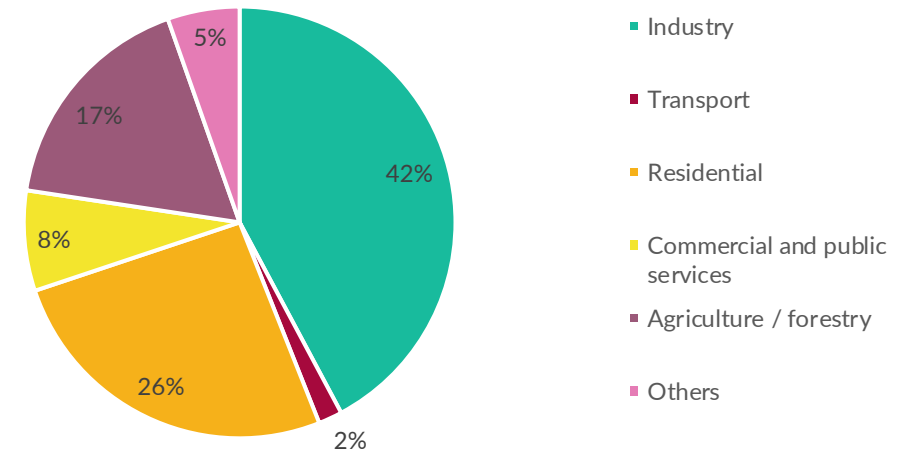
Emissions by sector, 2022



Largest sources of emissions:

- Electricity and heat producers = 53%
- Industry = 24%

Electricity consumption by sector, 2022



Largest consumers:

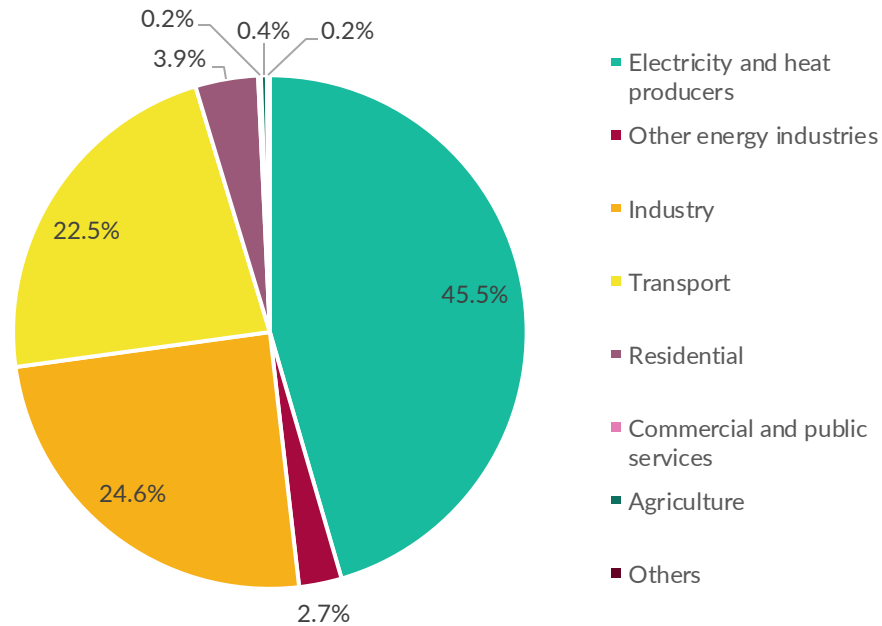
- Industry = 42%
- Residential = 26%

Source: <https://www.iea.org/countries/india>

EMISSIONS AND ELECTRICITY CONSUMPTION

Indonesia

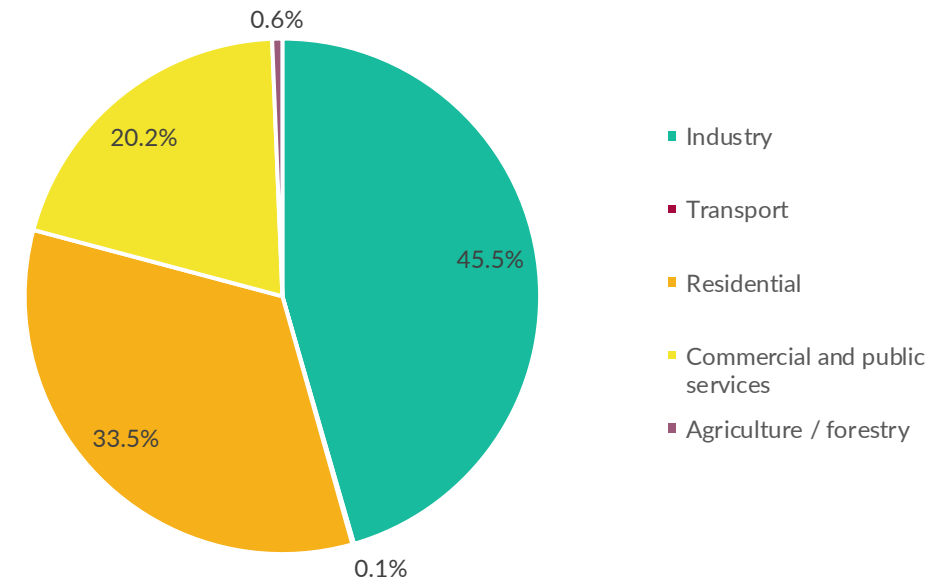
Emissions by sector, 2022



Largest sources of emissions:

- Electricity and heat producers = 45%
- Industry = 25%

Electricity consumption by sector, 2022



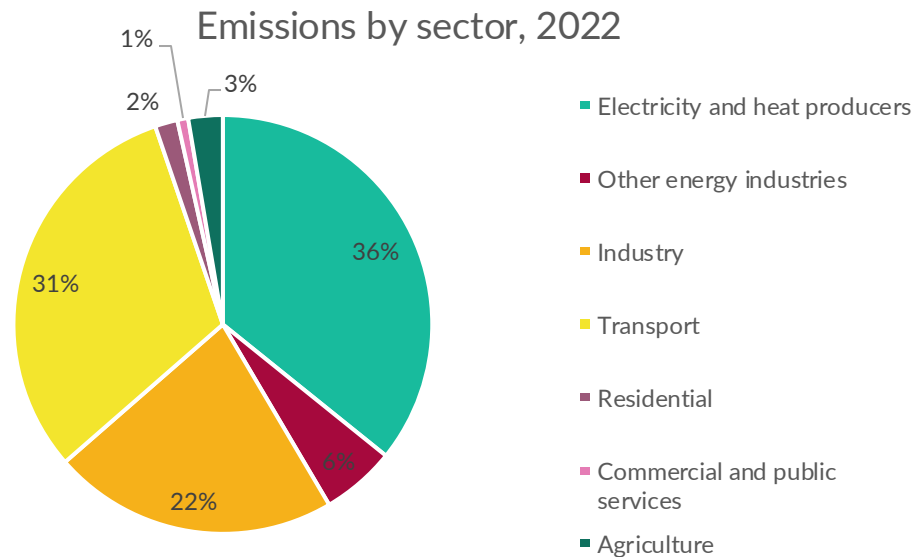
Largest consumers:

- Industry = 46%
- Residential = 34%

Source: <https://www.iea.org/countries/indonesia>

EMISSIONS AND ELECTRICITY CONSUMPTION

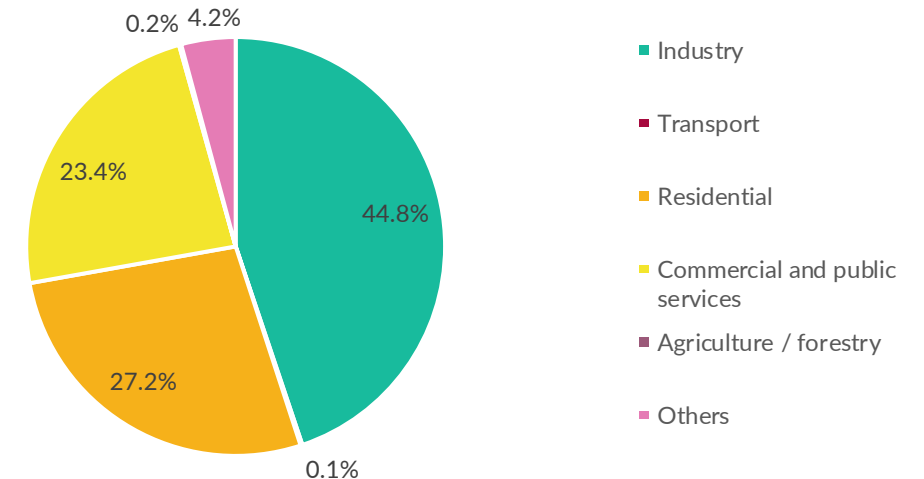
Thailand



Largest sources of emissions:

- Electricity and heat producers = 36%
- Transport = 31%

Electricity consumption by sector, 2022



Largest consumers:

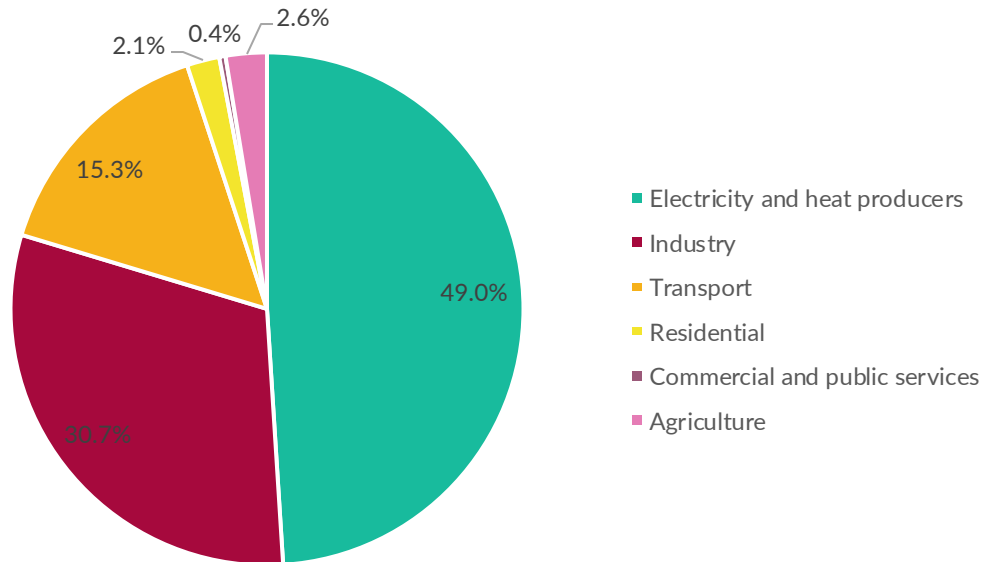
- Industry = 45%
- Residential = 27%

Source: <https://www.iea.org/countries/thailand>

EMISSIONS AND ELECTRICITY CONSUMPTION

Vietnam

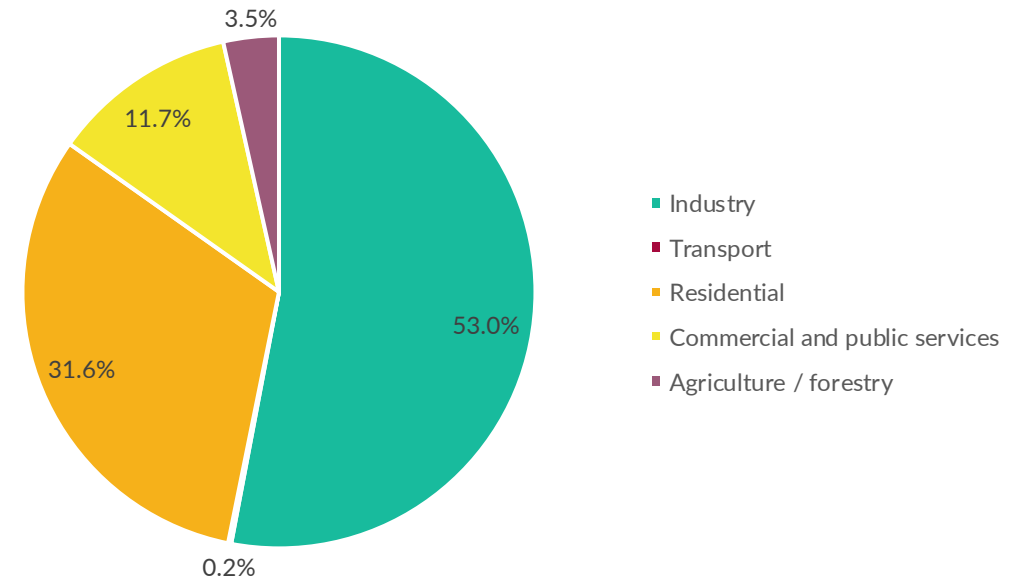
Emissions by sectors, 2022



Largest sources of emissions:

- Electricity and heat producers = 49%
- Transport = 31%

Electricity consumption by sector, 2022



Largest consumers:

- Industry = 53%
- Residential = 32%

Source: <https://www.iea.org/countries/vietnam>

Net Zero Carbon Buildings

Concepts and Approaches



NET ZERO CARBON BUILDINGS

The concept

- **Net zero carbon** means cutting carbon emissions to a small value of residual emissions that can be absorbed and durably stored by nature and other carbon dioxide removal measures, leaving zero in the atmosphere¹
- **Net zero carbon buildings** are designed so that the total greenhouse gas emissions from their entire life cycle amount to zero or less²
- However, there are different definitions and types of net zero buildings depending on the scope

¹ Source: United Nations Climate Action

² Source: Ramachandran, 2024



NET ZERO CARBON BUILDINGS

Definitions

- **Net zero carbon – construction** when the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through use of offsets or the net export of onsite renewable energy
- **Net zero carbon – operational energy** when the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from onsite and/or offsite renewable energy sources, with any remaining carbon balance offset
- **Net zero carbon – whole life** when the amount of carbon emissions associated with a building's embodied and operational impacts over the life of the building, including its disposal, are zero or negative



Source: UK Green Building Council, 2019

NET ZERO CARBON BUILDINGS

Levels of adoption

The adoption of net zero carbon buildings will need various approaches:

- i. **Energy efficient buildings:** Provide significant energy savings through optimized construction and systems for heating, cooling, lighting and other services
- ii. **Low carbon buildings:** Incorporate low carbon energy sources and may require upgrades in existing equipment to reduce carbon emissions fully
- iii. **Nearly zero carbon building:** Achieve high energy efficiency and include some form of zero-emission energy but fall short of completely neutralizing their energy consumption



Source: United Nations Environment Programme, 2024

Image source: <https://theleaflet.in/indias-challenges-towards-achieving-net-zero-goals/>

NET ZERO CARBON BUILDINGS

Levels of adoption (continued)

- iv. **Net zero carbon buildings:** Meet their energy needs with zero-emission sources over a set period, typically a year. Zero carbon buildings are similar but ensure that all energy demands are met with zero-emission energy throughout the period
- v. **Carbon negative buildings:** Produce more renewable energy than they consume, contributing the surplus to the grid for external use
- vi. **Whole life cycle net zero carbon buildings:** Represent the pinnacle of sustainability, maintaining a zero-carbon energy status while also ensuring that the embodied emissions from their construction materials are net zero, achieved through either decarbonization or offsets
- vii. **Green buildings:** Also known as green construction, sustainable building, or eco-friendly building, refer to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life cycle from planning to design, construction, operation, maintenance, renovation and demolition



Source: United Nations Environment Programme, 2024

Image source: <https://theleaflet.in/indias-challenges-towards-achieving-net-zero-goals/>

NET ZERO CARBON BUILDINGS

Whole life carbon approach

Total decarbonization of the built environment calls for the industry to adopt the **whole life carbon approach** that addresses emissions from operational energy use in buildings, and the embodied carbon, which comes from the building materials and construction or renovation processes



Source: World Green Building Council

WHOLE LIFE CARBON

Embodied and operational carbon

- The **whole life** of a building is the entire life of a building from the material sourcing, manufacturing, construction, use over a given period, demolition, and disposal or reuse
- **Whole life carbon** refers to the carbon impacts over the entire life cycle of a built asset, from its construction through to its end of life
- The whole life carbon of a building broadly consists of **embodied carbon and operational carbon**
- In addition, there are user carbon impacts from the activities of the users of a built asset, outside of the use of energy and water to operate the asset



Source: Royal Institute of Chartered Surveyors, 2023

Image source: Gensler, Garrett Rowland

Global Net Zero Buildings

Commitments



REDUCING CARBON EMISSIONS

Way forward for buildings

Lower reliance on fossil fuels by reducing operation energy consumption

- Passive design and improve building envelope
- Systems efficiency
- Energy management

Minimize embodied carbon, both upfront and during building life cycle

- Repurpose existing buildings and materials
- Reduce the need for material replacements
- Optimize material usage and design with low carbon materials
- Use low carbon construction technologies and eliminate waste

Increase renewable energy use

- Prioritize onsite renewable energy generation
- Procure offsite renewable energy

Offset any remaining carbon

Sources: UK Green Building Council, 2019; Ramachandran, 2024

NET ZERO BUILDINGS

Global commitments

World Green Building Council Commitment

By 2030, all new buildings, infrastructure and renovations must reduce embodied carbon by at least 40%, with significant upfront carbon reduction. Additionally, all new buildings must achieve net zero operational carbon. By 2050, all buildings, including existing ones, along with new infrastructure and renovations, must achieve net zero embodied carbon and net zero operational carbon

UK Green Building Council Advancing Net Zero Program

Aims to drive the transition toward net zero carbon buildings in the UK, focusing on reducing emissions from the construction and property sectors

The 2030 Challenge for Embodied Carbon by Architecture 2030

The target is to achieve a GWP of 40% below the current industry average immediately, with the following goals:

- 45% or better by 2025
- 65% or better by 2030
- Zero GWP by 2040

Source: Ramachandran, 2024

NET ZERO BUILDINGS

Global commitments

Race to Zero

UN-backed global campaign rallying non-state actors – including companies, cities, regions, financial and educational institutions – to take rigorous and immediate action to halve global emissions by 2030 and deliver a healthier, fairer zero carbon world in time

The American Institute of Architects (AIA) 2030 Commitment

A climate strategy that sets standards and goals for achieving net zero emissions in the built environment, with architects, engineers and owners urged to take immediate and decisive action to reach net zero emissions by 2030

C40 Cities Pledge

Aims to inspire and mobilize stakeholders to take action and implement policies that:

- Reduce embodied emissions by at least 50% for all new buildings and major retrofits by 2030, with a target of 30% by 2025
- Reduce embodied emissions by at least 50% for all infrastructure projects by 2030, with a target of 30% by 2025
- Procure and, where possible, use only zero-emission construction machinery from 2025 and ensure all construction sites are zero emission by 2030

The Royal Institute of British Architects (RIBA) 2030 Climate Challenge

A framework that sets ambitious targets for architects to help reduce the built environment's carbon footprint and contribute to global climate goals

Source: Ramachandran, 2024

Net Zero Buildings

Case Examples



ENERGY EFFICIENT BUILDINGS

Case example: Indira Paryawaran Bhavan, India

- Indira Paryawaran Bhawan, the new building of the Ministry of Environment and Forest, located in New Delhi is India's highest green rated building. It has achieved an **LEED platinum and GRIHA 5-star rating**
- The building uses **70% less energy** than a conventional building by applying several passive design strategies like adequate **natural light, shading and landscaping to reduce ambient temperature and energy use**



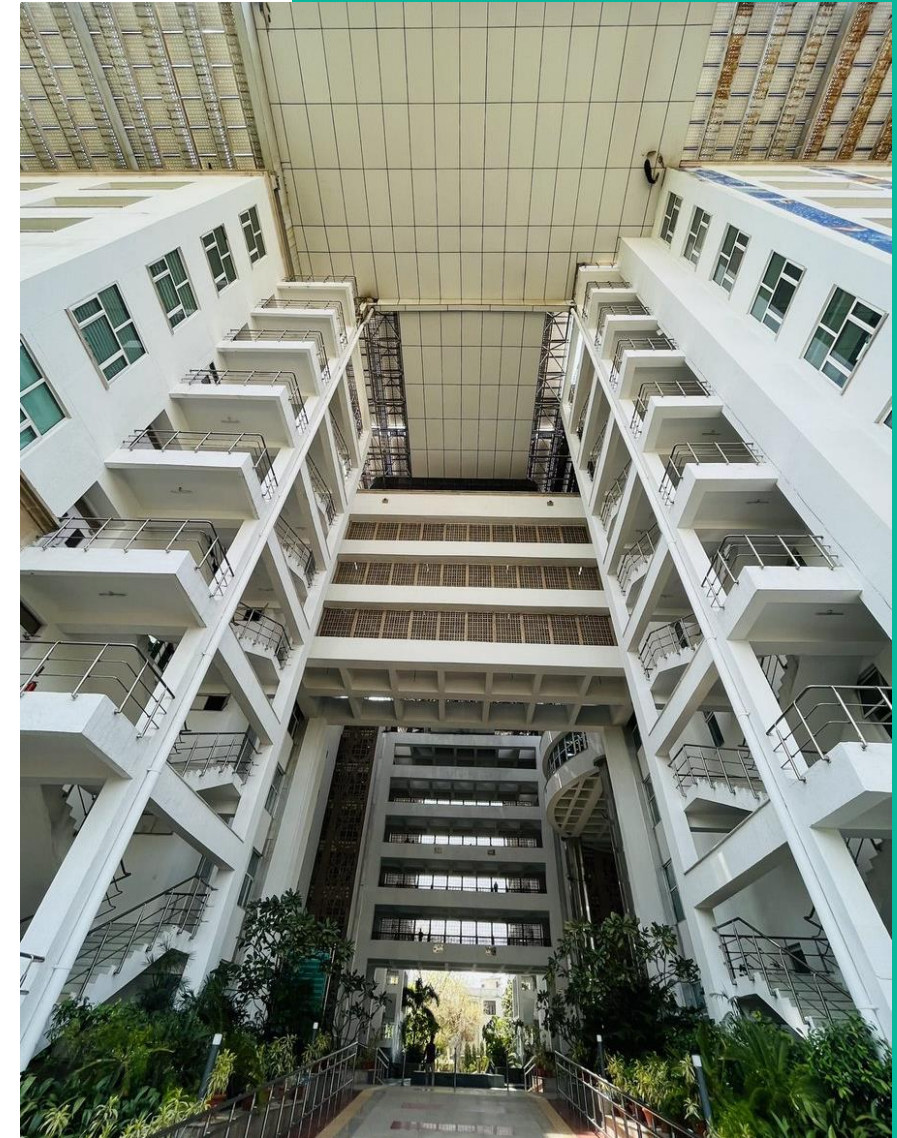
Image source: NBM and CW, 2018

Source: Bureau of Energy Efficiency, Government of India and United States Agency for International Development

ENERGY EFFICIENT BUILDINGS

Case example: Indira Paryawaran Bhavan, India (continued)

- Received **several awards** for exemplary demonstration of renewable energy technologies
- Demonstrates an **Energy Performance Index of 44 kWh/sqm/year**
- Generates about **1.43 million units per year** through solar panels that power the facility, and exports surplus power to the grid
- Integrates several effective passive and active measures:
 - Optimum orientation and building envelope
 - Energy efficient lighting systems
 - Sustainable cooling using strategies like chilled beams
 - Variable speed screw chillers
 - Precooling of fresh air is by a geothermal system
- Heating, ventilation and air conditioning (HVAC) load is 40 sqm/TR, surpassing India's Energy Conservation Building Code requirement of 20 sqm/TR



Source: Bureau of Energy Efficiency, Government of India and United States Agency for International Development

ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA

- The new city hall of Santa Monica is a **mid-rise office building** with a gross area of **50,000 sq. ft.**, designed to meet the standards of **Living Building Challenge aiming for a net zero energy performance certification**
- Modeled **Energy Use Intensity (EUI)** is **7.9 kWh/ sq. ft. /year**
- The project has a **292 kW DC solar PV system** that produces **7.9 kWh/sq. ft./year**, achieving the net zero energy goal



Source: Dean, 2022

ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA (continued)

Salient sustainable design features of the **building envelope**:

- The design requirement was to have a strong architectural contrast to the historic city wall where in the proposal for an all-glass curtain wall was approved
- **A highly-optimized double curtain wall design** with a **balance of openable windows** and choice of glass with **low-e coating** was chosen to optimize the daylighting and control solar loads
- The envelope could not have a very low U-value; however, several energy efficient strategies were integrated

Source: Dean, 2022

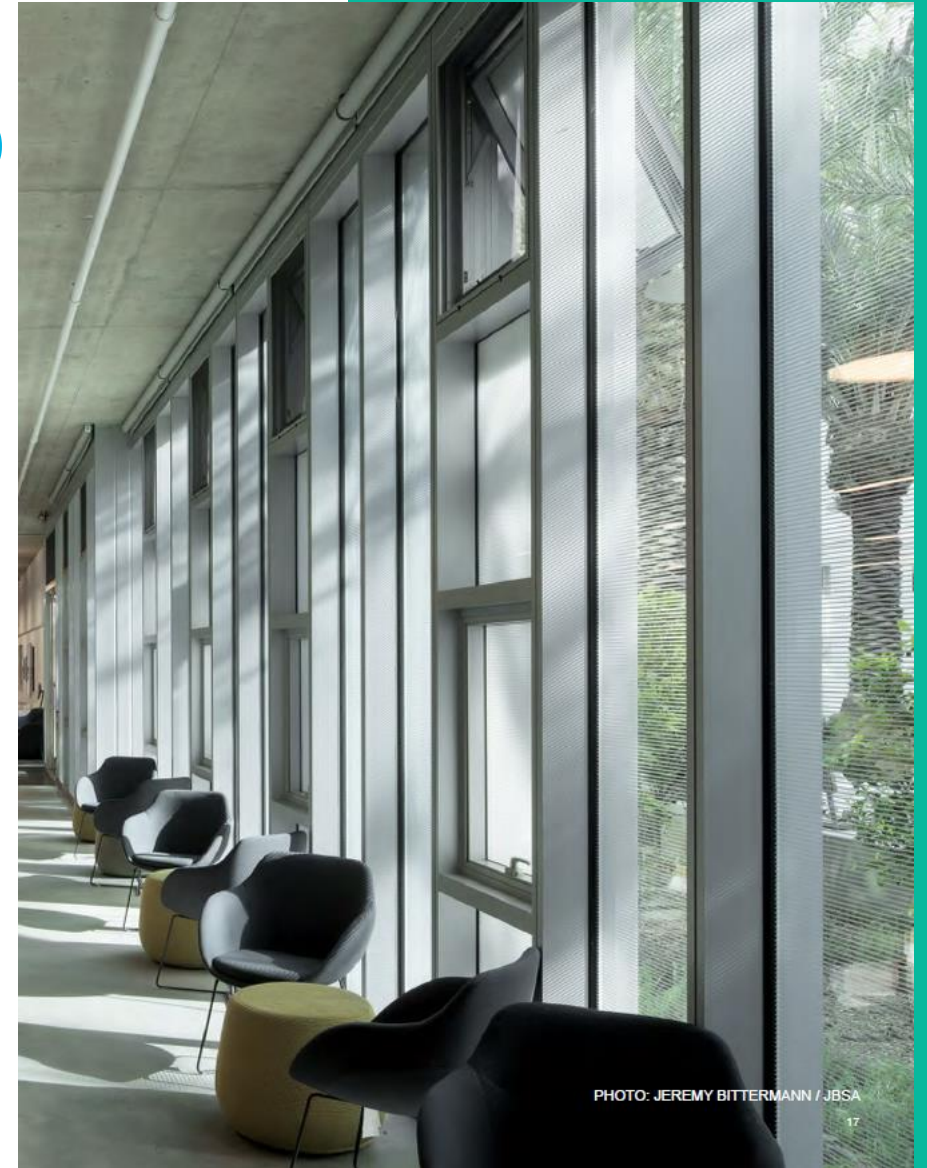


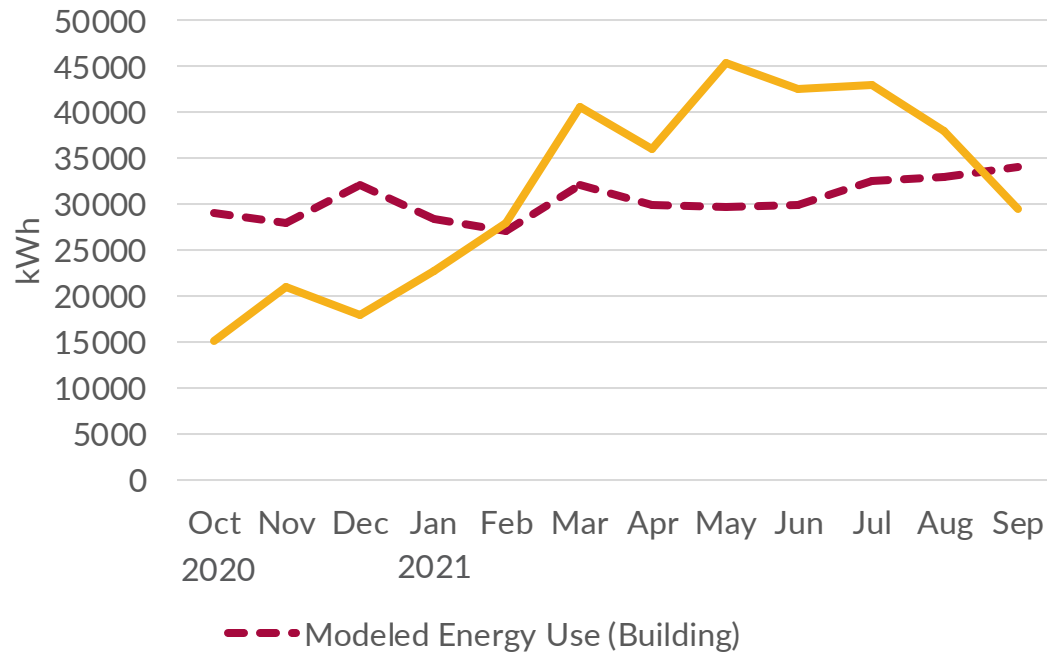
PHOTO: JEREMY BITTERMANN / JBSA

17

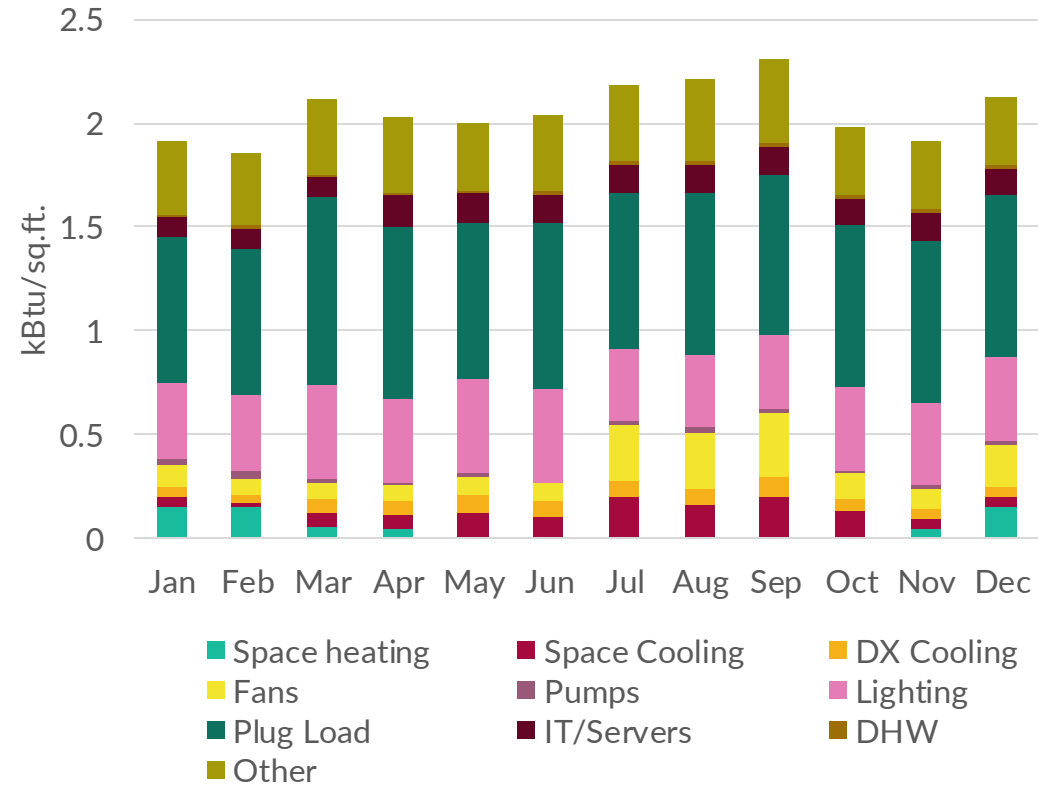
ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA (continued)

Solar Photovoltaic System Performance
(2020-2021)



Modeled Monthly Energy Use



Source: Dean, 2022

ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA (continued)

Strategies for energy efficiency

Thermal storage and phase change material

- Added phase change material to certain ceilings and walls and spandrel glass of the curtain wall as thermal mass to reduce peak load
- Installed large operable windows located at two heights on each floor, one at occupant level and a second one just below the ceiling, controlled by building management systems for optimum **cross ventilation and night purging**
- HVAC uses **air source heat pumps** to generate chilled water or hot water to circulate through concrete slabs
- **Reduced plug loads by having staff use only laptops**
- Conducted training for occupants on using the energy efficient features of the building

Source: Dean, 2022

NET ZERO BUILDING

Case example: Godrej Office Building, India

- Plant-13 Annexe Building of Godrej & Boyce Ltd., located in Mumbai, India, is a multi-use office built in the year 2010
- The building is equipped with facilities like offices, conference and meeting rooms, training rooms, auditorium, banquet rooms, cafeteria, food court, and 24x7 kitchen facilities
- The building is constructed over a site area of 4 acres and has ground + 4 floors with an area of 250,000 sq. ft.
- The building is occupied by around 400 employees and common facilities like cafeteria, and conference and meeting rooms are shared by over 2,000 staff members



Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

NET ZERO BUILDING

Case example: Godrej Office Building, India (continued)

Main features:

- Optimized window to wall ratio, north-south orientation, punched windows and light wells for daylight
- Double glass with low heat (25%) and high-light transmission values (40%)
- Walls with autoclaved aerated concrete (AAC) blocks and roof with thermal insulation and green vegetation to reduce heat ingress and mitigate urban heat island effects
- Central air-conditioning system with chilled water system and water-cooled screw chillers with coefficient of performance (COP) of 5.9 at full load, and COP of 8–9 at 50% load; and 2x250 TR (with twin compressors) and 2x125 TR distributed sizing for operational flexibility
- Variable frequency drives (VFDs) on cooling tower fans, chilled water pumps and AHU fans with temperature-based controls
- A building management system controls the air conditioning system

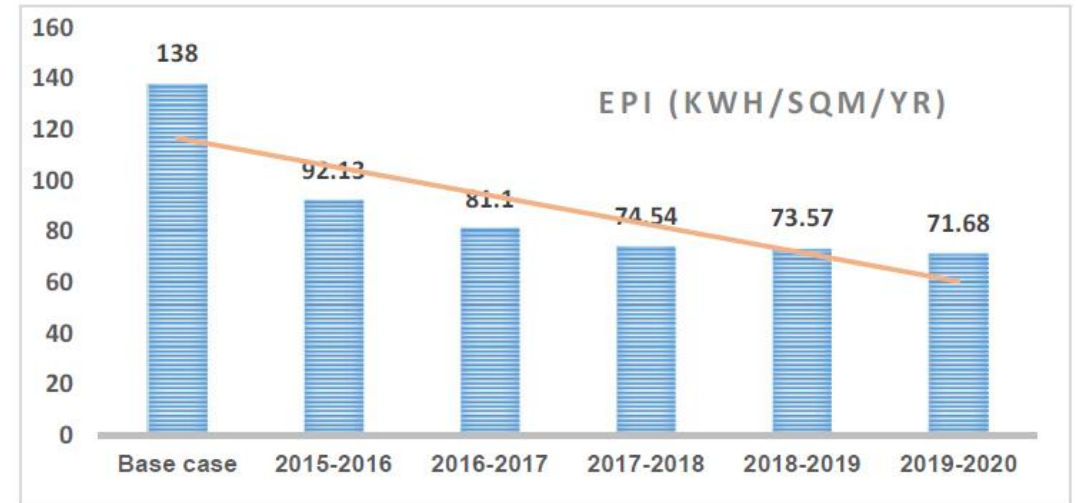
Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

NET ZERO BUILDING

Case example: Godrej Office Building, India (continued)

Main features (continued):

- A 120 kWp solar PV installed to provide 8% of the annual energy demand
- A tripartite power purchase agreement signed to receive wheeled solar power of approximately 1,200 kWp from a solar plant located at Sangli, India
- With the combination of 120 kWp onsite and 1,200 kWp offsite, Plant-13 Annexe Building can meet the Net Zero Energy targets



Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

Thank you!

