DynamicRenowave - Life Cycle Assessment and Energy Simulation of Building Renovation Strategies

Building Carbon Emissions Modeling Framework

Online Webinar 2 on 29 May 2024

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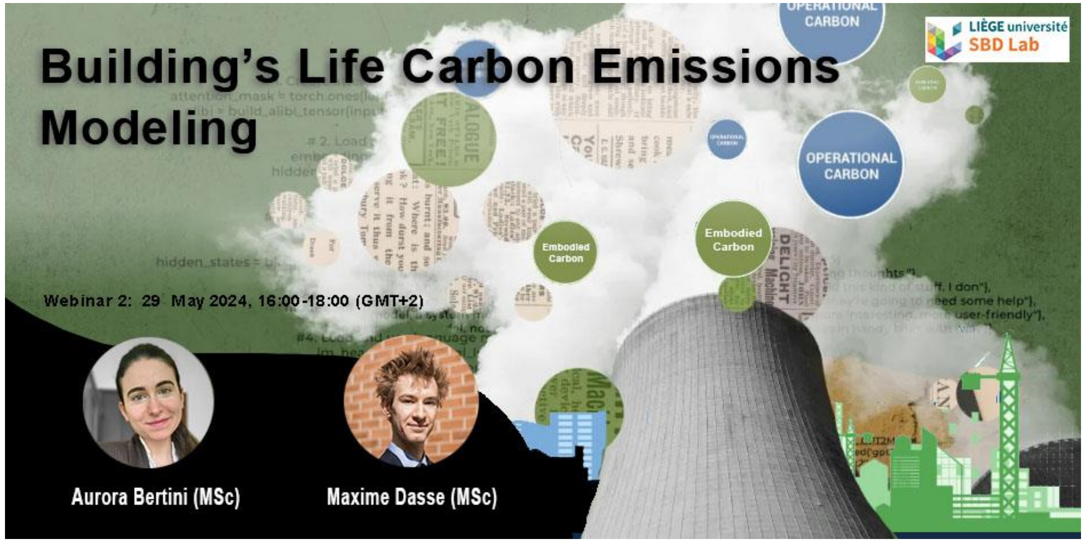

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DynamicRenowave - Life Cycle Assessment and Energy Simulation of Building Renovation Strategies

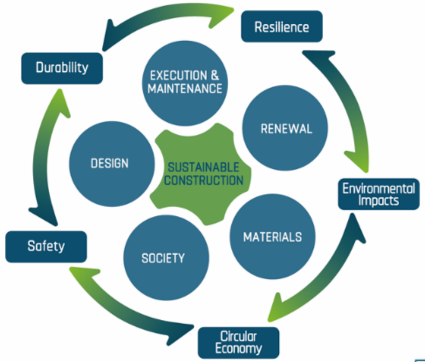
Building Carbon Emissions Modeling Framework

To realise these gains the industry needs to work together

GLOBE

Global consensus on sustainability in the built environment

- High level policy advice
- More than 150 nations
- 5000+ experts
- 50+ years of expert networks
- Standards and guidelines
- Research and education
- Innovation



www.globe-consensus.com

See on-line presentation from COP28 for more details

rilem
fib CEB-FIP
cib
ECCS CECM EKS
IABSE

Building Carbon Emissions Modeling Framework

Objective 1: Define a common performance-based simulation framework for a multi-scale (from a single building to whole building stocks), multi-sectoral (i.e. lifecycle-based), and multi-stakeholder approach to decarbonizing the building and real estate sector.

Objective 2: Publish the (Liege-Aarhus) framework by June 2024

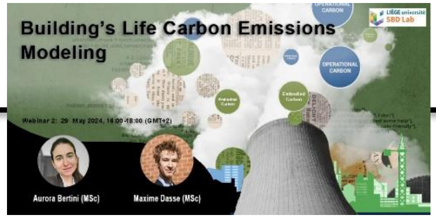
Objective 3: Define a common benchmark

Timeline:

24 April 2024

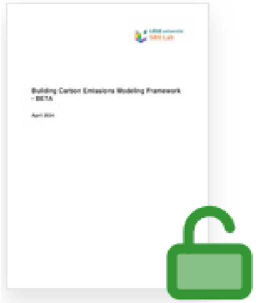
Building Carbon Emissions Modeling Framework (Webinar 1)

29 May 2024



Building Carbon Emissions Modeling Framework (Weinar 2)

30 June 2024



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Maxime Dasse

Engineer Architect - 1st year PhD student

UCLouvain

Architecture and Climate Department
Supervision : Prof. Emilie Gobbo

LIÈGE université
SBD Lab

Sustainable Buildings Development Lab Department
Supervision : Prof. Shady Attia

Topics of interest:
- Building LCA
- Parametric Design

Maxime Dasse

Building Engineer - 1st year PhD student

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SBD Lab

Architecture and Climate Department
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UCLouvain

Sustainable Buildings Development Lab Department
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Topics of interest:
- Building energy modelling
- Building physics

Case study

Step 1 – Modelling Approach: Bottom Up | Top Down

(1A) Climate change scenarios (Bottom Up)	(1B) Greenhouse Gas Emissions Budget (Top Down)
• Approach : Baseline & Improved Design • Identify benchmarks for later comparison	• Metric recommended : GWP (IPCC) • Paris compatible boundary : ~500GT CO2eq / y • Identify a GHG emissions budget for buildings

Climate Change Scenarios recommended:
IPCC RCP 4.5 & 8.5
(5th & 6th IPCC AR, 2021)

Time scale:
2030, 2050, 2100

Sources of benchmarks recommended:
National/Continental

Sources of GHG emissions budget for buildings recommended :
No commonly agreed budget yet.
Steffen & Foliente are each working on it.

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Step 2 – Climate & Location

(2) Weather data

Urban heat island effect excluded

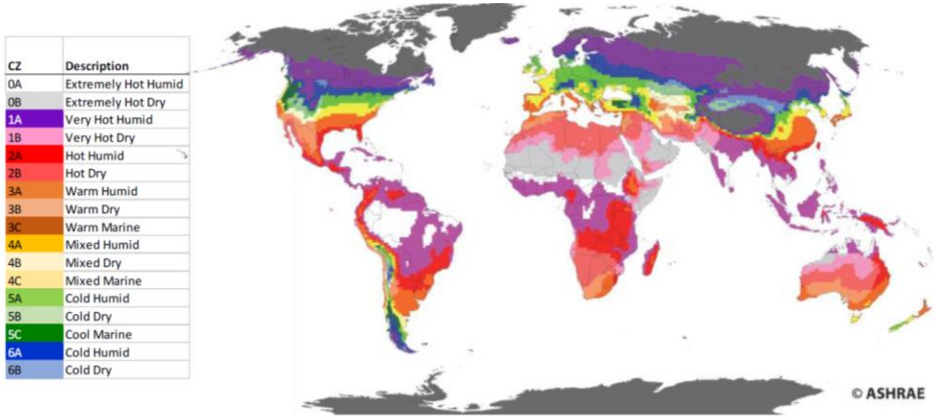
Urban heat island effect included

(2.2) City selection

Singapore (0A)	Sao Paulo (2A)	Busan (3A)	London (4A)	Toronto (5A)
Abu Dhabi (0B)	Cairo (2B)	Tehran (3B)	Gent (4A)	Copenhagen (5A)
Lagos (1A)	Barcelona (3A)	Los Angeles (3B)	Brussels (4A)	Vienna (5A)
Guayaquil (1A)	Rome (3A)	Santiago (3C)	Xian (4B)	Montreal (6A)
New Delhi (1B)	Buenos Aires (3A)	Paris (4A)	Vancouver (4C)	Stockholm (6A)

Source of weather data recommended:
Meteonorm

Weather files chosen:
2020 - 2050 (RCP 8.5) – 2100 (RCP 8.5)