For more information, visit us at <https://ALCBT.GGGI.ORG>
or scan the QR code below



IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at <https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/>.

 www.gggi.org

 [@gggi_hq](https://twitter.com/gggi_hq)

 [@GGGIHQ](https://www.instagram.com/gggi_hq)

 [@GGGIHQ](https://www.facebook.com/gggi_hq)

 [@gggi_hq](https://www.linkedin.com/company/gggi_hq)

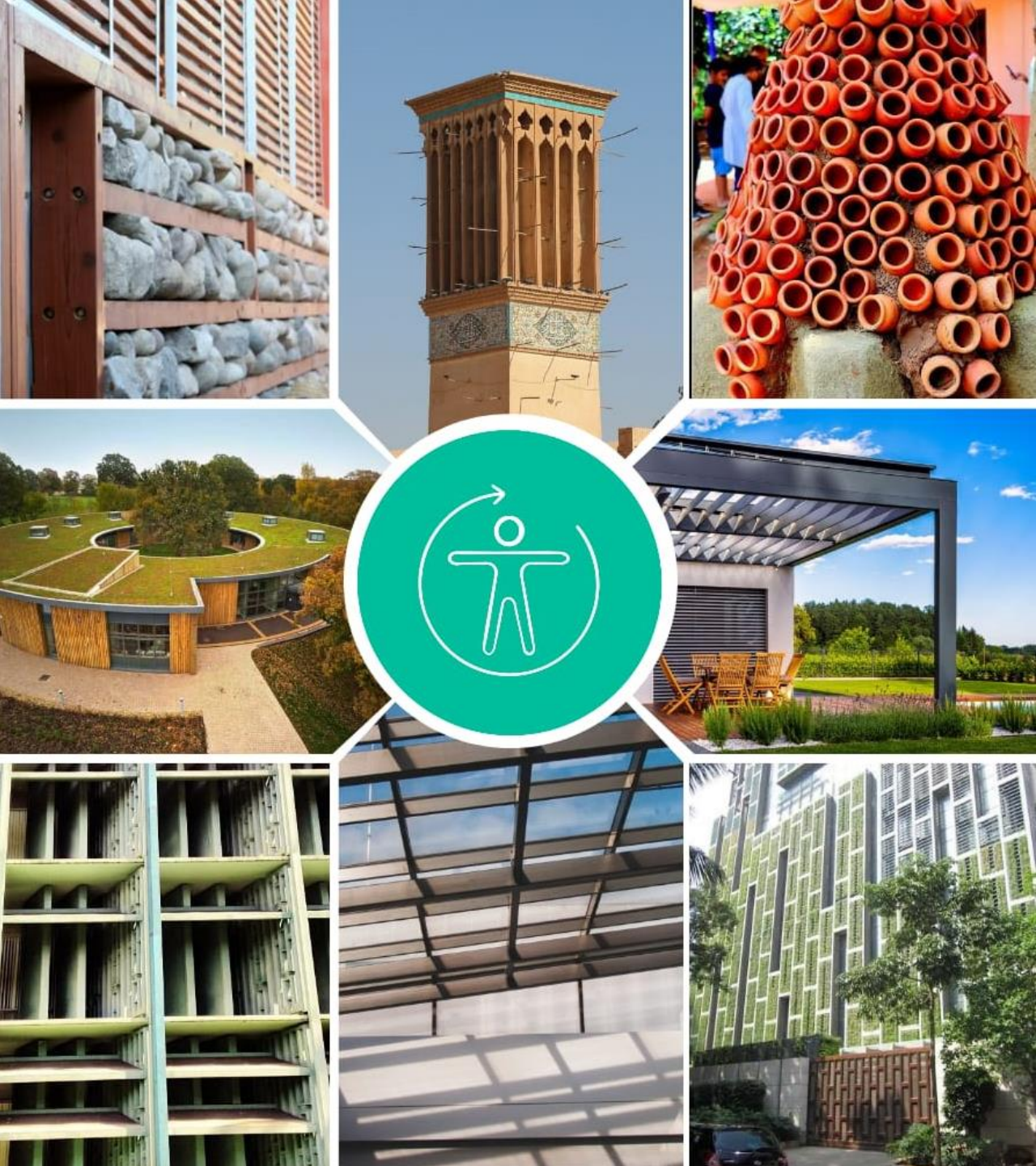
 [@GGGIMedia](https://www.youtube.com/channel/UCGgI-Media)



Supported by:



on the basis of a decision
by the German Bundestag



3.2 Understanding Embodied Carbon in Buildings

November 2024

WHAT WILL YOU LEARN?

Embodied Carbon and its Importance

Key Materials Driving Embodied Carbon

Calculating Embodied Carbon

Reducing Embodied Carbon

Embodied Carbon Regulations

Case Examples

01

02

03

04

05

06



WHOLE LIFE CARBON

Embodied and operational carbon

- The **whole life** of a building is the entire life of a building from the material sourcing, manufacturing, construction, use over a given period, demolition, and disposal or reuse
- **Whole life carbon** refers to the carbon impacts over the entire life cycle of a built asset, from its construction through to its end of life
- The whole life carbon of a building broadly consists of **embodied carbon and operational carbon**
- In addition, there are user carbon impacts from the activities of the users of a built asset, outside of the use of energy and water to operate the asset



Source: Royal Institute of Chartered Surveyors, 2023

Image source: Gensler, Garrett Rowland

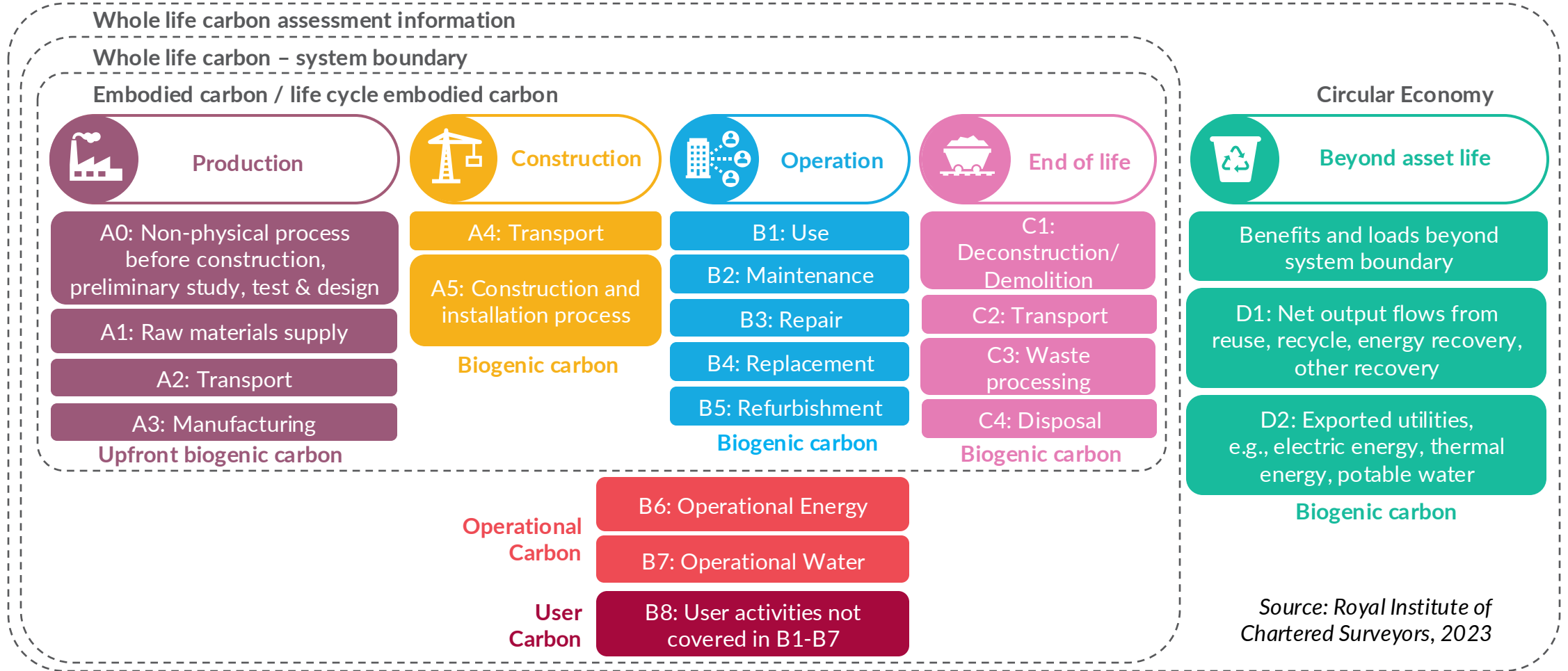
Embodied Carbon in Buildings

Relevance and Importance



Image source: <https://www.lek.com/insights/by/building-materials-supply-chain-disrupted-changes-consumer-behaviour>

BUILDING LIFE CYCLE STAGES

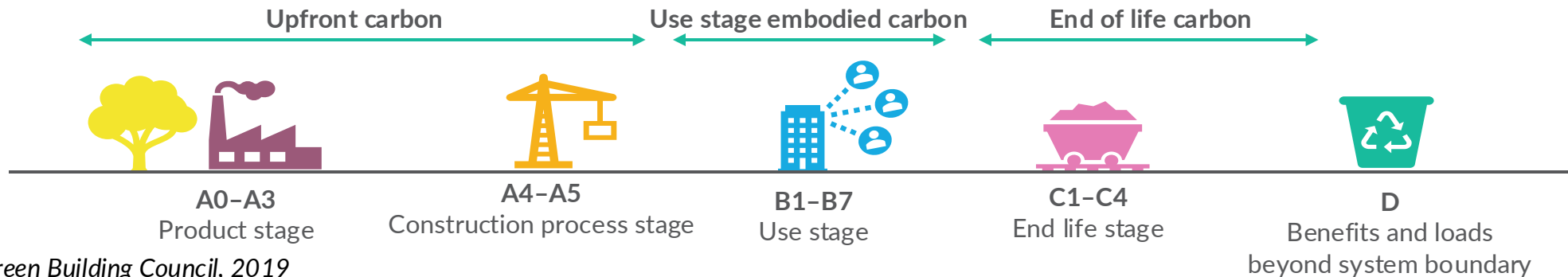


EMBODIED CARBON

Upfront, during use and end of life

Embodied carbon denotes carbon emissions associated with materials and construction processes throughout the whole life cycle of a building. This includes:

- **Upfront carbon:** The emissions caused during the building material production and construction phases (A0–A5) of the building's life cycle before it is used. In contrast to other categories of emissions, these emissions have already been released into the atmosphere before the building is occupied or the infrastructure begins operation
- **Use stage embodied carbon:** Emissions associated with building materials and processes needed to maintain the building or infrastructure during use, such as for refurbishments (B1 –B5). These are additional to operational carbon emitted due to heating, cooling and power etc.
- **End of life carbon:** The carbon emissions associated with deconstruction and demolition (C1), transportation from site (C2), waste processing (C3) and disposal (C4) phases of a building or infrastructure's life cycle which occur after its use



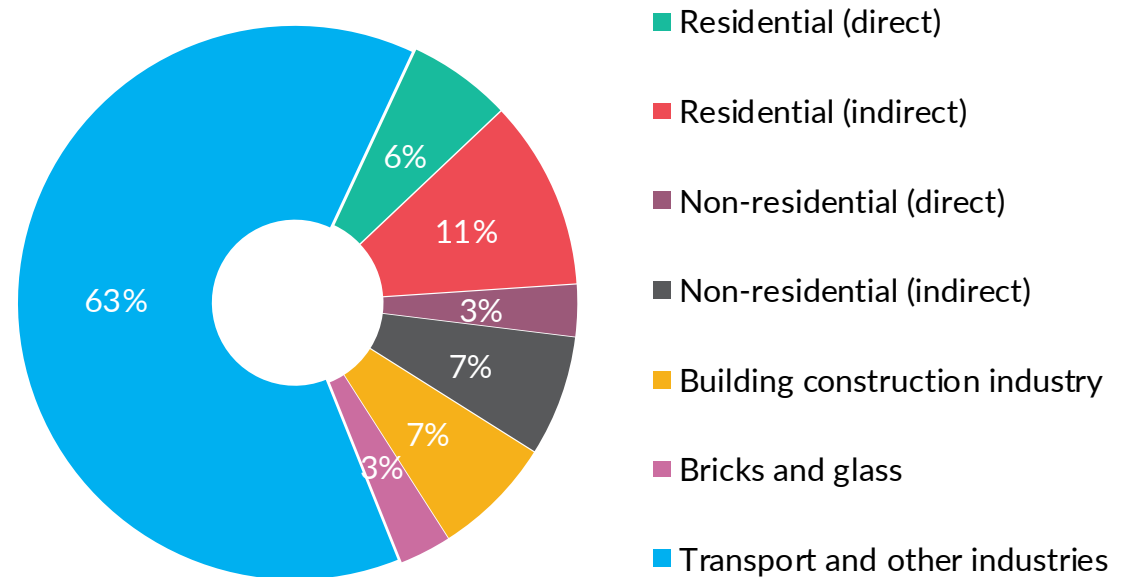
Source: World Green Building Council, 2019

EMBODIED CARBON

Its relevance and importance

- At least one-quarter of global emissions from buildings result from embodied carbon, i.e., carbon emissions associated with building materials and construction
- As global construction continues to rise, and existing building operations become more efficient, embodied carbon will become an increasingly significant issue – accounting for approximately 50% of global building sector emissions between now and 2050
- This will account for a significant amount of the remaining carbon budget, and it needs to be urgently addressed by policymakers and practitioners

Share of building in global energy and process emissions
Emissions by sector, 2022



Source: Jungclaus, M. et al., 2021

Source: United Nations Environment Programme, 2024

EMBODIED CARBON

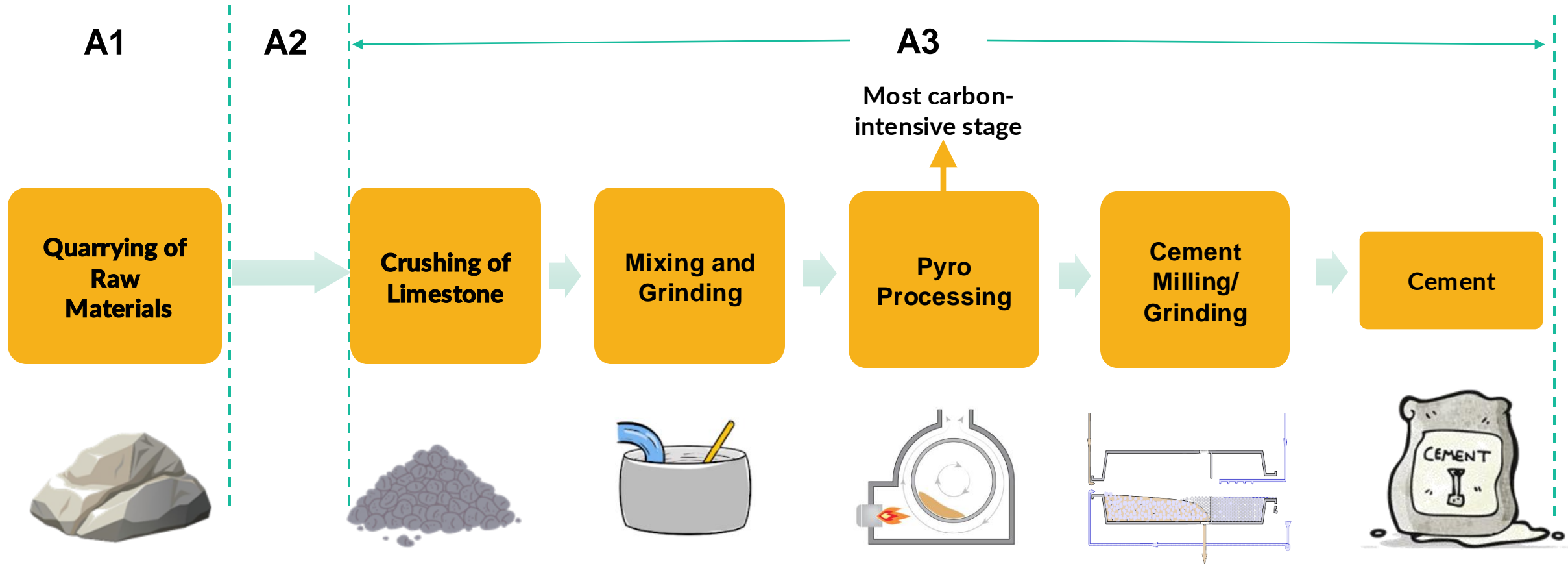
Its relevance and importance

- **Time value of carbon:** Unlike operational carbon emissions, which can be reduced over time with building energy efficiency renovations and the use of renewable energy, embodied carbon emissions are locked in place as soon as a building is built. It is therefore critical to reduce embodied carbon emissions as quickly as possible
- **Lowering embodied carbon can drive value:**
 - Reducing cost by reducing the construction materials needed in a project
 - Carbon-reduction strategies in the production of high-emitting materials like concrete can also reduce cost
 - Unless their process is driven by carbon-intensive chemical reactions, low embodied-carbon products will, by nature, result in energy savings upstream of a material's end use, resulting in cost savings for material manufacturers
 - Projects that reduce embodied carbon and/or include a whole-building life cycle assessment can help to meet green building certification requirements
 - Low-embodied-carbon building design will be better prepared for future code or policy changes that incentivize or require low embodied carbon
 - Reducing emissions in the extraction, manufacturing and transportation of low-embodied carbon materials improves air quality and public health in communities located close to industrial centers

Source: Jungclaus, M. et al., 2021

CEMENT MANUFACTURING

Manufacturing process outline



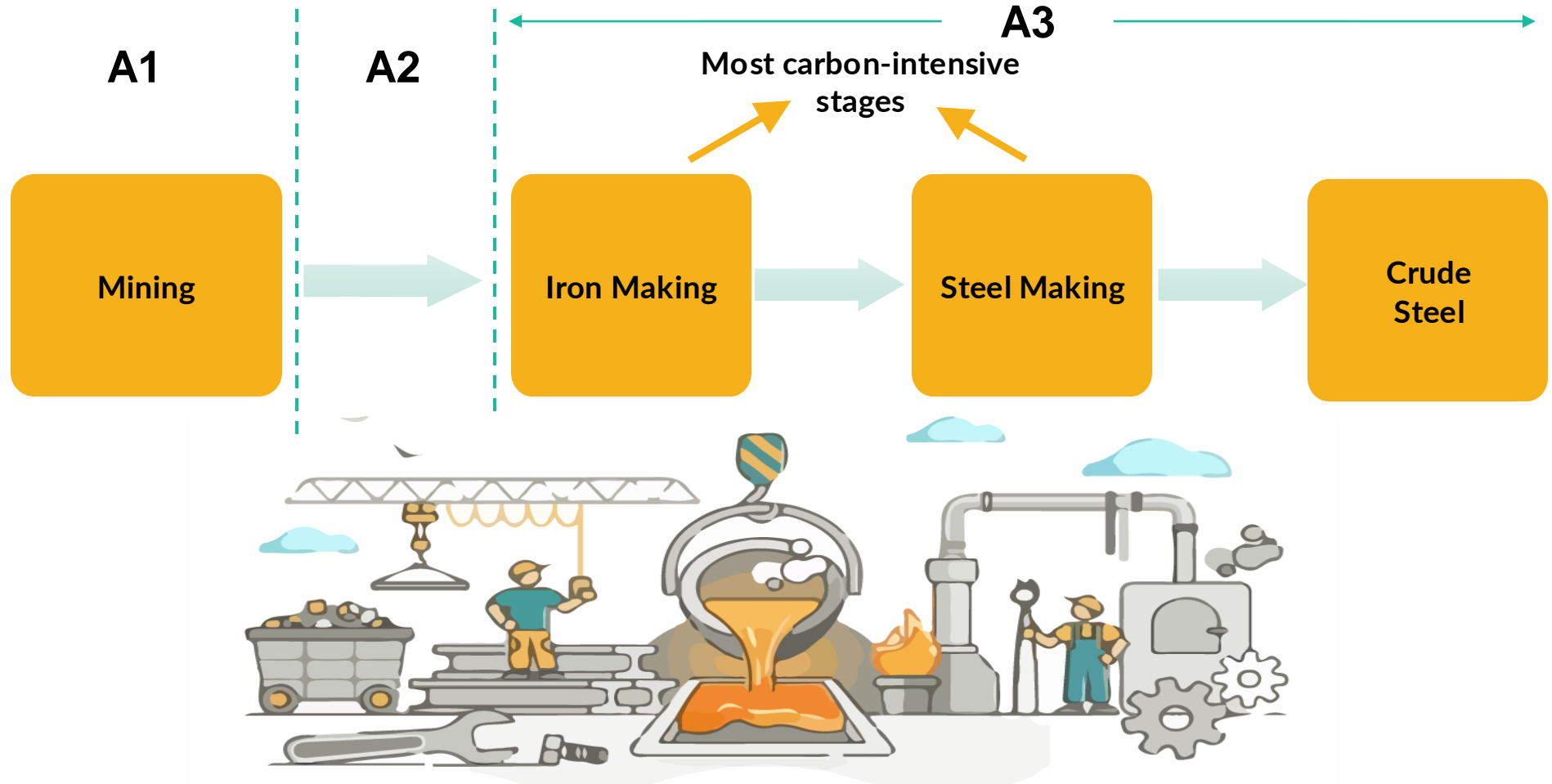
CEMENT MANUFACTURING

Options for reducing carbon footprint

- Use of alternative raw materials like fly ash, slag and other supplementary cementitious materials (SCMs)
- Use of alternative energy sources for reducing carbon footprint
 - Using waste materials like tyres, fabrics, paper, municipal solid waste, hazardous waste, etc. as supplementary fuels in kilns for pyro processing
 - Using sustainable fuels like biomass for partial substitution of fossil fuels in kilns
 - Increasing pre-calciner stages to reduce exhaust gas temperature
 - Generating electrical power from process waste heat
 - Using renewable energy sources (biomass / solar) for electricity power
 - Using green hydrogen as fuel in the pyro-processing / clinker-making process
 - Exploring possibility for electrification of kilns (technology is at a nascent stage)
- Carbon emissions management through carbon capture, utilization and storage (CCUS) and carbon offsets

STEEL MANUFACTURING

Manufacturing process outline



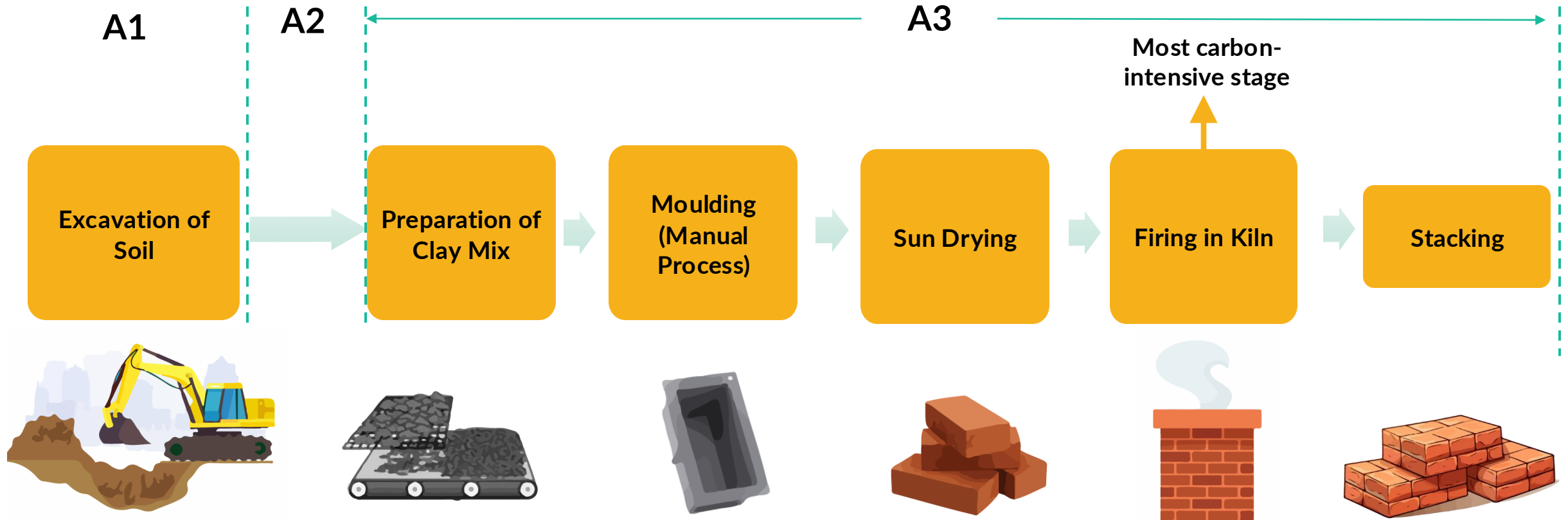
STEEL MANUFACTURING

Options for reducing carbon footprint

- **Energy efficiency measures**
 - Optimization of raw material consumption
 - Improvement in process and energy efficiencies
 - Augmenting waste heat recovery
 - Minimizing re-heating of intermediate products
- **Use of renewable energy for electricity power**
- **Alternative fuels for combustion and as reducing agents**
 - Explore possibilities for shifting from coal-based process to natural gas, biomass and green hydrogen; however, these options may be practically difficult to implement in existing plants
- **Carbon emissions management through carbon capture, utilization and storage (CCUS) and carbon offsets**

FIRED CLAY BRICK MANUFACTURING

Manufacturing process outline



FIRED CLAY BRICK MANUFACTURING

Options for reducing carbon footprint

- **Energy efficiency measures**
 - Efficient combustion of fuels
 - Manage and monitor use of raw materials and fuel as well as emissions
- **Alternative fuels for combustion**
 - Explore possibility of fuel substitution from coal to natural gas, biomass, etc.
- **Use of renewable energy for electrical power**
- **Changing the fired walling product**
 - Manufacturing alternative fired walling blocks like hollow or perforated bricks etc., which requires less raw material and fuel. This will entail changes in the production process

Embodied Carbon in Buildings

Key Driving Materials



Image source: <https://www.bricknbolt.com/blogs-and-articles/construction-guide/building-material-density-importance->

KEY DRIVING MATERIALS

Cement and steel

- A building's structure and substructure typically constitute the largest source of its upfront embodied carbon (up to 80%, depending on building type). However, because of the relatively rapid renovation of building interiors associated with tenancy and turnover, the total embodied carbon from interiors can account for a similar order of emissions over the lifetime of a building¹
- **Globally, cement and steel are two of the most significant sources of material-related emissions in construction.** Cement manufacture is responsible for 7% of global carbon emissions, with steel contributing 7%–9% of the global total (with half attributed to buildings)²
- Both cement and steel are used in buildings in large quantities. These materials are carbon intensive as the manufacturing processes demand very high temperatures, achieved by firing of fossil fuels; carbon dioxide emissions occur due to combustion of fuels and also as part of chemical reactions during the manufacturing process²
- **Cement / concrete and steel are the highest contributors in typical construction in India.** One study of residential buildings shows concrete and steel together account for 75%–94% of product stage carbon³

¹ Source: Jungclaus, M. et al., 2021

² Source: World Green Building Council, 2020

³ Source: Chetia, S. et al., 2024

KEY DRIVING MATERIALS

Other building materials

- **Walling materials are significant contributors to carbon emissions**, as large number of buildings are RCC-framed structures with masonry infill. Some of the walling materials like fired clay bricks and concrete blocks are carbon intensive
- **Glass and aluminum, which have manufacturing processes at high temperatures, are carbon intensive, although their impact on buildings is smaller in comparison with cement and steel**
- Depending on the type of buildings and the prevalent construction technology used in a region or country, the major materials driving embodied carbon may differ

Embodied Carbon in Buildings

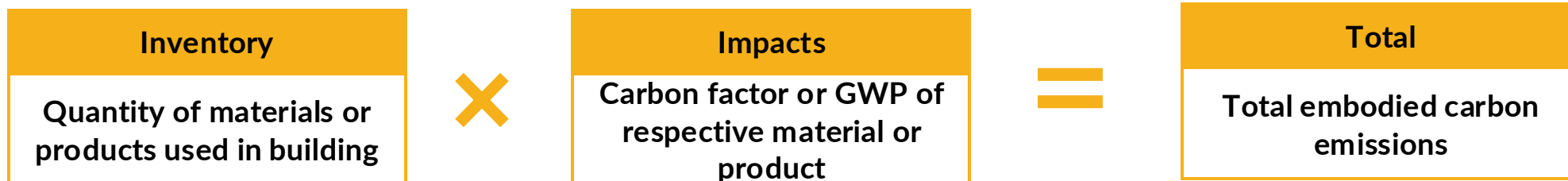
Calculation Methodology



EMBODIED CARBON

Calculation Methodology

- Embodied carbon in buildings is commonly measured in **kgCO₂e/m²** (kilograms of carbon dioxide equivalent per square meter of building). This allows comparison of embodied carbon in different buildings
- The calculation is:



- The product stage (A1–A3) emissions relating to the raw material extraction, shipping to factory and manufacturing is what is most commonly available in embodied carbon databases
- The calculation above, using figures from the carbon database, gives the carbon emissions of materials only for A1–A3 stages of the building life cycle

Source: Hrivnak, 2023

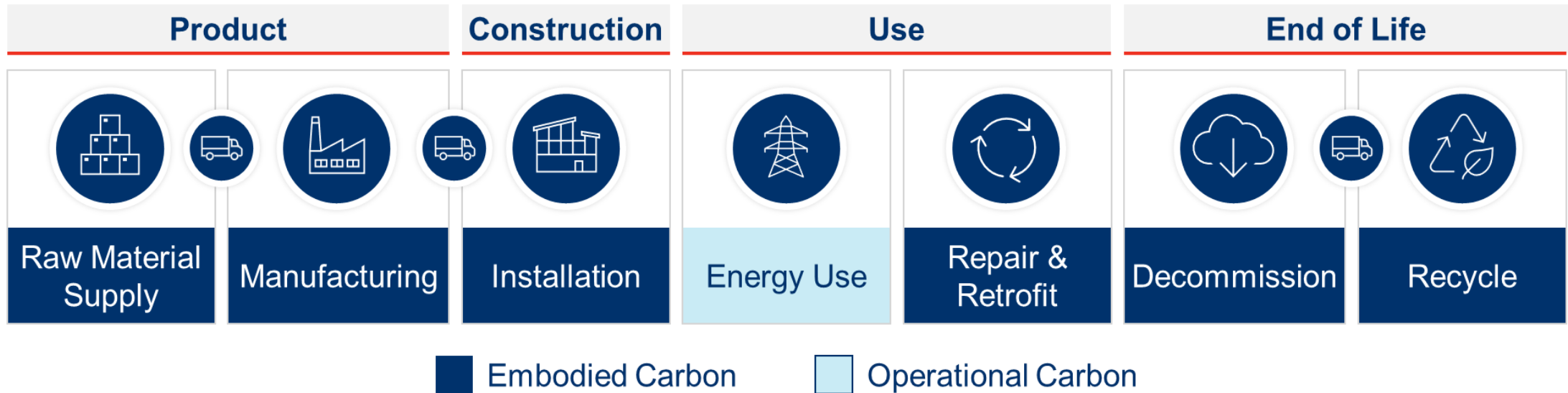
GLOBAL WARMING POTENTIAL (GWP)

Major building materials

Material / Product	Unit	GWP (kgCO ₂ /unit) (A1-A3 stages)	Geography	Source
Ordinary Portland Cement (OPC)	kg	0.842	India	Centre for Science and Environment, 2023
Portland Pozzolana Cement (PPC)	kg	0.582	India	
Portland Slag Cement (PSC)	kg	0.381	India	
Concrete	m ³	~450 to ~240 (varies as per mix used)	Global	Witte and Garg, 2024
Steel	kg	2.3–2.5	India	Various, including Ministry of Steel, 2020; CEEW, 2023; Centre for Science and Environment, 2023
Solid Burnt Clay Brick	m ³	198.87	India	Maithel, 2023
Solid Concrete Block	m ³	~200	India	India Construction Materials Database of Embodied Energy and Global Warming Potential, 2017
Aluminium	kg	26	India	India Construction Materials Database of Embodied Energy and Global Warming Potential, 2017
Glass (6mm thick)	m ²	~19	India	

LIFE CYCLE ASSESSMENT (LCA)

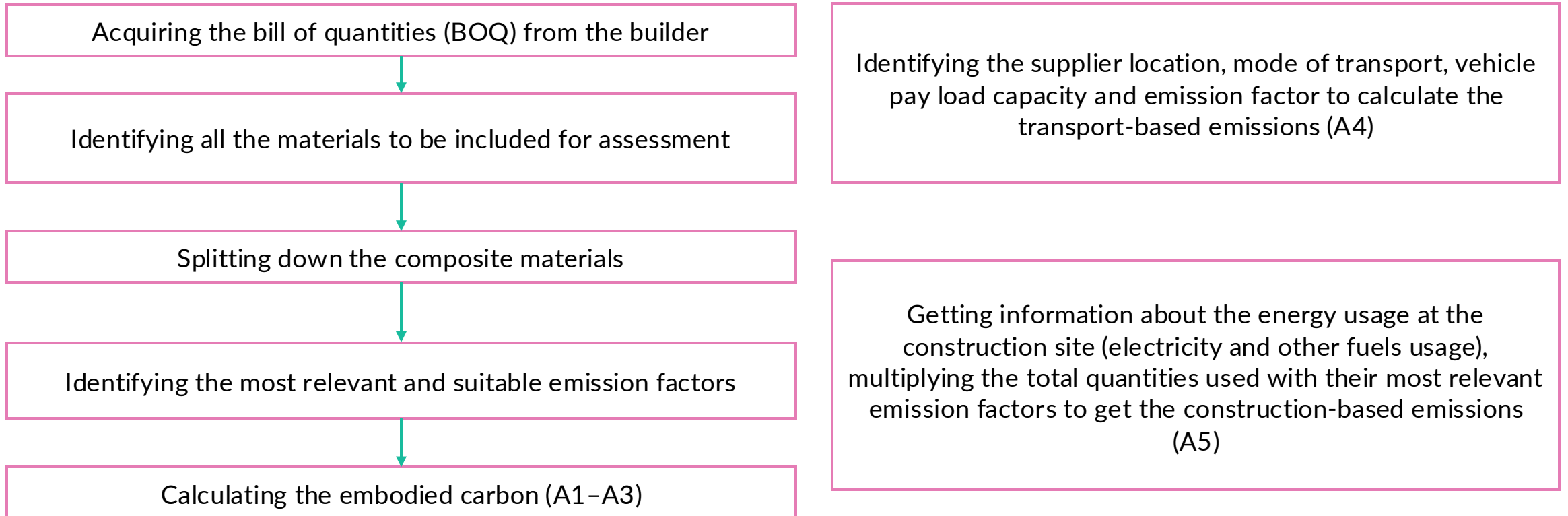
- Elements of an LCA: Goal and scope definition, inventory analysis, impact assessment, interpretation
- For all the segments reflected below, carbon emissions are quantified for the product level, transportation level, construction phase, use phase and end of life



Source: London Energy Transformation Initiative, 2020

EMBODIED CARBON

Quantifying upfront carbon



CALCULATING EMBODIED CARBON

Challenges in calculating embodied carbon from different life cycle stages

- **Product stage (A1–A3)** has been shown to have the highest contribution to the total embodied carbon of buildings. Hence, calculating product stage embodied carbon already shows the embodied carbon hotspots and direction for reduction
- **Emissions for transport to site (A4) and the construction process (A5)** need to be added to fully evaluate a project's upfront carbon. The easiest way to do this is to use industry-accepted proxies at the national level (if available) or global level
- **Use phase stages (B1–B5) emissions** are difficult to estimate as not all have methodologies for accurate estimation
- **End of life stages (C1–C4) emissions** depend heavily on how materials are handled during and after the building demolition. This data is not readily available

Percentage share of product stage carbon to total embodied carbon for buildings in UK

Building type	Percentage share of product stage carbon
Small-scale housing	80%
Medium and large-scale housing	64%
Commercial offices	48%
Schools	65%

Source: London Energy Transformation Initiative, 2020

EMBODIED CARBON

Calculations



Material quantities: Data for material quantities used in a building are usually available with the project proponent in the form of a bill of quantities (BoQ).