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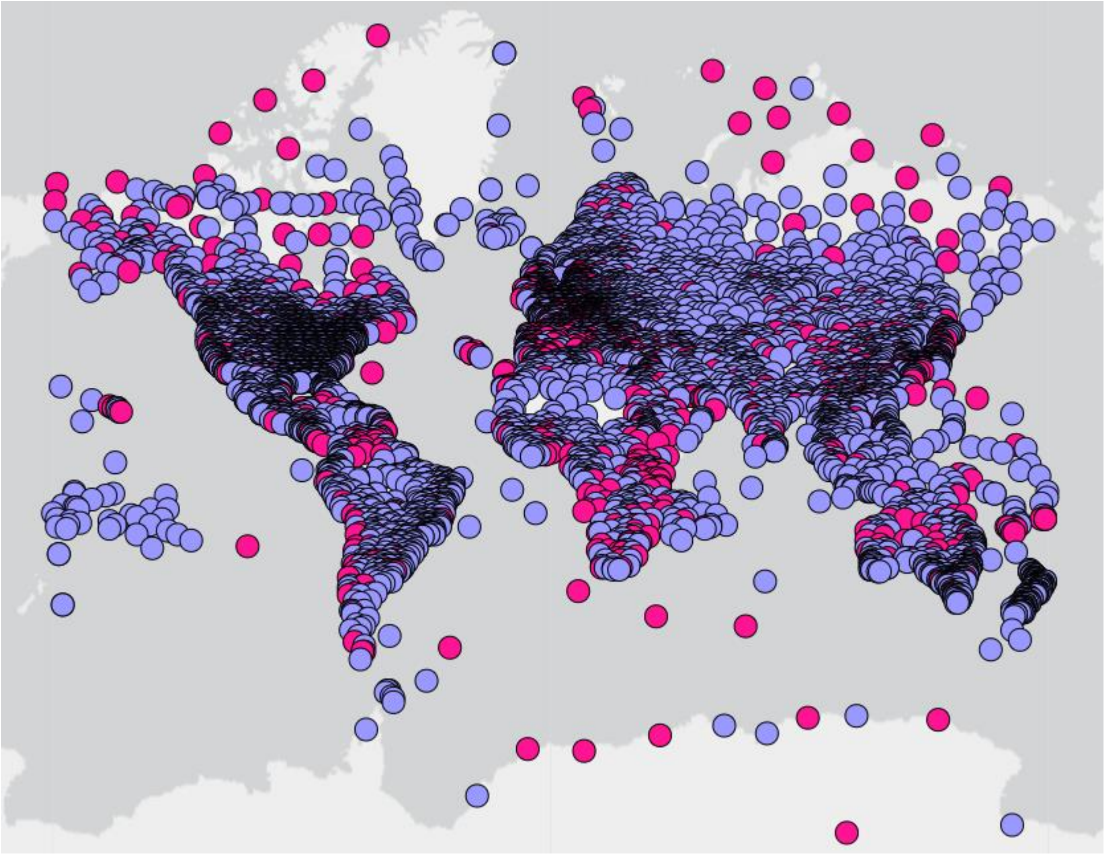
Weather data sources

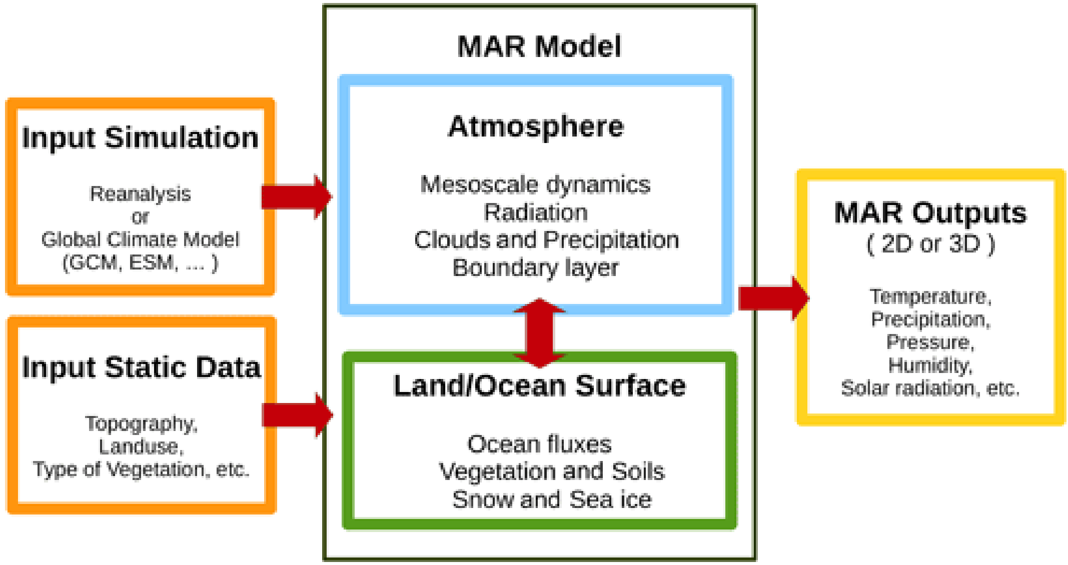
Meteonorm

Meteorological database
Periods covered: Historic, Contemporary, Future (up to 2100)
Scenarios implemented: RCP 2.6, 4.5, 8.5