Building information modeling (BIM) design tools can provide material quantity estimates in the design phase

Carbon factor / GWP of building materials:

Sources in order of preference:

- Manufacturer's specifications or product-specific environmental product declaration (EPD)
- Generic government, market-based or industry databases or life cycle inventories (LCIs)
- Other databases like the Inventory of Carbon and Energy (ICE) database

CALCULATING TOOLS

For life cycle assessment (LCA) and embodied carbon

Calculators

Simple online or spreadsheet-based tools designed to allow for targeted and quick decision-making:

- **Building calculators** help designers get a quick sense of the order of magnitude of embodied carbon. These are typically most helpful in early design stages before modeling has begun and are not typically appropriate for reporting embodied carbon to meet the requirements of standards or rating systems
Examples: Build Carbon Neutral, Athena EcoCalculator
- **Material-specific or assembly-specific calculators** help designers quickly evaluate design or sourcing decisions related to a single material or assembly, such as wood or façades
Examples: Kaleidoscope, Upstream Forestry, Carbon LCA Tool

Product selection/ procurement tools

These collect product data, such as EPDs, and facilitates comparison to help users select a product or supplier

Example: Embodied Carbon in Construction Calculator (EC3)

Source: Lewis, M. et al., 2023

CALCULATING TOOLS

For life cycle assessment (LCA) and embodied carbon (continued)

Design integrated LCA tools

These may be integrated into software that architects already use, or they may be freestanding tools:

- **Whole building LCA tools** allow users to easily model the whole building at a fair level of detail (in terms of material types and material quantities) and perform the calculations to produce the LCA results **Examples: Tally (a plug-in for Revit), One Click LCA, Athena Impact Estimator**
- **Assembly-specific design tools** have been developed to track and manage embodied carbon for a specific physical scope, such as structure or façade **Examples: Beacon, Building and Habitats object Model (BHoM)**

Professional LCA software

These are primarily used by LCA experts and consultants for all types of products, not just those related to the building industry. These tools are commonly used to perform the LCA that an EPD is based upon, and are used to create the background datasets used in most whole building LCA tools

Examples: SimaPro, OpenLCA, GaBi

Source: Lewis, M. et al., 2023

TOOL SELECTION CRITERIA

For life cycle assessment (LCA)

- **Background data: Life cycle inventories (LCIs)** are datasets that report emissions for different processes that contribute to the creation of a material or product. Different tools may use different LCIs, so it is important to know which datasets each tool uses, since the results can differ. LCI databases are created and managed by governmental, non-governmental and private organizations
- **Geographic location:** LCIs can have different geographic scopes. Ideally, the dataset in the tool should match the geographic location of the project
- **Life cycle scope:** Different standards and rating systems may require reporting of few or all the life cycle stages. If it is being used to report the results of a whole building LCA, the tool must include life cycle stages (product, construction, use and optionally end of life)
- **BIM integration:** BIM-integrated LCA tools are plug-in tools embedded into BIM software, such as Revit. They automate parts of the LCA process by extracting inventory data from the BIM model, increasing integration with the design process and reducing the chance of human errors from manual takeoffs

Source: Lewis, M. et al., 2023

Reducing Embodied Carbon in Buildings

Principles and strategies

Concrete



Optimize
concrete mix

14%–33% reduction
None to low cost premium

Rebar



Use high recycled
content rebar

4%–10% reduction
None to low cost premium

Insulation



Select low- or
no-embodied-carbon
insulation products

16% reduction
No cost premium

Glazing



Select low-
embodied-carbon
glazing products

3% reduction
10% cost premium

Finish Materials



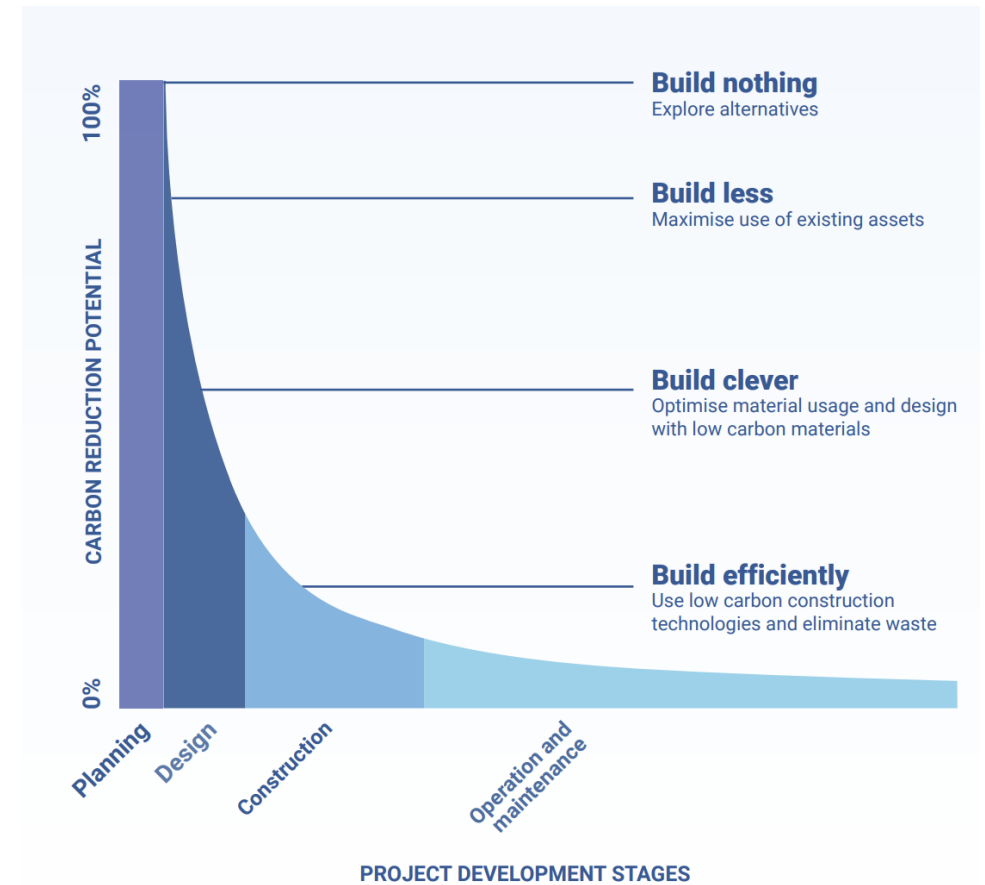
Select low- or
no-embodied-carb
on finish materials

5% reduction
None to low cost premium

REDUCING EMBODIED CARBON

Factors involved

- Embodied carbon emissions are affected by many factors:
 - Type and volume of structure installed
 - Materials used
 - Carbon intensity of manufacturing the materials
 - Modes and distances by which materials are transported
 - Processes by which these materials are constructed, maintained, and removed and treated at the end of life
- Opportunities for reducing or eliminating embodied carbon vary and will differ between types of projects and regions
- Greatest savings can usually be realized at the early stages of a project



Source: World Green Building Council, 2019

REDUCING EMBODIED CARBON

Principles

1. PREVENT

- Question the need to build new or use materials at all
- Encourage reuse, renovation and retrofitting part or whole of an existing building, rather than demolishing to build anew
- Reduce new floor area
- Reduce below-grade construction

2. REDUCE AND OPTIMIZE

- Apply design approaches that minimize the quantity of new material required to deliver the desired function, e.g., designing efficient structural system, minimize finishes where not required for functional performance, etc.
- Prioritize materials that are low or zero carbon (including MEP systems with low carbon refrigerants), responsibly sourced, and have low life cycle impact in other areas, such as:
 - Operational energy use
 - Health of occupant
- Choose low or zero carbon construction techniques having maximum efficiency and minimum waste on site

Sources: World Green Building Council, 2019; Lewis, M. et al., 2021

REDUCING EMBODIED CARBON

Principles (continued)

3. PLAN FOR THE FUTURE

- Consider future use scenarios and end of life, maximizing the potential for maintenance, repair and renovation, and ensure flexibility for future adaptation
- Design for disassembly and deconstruction to facilitate future reuse, selecting materials that can be recycled, and can be extracted and separated easily for processing

4. OFFSET

- As a last resort, offset residual embodied carbon emissions, either within the project or organizational boundary, or through verified offset schemes

Sources: World Green Building Council, 2019; Lewis, M. et al., 2021

REDUCING EMBODIED CARBON

Specifications and procurement strategies

- **Integrate EPDs and GWP limits into project specifications:** An environmental product declaration (EPD) is a document that transparently reports the environmental impact of a product or material, based on a product LCA. Embodied carbon limits can be integrated into the performance requirements for a product, requiring an EPD to document compliance with an embodied carbon limit
- **Optimize concrete specification and mix design:**
 - Using performance-based specifications (rather than prescriptive requirements)
 - Minimizing the volume of Portland cement by other supplementary cementitious materials (SCMs), allowing for longer cure times (specifying strength at 56 days instead of 28 days to allow more time for strength gain), etc.
- **Source sustainable wood:**
 - Using reclaimed/salvaged wood
 - Asking for chain-of-custody certificates or other supply chain transparency information
 - Asking for sustainable forest management certifications (e.g., FSC or SFI)
 - Specifying wood that is locally harvested and harvested from working (not primary) forests

Sources: Lewis, M. et al., 2021; Zacharia, M., 2024

REDUCING EMBODIED CARBON

Specifications and procurement strategies (continued)

- **Specify lower-carbon alternatives:**
 - For example, hollow clay bricks, autoclaved aerated concrete (AAC) blocks and cement stabilized earth blocks (CSEB) are low carbon alternatives to fired clay bricks
 - Two materials with the same performance may differ in their carbon footprints due to differing energy source, product design and/or lower-carbon ingredient sourcing
 - Due to the way products are specified and selected, EPDs are typically the best (or only) way for a project team to identify products made with the above strategies
- **Evaluate cost and carbon in the bid process:** Evaluate carbon, in addition to cost and other criteria, as award criteria in the bid process for both private and public projects

Source: Lewis, M. et al., 2021

REDUCING EMBODIED CARBON

Examples of possible routes for low carbon cement in India

Eliminate use of OPC

- Product stage carbon of OPC= 0.842 kg CO₂e/kg
- Product stage carbon of PPC (with 31% fly ash)= 0.582 kg CO₂e/kg

Increase percentage of fly ash and slag in PPC and PSC

- India: Maximum 35% fly ash allowed in PPC
- India: Maximum 70% slag allowed in PSC (average 57% current share)
- Brazil: Maximum 50% fly ash and 75% BF slag allowed
- Canada: 50%–60% fly ash allowed
- Europe: 36%–55% fly ash allowed

Use of calcined clay or other materials to replace clinker

- Limestone calcined clay cement (LC3) can reduce CO₂ emissions by up to 40%

Source: Centre for Science and Environment, 2023

REDUCING EMBODIED CARBON

Design with whole life carbon in mind

- While minimizing embodied carbon is vitally important, it must not create adverse or negative outcomes for both operational carbon and whole life carbon. A low embodied carbon building that performs poorly in operation has adverse financial, environmental and social implications
- Action to tackle upfront carbon must be done while designing with whole life carbon in mind. This holistic approach enables a concerted focus on transformational pathways for both net zero embodied carbon and net zero operational carbon

Source: World Green Building Council, 2019

Embodied Carbon in Buildings

Regulations



Image source: <https://www.storaenso.com/en/newsroom/news/2022/1/good-for-wood-new-embodied-carbon->

EMBODIED CARBON

Certifications and regulations

Significant improvements have been made in the area of operational carbon since the fuel crisis of the 1970s. Efforts to tackle embodied carbon emissions at a global scale needs to be increased, while continuing to address operational carbon.

One Click LCA in their report, *The Embodied Carbon Review (2018, updated 2021)* studied 156 certification and national regulation systems worldwide that address embodied carbon:

- These embodied carbon reduction systems were largely in the form of voluntary certifications (69%), with regulations (14%), standards like ISO and EN (12%) and guidelines (4%) being the remaining
- 105 included direct measures for embodied carbon, and almost all address it through practices like recycled material use, waste reduction and material efficiency measures
- The highest rates of adoption are in some European regions, and the lowest adoption rates are in Middle East, South America and Asia

Source: One Click LCA, 2018

EMBODIED CARBON REGULATIONS

Typical regulations

- **Carbon reporting:** Calculate the construction project's embodied carbon and report it
- **Carbon comparison:** Compare design options for carbon; e.g., design baseline and proposed designs and show improvements against a self-declared baseline value
- **Carbon rating:** Evaluate carbon performance based on variable scale from best to worst on which a project's carbon is rated, but no effective maximum value applied
- **Carbon cap:** Calculate the project's embodied carbon and prove it is not exceeding the CO₂e limit
- **Decarbonization:** Reduce carbon to a minimum, then compensate all residual emissions by own energy export or buying offsets

Source: One Click LCA, 2018

EMBODIED CARBON REGULATIONS

Incentives for applying carbon reduction policies



Most common form of incentive is better rating in rating systems or building certifications



Embodied carbon reduction policies being a funding condition for building



Provision of density bonus, similar to additional floor area ratio (FAR) provided for green certified buildings in India



Cash impact in the form of funded carbon offsetting or carbon performance payment



Being a mandatory criterion for building

Source: One Click LCA, 2018

EMBODIED CARBON

Benchmarks

- A benchmark establishes a reference point to evaluate the relative performance of a building. For example, Energy Use Intensity (EUI) or Energy Performance Index (EPI) benchmarks are used for operational energy
- Benchmarking for building-level embodied carbon and whole life carbon are not yet widely available. Most available benchmarking studies and standards are for European countries. The quality, representativeness, life cycle scope and included building components also vary greatly

EMBODIED CARBON

Benchmarks

Source	Geographic region	Reference study period	System boundary		Embodied carbon benchmarking values (kgCO ₂ e/m ²)				
			Life cycle scope	Physical scope	Building type				
					Residential	Office	School	Industrial	Mixed
CLF	North America	Assumptions unknown	A only	Foundation Structure Enclosure Interiors	200–660	270–540	230–460	–	200–640
LETI	UK	Assumptions unknown	A1–A5	Substructure Superstructure Façade Internal finishes MEP	800	1,000	1,000	–	–
RIBA	UK	Assumptions unknown	A1–A5 B1–B5 C1–C4	Substructure Superstructure Finishes / fixed FF&E Building services (and associated refrigerant leakage)	1,200	1,400	1,400	–	–

Source: Lewis, M. et al., 2023

EMBODIED CARBON

Benchmarks (continued)

Source	Geographic region	Reference study period	System boundary		Embodied carbon benchmarking values (kgCO ₂ e/m ²)				
			Life cycle scope	Physical scope	Building type				
					Residential	Office	School	Industrial	Mixed
One Click LCA	Europe	Assumptions unknown	A1–A3, A4 B4–B5 C1 – C4	<i>Varies</i>	–	520–680	380–490	500–560	–
Zimmerman et al.	Denmark	60 years	A1–A3, B4, B6 C3–C4	<i>Substructure Superstructure Façade Building services Vertical circulation</i>	315–425		–	–	–

Source: Lewis, M. et al., 2023

NET ZERO

Actions for embodied carbon

Government	Investors	Developers	Designers	Manufacturers	NGOs, networks and researchers
<ul style="list-style-type: none"> • Deliver education and training • Provide financial incentives • Create national roadmaps • Set low carbon public procurement policy • Set benchmarks, targets and require disclosure 	<ul style="list-style-type: none"> • Require a holistic whole life cycle approach • Provide sustainable financial products to incentivize low or zero carbon products or projects • Investor groups to agree and set embodied carbon benchmarks and targets • Collaborate with stock exchanges 	<ul style="list-style-type: none"> • Use LCA and whole life cycle approach • Optimize structural design • Prioritize low carbon materials and require disclosure • Seek innovative solutions • Use financial incentives or contractual obligations 	<ul style="list-style-type: none"> • Educate clients • Specify low carbon materials • Use LCA and whole life cycle approach • Optimize structural design • Seek innovative solutions 	<ul style="list-style-type: none"> • Develop product-specific EPDs • Implement recycling and circularity principles • Maximize process energy efficiency • Implement renewable energy sources • Work with industry to standardize EPDs • Develop innovative low or zero carbon construction materials and products 	<ul style="list-style-type: none"> • Contribute to collection of embodied carbon data • Promote findings of key research • Work with government, public and private sector • Deliver training • Certification schemes require disclosure, EPDs, and set measurement and performance targets

Source: World Green Building Council, 2020

Embodied Carbon in Buildings

Case Examples



Microsoft's headquarters in Redmond, Washington

Image source: <https://www.archdaily.com/976015/strategies-to-reduce-embodied-carbon-in-the-built>

CASE EXAMPLE

Houston Advanced Research Center



20%

**Embodied Carbon
Reduction**
(structural and enclosure)

0%

Cost Impact
(No cost premium)

Strategies:

- Structural system optimization
- Achieved a lighter overall structural framework
- Reduced the need for extensive foundations by minimizing long-span elements
- Optimized concrete slab thickness, reducing material usage
- Utilized advanced concrete mixes with extended strength development times and incorporated alternative cement materials
- Pursued LEED Platinum certification to meet top-tier sustainability standards

Source: Huynh, T. et al., 2023

CASE EXAMPLE

Toronto Emergency Medical Services Station



30%

Embodied Carbon
Reduction

0%

Cost Impact
(No cost premium)

Strategies:

- Utilized low-impact extruded polystyrene (XPS) insulation
- Increased the percentage of supplementary cementitious materials (SCMs) in the concrete mix
- Applied an environmentally-friendly concrete slab sealant
- Incorporated steel with high recycled content
- Substituted traditional concrete masonry units (CMU) with hempcrete blocks
- Employed recycled glass gravel as insulation

Source: Huynh, T. et al., 2023

CASE EXAMPLE

Mixed use mid-rise office building



46%

Embodied Carbon
Reduction

0%

Cost Impact
Premiums due to lower carbon
glazing products and strategic
procurement of steel

Strategies:

- Used concrete mixes with reduced cement content
- Opted for mixes with extended concrete curing times
- Replaced XPS insulation with polyiso or mineral wool alternatives
- Incorporated steel with a high recycled content
- Substituted standard gypsum sheathing with alternative materials
- Used glazing products with a lower carbon footprint

Source: Huynh, T. et al., 2023

CASE EXAMPLE

SDE1 and SDE3 Blocks, NUS Kent Ridge Campus



Adaptive reuse of old building

Net zero operational carbon

- SDE1 and SDE3 are among the oldest buildings on the National University of Singapore (NUS) Kent Ridge Campus, built in the 1970s
- By adaptive reuse of the building, embodied carbon of the building is to be lower than a third of a similar new construction
- Cost of renovating the buildings is substantially lower than demolishing it and constructing a new building
- By incorporating strategies like extended west façade, hybrid cooling system, and building management system for better operation, it is targeting to achieve net zero operational carbon emissions

Source: National University of Singapore, 2023

Thank you!

For more information, visit us at <https://ALCBT.GGGI.ORG>
or scan the QR code below



IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at <https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/>.

 www.gggi.org

 [@gggi_hq](https://twitter.com/gggi_hq)

 [@GGGIHQ](https://www.instagram.com/GGGIHQ)

 [@GGGIHQ](https://www.facebook.com/GGGIHQ)

 [@gggi_hq](https://www.linkedin.com/company/gggi_hq)

 [@GGGIMedia](https://www.youtube.com/GGGIMedia)



Supported by:



on the basis of a decision
by the German Bundestag



3.3 Understanding Operational Energy in Buildings

November 2024



Supported by:



on the basis of a decision
by the German Bundestag

WHAT WILL YOU LEARN?

Operational energy and its end uses for different services

01

HVAC: Basics and commonly-used systems

02

Lighting: Basics and commonly-used systems

03

Commonly-used systems for other services

04

Operational energy indices

05

Energy star rating for buildings and key appliances

06



BUILDING OPERATIONAL ENERGY

The energy used for operating equipment in a building

Operational energy of buildings is the energy in the form of electricity and fuels for operating various equipment for providing comfortable room conditions for the occupants and operate various building equipment



HVAC equipment:
Heating, ventilation and air-conditioning equipment to maintain comfortable indoor temperature and air quality



Electric lighting:
Artificial lighting system to perform task when daylight is not sufficient or available



Hot water systems:
Electric or fuel-fired equipment providing hot water for bathing, cooking, laundry, cleaning, etc.



Appliances:
Refrigerators, deep freezers, computers, printers, projectors, television sets, etc.



Other services:
Elevators, escalators, water pumps, kitchen and pantry appliances, etc.

OPERATIONAL CARBON

Emissions associated with operational energy use

$$\text{Operational carbon (kgCO}_2\text{e)} = \text{Total Operational energy usage (kWh)} * \text{Emission factor fuel used} \left(\frac{\text{kgCO}_2}{\text{kWh}} \right)$$

- In most cases, the fuel used is grid electricity, thereby emission factor of grid electricity for the particular country is considered
- For other fuels, standard emission factors accepted globally are considered

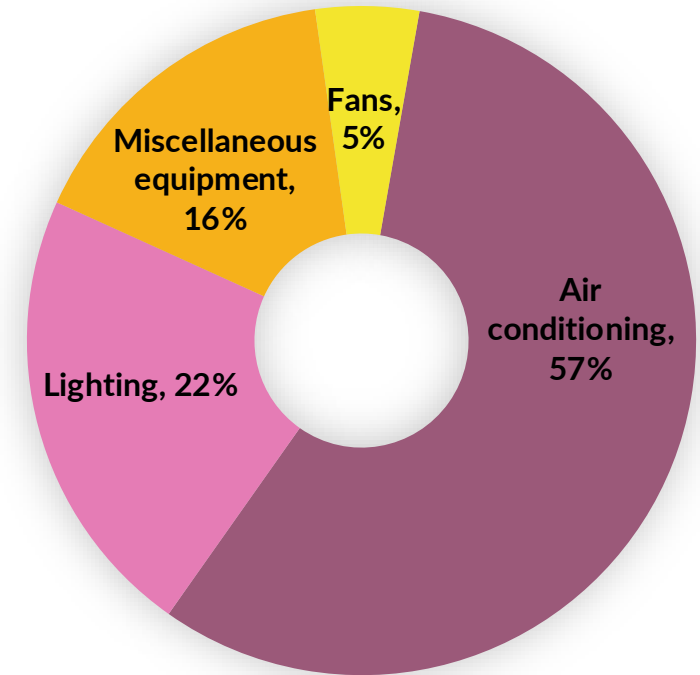
BUILDING OPERATIONAL ENERGY

End-use energy distribution in commercial buildings

Typically, in an air-conditioned commercial building, the energy consumption has four major components:

- i. HVAC system (50%–70%)
- ii. Lighting (5%–20%),
- iii. Appliances (10%–20%)
- iv. Ventilation and exhaust fans (1%–5%)

End-use energy distribution
in a typical commercial building



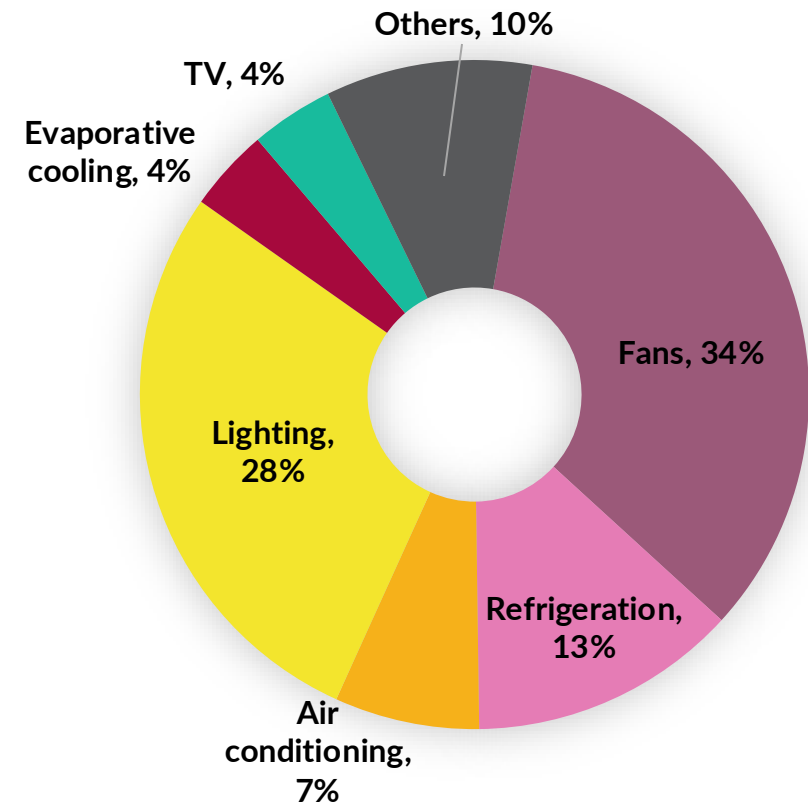
BUILDING OPERATIONAL ENERGY

End-use energy distribution in residential buildings

In India, studies of end uses in residential buildings show the following estimates:

- Energy for thermal comfort (air conditioning, evaporative coolers and fans) is about 45%
- Lighting is the second large end use accounting for about 28%
- Other appliances (including television sets, refrigerators, water heaters and various appliances) account for about 27%

End-use energy distribution in a typical residential building



Source: Bureau of Energy Efficiency, Government of India

HVAC

Basics and Commonly-used Systems

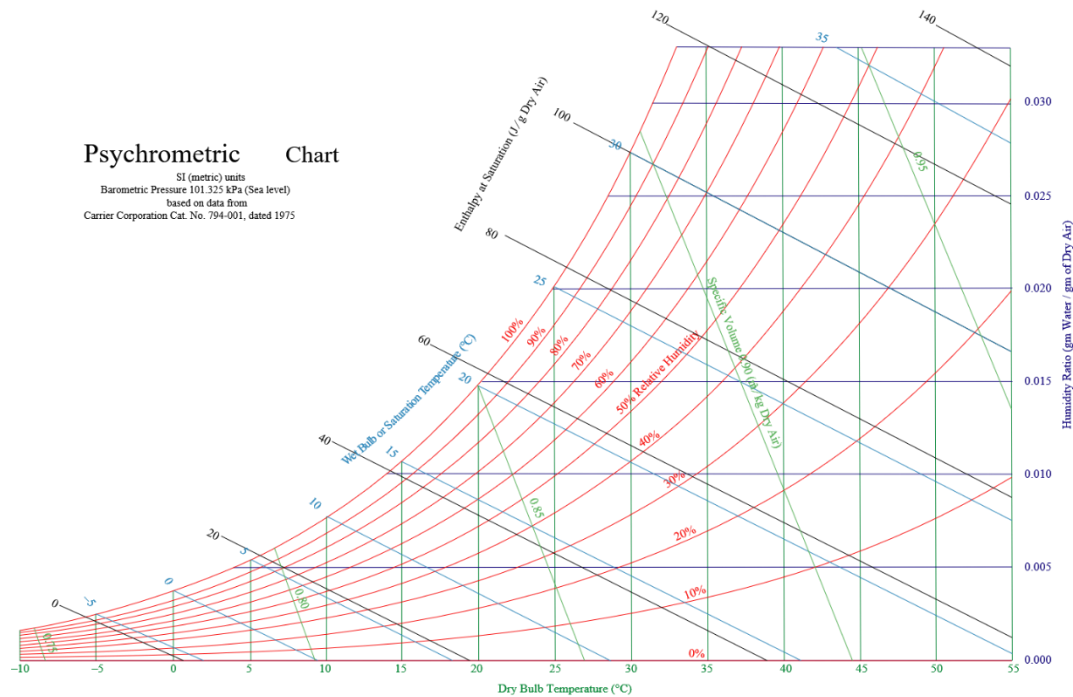


Image source: <https://envigaurd.com/topics/what-is-hvac->

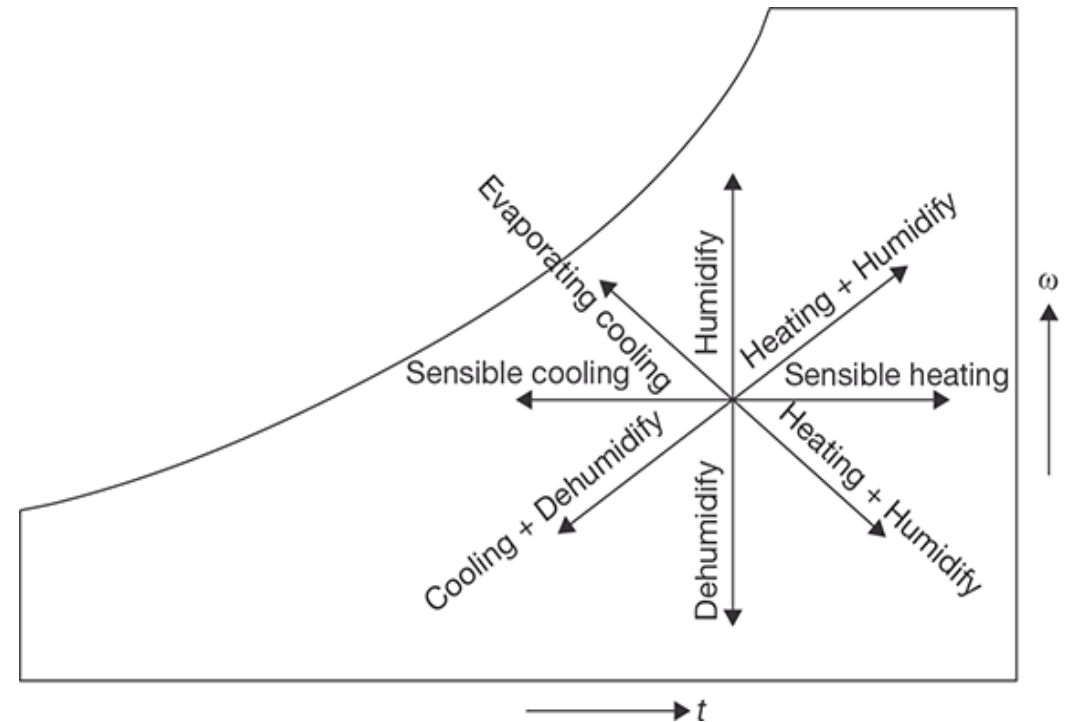
AIR PROPERTIES

Understanding condition of air on the psychrometric chart

A psychrometric chart is a family of graphs that shows the properties of air – dry bulb temperature, wet bulb temperature, relative humidity, dew point temperature, humidity ratio, total heat content (enthalpy) and specific volume at a specific barometric pressure



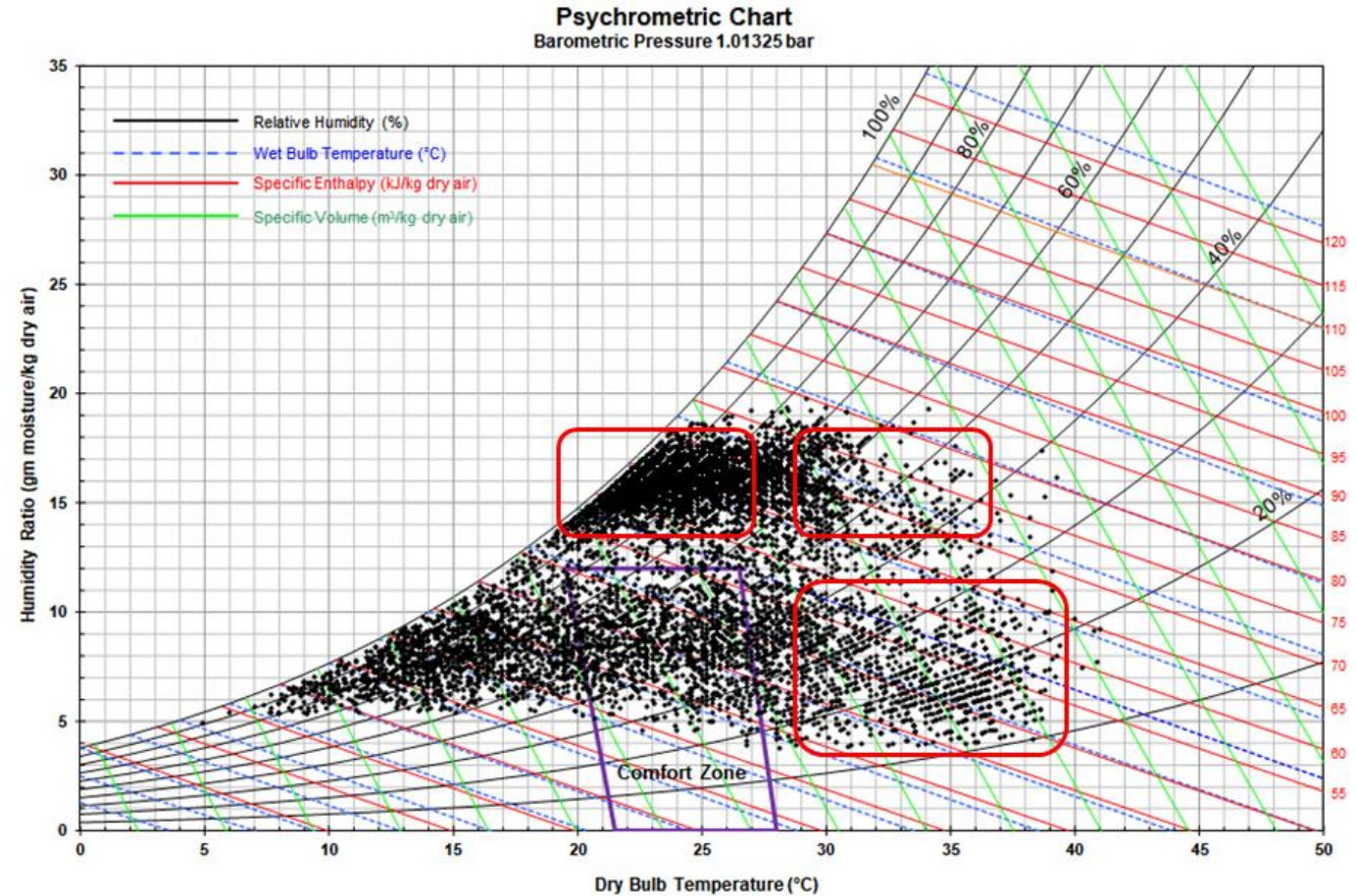
It is important to assess thermal comfort and understand the process of cooling, heating, dehumidification and humidification of air properties