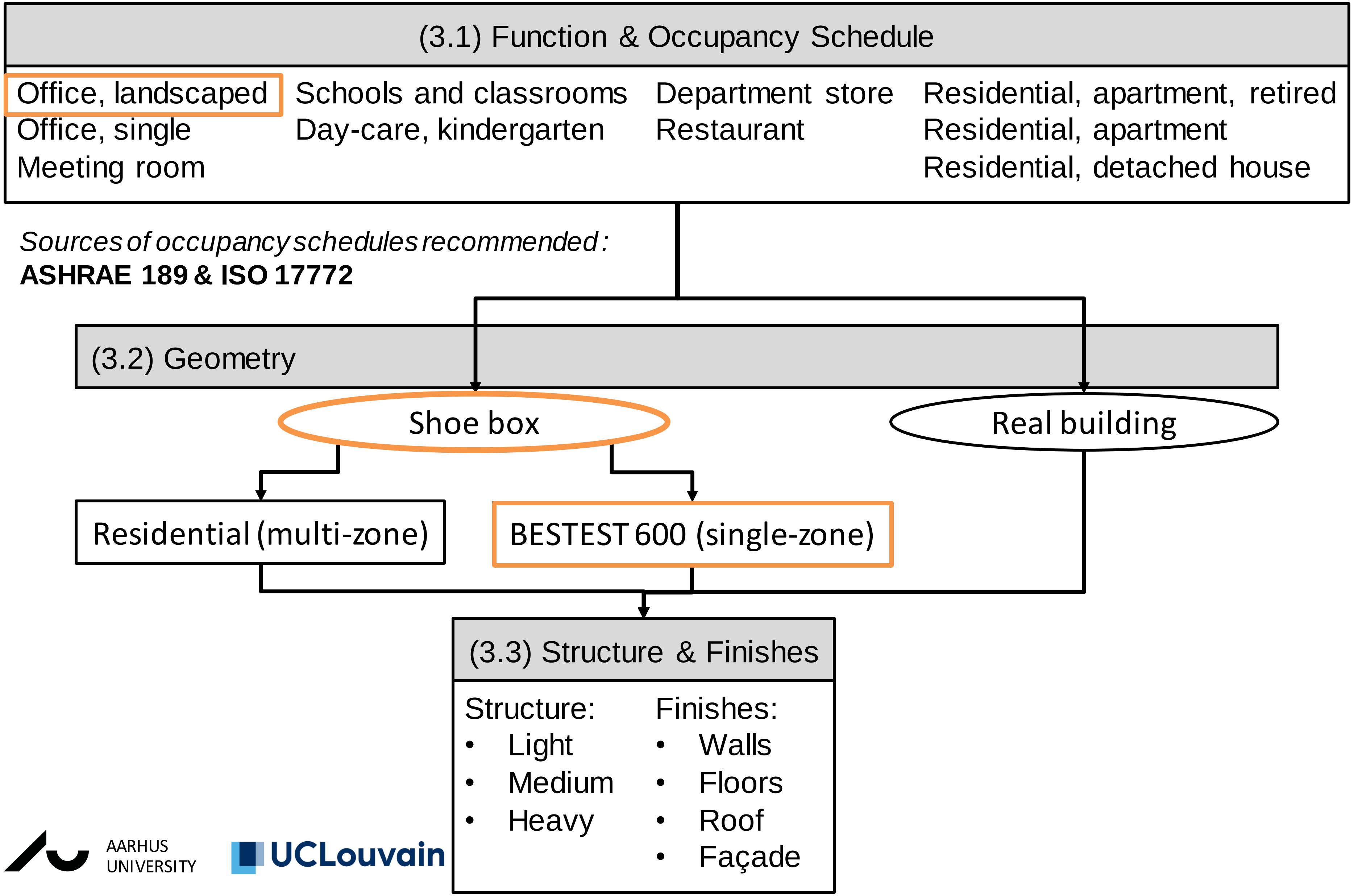
Make your own weather file

E.g., *Belgium*: Use of the Regional Atmospheric Model (MAR) model to downscale a global model to get weather outputs at a finer spatial and temporal resolution



Doutreloup, S., Fettweis, X., Rahif, R., Elnagar, E., Pourkiaei, M. S., Amaripadath, D., and Attia, S.: Historical and future weather data for dynamic building simulations in Belgium using the regional climate model MAR: typical and extreme meteorological year and heatwaves, Earth Syst. Sci. Data, 14, 3039–3051, https://doi.org/10.5194/essd-14-3039-2022, 2022.

Step 3 – Building Characterisation

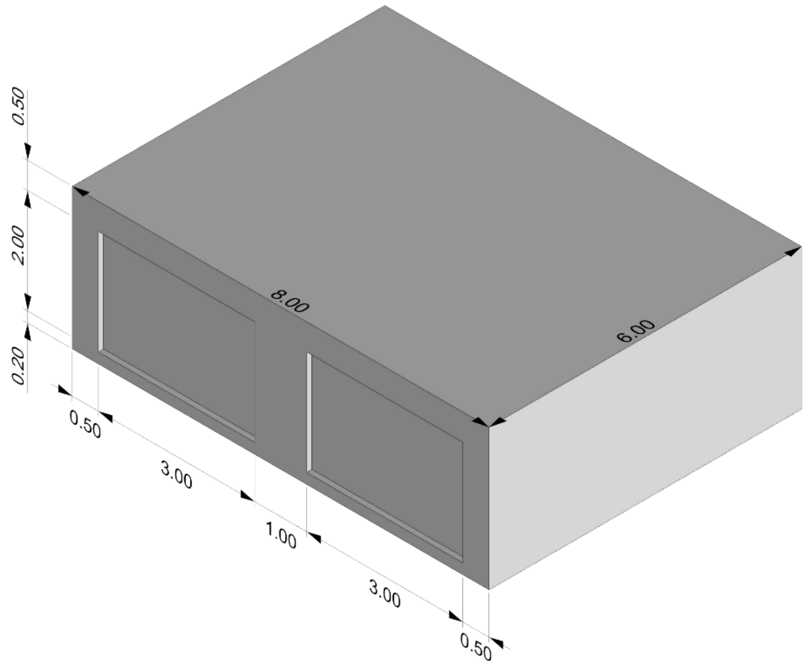


Step 3 – Building Characterisation

(3.2) Geometry

Shoe box | Real building

Residential (multi-zone) | BESTEST 600 (single-zone)



Recommendations:

- **Models based on archetypes**
- **Dimensions as a function of the surface**
- **Single zone x multi zone**
- **Adjacencies and orientations: worst case**

Step 3 – Building Characterisation

(3.3) Structure & Finishes	
Structure:	Finishes:
• Light	• Walls
• Medium	• Floors
• Heavy	• Roof
	• Façade

Materials	Quantity
Plasterboard	1000kg
Glass	150kg
Glasswool	**175kg**
Structural timber	3m3
Wood cladding	9.6m²
Timber flooring	48m²

→

Materials	Quantity
Plasterboard	1000kg
Glass	150kg
Glasswool	**625kg**
Structural timber	3m3
Wood cladding	9.6m²
Timber flooring	48m²

Step 4 – Building Envelope

Poor (E,F,G) | Low Energy (C,D) | Passive House (A,B)

ASHRAE 90.1
Energy Standard for Buildings except Low-Rise Residential Buildings

Passivhaus standard

(4) Performance Level Selection

Climatic zones :

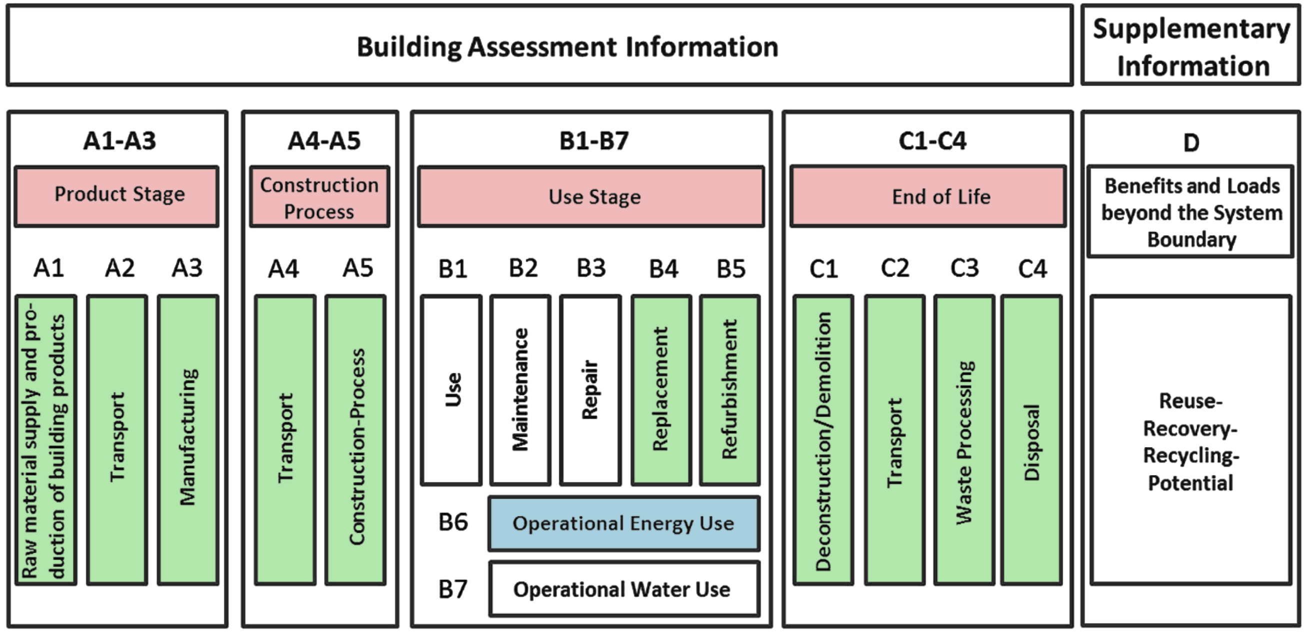
- Zone 1 -> A,B
- Zone 2 -> A,B
- Zone 3 -> A,B,C
- Zone 4 -> A,B,C
- Zone 5 -> A,B,C
- Zone 6 -> A,B
- (Zone 7 -> A,B)
- (Zone 8 -> A,B)

Parameter	Value
External wall U-value	0.516 W/m²K
Thickness	8.7 cm
Roof U-value	0.32 W/m²K
Thickness	14.3 cm
Glazing stratigraphy	3-13(air)-3
SHGC	0.79
U-value	3.0 W/m²K
Air tightness	0.5 ach (fixed)