THE NEED FOR HVAC

An example of Pune, India: Ambient conditions

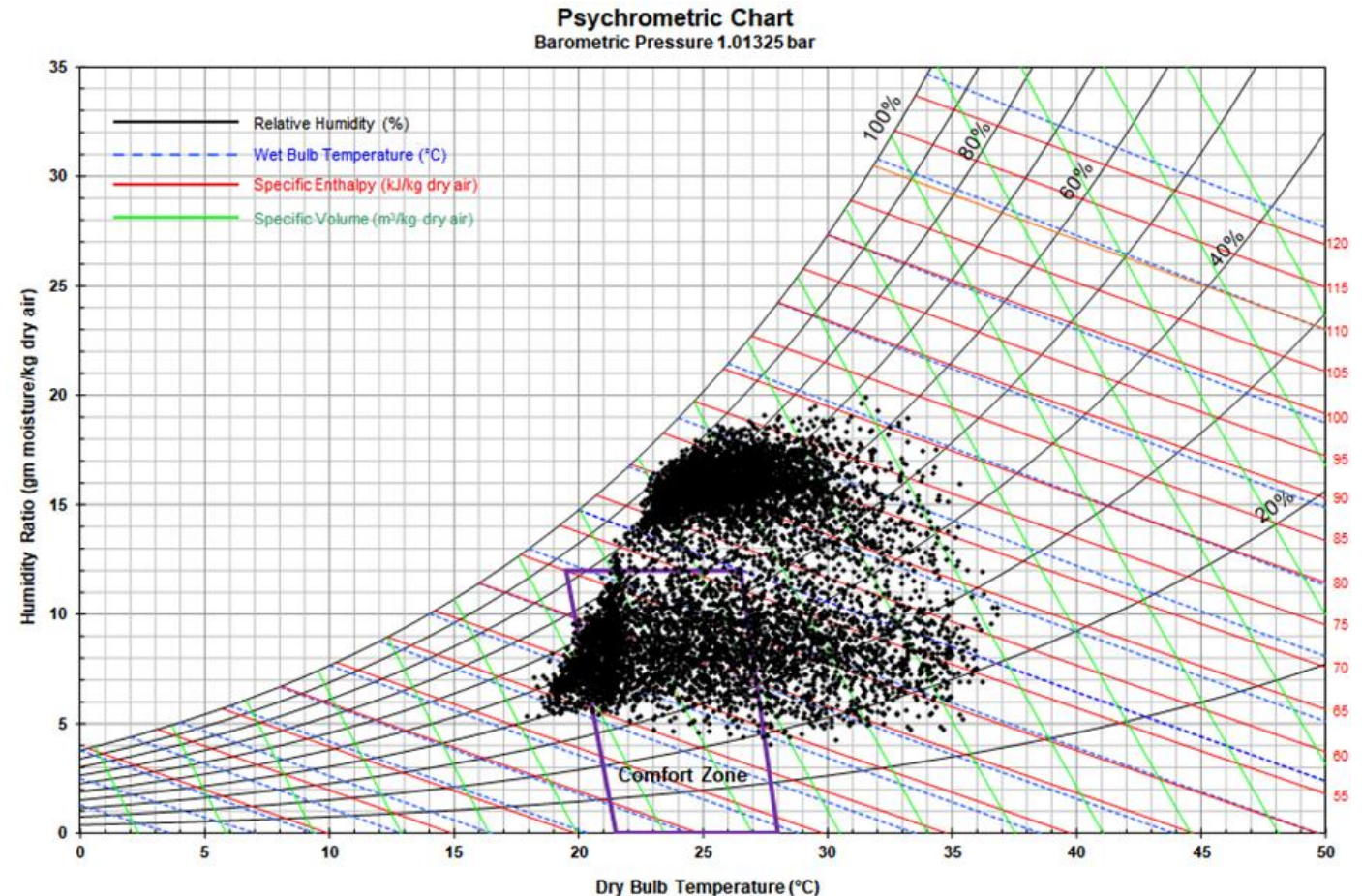
On an annual basis, the ambient conditions (indicated by black dots) are outside the human thermal comfort zone for a significant duration of the time



THE NEED FOR HVAC

Room conditions inside the building without HVAC

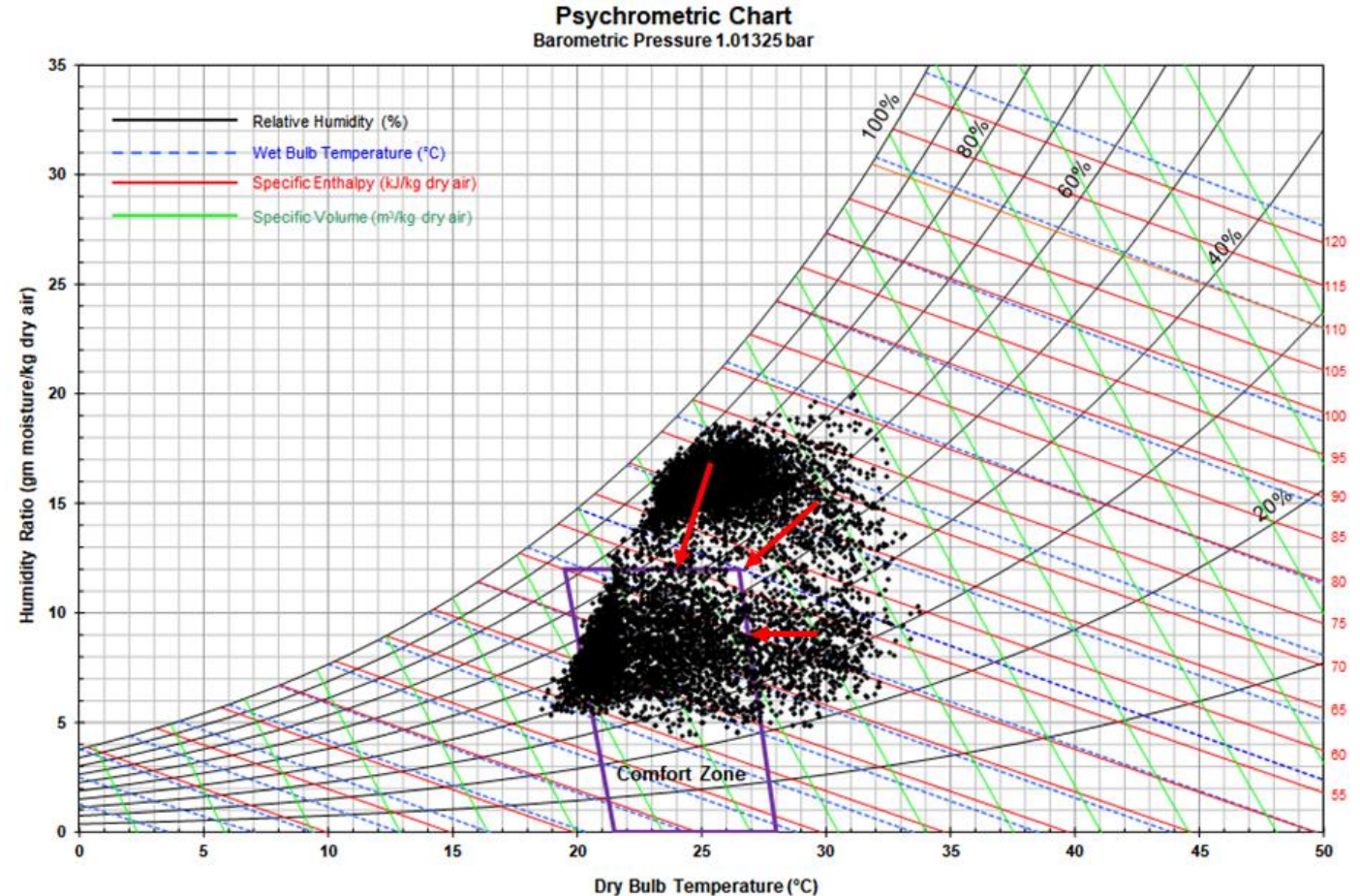
- Even with a business-as-usual building design, the conditions inside the building, compared to the ambient conditions, have less variations (observe the higher density of black dots in the comfort zone)
- However, for significant duration of time, the inside conditions fall outside the thermal comfort zone



UNDERSTANDING THE NEED FOR HVAC

Room conditions with passive architectural measures

- Passive architectural measures help in partially moving inside conditions toward the thermal comfort zone
- Still, a significant portion of time duration will remain outside the thermal comfort zone
- HVAC systems are needed to ensure that the entire time duration is within the comfort zone



AIR CONDITIONING

Objectives

- Remove sensible heat from a confined place to maintain constant temperature inside the space
- Remove water (latent heat) from a confined space to maintain constant humidity inside the space
- Remove dust generated and contaminants in a confined space by air-sweeping
- Prevent dust and atmospheric contaminations from entering into a confined space
- Prevent microbial growth and cross-contamination between spaces

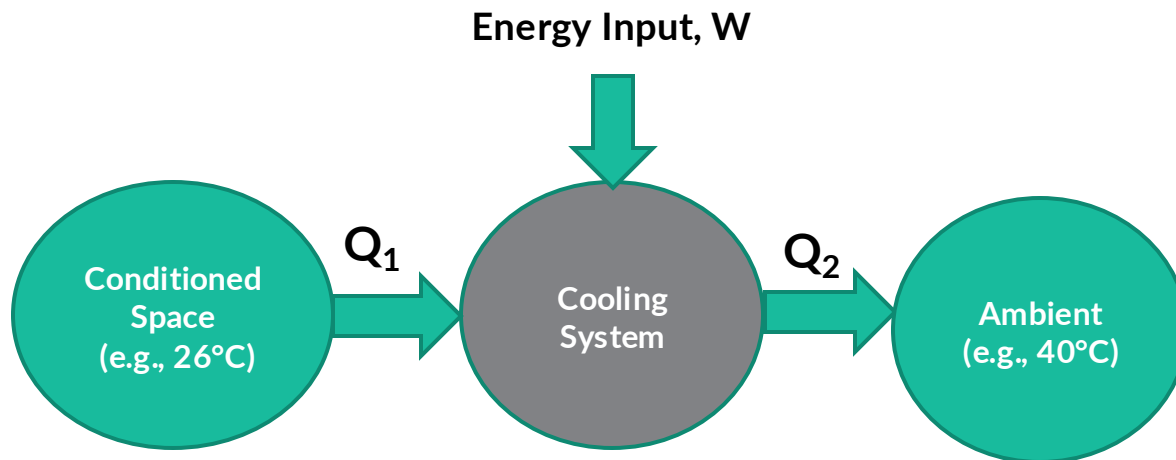


Image source: SM Solutions

TYPICAL COOLING AND HEATING SYSTEMS

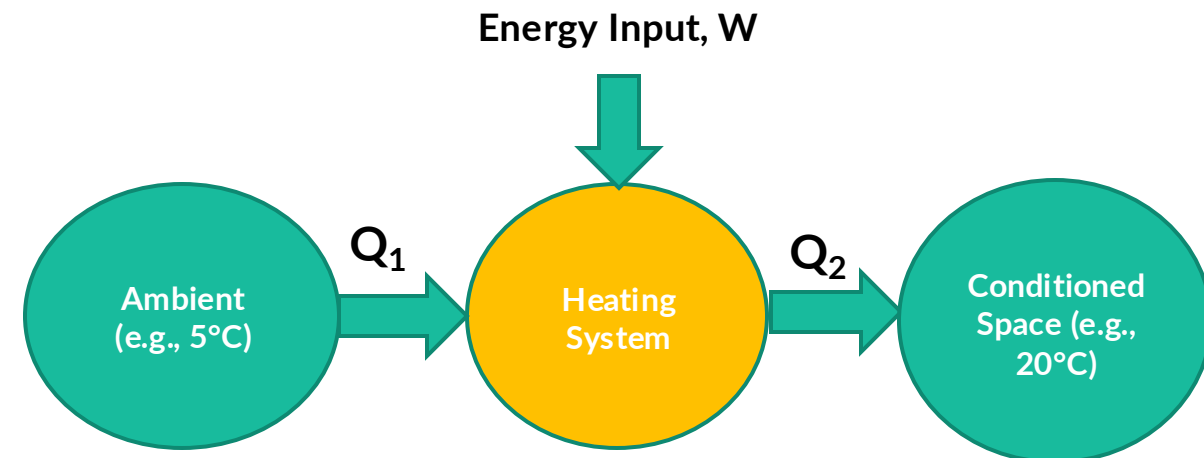
Basic heat balance and figure of merit

- Typical cooling uses some amount of energy (work) to move heat from low temperature to high temperature
- The figure of merit for assessing the efficiency is the coefficient of performance (COP)



$$\text{Energy Balance, } Q_1 + W = Q_2$$

$$\text{Coefficient of Performance (COP)} = \frac{\text{Desired effect } Q_1}{\text{Required Input } W}$$



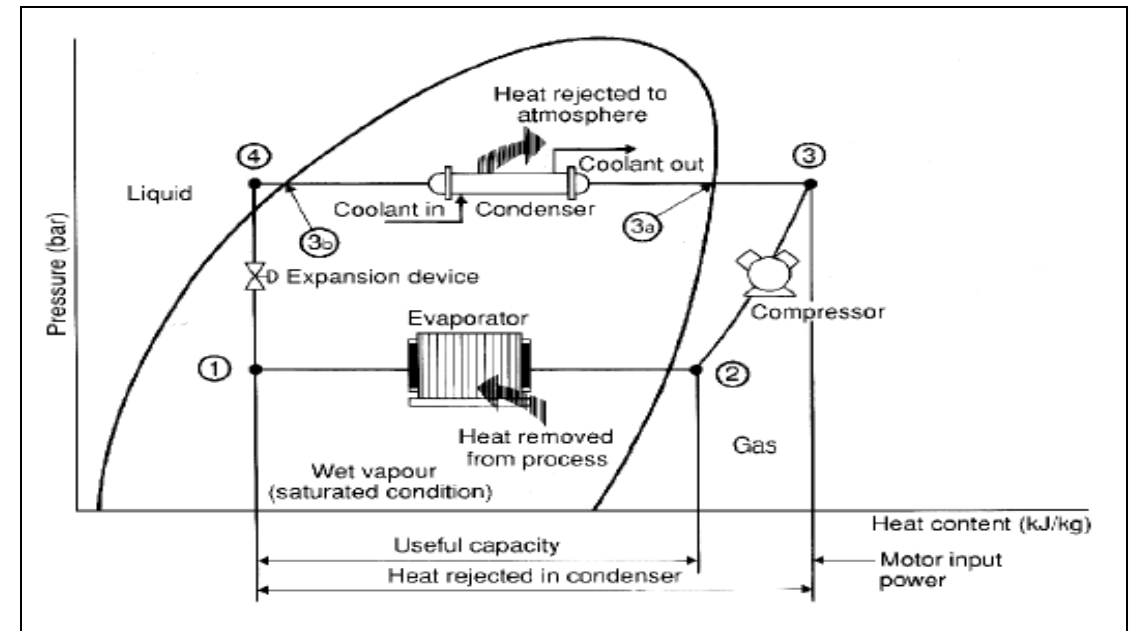
$$\text{Energy Balance, } Q_1 + W = Q_2$$

$$\text{Coefficient of Performance (COP)} = \frac{\text{Desired effect } Q_2}{\text{Required Input } W}$$

VAPOR COMPRESSION SYSTEM

Understanding the thermodynamics

- Heat naturally flows from higher to lower temperature. However, in refrigeration, heat must be transferred from a lower temperature to the ambient at a higher temperature. The second law of thermodynamics says that for transferring heat from a lower temperature to a higher temperature, work must be done
- In a vapor compression refrigeration system, this work is done by the condenser. The figure shows the vapor compression process on a pressure – enthalpy (or heat content) diagram:
 - Refrigerant evaporates in the evaporator at low temperature and pressure to chill water or air (1–2)
 - The vaporized refrigerant gas is compressed to raise its pressure and temperature above ambient temperature (2–3)
 - The heat is rejected to the atmosphere in water-cooled or air-cooled condenser, resulting in the condensation of the refrigerant gas into liquid at high pressure and low temperature (3–4)
 - The high pressure, low temperature liquid refrigerant from the condenser returns to the low pressure evaporator, resulting in evaporation of the refrigerant, providing cooling; the cycle repeats



Pressure – enthalpy (heat content) diagram

AIR-CONDITIONING (AC) SYSTEMS

Typical equipment and configurations

- Window air-conditioners
- Split ductable / non-ductable systems
- VRV ductable / non-ductable systems
- Centralized AC systems comprising of:
 - The chiller (chilled water generator)
 - Chilled water storage and pumping system
 - Air handling units (AHUs)
 - Ducting of air and its filtration



Window air conditioner



Split air conditioner



VRV AC system



Centralized AC system

SMALL COOLING SYSTEMS

Window and split air conditioners

Window air conditioner

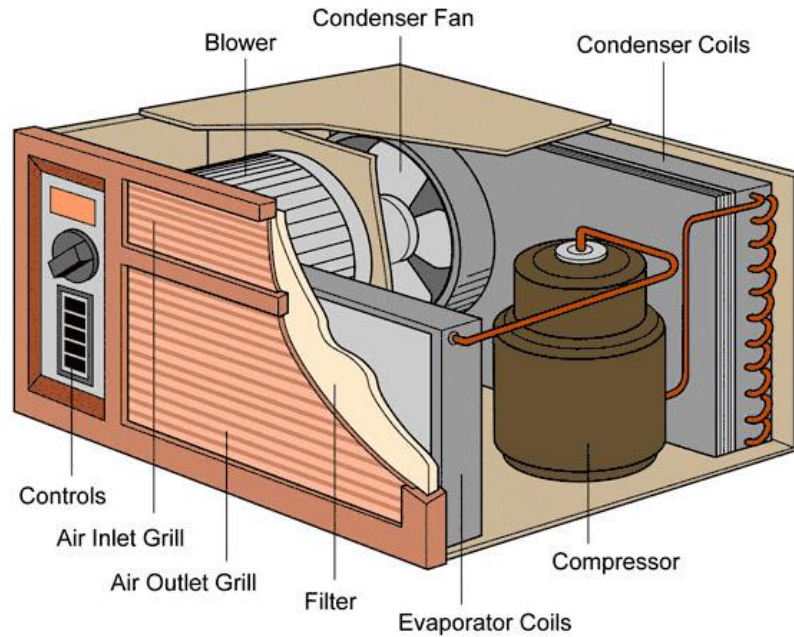
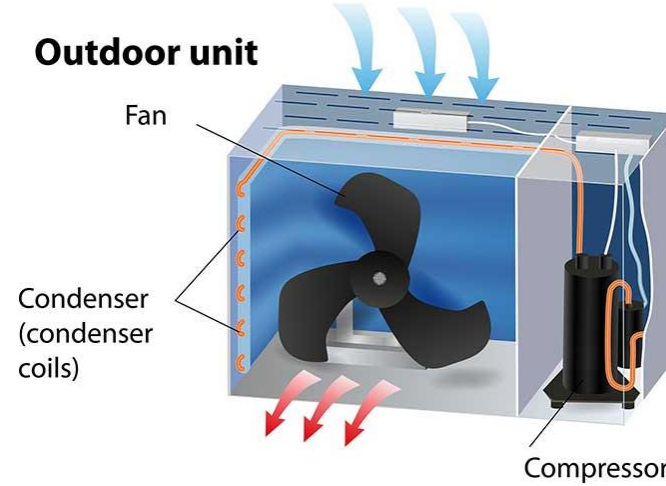


Image source: <https://www.hometips.com/how-it-works/air-conditioners-room-window.html>

Split air conditioner

Outdoor unit



Indoor unit

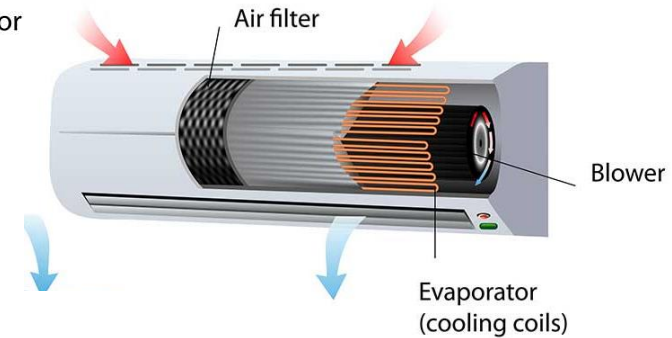


Image source: https://bprassets.s3.amazonaws.com/blogfiles/assets/images/post/Body%20Pics/05-03-12_images/split-system-indoor-and-outdoor-air-conditioning-units-diagram.jpg

VRF AIR CONDITIONERS

Variable refrigerant flow (VRF) for mid-sized applications

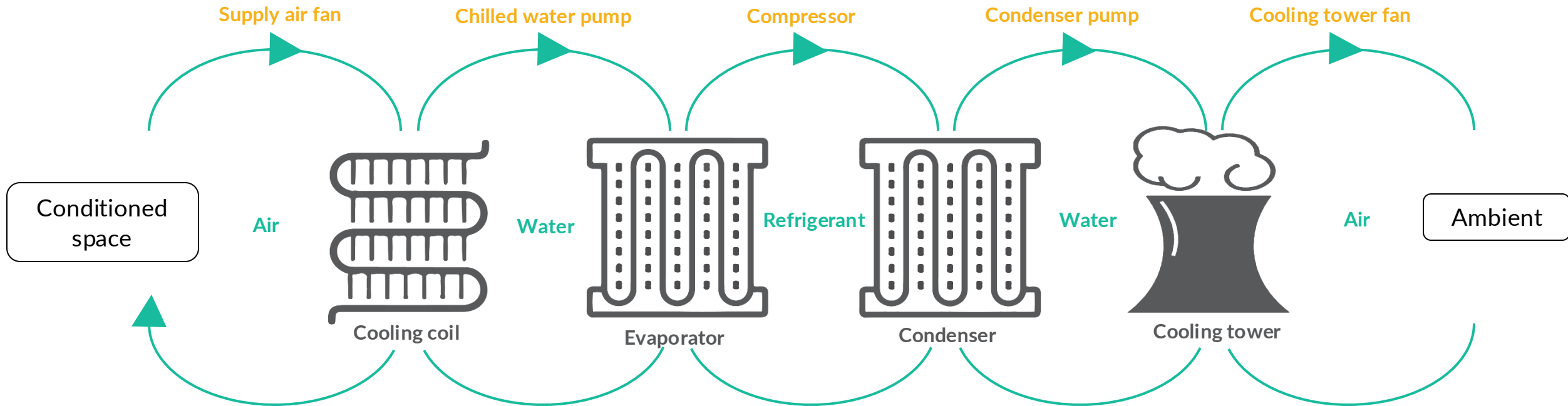
- For addressing variable loads, VRF type DX systems are gaining popularity
- It avoids installation of large ducts in user areas and avoids issues related to managing false ceiling heights
- In the user areas, cassette units or hi-wall units can be installed, depending on convenience of installation
- Even DX type AHUs can be designed to cater to special requirements of high static head and filtration levels



Image source: SM Solutions

CENTRAL COOLING SYSTEM

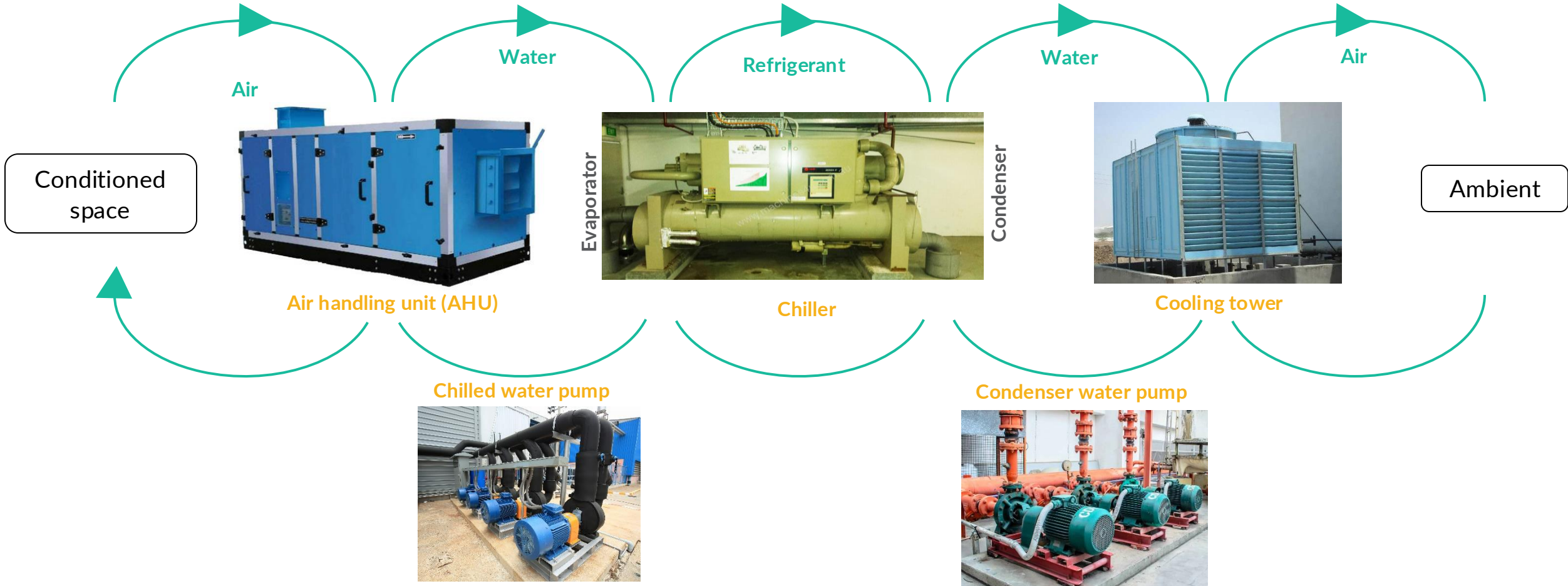
A conceptual overview



Thermodynamically, heat rejected at cooling tower is equal to summation of cooling effect delivered at evaporator and energy consumed by the chiller compressor

CENTRAL COOLING SYSTEM

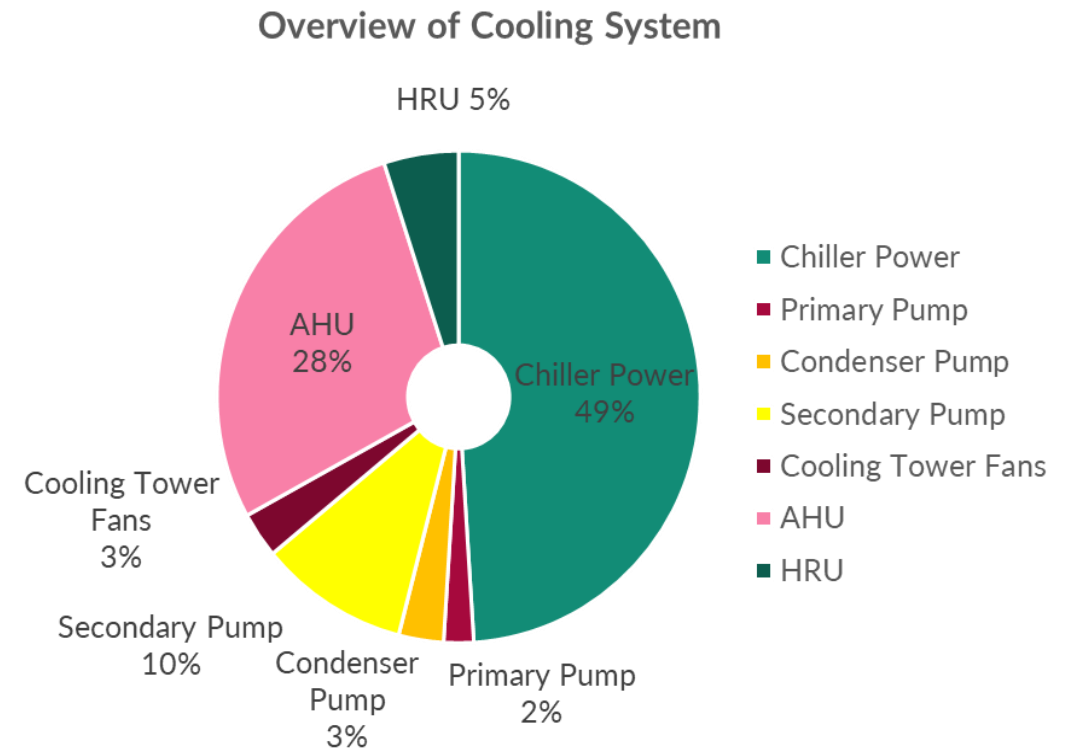
Main components



HVAC: ENERGY DISTRIBUTION

Water chillers are the major load

- In HVAC systems in commercial buildings, the water chillers account for almost 50% of load
- The other loads account for the following:
 - AHUs (28%)
 - Pumps (15%)
 - Heat recovery wheels (5%)
 - Cooling tower fans (3%)



QUANTIFYING COOLING EFFECT

Common terminologies and conversions

Definition of 'ton of refrigeration (TR)':

The amount of energy required to convert 1 ton of water at 0°C into ice within 24 hours

The relation between TR and its equivalent energy terms is as follows:

1 TR equals to:

- 3,024 kcal/h
- 3.51 kW
- 12,000 Btu/h

REFRIGERATION

Energy efficiency: Figures of merit

Quantification of Refrigeration Effect

$$\begin{aligned}
 1 \text{ Ton of Refrigeration (TR)} &= 3,023 \text{ kcal/h} \\
 &= 3.51 \text{ kW}_{\text{thermal}} \\
 &= 12,000 \text{ Btu/h}
 \end{aligned}$$

$$\text{Coefficient of Performance (COP)} = \frac{\text{Refrigeration Effect}}{\text{Work Done}}$$

$$\text{Energy Efficiency Ratio (EER)} = \frac{\text{Refrigeration Effect (Btu/h)}}{\text{Work Done (Watts)}}$$

$$\text{Specific Power Consumption (SPC)} = \frac{\text{Power Consumption (kW)}}{\text{Refrigeration Effect (TR)}}$$

Sample calculations

$$\begin{aligned}
 \text{Refrigeration Load} &= 50 \text{ TR, say} \\
 &= 175.5 \text{ kW}_{\text{thermal}} \\
 &= 600,000 \text{ Btu/h}
 \end{aligned}$$

$$\text{Compressor power consumption} = 40 \text{ kW, say}$$

$$\text{COP} = \frac{175.5}{40} = 4.39$$

$$\text{EER} = \frac{600,000}{(40 \times 1,000)} = 15$$

$$\text{SEC} = \frac{40}{50} = 0.80 \text{ kW/TR}$$

CHILLER EFFICIENCY

Figures of merit for water-cooled and air-cooled chillers

For water-cooled chillers:

SEC = 0.45 kW/TR – 0.65 kW/TR

COP = 5.4–7.8

EER = 18.5–26.7

For air-cooled chillers:

SEC = 0.90 kW/TR – 1.20 kW/TR

COP = 2.9–3.9

EER = 10–13.3

Higher COP / EER and lower SEC imply better system performance

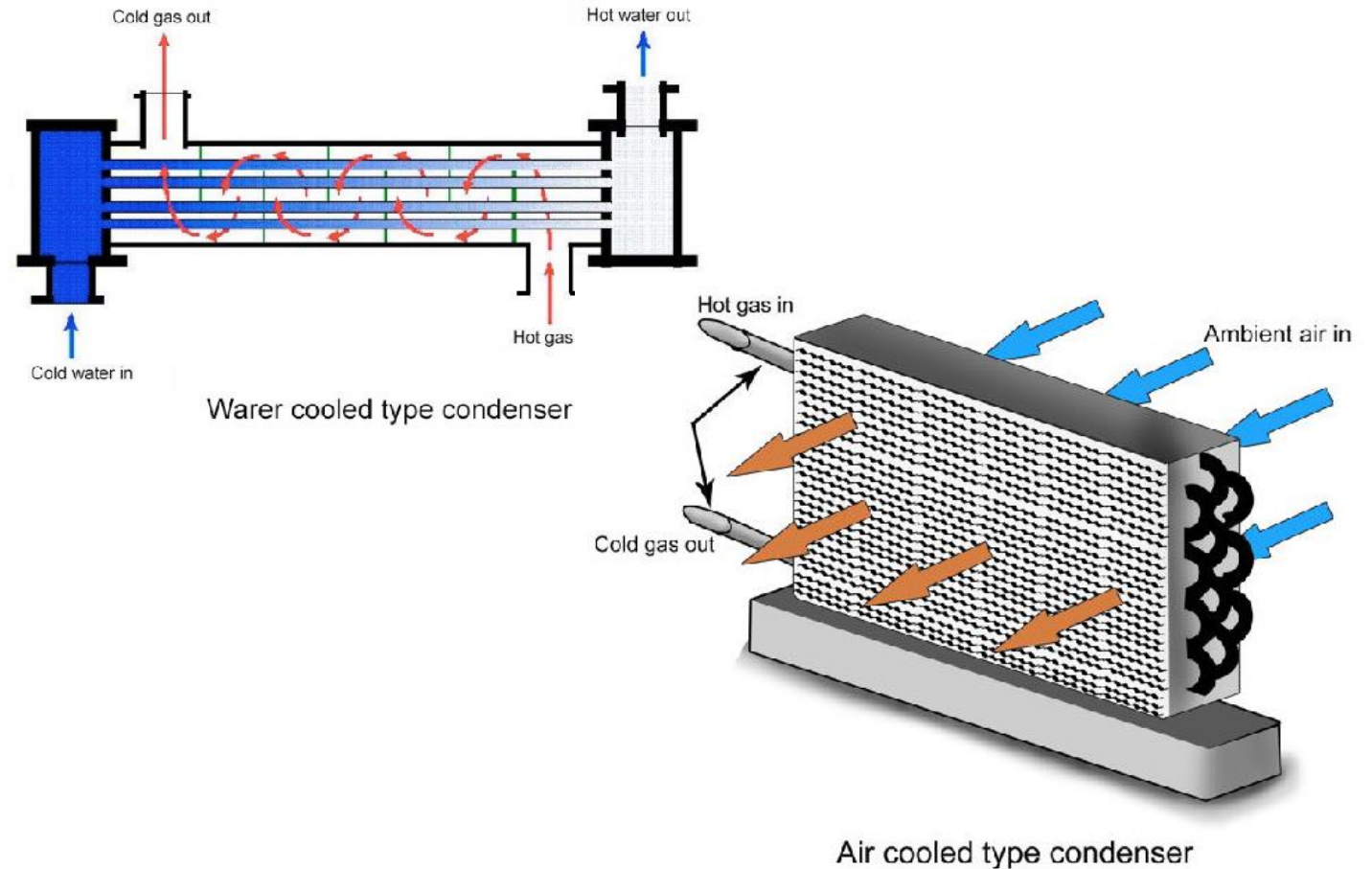
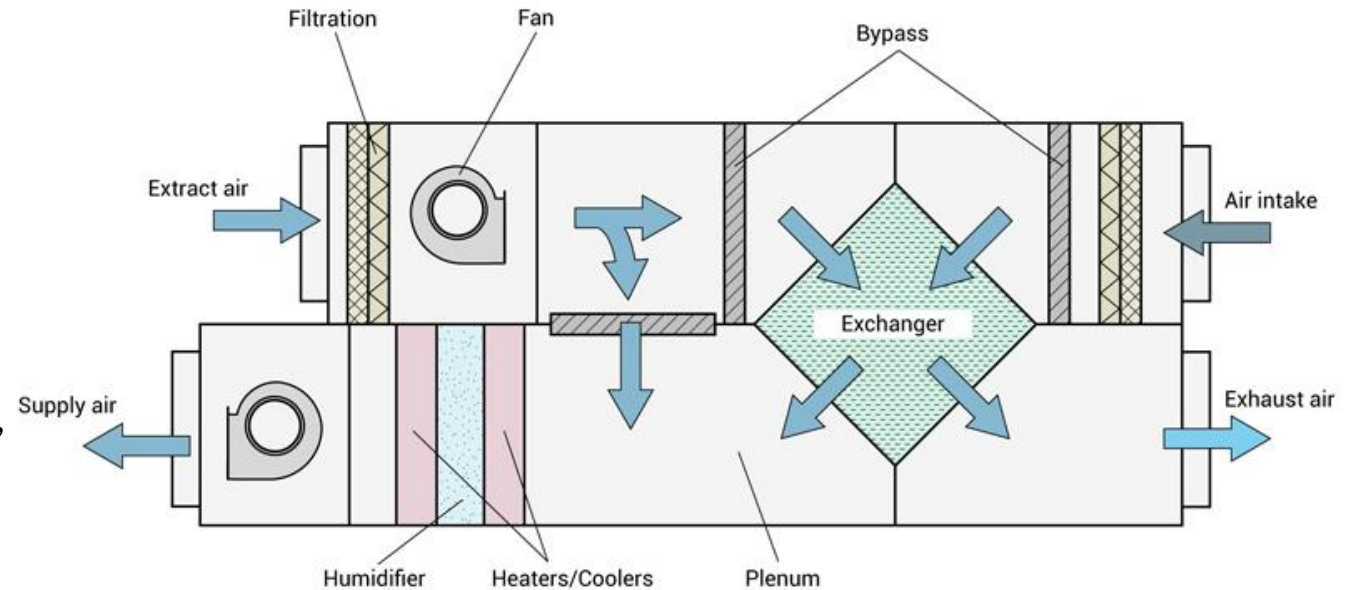


Image source: <https://www.senho-chiller.com/technical-suport/difference-between-air-cooled-and-water-cooled-chiller.html>

AIR HANDLING UNIT (AHU)

Components and energy consumption

- Key components
 - Supply fan
 - Return fan
 - Filters
 - Heating / cooling coils
 - Heat exchanger (optional)
- The energy consumption is determined by the air flow, pressure, and fan and motor efficiencies
- Operation at optimal air flows, determined by cooling load, optimal pressure (without excessive damper control), and use of appropriately-sized, high-efficiency fans and motors, preferably controlled by variable frequency drives, are desirable



Air handling unit

Image source: <https://www.airtechnics.com/news/what-is-an-air-handling-unit-ahu>

PUMPS IN HVAC SYSTEM

Components and energy consumption

- **Chilled water pumps** supply chilled water to AHU, which is cooled through the chiller. The connecting pipes are insulated to reduce heat loss
- **Condenser water pumps** circulate water to the cooling tower, removing heat from the condenser (heat rejection side) of the chiller. The connecting pipes are generally not insulated

The energy consumption is determined by the water flow, pressure, and pump and motor efficiencies

Operation at optimal water flows, determined by cooling load, optimal pressure (with excessive valve throttling), and use of appropriately-sized, high-efficiency pumps and motors, preferably controlled by variable frequency drives, are desirable



Chiller water pump



Condenser water pump

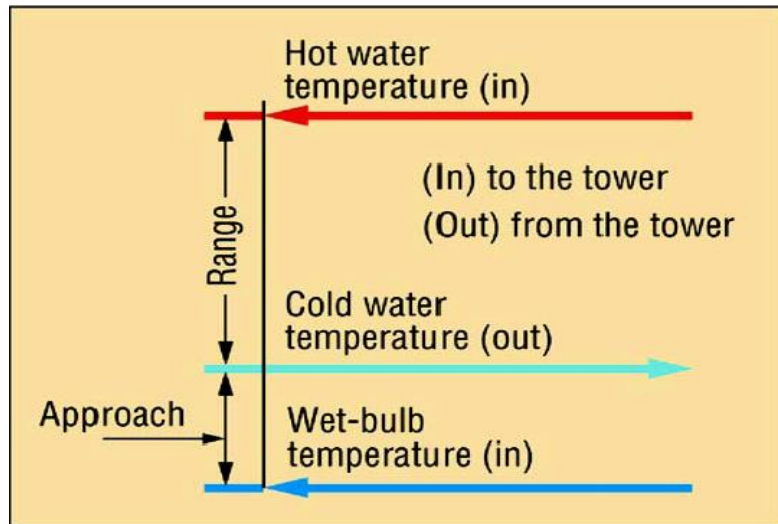
Image source: <https://www.durapump.co.uk/how-to-improve-chilled-cooled-water-system-efficiency/>

Image source: <https://aircondlounge.com/how-to-calculate-chilled-water-pump-head/>

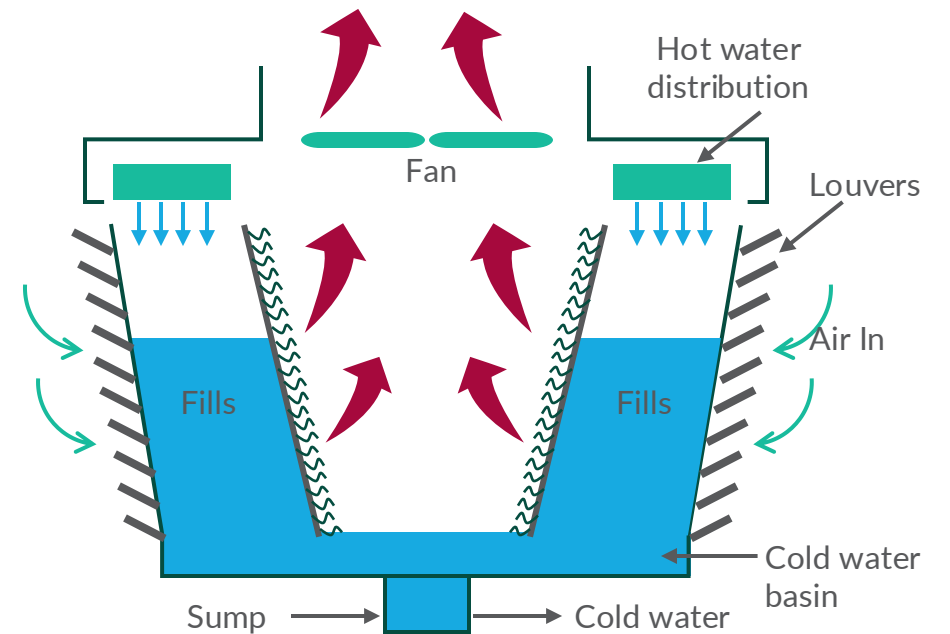
COOLING TOWER

Important parameters: Temperature range and temperature approach

Latent heat of condensation of the refrigerant vapor is transferred to the cooling water and rejected to the atmosphere by vaporization of water in the cooling tower, assisted by air flow



- **Range:** Entering Water Temperature - Leaving Water Temperature
- **Approach:** Wet-bulb Temperature - Leaving Water Temperature
- **Effectiveness:** $\text{Range} / (\text{Range} + \text{Approach})$ {higher is better}



Induced draft, double-flow crossflow tower

Source: Bureau of Energy Efficiency, Government of India, 2015

OVERALL SYSTEM EFFICIENCY

Including all components of the chilled water system.

- The combined central chilled water plant includes chillers, chilled water pumps, cooling water pumps and cooling tower fan (excluding air handling units)
- The figure of merit for assessing design system efficiency of central chilled water plant is defined as:

(total installed motor capacity, kW) per (refrigeration capacity, kW_r)
- In India, the Energy Conservation Building Code 2017 defines this threshold as 0.26 kW / kW_r

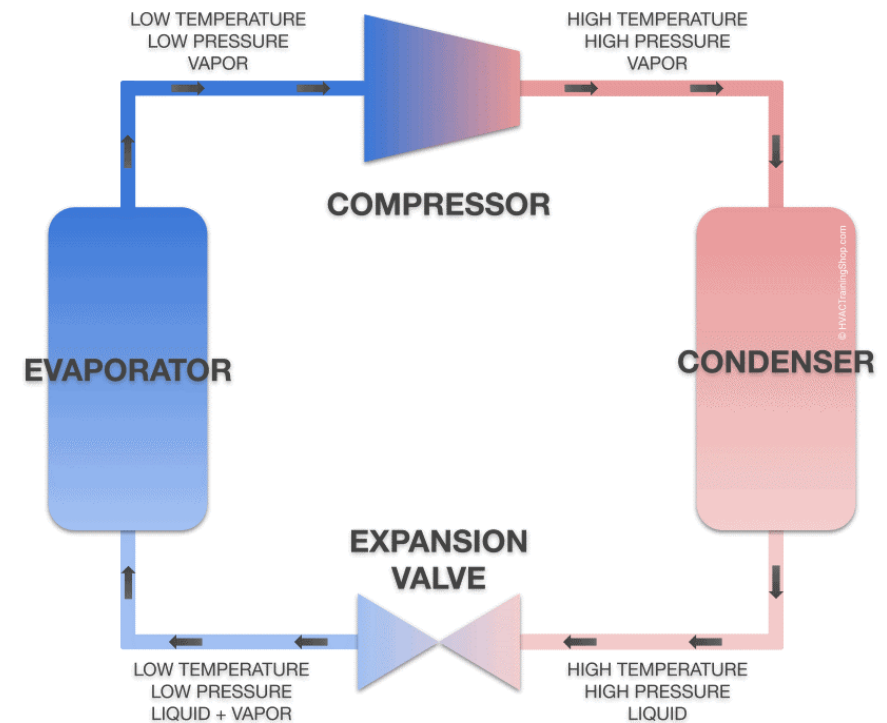
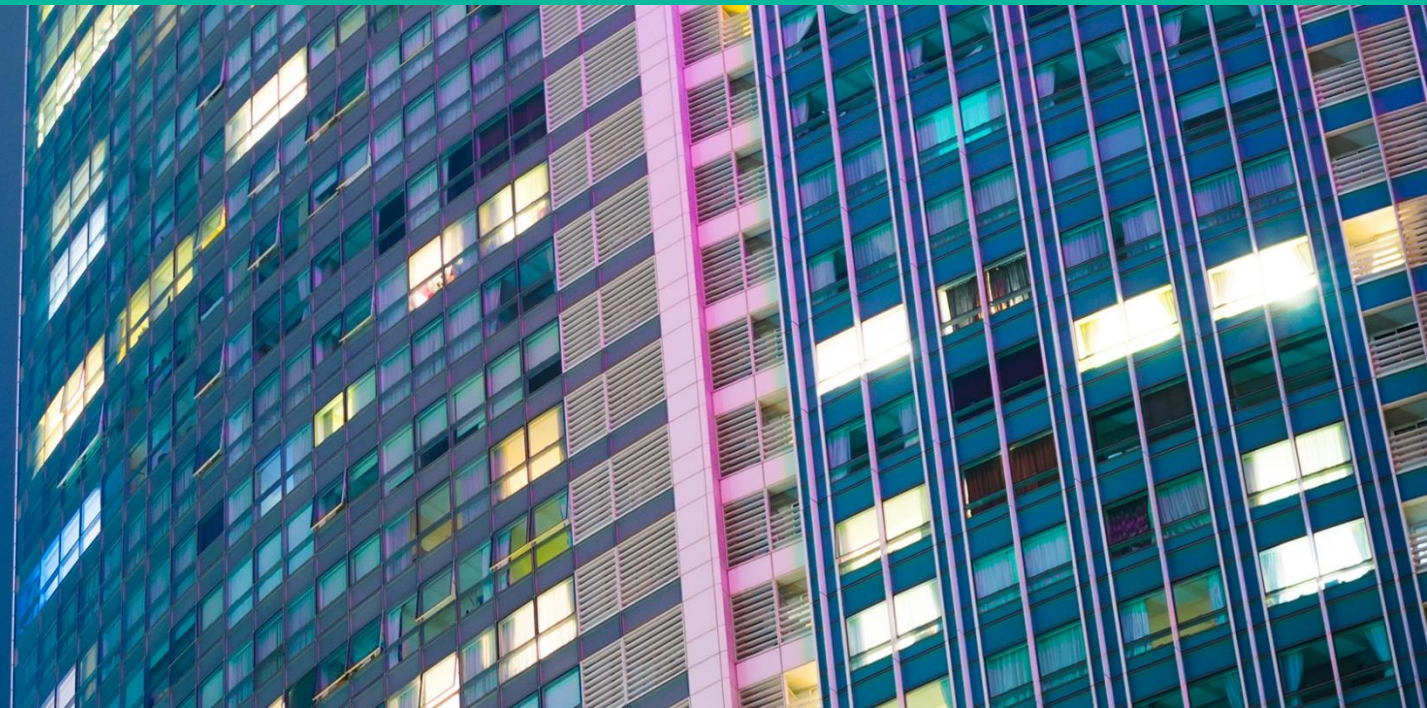


Image source: <https://www.linkedin.com/pulse/how-chilled-water-system-works-muhammad-adnan-arshad/>

LIGHTING

Basics and Commonly-used Systems



LIGHTING LUMINAIRES

Common indoor and outdoor luminaires



LIGHTING SYSTEMS

Performance parameters

- **Luminous flux** describes the quantity of light emitted by a light source. The most common measurement or unit of luminous flux is the **lumen (lm)**. The lumen rating of a lamp is a measure of the total light output of the lamp
- **Illuminance** is the quotient of the luminous flux incident on an element of the surface at a point of surface containing the point, by the area of that element. **Lux (lx)** is the metric unit of measure for illuminance of a surface
- **Luminous efficacy** is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. It is a reflection of efficiency of energy conversion from electricity to light form (**unit: lumens per lamp watt (lm/W)**)
- **Color Rendering Index (CRI)** is a measure of the effect of light on the perceived color of objects. It ranges from 0–100. A low CRI indicates that some colors may appear unnatural when illuminated by the lamp

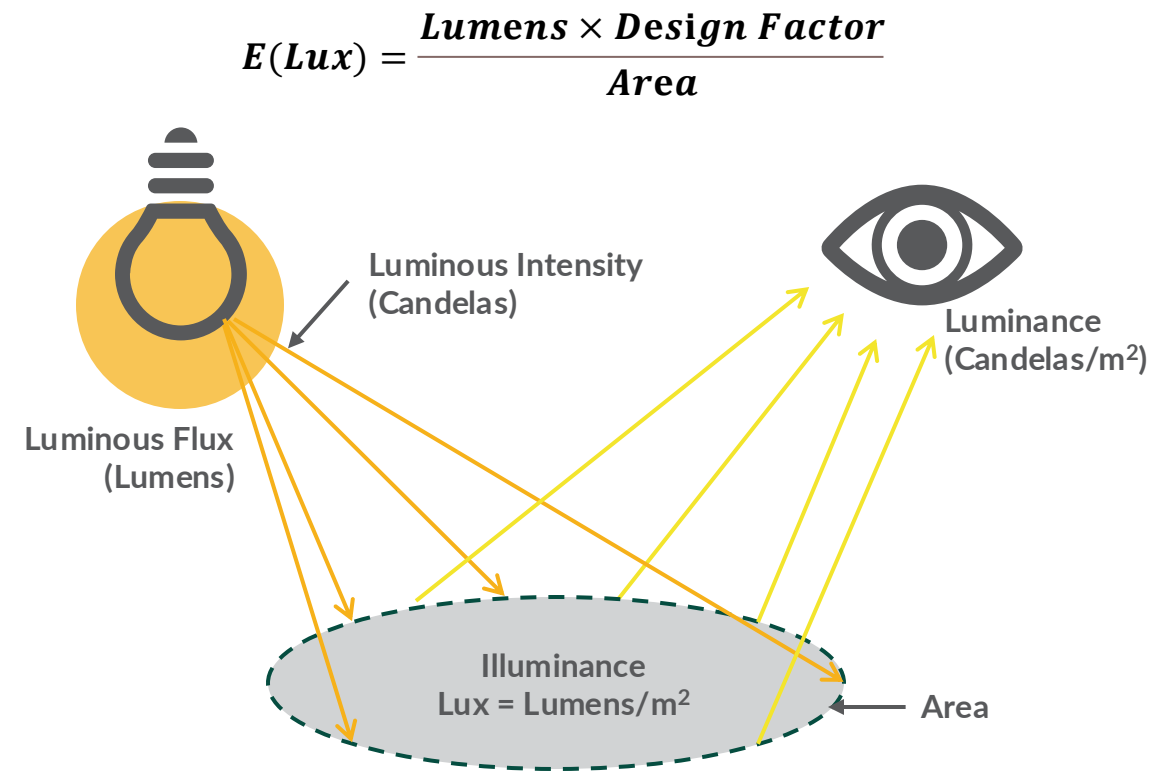


Image source: <https://www.etaplighting.com/en/blog/lux-and-lumen-whats-difference>

LIGHTING SYSTEMS

Commonly-used lamps

Conventional Lamps



Incandescent Lamp



Tubular Fluorescent Lamp

LED Lamps



Compact Fluorescent Lamp



LED Lamp



LED Tube Light

Lamps: Important Parameters

Type of Lamp	Life Span (in hours)	Lumens/watt	Color Rendering Index (CRI)
Incandescent Lamp	1,000–2,000	8–18	100 (Excellent)
Compact Fluorescent Lamp (CFL)	12,000	40–70	85 (Very Good)
Tubular Fluorescent Lamp	25,000–40,000	46–60	67–77 (Good)
LED Tube Light/Bulb	50,000–100,000	50–130	80 (Very Good)

Source: Bureau of Energy Efficiency, Government of India, 2015

OTHER SERVICES

Commonly-used Equipment and Systems



Image source:

OTHER SERVICES

Efficiency metrics and minimum efficiency levels

- The system efficiency levels are prescribed at both international and national levels, and are updated at regular intervals
- Internationally, the minimum equipment efficiency values defined in **ASHRAE Standard 90.1** are well recognized and widely used. Meeting the prescriptions of the latest edition can ensure that selected systems will require lower operational energy
- At national levels, the local codes or standards will **supersede**; for example, in **India**, the **Energy Conservation Building Code (ECBC)** is applicable to both commercial and residential buildings. The minimum equipment efficiency values are prescribed with reference to the local conditions, available systems and future prescriptions on minimum performance levels
- The metrics for India's Star Labeling Program for appliances and equipment is referred to later in this module

SERVICE EQUIPMENT

With significant energy consumption: Ceiling fans and electric water heaters

PRESCRIBED PERFORMANCE PARAMETER

Service value is calculated as the ratio of air delivery (in cubic meters per minute) to power consumption (in watts)



PRESCRIBED PERFORMANCE PARAMETER

Standing loss is measured in kilowatt-hours per day (kWh/24 hours) for a temperature difference of 45°C. It indicates how much energy the water heater loses while maintaining the water temperature



SERVICE EQUIPMENT

With significant energy consumption: Pumps and elevators (lifts)

PRESCRIBED PERFORMANCE PARAMETER

Power consumption (kW) at specified head and flow



PRESCRIBED GUIDELINES

- **Compliance:** Guideline VDI 4707: Class 1–5 for energy efficiency of lifts
- **Type of motor:** Use of IE3 motor and above
- Use of variable voltage variable frequency drives and regenerative drives
- **Lumen efficacy of lamps in lifts:** Over 85 lumen/W



Operational Energy Indices

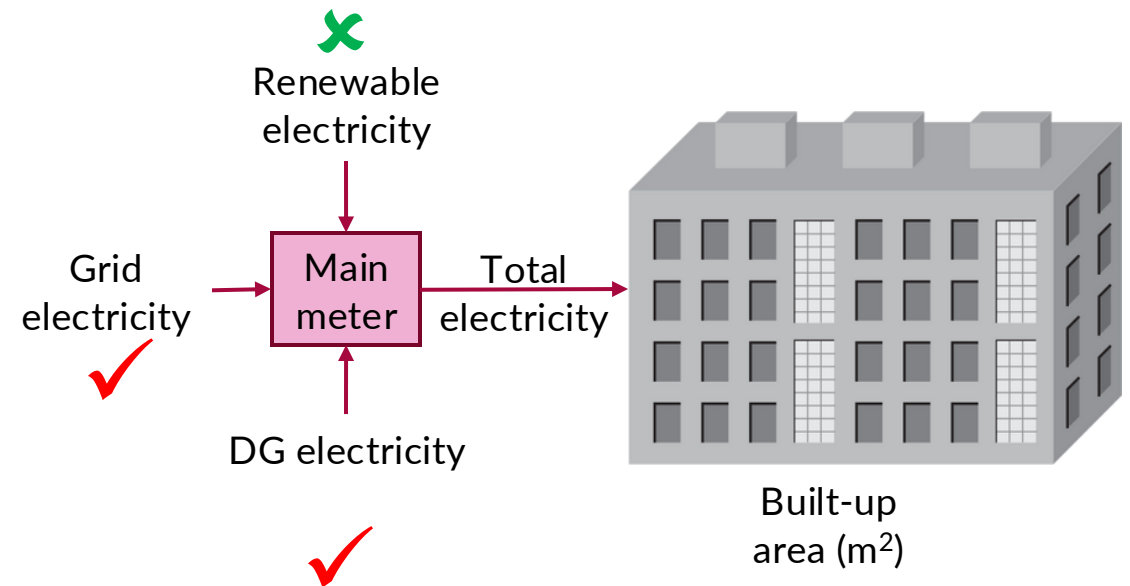


ENERGY PERFORMANCE INDEX (EPI)

Overall energy efficiency metric for buildings

- **Definition:** EPI is a metric used to measure the energy efficiency of a building or facility. It is typically defined as the total energy consumption per unit area, expressed in kWh/m² per year
- **Purpose of EPI:** EPI is crucial for assessing and comparing the energy efficiency of different buildings or urban areas. It helps identify opportunities for improvement and track energy conservation efforts over time
- EPI plays a key role in reducing operational costs, lowering carbon footprints, and contributing to sustainability goals. It is often used in compliance with energy efficiency regulations and certifications
- **Formula:**

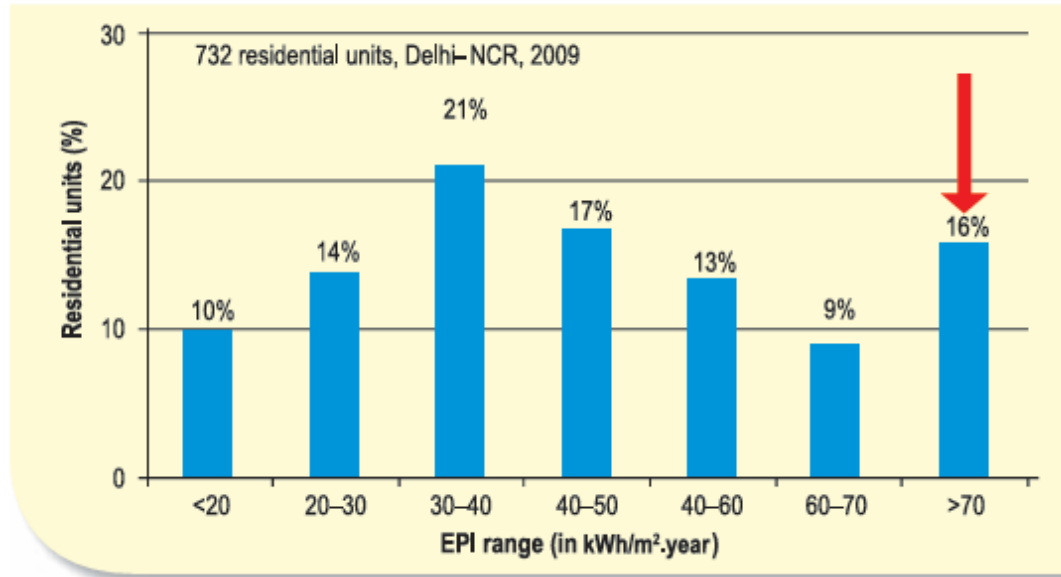
$$\text{EPI} = \frac{\text{Total Energy Consumption (kWh/year)}}{\text{Total Floor Area (m}^2\text{)}}$$



Sources: Bureau of Energy Efficiency, Government of India, 2022; Bureau of Energy Efficiency, Government of India, 2023b

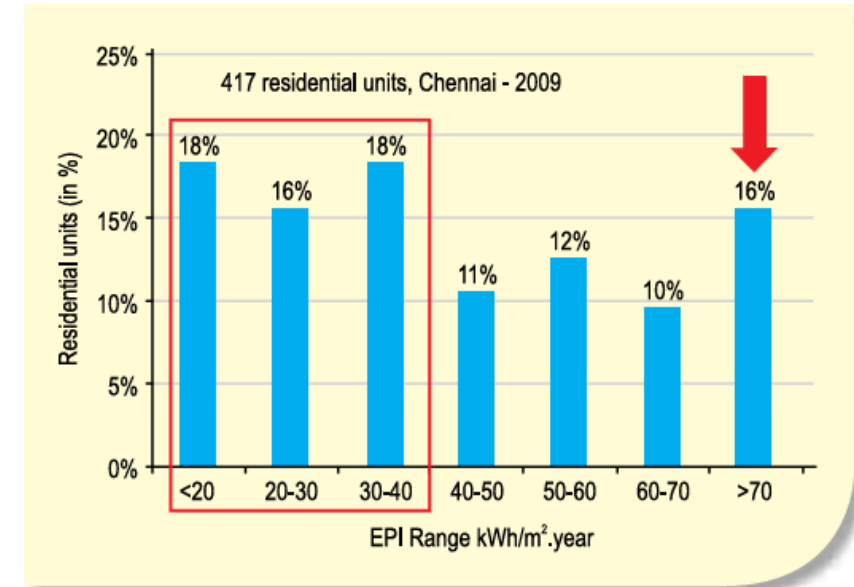
ENERGY PERFORMANCE INDEX (EPI)

For residential buildings



For **composite climate** in India, the average EPI, based on data collected from over 700 residential units for 2009 is **48 kWh/m².year**. The EPI does not include electricity consumption for common services

Over **16%** of the residential units have an EPI value **greater than 70 kWh/m².year**. Most of these residential units have three or more air-conditioners



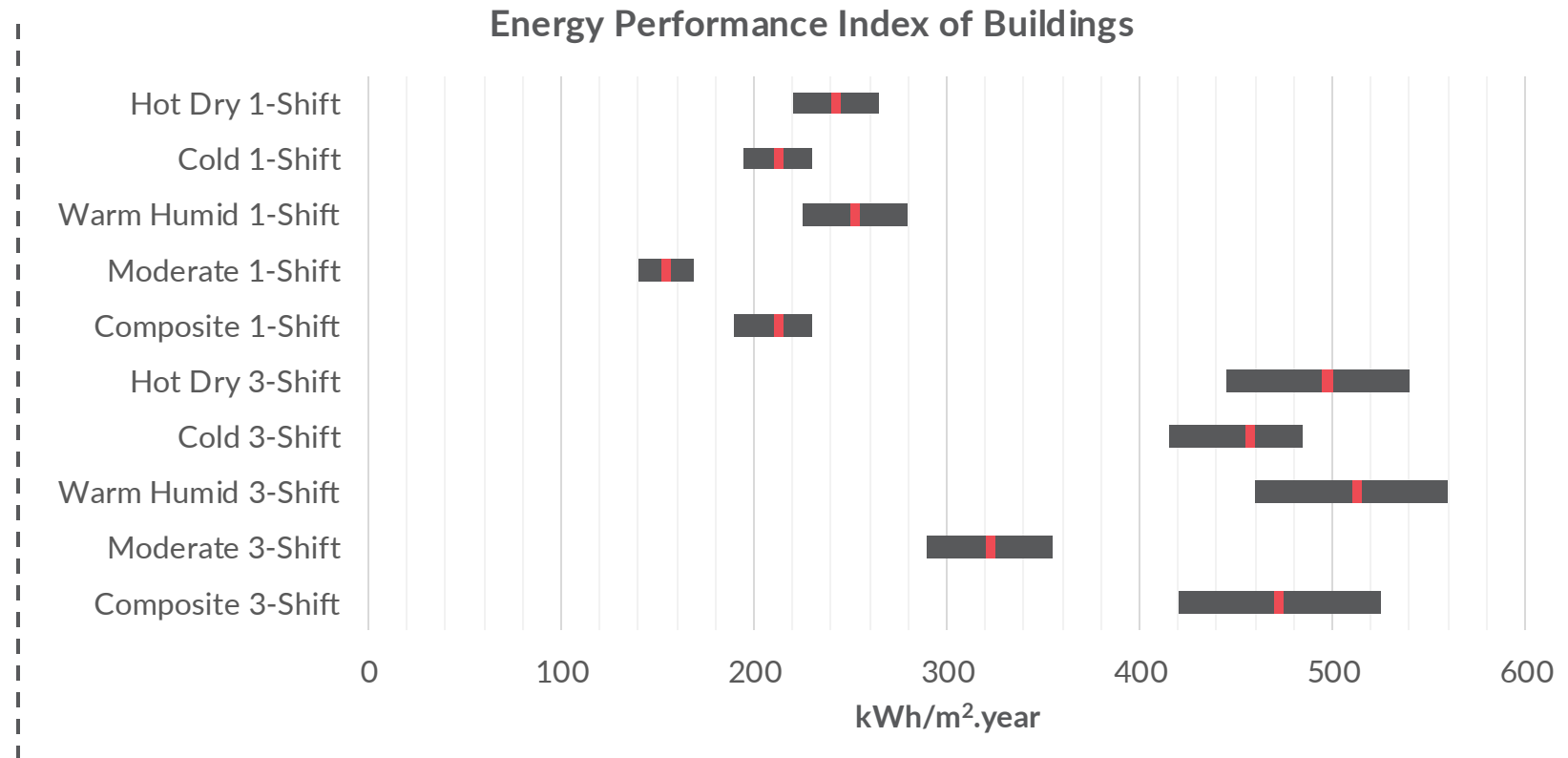
For **warm-humid climate** in India, the average EPI, based on data collected from over 400 residential units for 2009 is **44 kWh/m².year**. The EPI does not include electricity consumption for common services

ENERGY PERFORMANCE INDEX (EPI)

For buildings (1-shift and 3-shift operation)

A national survey for assessing the EPI of existing buildings in India was conducted in five climatic zones and two types of buildings:

- Daytime use
- 24 x 7 use



Source: CEPT University, Ahmedabad, & Shakti Foundation, New Delhi, "A stepped bundle approach to ECBC".

Energy Star Rating for Buildings



STAR RATING FOR BUILDINGS

For buildings (1-shift and 3-shift operation)

The star rating system is designed to evaluate and rate the energy efficiency of buildings on a scale, typically from 1 to 5 stars. It offers an easy-to-understand metric for homeowners, buyers and tenants to evaluate how energy efficient a property is.

Rating scale: A 1-star rating indicates poor energy performance, while a 5-star rating signifies excellent energy efficiency. Each additional star represents a higher level of energy efficiency:

- **1-Star:** Basic compliance with local building codes; minimal insulation and little to no energy efficient systems
- **2-Star:** Slight improvements over baseline requirements, with some energy efficient appliances and insulation
- **3-Star:** Moderate energy efficiency with adequate insulation, and energy efficient HVAC and LED lighting
- **4-Star:** Above-average energy efficiency, possibly including double-glazed windows, higher-quality insulation and efficient HVAC systems
- **5-Star:** Top-tier energy efficiency with renewable energy sources, comprehensive insulation, advanced window glazing, smart home technology and low energy consumption throughout



Source: Bureau of Energy Efficiency, Government of India

RESIDENTIAL BUILDINGS

Star rating system

- The Star Rating System for Residential Buildings in India, established by the Bureau of Energy Efficiency (BEE), is a program that rates the energy efficiency of residential buildings on a scale from 1 to 5 stars
- **EPI calculation:**
EPI for air-conditioned spaces (25% area) with 24°C as set point (E1) + EPI for other spaces (75% area) with natural ventilation (E2) set points defined by IMAC with air conditioner switched on
- EPI for other appliances: E3 (constant value)
- **Calculation of the EPI** is through a simulation-based tool to calculate the EPI of dwelling units. The user is required to feed-in information of the dwelling unit in the tool based on which the tool will automatically calculate the EPI

Residential Building Star Rating Plan				
Period: 14 December 2018 to 31 December 2024				
Star Rating	Energy Performance Index ¹ (E1 + E2) of Dwelling Unit			
	Composite	Warm & Humid	Hot and Dry	Temperate
1-star	52 < EPI ≤ 60	58 < EPI ≤ 64	55 < EPI ≤ 67	28 < EPI ≤ 31
2-star	45 < EPI ≤ 52	49 < EPI ≤ 58	47 < EPI ≤ 55	24 < EPI ≤ 28
3-star	37 < EPI ≤ 45	39 < EPI ≤ 49	38 < EPI ≤ 47	21 < EPI ≤ 24
4-star	29 < EPI ≤ 37	30 < EPI ≤ 39	29 < EPI ≤ 38	17 < EPI ≤ 21
5-star	EPI ≤ 29	EPI ≤ 30	EPI ≤ 29	EPI ≤ 17

- **E1 and E2** includes following systems: Building envelope characteristic; lighting system; and comfort system (AC)
- **E3** includes appliances such as: microwave oven, grinder, refrigerators, television, water pump, washing machine, etc.

Source: Bureau of Energy Efficiency, Government of India

OFFICE BUILDINGS

Star rating system

- The three building categories are based on built-up area (BUA) and in line with the categories in ECBC 2017
- The star rating band is formed by straight line equations in the form $y = (a*b) + c$:
 - 'y' denotes the EPI
 - 'a' denotes the coefficient in the table
 - 'b' denotes the percentage of AC area out of total built-up area

Star rating for office buildings

Climatic Zone	Building Category	1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Large Office	$y = 0.95x + 60$	$y = 0.9x + 50$	$y = 0.85x + 40$	$y = 0.8x + 30$	$y = 0.75x + 20$
	Medium Office	$y = 1.1x + 60$	$y = 1.05x + 50$	$y = x + 40$	$y = 0.95x + 30$	$y = 0.9x + 20$
	Small Office	$y = 0.65x + 60$	$y = 0.6x + 50$	$y = 0.55x + 40$	$y = 0.5x + 30$	$y = 0.45x + 20$
Warm & Humid	Large Office	$y = 0.9x + 65$	$y = 0.85x + 55$	$y = 0.8x + 45$	$y = 0.75x + 35$	$y = 0.7x + 25$
	Medium Office	$y = 0.9x + 65$	$y = 0.85x + 55$	$y = 0.8x + 45$	$y = 0.75x + 35$	$y = 0.7x + 25$
	Small Office	$y = 0.7x + 65$	$y = 0.65x + 55$	$y = 0.6x + 45$	$y = 0.55x + 35$	$y = 0.5x + 25$
Hot & Dry	Large Office	$y = 1.1x + 55$	$y = 1.05x + 45$	$y = x + 35$	$y = 0.95x + 25$	$y = 0.9x + 15$
	Medium Office	$y = 1.25x + 55$	$y = 1.2x + 45$	$y = 1.15x + 35$	$y = 1.1x + 25$	$y = 1.05x + 15$
	Small Office	$y = 0.75x + 55$	$y = 0.7x + 45$	$y = 0.65x + 35$	$y = 0.6x + 25$	$y = 0.55x + 15$

Source: Bureau of Energy Efficiency, Government of India, 2023b

OFFICE BUILDINGS

Star rating system: Understanding the band for each star category

Star rating for office buildings

Climatic Zone	Building Category	1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Large Office	$y = 0.95x + 60$	$y = 0.9x + 50$	$y = 0.85x + 40$	$y = 0.8x + 30$	$y = 0.75x + 20$
	Medium Office	$y = 1.1x + 60$	$y = 1.05x + 50$	$y = x + 40$	$y = 0.95x + 30$	$y = 0.9x + 20$
	Small Office	$y = 0.65x + 60$	$y = 0.6x + 50$	$y = 0.55x + 40$	$y = 0.5x + 30$	$y = 0.45x + 20$
Warm & Humid	Large Office	$y = 0.9x + 65$	$y = 0.85x + 55$	$y = 0.8x + 45$	$y = 0.75x + 35$	$y = 0.7x + 25$
	Medium Office	$y = 0.9x + 65$	$y = 0.85x + 55$	$y = 0.8x + 45$	$y = 0.75x + 35$	$y = 0.7x + 25$
	Small Office	$y = 0.7x + 65$	$y = 0.65x + 55$	$y = 0.6x + 45$	$y = 0.55x + 35$	$y = 0.5x + 25$
Hot & Dry	Large Office	$y = 1.1x + 55$	$y = 1.05x + 45$	$y = x + 35$	$y = 0.95x + 25$	$y = 0.9x + 15$
	Medium Office	$y = 1.25x + 55$	$y = 1.2x + 45$	$y = 1.15x + 35$	$y = 1.1x + 25$	$y = 1.05x + 15$
	Small Office	$y = 0.75x + 55$	$y = 0.7x + 45$	$y = 0.65x + 35$	$y = 0.6x + 25$	$y = 0.55x + 15$

- **Star label bands**
 - Upper value of band: As per the equation given
 - Lower value of band: As per the equation of the next high rating (e.g., equation of the 2 star for a 1-star rating)
- **Example:** Any large office building in composite climatic zone, having 75% AC area ($b=75$)
 - For 1-star rating the upper value of band will be: $0.95 \cdot 75 + 60 = 131.25 \text{ kWh/m}^2$
 - For 1-star rating the lower value of band will be: $0.9 \cdot 75 + 50 = 117.5 \text{ kWh/m}^2$
 - For a building with 75% air-conditioned area, the **EPI band** for 1 star will be **117.5– 131.25 kWh/m²**

Source: Bureau of Energy Efficiency, Government of India, 2023b

Standards and Labeling

For Appliances



Image source: <https://www.paiinternational.in/blogs/understanding-the-bee-star-rating-in-electronics->

STANDARDS AND LABELING (S&L)

For appliances

- In India, the S&L system provides consumers with an easy way to compare the energy use and operating costs of different products, encouraging the purchase of energy efficient models
- **Rating scale:** Appliances are rated from 1 star (least efficient) to 5 stars (most efficient)
- **Energy consumption labeling:** Each appliance label includes information about the product's energy consumption and an efficiency rating
- **Product testing and standards:** Appliances are tested against standards set by the Bureau of Energy Efficiency, which periodically updates the criteria to reflect advancements in technology
- **Commonly-rated appliances:** Refrigerators, air conditioners, ceiling fans, televisions, washing machines, water heaters, LED bulbs and tube lights
- **Star rating criteria**
 - **Energy efficiency ratio (EER):** Indicates efficiency for appliances like air conditioners and refrigerators
 - **Annual energy consumption:** Specifies the estimated annual electricity consumption in kilowatt-hours (kWh) for typical usage



S&L

Appliances covered – mandatory and voluntary

S NO	MANDATORY
1	Frost Free Refrigerator
2	Direct Cool Refrigerator
3	Deep Freezer
4	Room AC (Variable Speed)
5	Room AC (Fixed Speed)
6	RAC (Cassette, Floor Standing Tower, Ceiling Corner AC)
7	Light Commercial AC (Fixed Speed)
8	Stationary Storage Type Electric Water Heater
9	Tubular Fluorescent Lamp
10	LED Lamp
11	Ultra High Definition Television
12	Colour Television
13	Distribution Transformer
14	Ceiling Fan
15	Chiller
16	Washing Machine

S NO	VOLUNTARY
1	General Purpose Industrial Motor
2	Submersible Pump Set
3	Domestic Gas Stove
4	Computer
5	Ballast
6	Office Automation Product
7	Diesel Engine Driven Monoset Pump for Agricultural Purposes
8	Solid State Inverter
9	Diesel Generator Set
10	Microwave Oven
11	Solar Water Heater
12	Air Compressor
13	High Energy Li-Battery
14	Tyre
15	Multi Door Refrigerator
16	Pedestal Fan, Table Fan, Wall Fan
17	Induction Hob
18	Solar Photovoltaic

Thank you!

For more information, visit us at <https://ALCBT.GGGI.ORG>
or scan the QR code below



IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at <https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/>.

 www.gggi.org

 [@gggi_hq](https://twitter.com/gggi_hq)

 [@GGGIHQ](https://www.instagram.com/GGGIHQ)

 [@GGGIHQ](https://www.facebook.com/GGGIHQ)

 [@gggi_hq](https://www.linkedin.com/company/gggi-hq)

 [@GGGIMedia](https://www.youtube.com/GGGIMedia)



Supported by:



on the basis of a decision
by the German Bundestag

3.4 Building Life Cycle Assessment (LCA)

Concept and Approaches

November 2024



HEAT

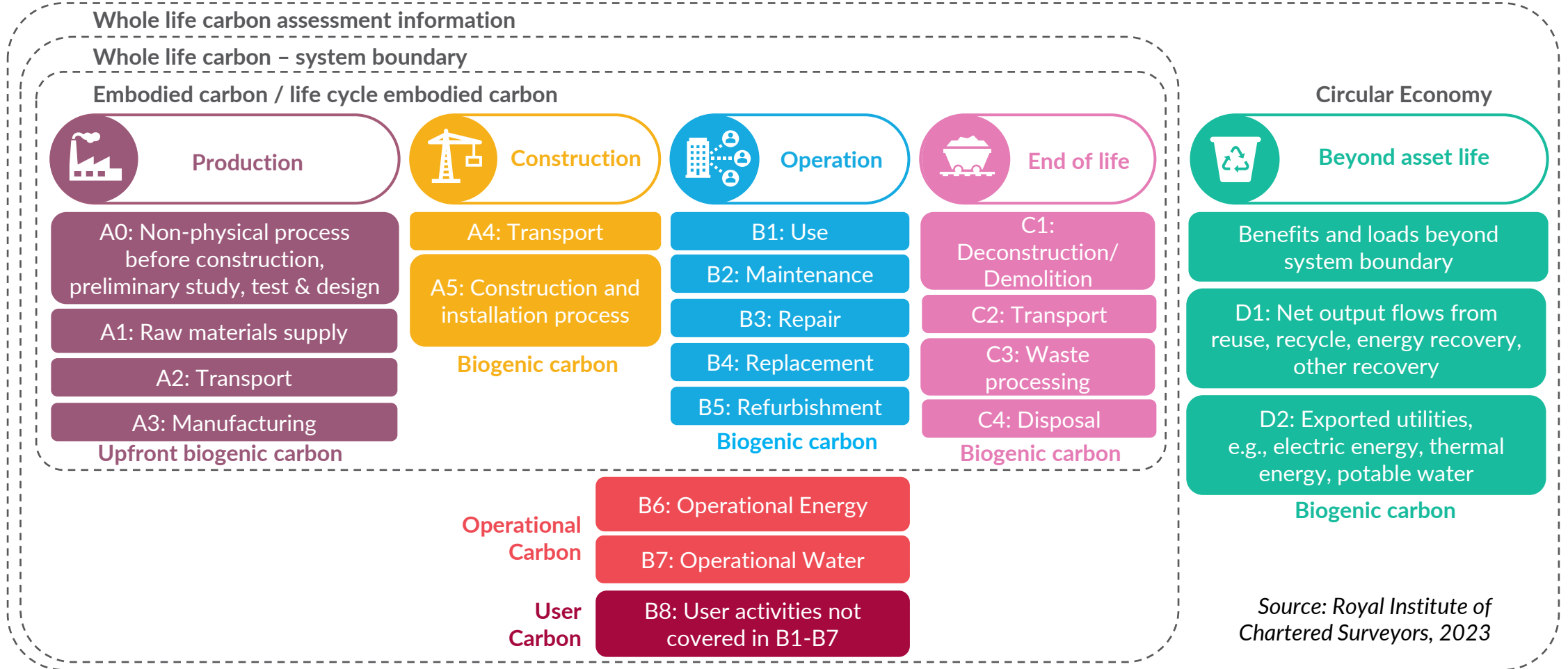
Supported by:



on the basis of a decision
by the German Bundestag

WHOLE LIFE CARBON

Building life cycle stages



BUILDING LIFE CYCLE STAGES

Phases for embodied and operational carbon

Embodied carbon denotes carbon emissions associated with materials and construction processes throughout the whole life cycle of a building. This includes:¹

- **Upfront carbon:** The emissions caused during the building material production and construction phases (A0–A5) of the building's life cycle before it is used. In contrast to other categories of emissions, these emissions have already been released into the atmosphere before the building is occupied or the infrastructure begins operation
- **Use stage embodied carbon:** Emissions associated with building materials and processes needed to maintain the building or infrastructure during use, such as for refurbishments (B1–B5). These are additional to operational carbon emitted due to heating, cooling and power etc.
- **End of life carbon:** The carbon emissions associated with deconstruction and demolition (C1), transportation from site (C2), waste processing (C3) and disposal (C4) phases of a building or infrastructure's life cycle which occur after its use

Operational carbon denotes the emissions associated with energy and water consumed (B6–B7) to operate the building over its life cycle²

¹ Source: World Green Building Council, 2019

² Source: Royal Institute of Chartered Surveyors, 2023

LIFE CYCLE ASSESSMENT

Scope of LCA

Life cycle assessment (LCA) is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product or material throughout its life cycle (ISO 14040: 2006)¹

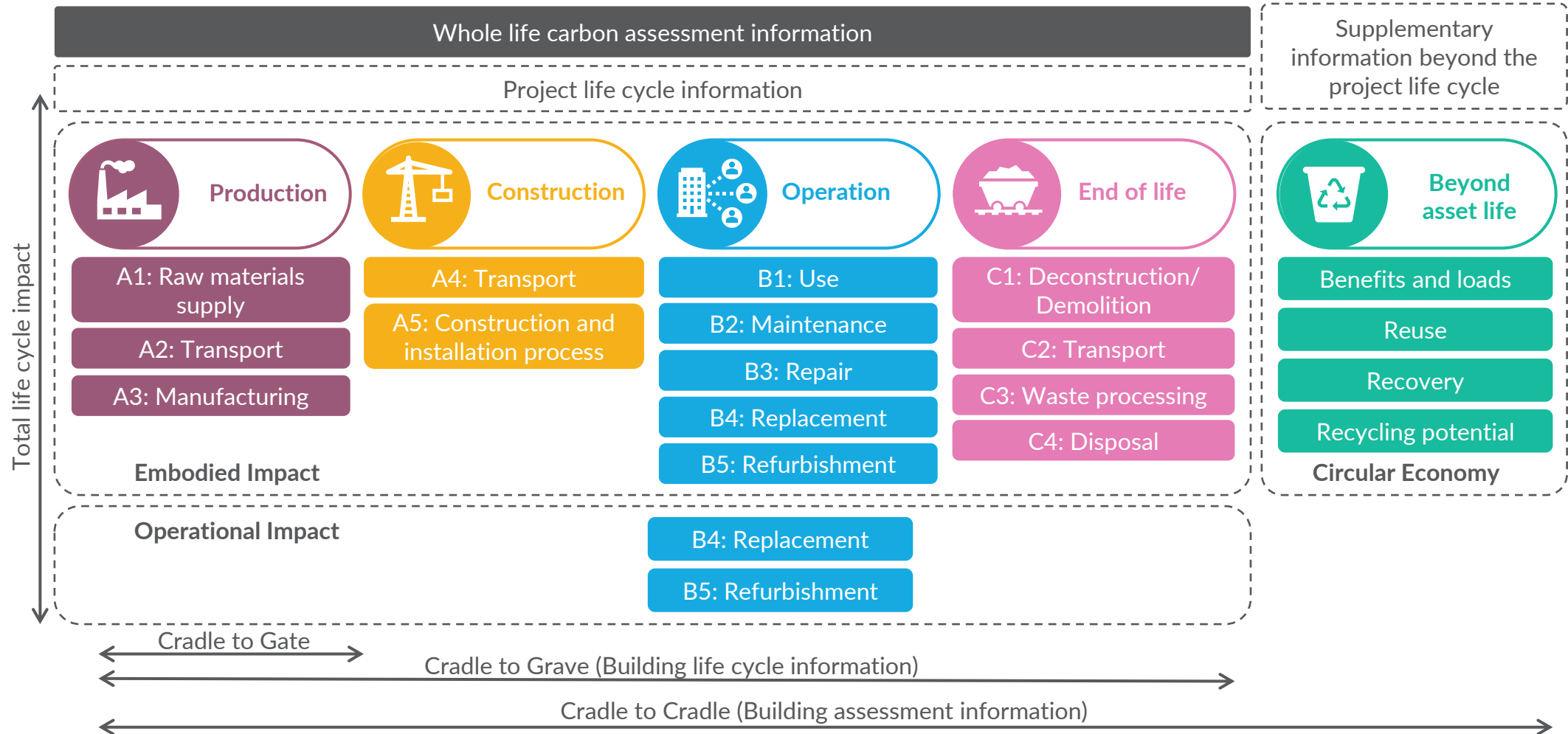
Based on the scope of the LCA or stages for which data is available, one can choose to leave in or take out building life cycle stages. Thus, LCA could be of the following types:²

- **Cradle-to-gate** considers all activities starting with the extraction of materials from the earth (the cradle), their transportation, refining, processing and fabrication activities until the material or product is ready to leave the factory gate (A0–A3)
- **Cradle-to-practical completion (handover)** includes the cradle-to-gate results to just before building occupation and use (A0–A5)
- **Cradle-to-grave** includes the cradle-to-practical handover results plus the GHG emissions associated with the use of the material or product (maintenance) and the end of life (disposal, reuse, recycling) (A0–C4)
- **Cradle-to-cradle** goes beyond cradle to grave and conforms more to the model of the circular economy. In a cradle-to-cradle model, products would be designed in a way so that at the end of their initial life they can be reused or recycled, and therefore avoid landfill

¹ Source: World Green Building Council, 2019

² Source: Royal Institute of Chartered Surveyors, 2017

LCA SCOPES



Source: Royal Institute of Chartered Surveyors, 2017

WHOLE LIFE CARBON ASSESSMENT

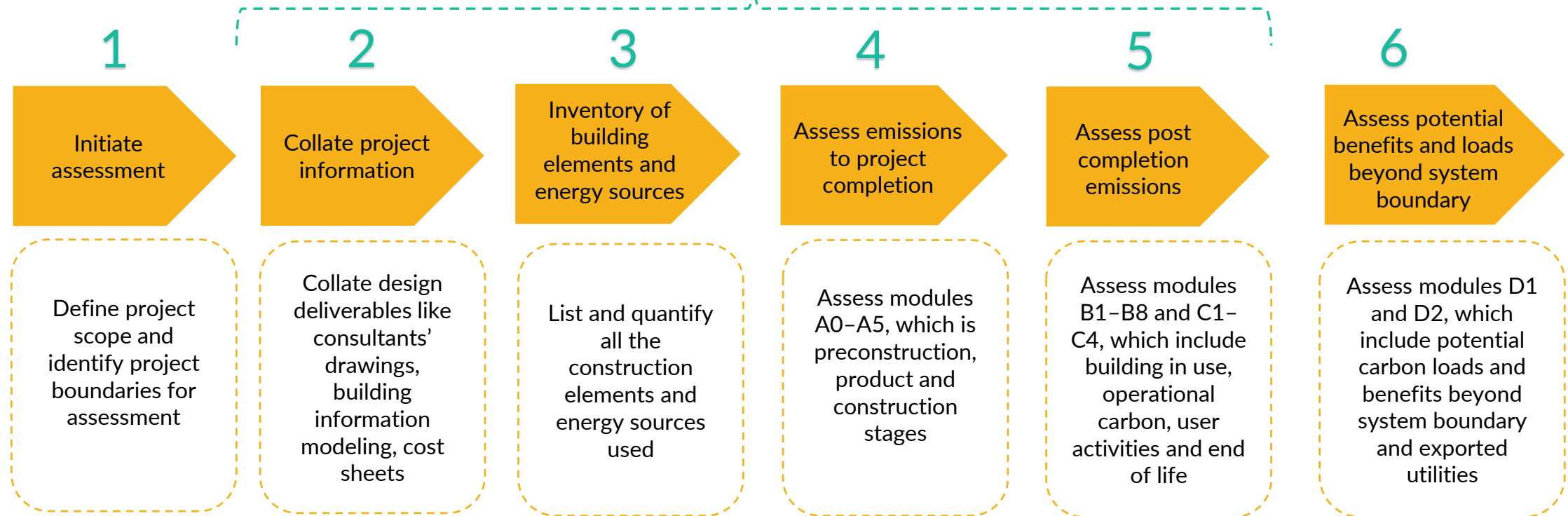
- **A whole life carbon assessment (WLCA)** is the calculation and reporting of the quantity of carbon impacts expected throughout all life cycle stages of a project and includes an assessment of the potential benefits and loads occurring beyond the system boundary.¹ **It is in effect a cradle-to-cradle LCA**
- All WLCAs follow a modular structure for carbon reporting, which breaks down the building life cycle into stages and modules
- A WLCA is intended to examine all carbon impacts from production of materials, construction, use and disposal of a built asset over its entire life cycle. This approach helps to mitigate the carbon at any stage of the life cycle

¹ Source: Royal Institute of Chartered Surveyors, 2023

WLCA METHODOLOGY

Steps for assessing WLCA

Potential to assess, review and reduce building carbon emissions



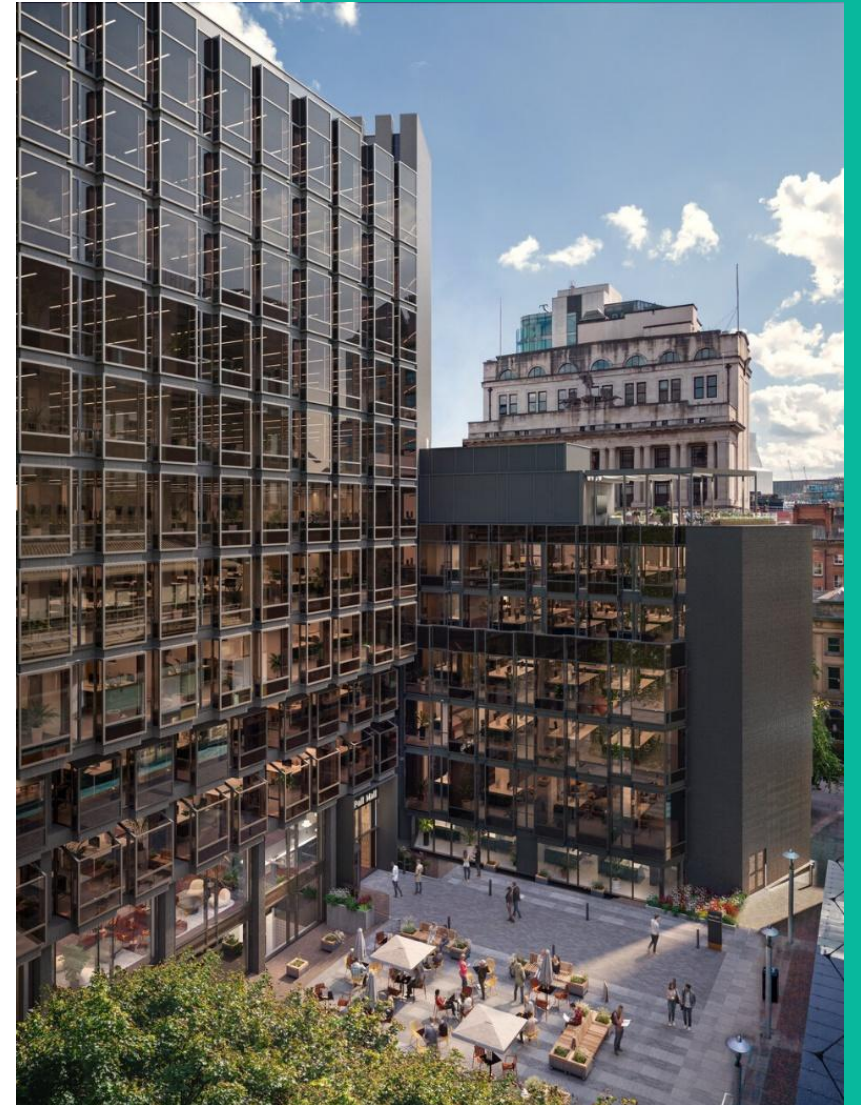
Source: Modified from Royal Institute of Chartered Surveyors, 2023

WLCA BUILDINGS

Retrofit case example: Pall Mall, Manchester, UK

- Pall Mall, built in 1969 and acquired by Bruntwood in 2021, is a property **of 85,000 sq. ft.** of office and hospitality spaces
- Whole life carbon was a driving factor for the decision to retain the building and undertake **a deep retrofit**
- **The WLCA revealed that deep retrofit is the most carbon-efficient solution** due to the proposed switch, away from gas heating to hybrid variable refrigerant flow, with an air source heat pump serving domestic hot water and air handling unit (AHU) coils

Source: Hollyman and Dodkin, 2024



WLCA BUILDINGS

Retrofit case example: Pall Mall, Manchester, UK (continued)

- The project, when completed in 2025, will achieve a **74% reduction in EUI** due to the deep retrofit
- The project will achieve a **higher energy performance rating (EPC), moving from G to A** (A+ being the highest; higher ratings being preferred by tenants)
- The project will achieve a **'very good' BREEAM rating with a 100% increase in rental value**

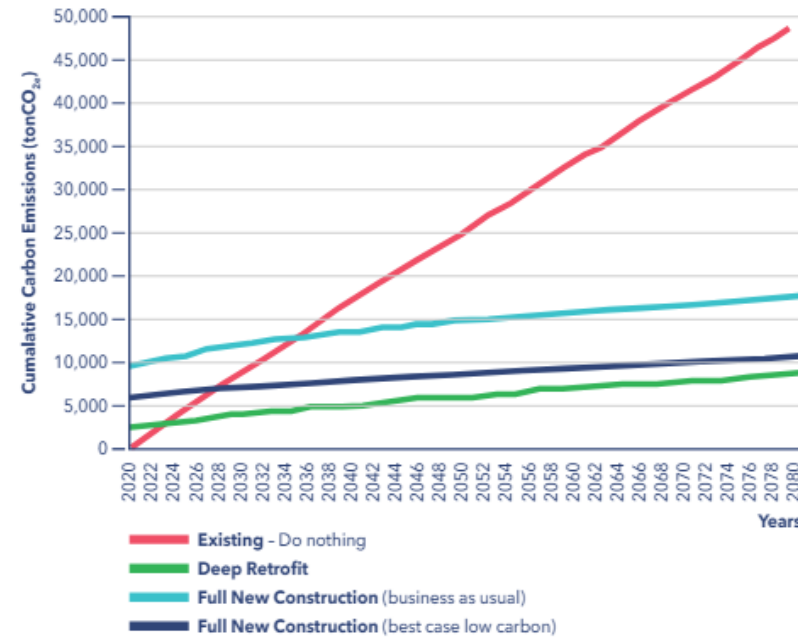


FIGURE 5: Whole Life Carbon Timeline (in tons).

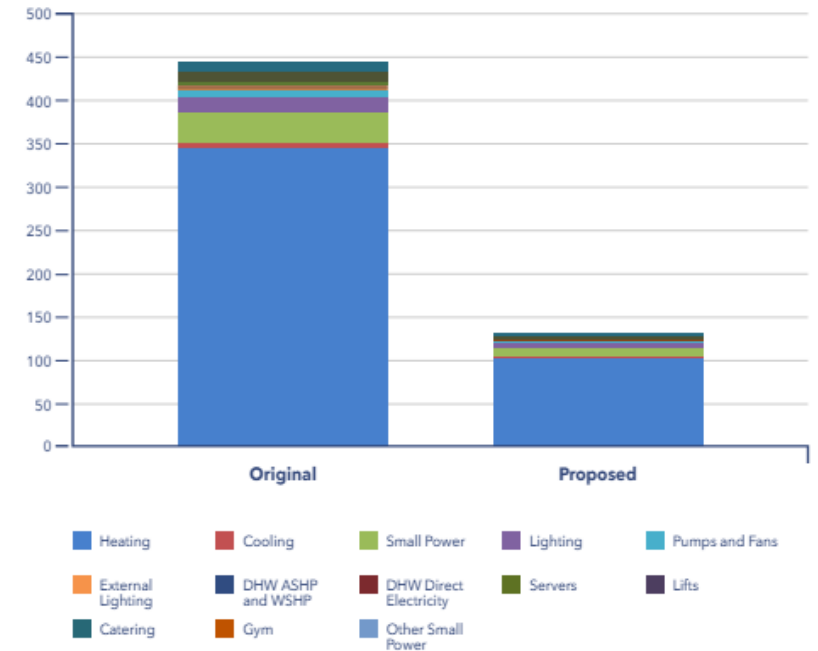


FIGURE 6: Annual Energy Consumption of original and proposed building (kW/m²).

Source: Hollyman and Dodkin, 2024

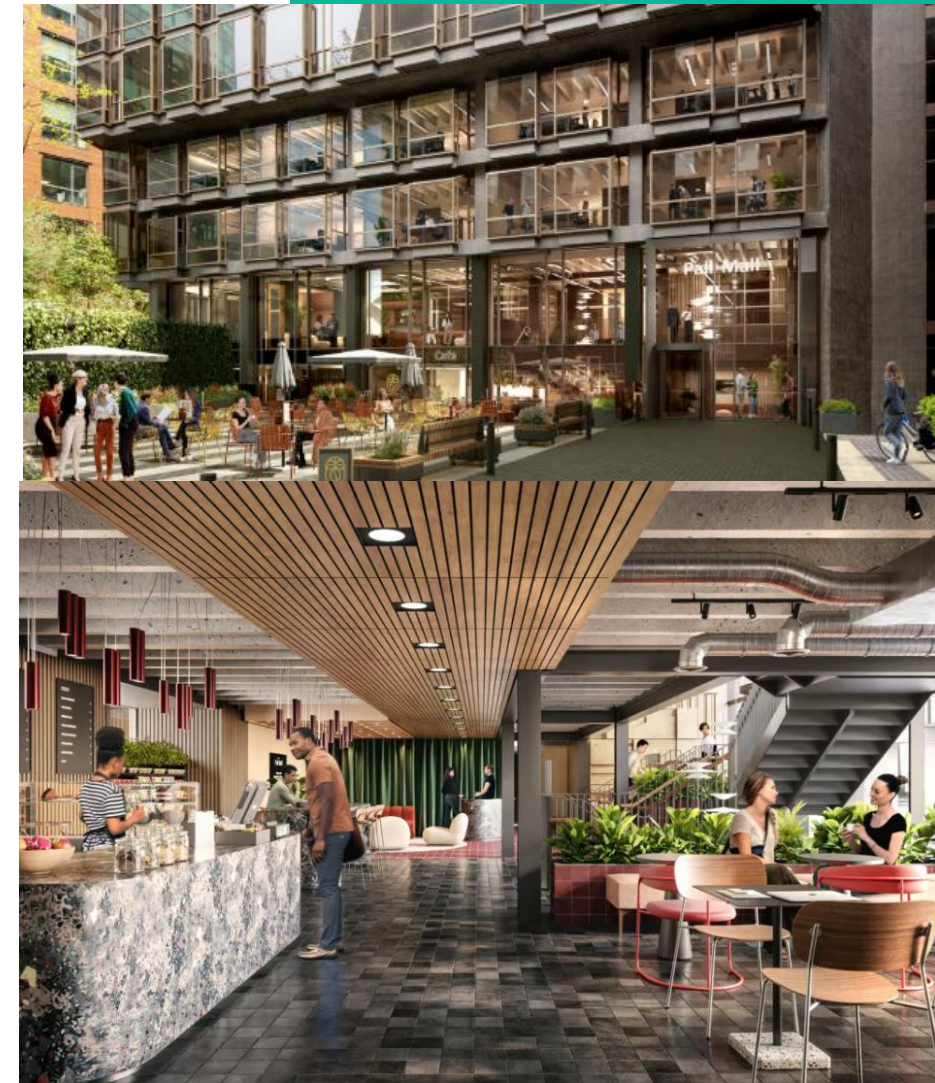
WLCA BUILDINGS

Retrofit case example: Pall Mall, Manchester, UK (continued)

Other features of low carbon design:

- The fit out uses circular economy principles by **utilizing recycled and reclaimed furniture and materials for timber partitions and reclaimed raised access floors**
- The façade and glazing system designed reduces the need to cool the building

Bruntwood has **avoided 7,900 tons** of additional carbon by eliminating the need to rebuild (equivalent to around 16,000 flights from London to New York)



Source: Hollyman and Dodkin, 2024

Thank you!

For more information, visit us at <https://ALCBT.GGGI.ORG>
or scan the QR code below



IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at <https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/>.

 www.gggi.org

 [@gggi_hq](https://twitter.com/gggi_hq)

 [@GGGIHQ](https://www.instagram.com/gggi_hq)

 [@GGGIHQ](https://www.facebook.com/gggi_hq)

 [@gggi_hq](https://www.linkedin.com/company/gggi_hq)

 [@GGGIMedia](https://www.youtube.com/channel/UCGgIMedia)



Supported by:



on the basis of a decision
by the German Bundestag



3.5 Low Carbon Building Assessment Tools

Updated: August 2025

WHAT WILL YOU LEARN?

**Carbon Assessment
Tools for Buildings**

**Typical Internationally-used
Carbon Assessment Tools: How it
Works and Case Examples**

**ALCBT Building Emission
Assessment Tool (BEAT):
How it Works, Scope and
Benefits**

01

02

03



CARBON ASSESSMENT TOOLS

Analytics for sustainable buildings

Carbon assessment tool provides analytics for:

Assessing
carbon footprint
and reduction
potential

Regulatory
compliances

Achieving
emissions
reduction
targets and
other
sustainability
goals

Increasing
market
competitiveness

Informed
decision-making

CARBON ASSESSMENT TOOLS

Design-integrated tool



- Web-based tool
- Whole life carbon analysis
- Environmental product declaration (EPD) generation
- Licensed access
- Tailored for the construction sector

Source: Carbon Leadership Forum

CARBON ASSESSMENT TOOLS

Calculators

The logo for 'epic.' is displayed in a bold, black, lowercase sans-serif font. A small green square is positioned at the end of the period.

- Web-based tool
- Whole life carbon analysis
- Pre-fed cases
- Comparative energy and material efficiency measures
- Free access



- Embodied Carbon in Construction Calculator
- Access to building material EPDs
- Useful for selection and procurement
- More like a comparison tool
- Focuses on A1-A3 emissions
- Free access

Source: Carbon Leadership Forum

CARBON ASSESSMENT TOOLS

Other life cycle assessment (LCA) tools in construction sector



- Software application for LCA and green building certification
- Free access

BEAT

- Software tool for assessing embodied and operational carbon in the building sector, launched under the ALCBT Project in June 2025.

CARBON ASSESSMENT TOOLS

Other life cycle assessment tools targeting a range of industries: automotive, electronics, agriculture...



thinkstep
GaBi

- Whole life carbon analysis
- Licensed access
- Used mainly by industry professionals

SimaPro

- Paid service
- Whole life carbon analysis
- Used mainly by industry professionals

openLca

- EPD generation
- Free + paid datasets, popular in academia

Source: Carbon Leadership Forum

EC3 TOOL: EMBODIED CARBON CALCULATOR

Life cycle assessment tool

- The Embodied Carbon Calculator EC3 is a free, open-access tool developed by Carbon Leadership Forum and Building Transparency. It covers LCA scope A1 to A3, and has a straightforward, easy-to-use interface for global application
- How:
 - Uses building material quantities from construction estimates (and/or information from BIM/REVIT)
 - Uses transparent, free-to-access database for EC of each material used consisting of **digital, third-party-verified EPDs**
 - This allows the user to directly specify which low carbon material should be procured for construction
- EC3 tool does not have a certification scheme, but helps certification programs, owners and policy-makers assess supply chain data (data granularity)
- EC3 tool is highly specific **to embodied carbon in materials** and this tool is ideal for architects and engineers focused on material choices

Source: Building Transparency

EC3 APPLICATION

Data entry screen

Commercial Building Template (SI) Office 2020-07-10

Project Address
500 Yale Avenue North, Seattle, WA 98109

Map Satellite

INTERBAY QUEEN ANNE Lake Union Capitol Hill Madrona Park Bellevue Square Bellevue

Space Needle Washington Park Arboretum Clyde Hill Medina Bellevue

Seattle

Map data ©2024 Google Terms Report a map error

▶ NOTES & LINKS

BUILDING CLASSIFICATION 23% Complete

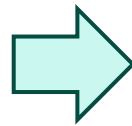
Level of Development
300 : Detailed Design

Material Quantity Source

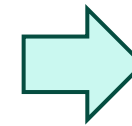
A5 Construction Source

Construction Project Scope

Choose the specific building type and location



Add additional data (floor area, natural gas/electricity consumption, etc.)



Start work in materials in the building

Source: EC3

EC3 APPLICATION

Substructure, shell and interior

NAME	QUANTITY	UNIT	Collection	Selected (1/32)	REALIZED	%
Substructure					10.66K kgCO2e	
Foundations					278.2 kgCO2e	
Concrete Foundations, 5000 psi	1	m3	Ready Mix		276.9 kgCO2e	10...
e.g. Concrete Reinforcing	1	kg	Reinforcing Bar		1.296 kgCO2e	≈ ...
Basement Construction					10.38K kgCO2e	
Shell					14.15K kgCO2e	
Superstructure					7.242K kgCO2e	
e.g. Steel Framing	167	kg	Hot-Rolled Sections		351.3 kgCO2e	5 %
e.g. Steel Columns	1	kg	Hollow Sections		2.621 kgCO2e	≈ ...
e.g. CLT Panels	1	m3	Mass Timber		226 kgCO2e	3 %
e.g. Glulam Beams	1	m3	Mass Timber		226 kgCO2e	3 %
e.g. Metal Floor Decking	1	t	Composite and Form Decks		2.981K kgCO2e	41...
e.g. Metal Roof Decking	1	t	Composite and Form Decks		2.981K kgCO2e	41...
e.g. Concrete Columns	1	m3	Ready Mix		471.8 kgCO2e	7 %
e.g. Concrete Reinforcing at Columns	1	kg	Reinforcing Bar		1.296 kgCO2e	≈ ...
Exterior Enclosure					5.446K kgCO2e	

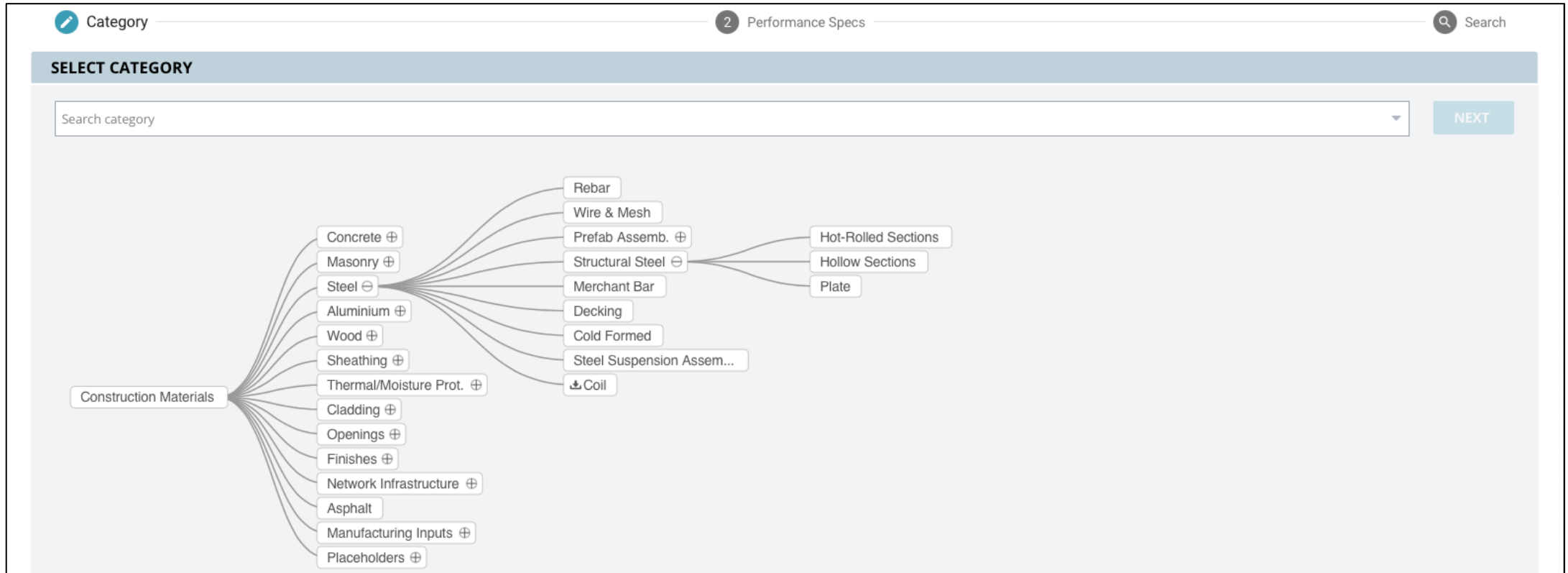
1. Subdivide into: e.g., substructure (foundations), shell (superstructure, exterior enclosure, roofing), and interior (insulation, ceiling tiles, carpet), ...

2. Additional emissions for transport and construction can be added (see tabs at the top). The importance is to know: the quantity of each material and the distance/how materials are transported

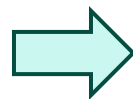
Source: EC3

EC3 APPLICATION

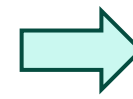
Material workflow



Choose the specific construction material



Choose the specific requirements (e.g., compressive strength), distance from location



Search and compare for relevant EPDs

Source: EC3

EC3 APPLICATION

Find and compare materials

AllMaterials / Steel / Rebar

SEARCH BY PROPERTIES: 03 21 00 REINFORCEMENT BARS

PERFORMANCE SPECIFICATIONS

Yield Tensile Strength \geq Recycled Content \geq Post-Consumer Recycled Content

Steel Rebar Grade Options Compliance

\leq EC3 / 1 kg

Search by performance characteristics

GEOGRAPHIC

Geography Global Distance Search only available in Building Projects

Search by location of manufacturing plant

MORE...

Filter by Manufacturer Group Filter by Product Name

Filter by Product Description Filter by Industry standards Valid after 2022-03-21

Filter by PCR

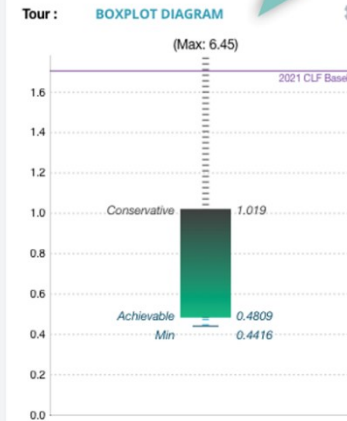
EPD Type Product EPDs Industry EPDs Languages

More specialized search terms

Valid after: 2022-03-21 X and EPD Type: Product EPDs, Industry EPDs X

"Search chips" that show exactly what you're searching. By default, the search is for Product and Industry EPDs valid as of today

kgCO2e embodied per 1 kg



Box/Whisker plot of results

Date on which the EPD needs to be valid (e.g., your construction start)

SEARCH

Image source: <https://docs.buildingtransparency.org/ec3/main-features>

EC3 APPLICATION

Plan and compare buildings

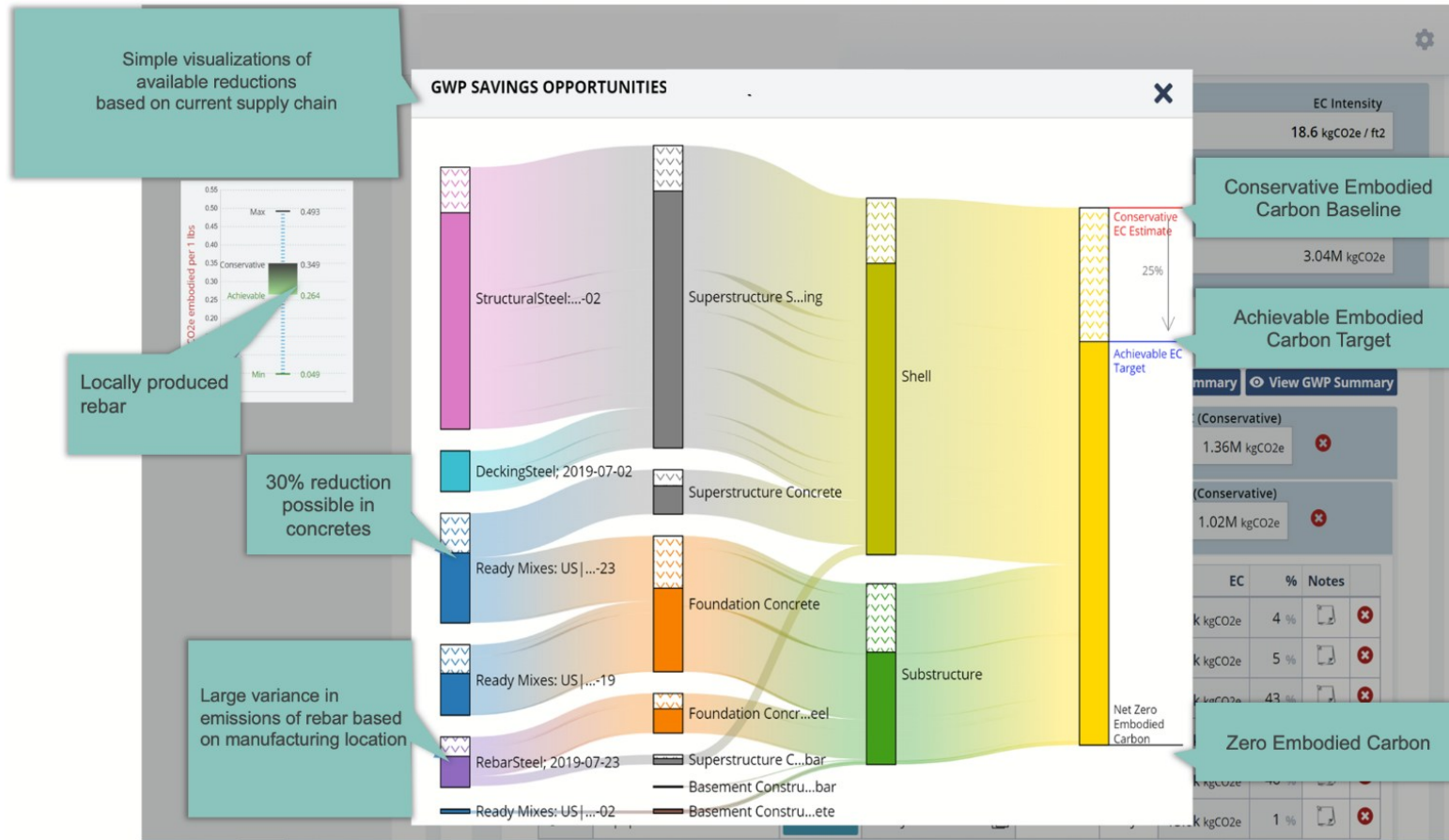


Image source: <https://docs.buildingtransparency.org/ec3/main-features>

EC3 APPLICATION

Results

The screenshot displays the 'FLOOR AREA' section of the EC3 APPLICATION Results. It includes input fields for Gross Floor Area (1k m2), Floor Area Above Grade (1,000 m2), Floors Stories, Weight (250 t), Floor Area Below Grade, and Height. Below this, there are filters for building types A1-A3 (checked), A4, and A5. The 'EC Building Intensity' and 'EC Building Total' are shown with Achievable, Realized, and Conservative values.

FLOOR AREA			
Gross Floor Area	Floor Area Above Grade	Floors Stories	Weight
1k m2	1,000 m2		250 t
	Floor Area Below Grade	Height	

	Achievable	Realized	Conservative
EC Building Intensity	36.3 kgCO2e / m2	51.6 kgCO2e / m2	51.6 kgCO2e / m2
EC Building Total	36.3k kgCO2e	51.6k kgCO2e	51.6k kgCO2e

Navigation and utility buttons: A1-A3, A4, A5, Only Errors, Charts, Reports, Comparisons, Import.

Image source: <https://docs.buildingtransparency.org/ec3/main-features>

EDGE APPLICATION

Life cycle assessment and certification tool

- EDGE is a green building certification system focused on making buildings more resource efficient. An innovation of IFC, a member of the World Bank Group, EDGE empowers emerging markets to scale up resource-efficient buildings in a fast, easy and affordable way
- EDGE enables developers and builders to quickly identify the most cost-effective strategies to reduce energy use, water use and embodied energy in materials. The strategies that are integrated into the project design are verified by an EDGE Auditor and certified by Green Business Certification Inc. (GBCI)
- EDGE is comprised of:
 - EDGE Software – The web-based EDGE App, available for free at edgebuildings.com, allows you to quickly determine the optimum combination of building design strategies for the best return on investment
 - Global Standard – EDGE requires a minimum projected reduction of 20% in energy use, water use and embodied energy in materials as benchmarked against a standard local building
 - Certification System – Certification by GBCI validates your achievements at a modest cost for nearly all building types, both new and existing

Source: US Green Building Council

EDGE APPLICATION

Life cycle assessment tool

- It is a comparative assessment tool, usually used for green building certification
- Based on location, typology and income group, pre-fed base case results are displayed:
 - Final energy usage
 - Final water use
 - Operational carbon
 - Embodied carbon
- The basic sections of the tool are:
 - Building design parameters
 - Energy efficiency measures
 - Water efficiency measures
 - Material efficiency measures
 - Operational energy

Source: EDGE

EDGE APPLICATION

Data entry screen

Apartment Metrics Summary:

Metric	Value	Unit
Subproject Floor Area	1,200.00	m ²
Final Energy Use	440.00	kWh/Month/Apartment
Final Water Use	13.00	m ³ /Month/Apartment
Final Operational CO ₂ Emissions	0.26	tCO ₂ /Month/Apartment
Final Embodied Carbon	549.00	Kg CO ₂ e/m ²

Taskbar: Design | Energy 0.00% | Water 0.00% | Materials 0.00% | Operations

Building Type: Primary Building Type: Apartments, Subtype, Low Income

Location: Country: India, City: Gurugram

Annotations:

- Taskbar displays the results, as per the default case or improved case
- Main parameters requiring user inputs

Source: EDGE

EDGE APPLICATION

Data entry screen

Design | Energy 0.00% | Water 0.00% | Materials 0.00% | Operations

Building Type

Primary Building Type
Apartments

Subtype
Low Income

Location

Country
India

City
Gurugram

Building Type

Primary Building Type

- Homes
- Apartments
- Serviced Apartment
- Hotel
- Resort
- Retail
- Industrial
- Office
- Healthcare
- Education
- Mixed Use

Subtype

- Subsidized/Gap
- Middle
- High

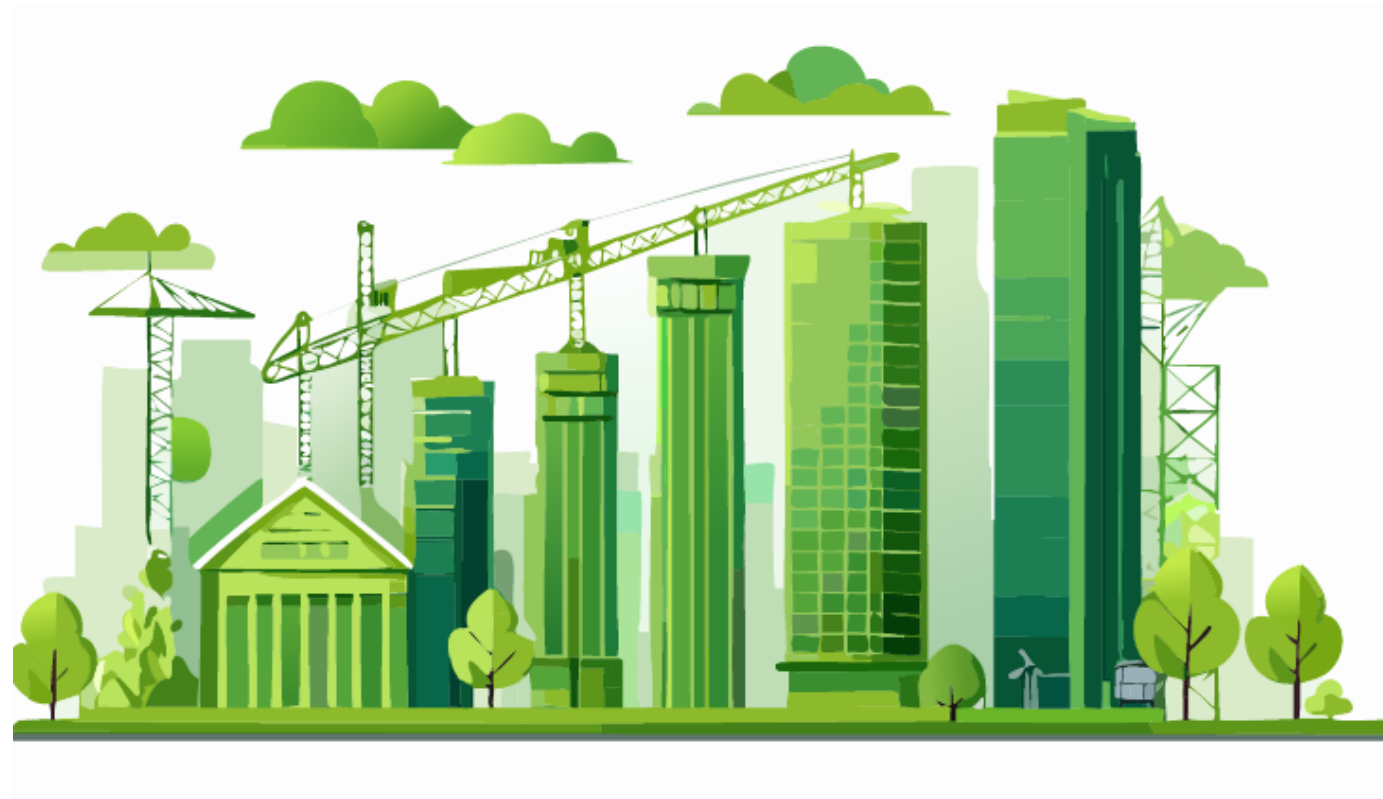
Base case values are governed by choosing building type, income group and location

Source: EDGE

BUILDING DESIGN PARAMETERS

User data entry

- User needs to input basic project details – name, organization, address, etc.
- Building data – number of apartments, floors above and below the grade, floor-to-floor height, etc.
- User can modify the typology according to project-specific details
- Building dimensions – building length in different directions
- HVAC system details
- Area and loads breakdown
- Fuel usage details (emissions factors of fuels can be customized)
- Climate data – elevation, annual rainfall, monthly average temperatures



Source: EDGE

ENERGY EFFICIENCY MEASURES

EDGE: List of measures available

- Air infiltration of envelope
- Natural ventilation
- Ceiling fans
- Cooling system efficiency: COP
- Variable speed drives
- Fresh-air pre-conditioning system
- Space heating system efficiency
- Room heating controls with thermostatic valves
- Domestic hot water system
- Window-to-wall ratio
- Reflective roof: solar reflective index
- Reflective exterior walls: solar reflective index
- Insulation of roof: U-value
- Insulation of ground/raised floor slab: U-value
- Green roof
- Insulation of exterior walls: U-value
- Efficiency of glass: U-value, SHGC, VT
- Domestic hot water pre-heating system
- Economizers
- Demand control ventilation using CO₂ sensors
- Efficient lighting for internal areas
- Efficient lighting for external areas
- Lighting controls
- Efficient appliances
- Efficient smart meters and submeters
- Power factor corrections
- Onsite renewable generation
- Low impact refrigerants
- External shading devices: annual average shading factor

Source: EDGE

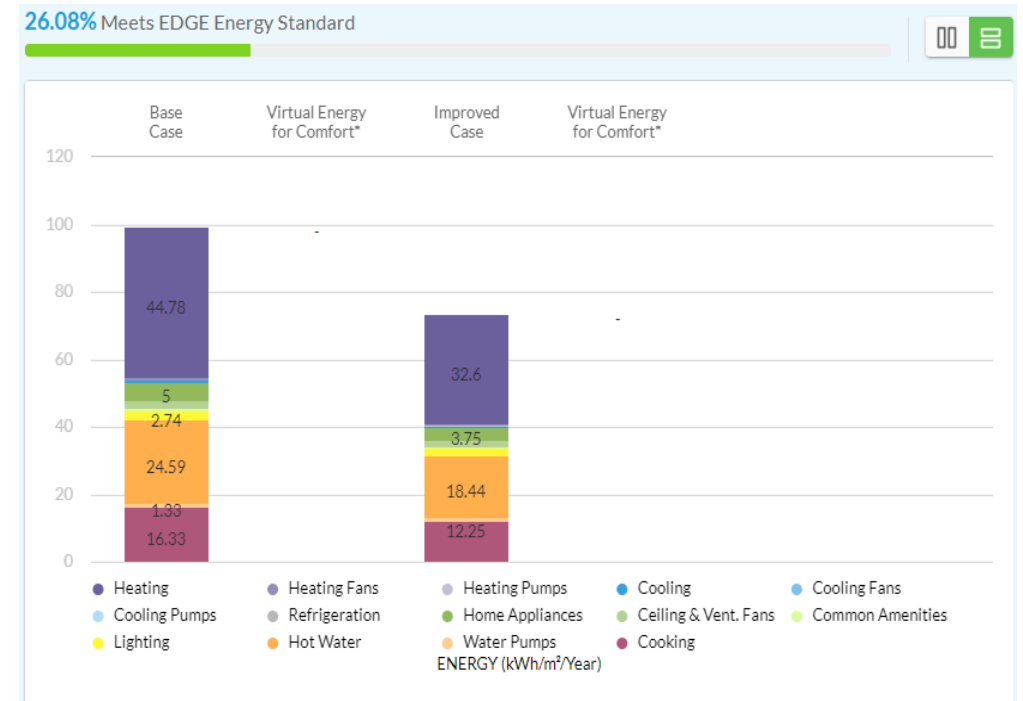
ENERGY EFFICIENCY MEASURES

Comparative analysis

EEM01* Window-to-Wall Ratio: 8%
 Base Case Value: 10%
 WWR (%) WFR

EEM05* Insulation of Roof: U-value 0.27 W/m²·K
 Base Case Value: 0.27 W/m²·K
 U-Value ...

EEM33 Onsite Renewable Energy: 25% of Annual Energy Use
 Base Case: No Onsite Renewable Energy
 Annual E... Annual E...



After choosing some measures, improved case shows the respective changes in the energy numbers

Source: EDGE

MATERIAL EFFICIENCY MEASURES

EDGE: List of measures available

- Bottom floor construction
- Intermediate floor construction
- Floor finish
- Roof construction
- Exterior walls
- Interior walls
- Window frames
- Window glazing
- Roof insulation
- Wall insulation
- Floor insulation

Source: EDGE

MATERIAL EFFICIENCY MEASURES

EDGE: List of measures available

Bottom Floor Construction ⋮

Base Case Material: Concrete Slab | In-situ Reinforced Conventional Slab
Thickness : 100mm & Steel : 35kg/m²
Type 1

Default Base Case Material ▼

MEM01*

Proportion %	Thickness (mm)	Steel Rebar (kg/m ²)
<input type="text" value="100"/>	<input type="text"/>	<input type="text"/>

U-Value (W/m ² ·K)	Embodied Carbon (kg/m ²)
<input type="text" value="0.49"/>	<input type="text"/>



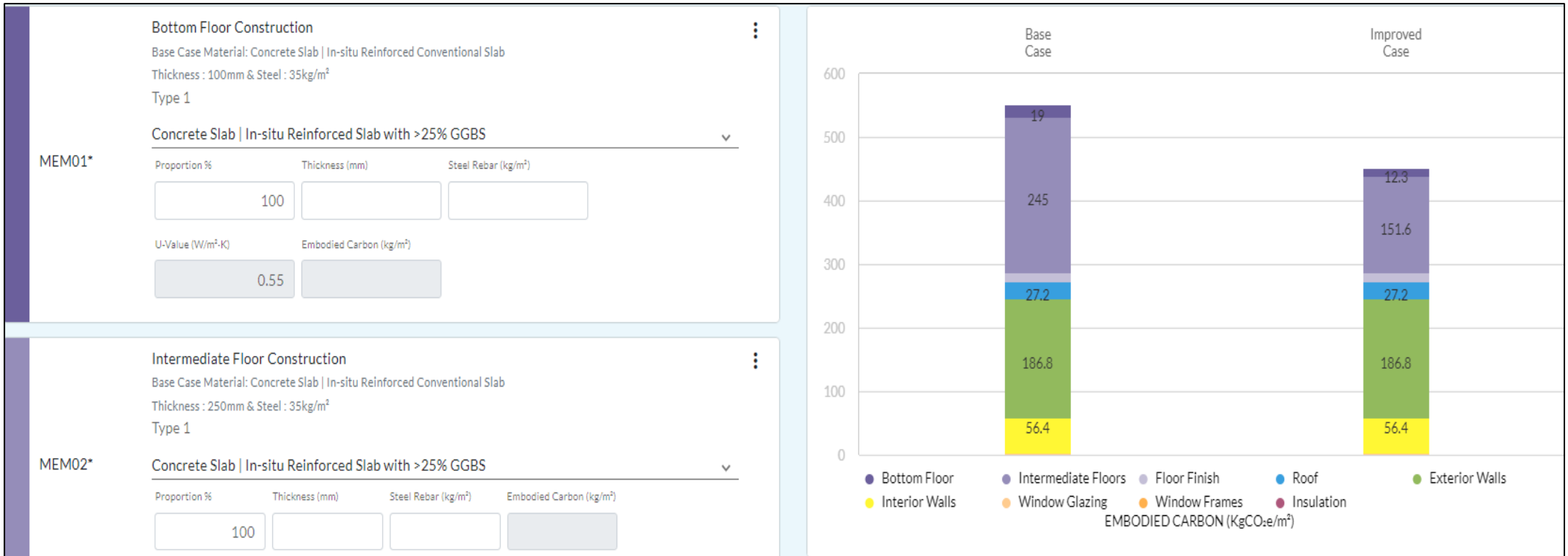
- Default Base Case Material
- X - Re-use of Existing Floorslab
 - Concrete Slab | In-situ Reinforced Conventional Slab
 - Concrete Slab | In-situ Reinforced Slab with >25% GGBS
 - Concrete Slab | In-situ Reinforced Slab with >30% PFA
 - Concrete Slab | Filler Slab
 - Composite Slab | In-situ Concrete over RC Planks and Joist System
 - Concrete Slab | Filler Slab with Polystyrene Blocks
 - Concrete Slab | In-situ Trough Slab
 - Concrete Slab | In-situ Waffle Slab
 - Concrete Precast | Hollow Core Slab
 - Composite Slab | In-situ Concrete on Precast Slim Deck with Embedded I-beam
 - Composite Slab | In-situ Concrete on Corrugated Steel Deck over I-beam
 - Concrete Precast | Double Tee Units
 - Composite Slab | In-situ Concrete over Thin Precast Concrete Deck
 - Timber Floor | Timberboard or Chipboard on Timber Joists
 - Steel Floor | Light-gauge Steel Floor Cassette
 - Customized Material

For every measure, there is a default case available. The user can change it to other available variants, as shown in the drop down menu on the right

Source: EDGE

MATERIAL EFFICIENCY MEASURES

Comparative analysis



After choosing the measures, improved case shows the respective changes in the embodied carbon numbers

Source: EDGE

OPERATIONAL ENERGY

User data entry

- User needs to input energy consumption data for all the months, the energy sources being:
 - Conventional electricity
 - Onsite renewable electricity
 - Offsite renewable electricity
 - Carbon offsets purchased
- For onsite non-renewable energy generation (if applicable), user can input fuel type and fuel consumption values for different months
- Outputs from the tool:
 - Total energy consumption
 - Onsite carbon emissions
 - Carbon mitigation from exported renewable energy
 - Net carbon emissions onsite
 - Total GHG offset
 - Net carbon emissions balance




Source: EDGE

EDGE

Case example: Residential home in Philippines

- Location: Philippines
- Energy measures: Window-to-wall ratio, LED lighting, solar photovoltaics
- Material measures: Corrugated zinc sheets for roof, in-situ reinforced wall for external walls, ferrocement wall panel for internal walls

GHG reductions: 0.4 tCO₂/year/home

SOLUTIONS		SAVINGS
Energy  <ul style="list-style-type: none"> ▶ Reduced Window to Wall Ratio ▶ LED Lighting ▶ Solar Photovoltaics 		42%
Water  <ul style="list-style-type: none"> ▶ Low-Flow Showerheads ▶ Low-Flow Faucets for Kitchen Sinks ▶ Low-Flow Faucets for Washbasins 		20%
Materials  <ul style="list-style-type: none"> ▶ Corrugated Zinc Sheets for Roof ▶ In-Situ Reinforced Wall for External Walls ▶ Ferrocement Wall Panel for Internal Walls 		26%
RESULTS		
Savings Utility Bills (\$/month/home) Energy (kWh/month/home) Water (kL/month/home) Embodied Energy (MJ/home)		11 135 2.4 1,320
Environmental Benefits GHG Reductions (tCO ₂ /year/home)		0.4




Source: EDGE

EDGE

Case example: Commercial building in Mexico

- Location: Mexico
- Energy measures: Window-to-wall ratio, external shading, AC with water-cooled chiller, low E-coated glass, energy efficient lighting system, insulation of roof and wall
- Material measures: Concrete filler slab for floors and roof, medium-weight hollow concrete blocks, finished concrete flooring, uPVC window frames

GHG reductions: 497 tCO₂/year

SOLUTIONS	SAVINGS
Energy  <ul style="list-style-type: none"> ▶ Reduced Window to Wall Ratio ▶ External Shading ▶ Air Conditioning with Water-Cooled Chiller ▶ Low-E Coated Glass ▶ Energy-efficient Lighting System ▶ Insulation of Roof and Wall 	51%
Water  <ul style="list-style-type: none"> ▶ Low-Flow Showerheads ▶ Dual Flush Water Closets ▶ Water-efficient Urinals 	32%
Materials  <ul style="list-style-type: none"> ▶ Concrete Filler Slab for Floors and Roof ▶ Medium-weight Hollow Concrete Blocks ▶ Finished Concrete Flooring ▶ uPVC Window Frames 	44%
RESULTS	
Extra Costs & Payback Time Green Solutions (\$)	56,000
Payback (Yrs.)	0.6
Savings Utility Bills (\$/month)	7,634
Energy (kWh/month)	90,028
Water (lt./room/night)	121
Embodied Energy (MJ/m ²)	744
Environmental Benefits GHG Savings (tCO ₂ /year)	497

Source: EDGE

EDGE

Case example: Unlocking green buildings market for banks

- ProCredit is an international group of development-oriented commercial banks mainly active in South-Eastern and Eastern Europe
- ProCredit has been interested and engaged in financing green buildings for years but has had to develop an individual assessment approach for each country. This approach has posed a serious challenge due to the substantial additional workload involved, coupled with the difficulty of obtaining relevant information
- The group launched its first green loans in 2006 and gradually developed a green lending methodology and a green bonds framework to standardize its lending process and ensure specific environmental impacts are achieved. As of the end of 2020, the group's green loan portfolio amounted to almost EUR1 billion, representing 19% of its total loan portfolio
- Initially, the group has assessed green buildings against country baselines and according to country building codes. The process is intensive and often difficult to implement, owing to a lack of data or proper regulation in its countries of operation
- The situation changed when ProCredit integrated EDGE into the environmental impact assessments carried out for the head offices of its banks, where the benefits of EDGE were apparent: user-friendly application, availability of data, the possibility of preliminary assessment and recognized certification

Source: Polychroniadou, 2021

EDGE

Case example: Unlocking green buildings market for banks (continued)

- ProCredit decided to promote this certification further in its markets by using it as a tool in the assessment process for green buildings. The banks can now use EDGE instead of conducting individual analyses for the purpose of assessing a building's eligibility for a green loan
- ProCredit proposes conducting a preliminary assessment using the EDGE app to make an initial determination whether the project has potential for improved performance of 20% compared to the local baseline. This is done in partnership with Sintali-SGS, who offers EDGE Expert support through its partner network. EDGE Experts provide support in using the application and conducting initial analyses of ProCredit clients' projects
- This assessment is then submitted to the business committee of the bank for review and if approved, the client can benefit from preferential loan rates for the development of the green building project. A further requirement to be eligible for these loan rates is the actual completion of the EDGE certification process
- The use of EDGE data to define eligibility criteria enables the ProCredit banks to have a standardized and comparable approach across its markets, thus unlocking significant potential for building improvement and green finance. It also reduces the time required to conduct an initial eligibility analysis, as local baselines have already been calculated in the EDGE app
- By implementing green lending programs and leading by example through the certification of its own buildings, ProCredit is putting sustainability into action

Source: Polychroniadou, 2021

EC3 AND EDGE TOOLS

Comparison: Easy-to-use tools with different visions



Not a Certification Scheme

- Focuses on construction materials
- Uses EPDs
- Compares individual materials to be procured
- Ideal for architects and engineers focused on material choices



**Perspectives:
Granular Value Chain of
Products (EC3) vs
Financing/Policy
(EDGE)**



**Current Focus:
Developed Countries
(EC3) vs Developing
Countries (EDGE)**



Certification Scheme

- Financial calculator
- Simplified compliance
- Reduced processing
- Cost effective
- Better suited for broader assessments and policy-making

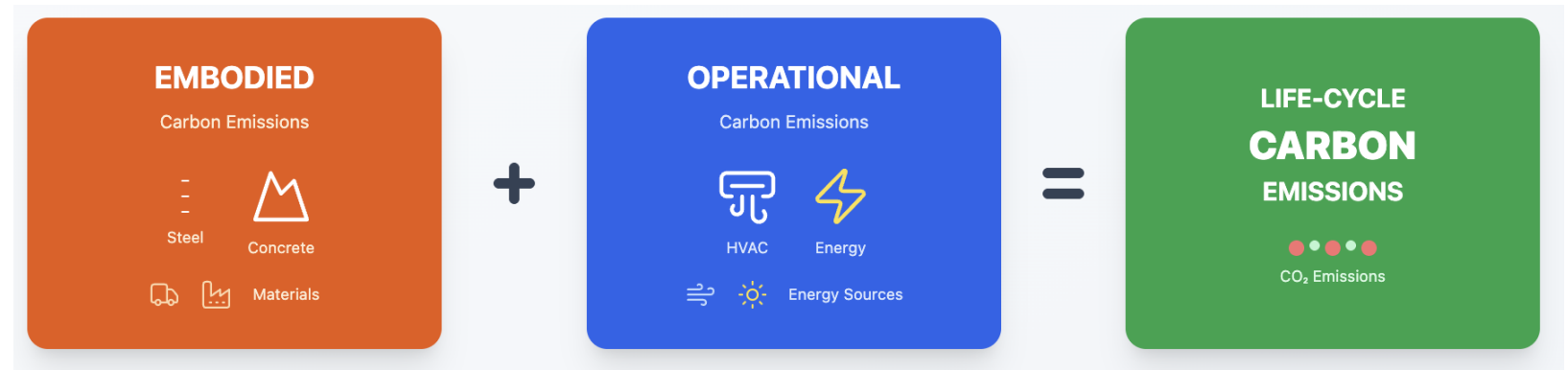
BEAT (Building Emission Assessment Tool)

Developed under the ALCBT Project

An easy-to-use **interactive tool** designed to help you **calculate your buildings carbon emissions** and make **informed decisions toward a low-carbon transition**.

Key Benefits

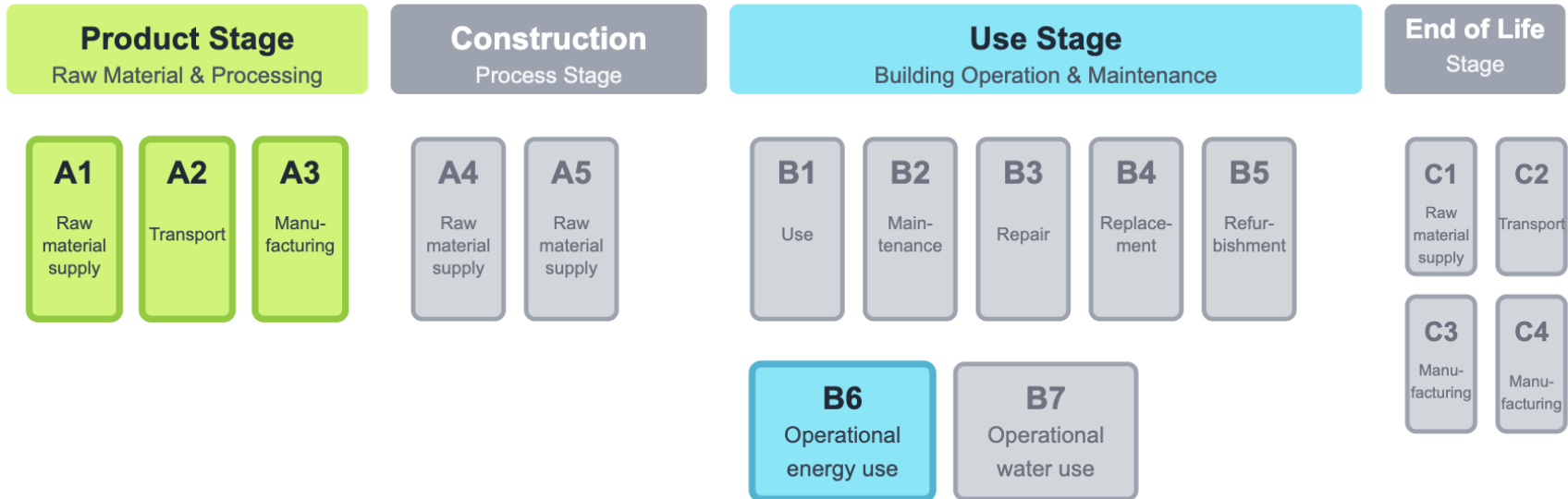
- Tailored to Asia's fast-growing building markets
- Supports national GHG inventories and climate targets
- Measures full building emissions by **quantifying both embodied and operational carbon**
- Enables **low-carbon investment decision-making**
- Fills data gaps with innovative **EPD-based methods**
- Promotes **transparency** in building-related emissions



Embodied Emissions:
Assess emissions from manufacturing, transport and installation of building materials.

Operational Emissions:
Calculate energy consumption during building operation.

Building Life Cycle Information

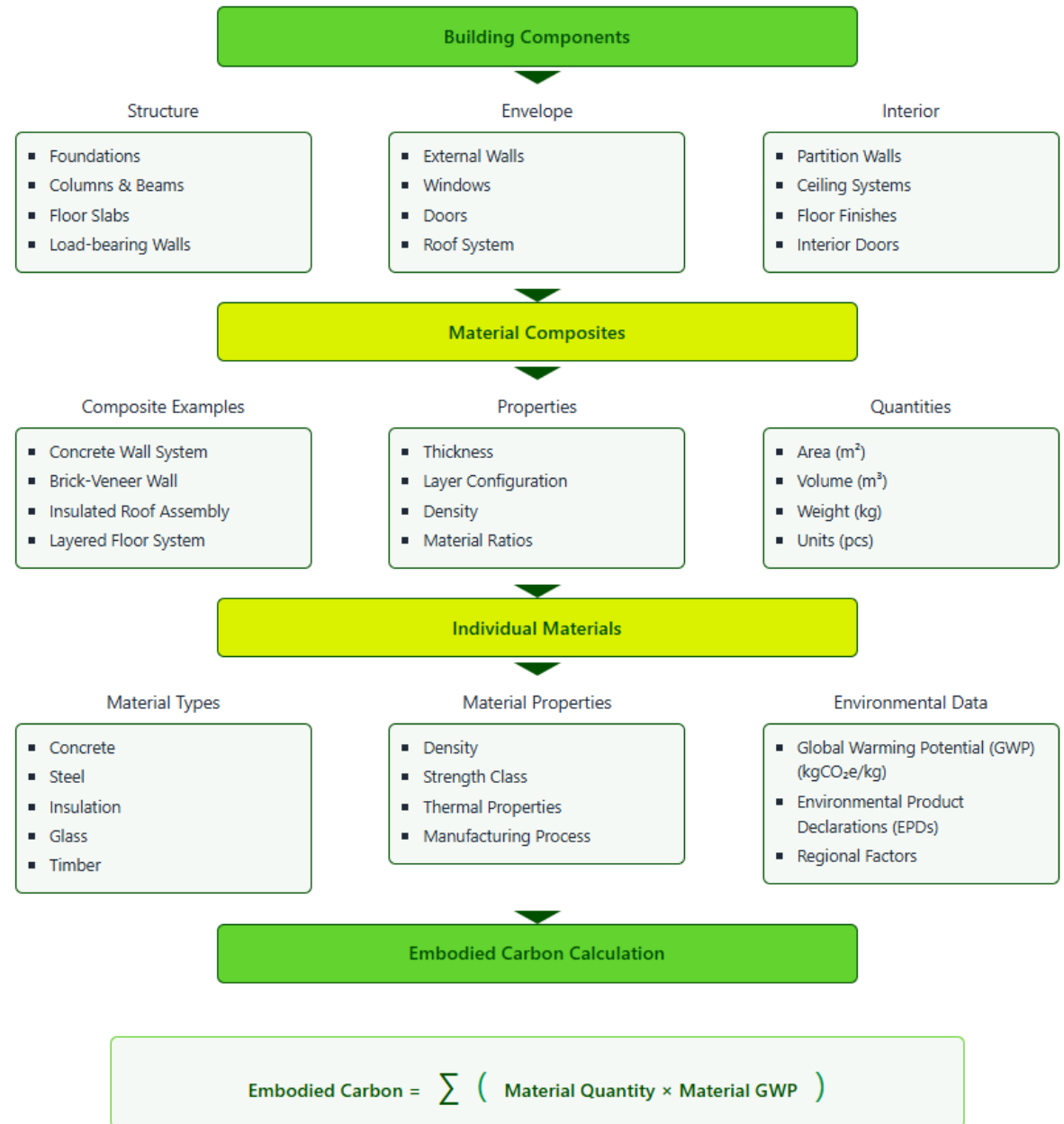


Legend: Modules covered by BEAT

■ Product Stage ■ Use Stage

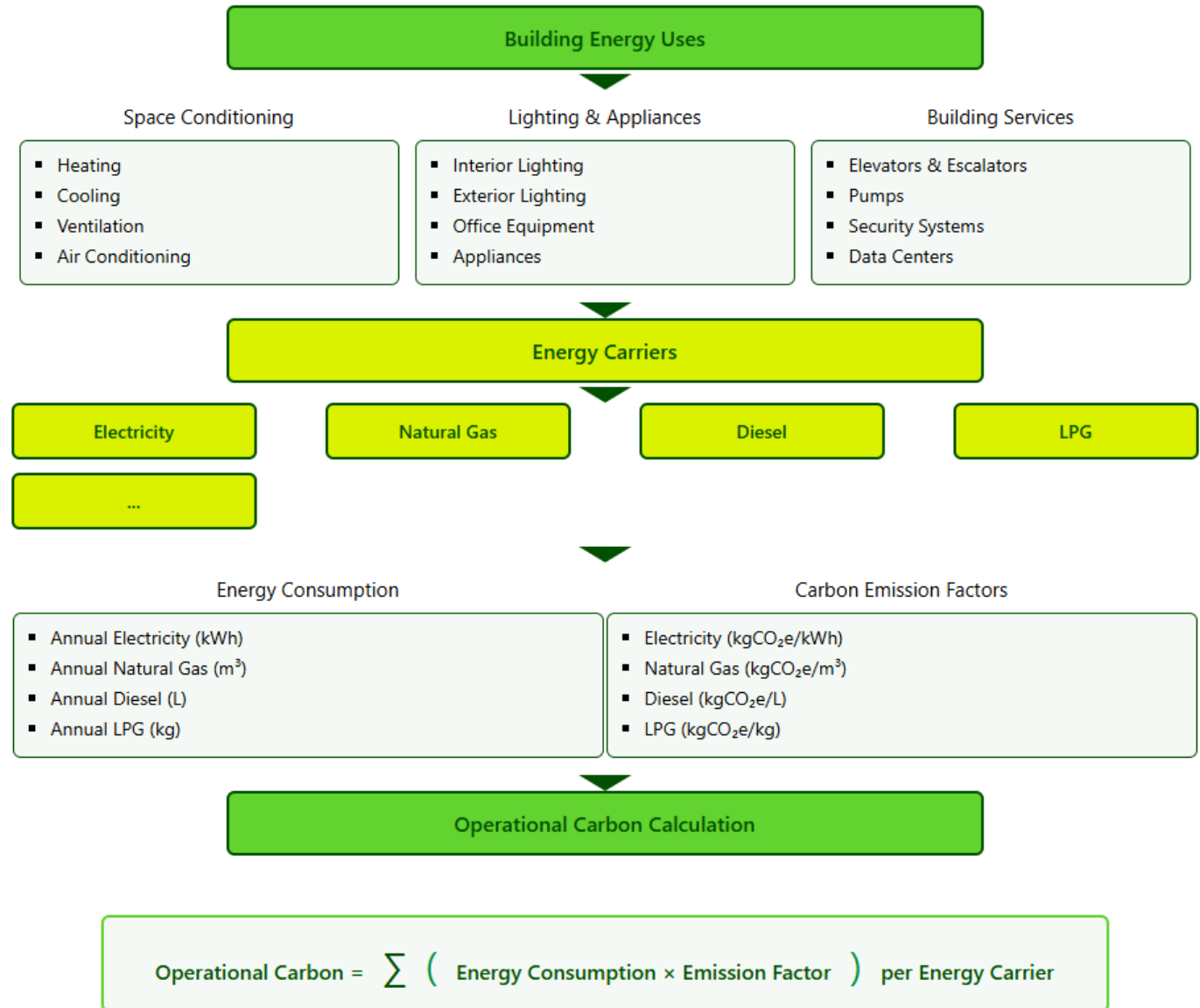
BEAT Methodology

How BEAT Calculates Embodied Carbon



BEAT Methodology

How BEAT Calculates Operational Carbon



Environmental Product Declaration (EPD)

Example: 1 m³ Construction concrete C20/25 (Germany)



<https://epd-online.com/EmbeddedEpdList/Download/8773>



BEAT Builds on Three Types of EPDs

1 Official EPDs (Highest Quality)

- Third-party verified and published in recognized databases
- Sources: ÖKOBAUDAT, ECO Platform, Asian National EPD Platforms

2 Generic EPDs (Gap-Filling Solutions)

- Industry-average data when official EPDs are unavailable
- Maintains data quality standards for comprehensive coverage

3 Custom EPDs (Future Feature)

- EPDs in process of national certification – complies with recognized standards but not yet officially certified at national levels
- Not available in national or international EPD databases – BEAT facilitates national certification process

BEAT

Status Quo of Available EPDs in ALCBT Countries

Cambodia	1
India	242
Indonesia	34
Thailand	27
Vietnam	38
Reference	
Germany	2,697

Solution: Three Tier Approach



Use official EPDs when available

Leverage existing verified data



Apply generic EPDs as placeholders

Ensure comprehensive coverage



Enable custom EPDs for future locally certified EPDs

Support national database development

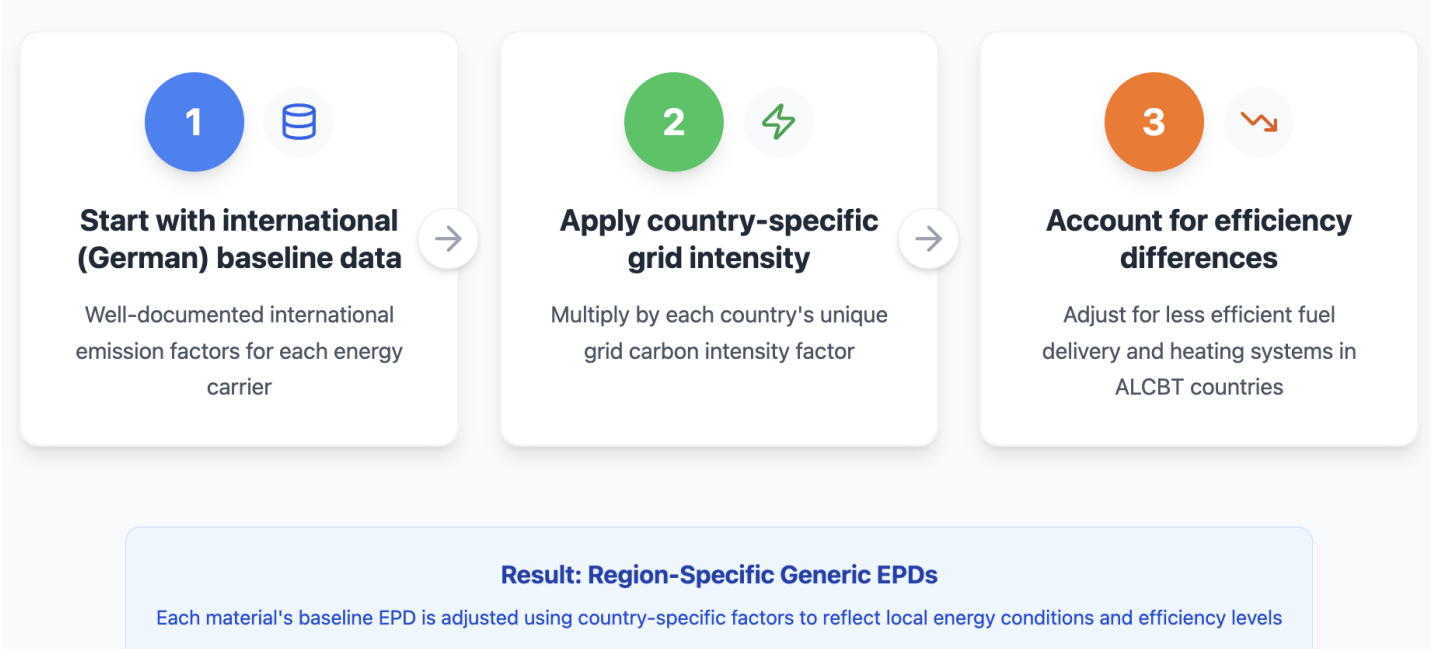
Goal: Complete coverage with increasing accuracy

As local data develops, transition from generic to official EPDs for improved regional accuracy

Encouragement

Local governments and industry to develop region-specific EPD datasets

Interim Step: Generic EPDs



Generic EPD Adjustment Factors: Grid Intensity and Energy Intensity Data Combined to Create Country-Specific EPD Adjustment Factors

Country	Grid Intensity (kgCO ₂ e/kWh)	Energy Intensity (kg oil ₃ /1000\$)	Final EPD Adjustment
International (German) Baseline	0.42 100%	82 100%	100%
Cambodia	0.42 99%	142.5 174%	173%
India	0.71 168%	134.5 164%	275%
Indonesia	0.68 161%	118.9 145%	233%
Thailand	0.56 133%	98.7 120%	161%
Vietnam	0.41 98%	85.6 104%	102%

Source: <https://ourworldindata.org/grapher/carbon-intensity-electricity?tab=table>

BEAT

Value Addition:
FREE
ACCESSIBLE
OPEN SOURCE

Feature	BEAT ★	One Click LCA	SimaPro	EDGE v3
 Cost & Access Cost & Accessibility	✓ Free & open access	✗ Paid license	✗ Paid license	✓ Free access
 Carbon Assessment Embodied Carbon Assessment	✓ Full assessment	✓ Full assessment	✓ Full assessment	⚠ Partial coverage - structural elements limited
 Data Sources Environmental Product Declarations	✓ Open EPD database with generic options	✓ Licensed global EPDs	✓ Licensed global EPDs	⚠ Limited transparency in data sources
 Operations Operational Carbon Assessment	⚠ Current: electricity bills analysis. Future: appliance efficiency	✓ Full energy modeling	✓ LCA-based energy impact	✓ Energy savings estimation
 Regional Data Local Building Dataset & Benchmarks	✓ 200-250 ALCBT buildings with local benchmarks	⚠ Limited ALCBT coverage	✗ Academic focus, no project dataset	⚠ Limited public project data
 Transparency Data Transparency	✓ Full emission factor traceability	✗ Static, non-editable coefficients	⚠ Proprietary database	⚠ Proprietary methodology

BEAT

Adopts GCCA Concrete Labels



GCCA EPD labels define performance benchmarks and provide verified data to assess embodied carbon in cement and concrete.

- **Every concrete EPD in BEAT** automatically receives GCCA band (A-G)
- Band A (excellent) to Band G (high carbon)
- **BEAT** plans to adopt similar labels to assist users in comparing EPDs for other building materials such as steel

Benefits:

- **For Users:** Instant product comparison
- **For Industry:** Market differentiation & drive low-carbon products demand

The screenshot shows the 'EPD Library' interface with a search bar and a list of products. Each product entry includes the product name, origin (India), material type, unit, carbon footprint (kgCO2e), and a GCCA label (A-G). The products listed are:

Product Name	Origin	Material Type	Unit	Carbon Footprint (kgCO2e)	GCCA Label	Action
JSW M 25 Ready Mixed Concrete (RMC)	India	Ready mixed concrete	m3	171	C	Add
Dense concrete block	India	Precast concrete elements and goods	kg	0.16		Add
JSW M 40 Ready Mixed Concrete (RMC)	India	Ready mixed concrete	m3	256	D	Add
Ready mix concrete with ordinary Portland cement (OPC)	India	Ready mixed concrete	kg	0.11		Add
Lightweight concrete block	India	Light concrete	kg	0.37		Add

At the bottom of the interface, there is a pagination control showing 'Start', '1', '2', '3', 'End' with '1' selected.

BEAT

Inputting Data Requirements

<https://BEAT-ALCBT.GGGI.ORG>



Building Information

Data Category	Required Information	Example
Basic Identification	Building name, ID, location, year of construction	Office Tower A, Jakarta, 2018
Building Type	Primary use/classification	Office (Grade B), Residential, Hospital
Building Size	Gross floor area, number of floors (above/below ground)	10,000 m ² , 15 floors above + 2 basement
Climate	Climate zone, location coordinates	Tropical wet, -6.2088° S, 106.8456° E
Occupancy	Typical occupancy patterns	9am-6pm weekdays, 20% weekends

Note: Building information forms the foundation for all carbon calculations. Complete and accurate basic data ensures proper benchmarking against similar buildings.

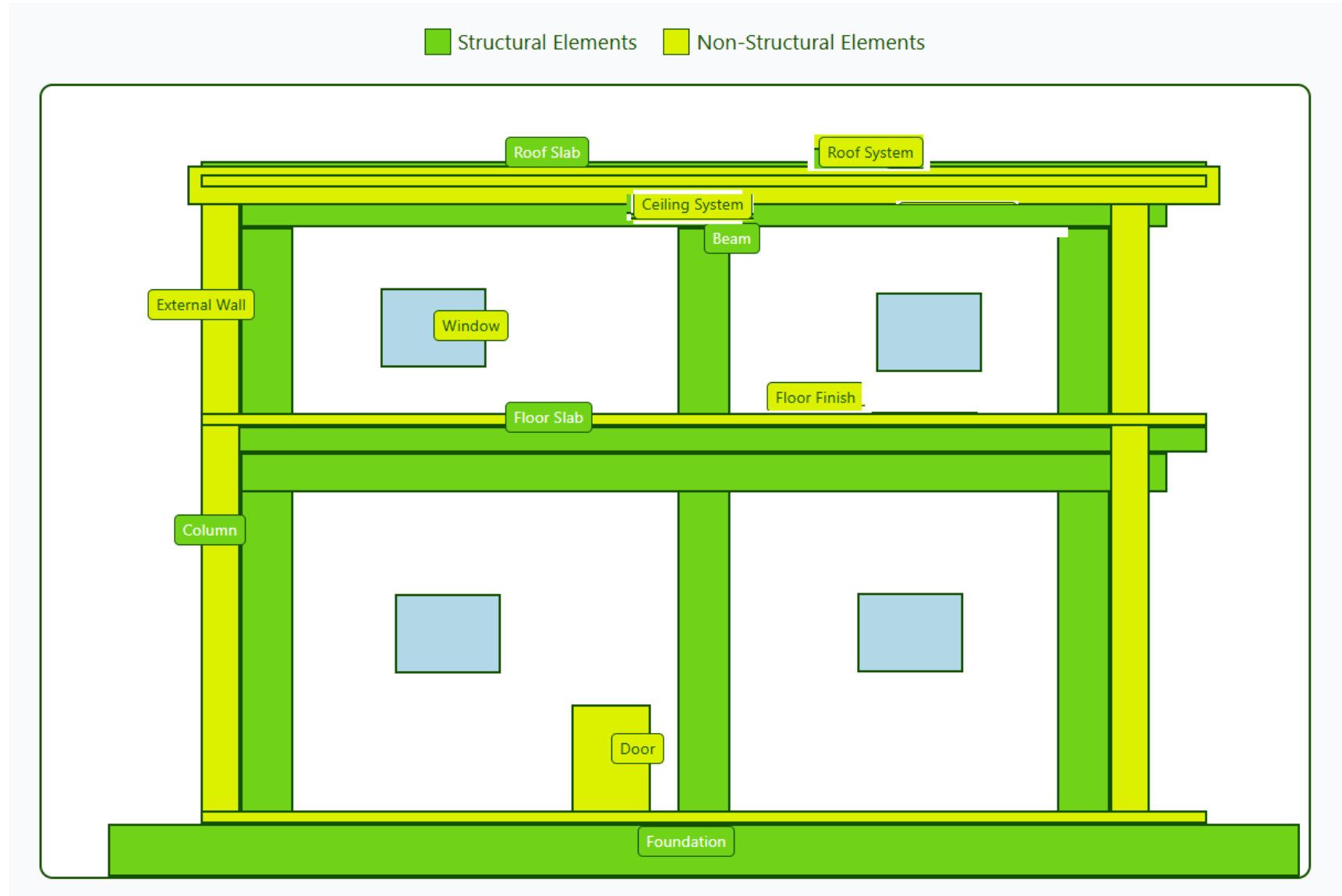
Operational Information

Data Category	Required Information	Units
Electricity Consumption	Annual electricity usage	kWh/year
Fuel Consumption	Natural gas, diesel, LPG usage	m ³ /year, L/year, kg/year
HVAC Systems	System type, capacity, efficiency	Type, kW, COP/EER
Lighting	Lighting system, lighting capacity	Type, kW
Comfort Parameters	Heating/cooling temperature setpoints	°C

Note: Operational data should ideally be based on actual measurements for existing buildings or detailed energy modeling for new buildings. Include at least 12 months of data when available.

BEAT

Building Components Evaluated



Material Quantities

Measurement Type	Material Type	Unit
Volume (m ³)	Concrete (foundations, columns, beams, slabs)	m ³
	Insulation materials	m ³
Mass (kg/tons)	Steel reinforcement	tons
	Structural steel	tons
	Aluminum (windows, facade)	kg
	Glass	kg
Area (m ²)	External walls, facades	m ²
	Windows, glazing	m ²
	Floor/wall/ceiling finishes	m ²
Length (m)	Railings	m

Note: Material quantities should be extracted from the Bill of Quantities (BoQ) or calculated from architectural and structural drawings. Include materials that contribute significantly to the building's carbon footprint.

BEAT Quality Data Requirements

For accurate embodied carbon assessment, all quantities must include:

Material Type	Quantity	Unit Measure	Building Component
JSW M30 Concrete	150	m ³	Foundation
Tata Steel Fe500 TMT	1	ton	Column
Penetron Seal Coat	5	kg	
Aluminium door	2	pieces	

All material quantities must be specified with precise measurement units and building component allocation for accurate carbon assessment

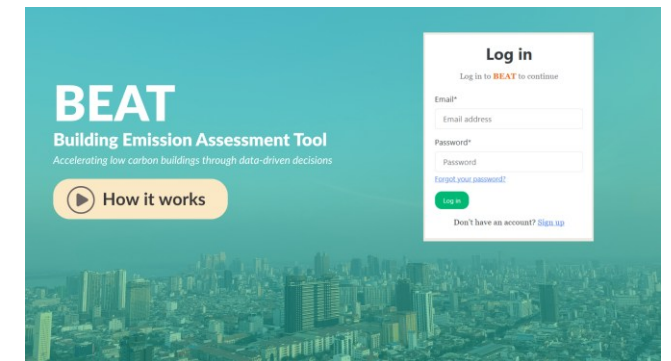
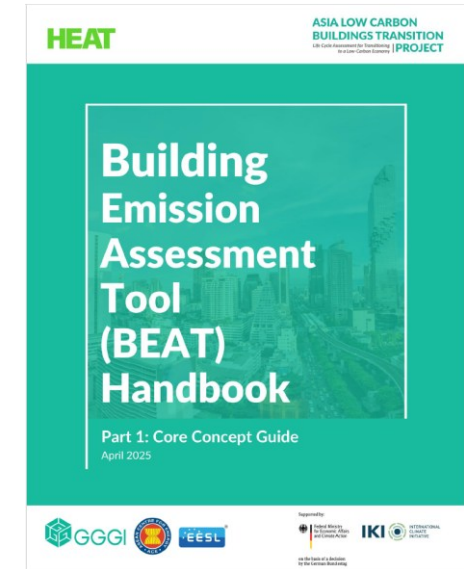
BEAT

Understanding Results

From 1 sample building in India

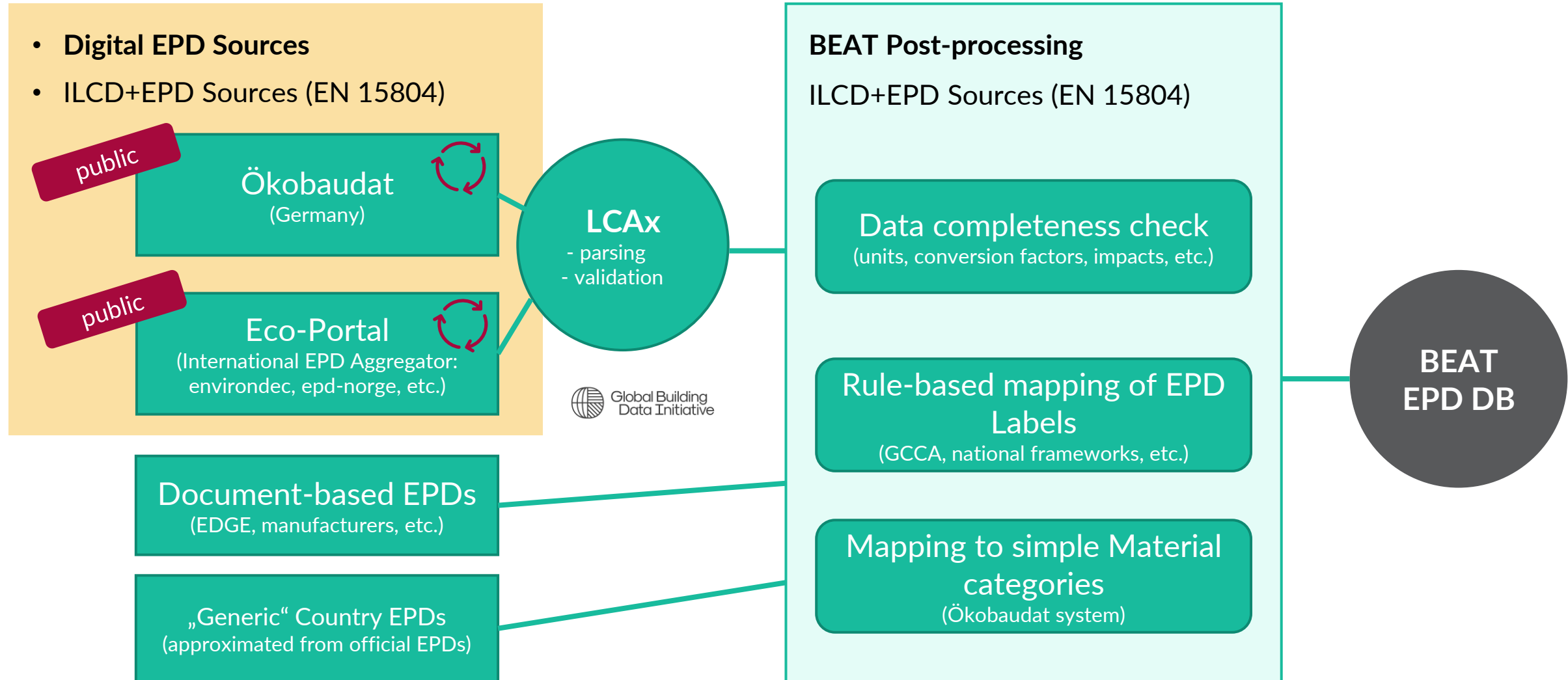
- 1. Material Carbon Hotspots:** BEAT identifies biggest carbon contributors: (e.g. Ready-mix concrete & cement: 35%, Steel: 18%, Rebar: 12%...)
Value: Target high-impact materials first
- 2. Building Element Breakdown:** BEAT shows carbon by elements: (e.g. Exterior walls: 31.7%, Foundations: 22.2%, Staircases & ramps: 12.4%...)
Value: Optimize design where it matters most
- 3. Complete Carbon Picture:** BEAT provides full lifecycle view: Total: 983 kg CO₂eq/m² (Embodied: 463 kg CO₂eq/m² (47%) & Operational: 520 kg CO₂eq/m² (53%))
Value: See both material and energy impacts
- 4. Regional Benchmarking:** BEAT enables performance comparison: Country-specific benchmarks and Clear performance indicators with Visual comparison tools
Value: Know where you stand vs. regional standards
- 5. Optimization Potential:** BEAT quantifies possible savings: (Current: 983 kg CO₂eq/m², Optimized: 778 kg CO₂eq/m²) Total reduction: 20.9%
Value: See exactly what's achievable
- 6. Strategic Insights:** BEAT transforms decision-making: Data-driven material choices, Science-based targets, Investment justification, Progress tracking
Value: Turn carbon data into competitive advantage

The BEAT website provides a handbook and video tutorial:
<https://beat-alcbt.gggi.org>



BEAT

Data Quality

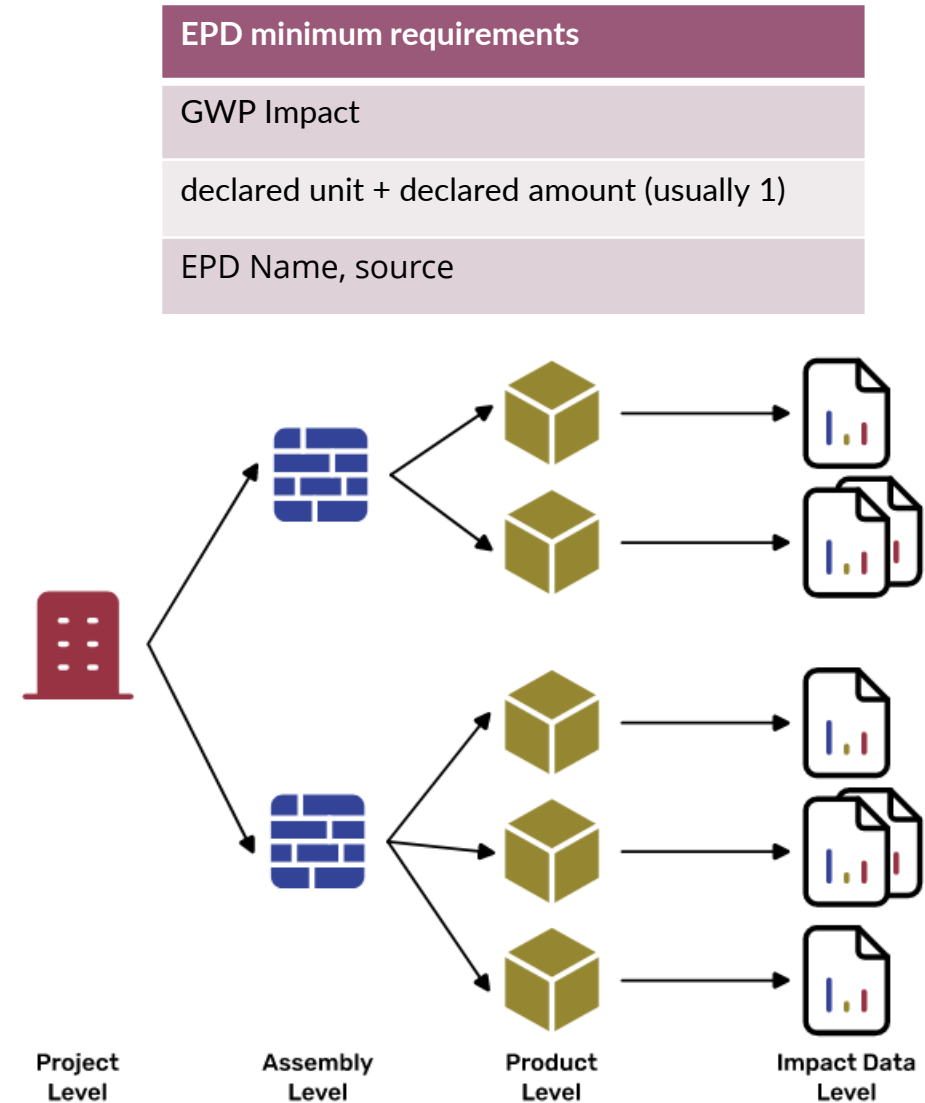


BEAT

Data Sharing Protocols

- BEAT closely follows the structured LCAx format, to define **buildings, assemblies, and EPDs**.
- **Import of EPD Data**
 - Parsing of ILCD+EPD format
 - Easily integrate other formats: BEAT only has minimal EPD requirements, allowing import from Document-based EPDs and national sources
- **Export of Data**
 - Export EPDs as Excel
 - Potential export of assemblies and buildings (e.g. LCAbyg)

Source: LCAx Website, <https://docs.lcax.org/concept/data-structure>



BEAT

Design Principles and Functions

✓ Ready:

User Management

Embodied Carbon Assessment

EPD Database

Custom Structural Elements

Generic EPDs

Operational Carbon

🕒 In Progress:

Reuse of Customised Materials

Excel Import & Reports

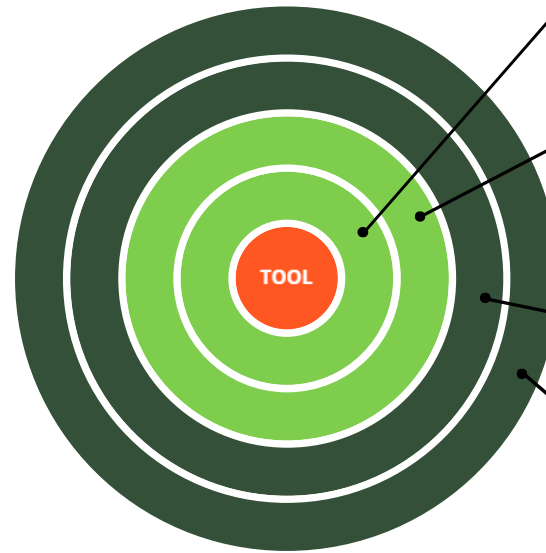
Benchmarking View

Language Translation

📅 Planned:

Carbon Optimisation & Potential Savings

Advanced analytics for carbon reduction recommendations



Modular structure

Allows for updates and expansion

Comprehensive built-in material and EPD database and interface

Adaptive functionality

Accommodates limited data availability in certain regions

Full transparency

In calculations and data sources to ensure credibility and trust

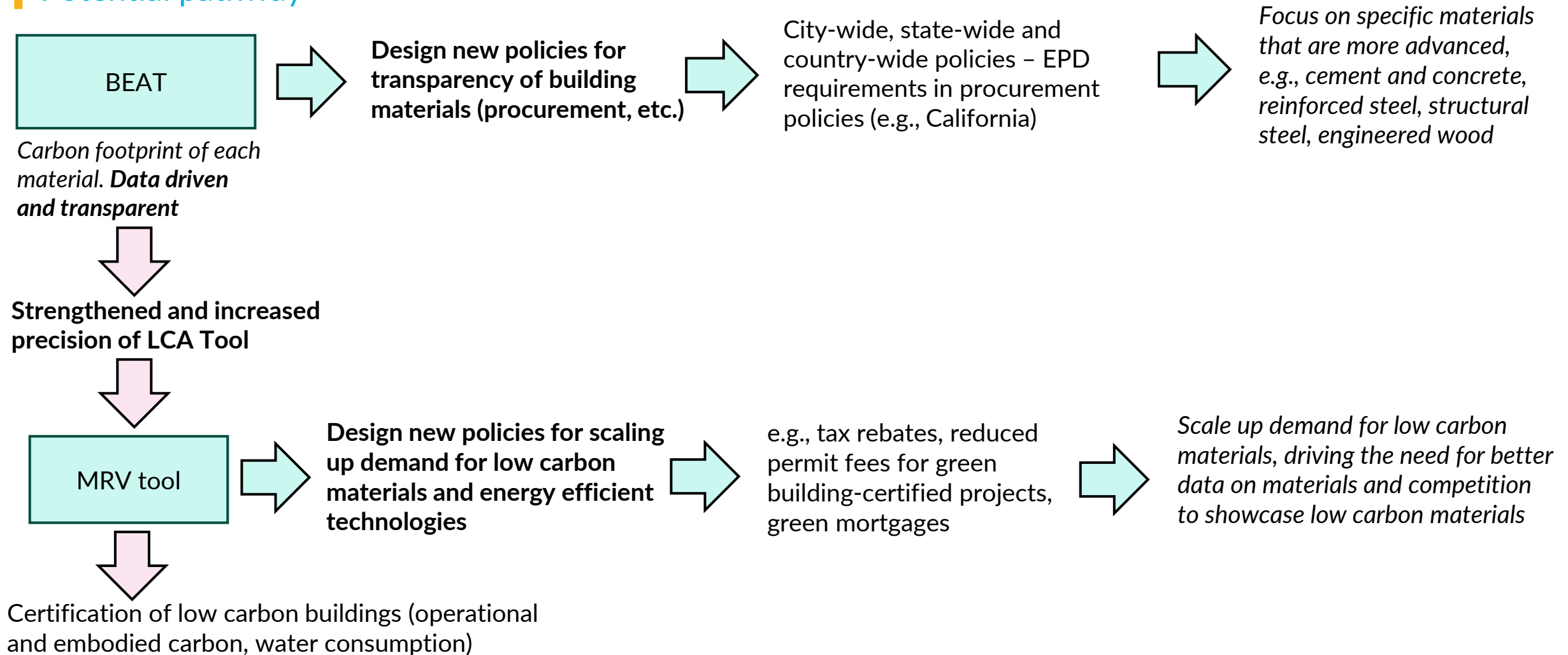
MRV CONCEPTS

Distinction between MRV Tool and BEAT

- BEAT helps to **create a baseline for a building stock** from ALCBT countries. This will help to feed in entry data for the monitoring, reporting and verification (MRV) tool.
- The MRV tool **calculates or estimates emissions under different future scenarios** by allowing users to change selected factors that impact projected emissions from the building sector at given time periods, including any significant actions such as regulations and policies, or introduction of efficient and low carbon solutions at specific periods, alone or in combination.
- The MRV tool supports large-scale modeling of buildings, building populations, and future pathways, scenarios and baselines. **This tool enables policy-makers to set national targets in NDCs and LT-LEDS.**
- BEAT can provide both quick and detailed modeling of whole life carbon of a building. This tool helps to define baselines for city- and country-specific buildings, and design new policies for scaling up the demand for low carbon materials and energy efficient technologies.

SCALING UP BUILDING LCA

Potential pathway



Thank you!

For more information, visit us at <https://ALCBT.GGGI.ORG>
or scan the QR code below



IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at <https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/>.

 www.gggi.org

 [@gggi_hq](https://twitter.com/gggi_hq)

 [@GGGIHQ](https://www.instagram.com/gggi_hq)

 [@GGGIHQ](https://www.facebook.com/gggi_hq)

 [@gggi_hq](https://www.linkedin.com/company/gggi_hq)

 [@GGGIMedia](https://www.youtube.com/channel/UCGgIMedia)



Supported by:



on the basis of a decision
by the German Bundestag