→

Parameter	Value
External wall U-value	0.15 W/m2K
Thickness	28.1 cm (26cm)
Roof U-value	0.15 W/m²K
Thickness	29.1 cm (26cm)
Glazing stratigraphy	3-13(Argon)-3-13(Argon)-3
SHGC	0.47
U-value	0.78
Air tightness	0.5 ach (fixed)

Step 4 – Life Cycle GHG emissions calculations

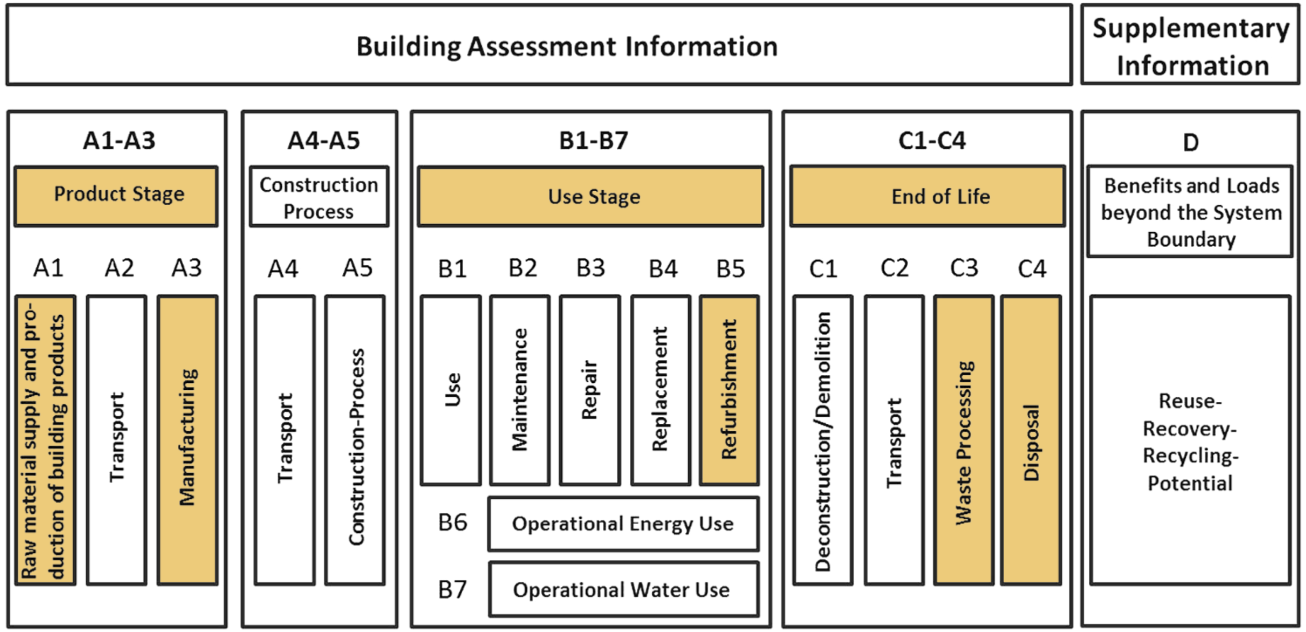


Focus recommended:
Stages A, B & C

Embodied:
Stages A1-5 + B4-5 +C1-4

Operational:
Stage B6

Step 4 – Embodied GHG emissions calculations



Recommended source of data:
Ecoinvent

Recommended linking method:
Allocation, cut-off, EN 15804

Recommended calculation method:
IPCC 2021

/!\ Transport

EPDs issue:
Last resort

HVAC issue:
One Click LCA
Sebastien Loreau's work (UCLouvain)

Biogenic Carbon issue:
Recommended: -1 +1

Data type issue:
Process – Hybrid (EPiC) – I/O

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Step 5 – HVAC systems

Poor (E,F,G)	Low Energy (C,D)	Passive House (A,B)
Building level (onsite) and District level		
Existing No mechanical ventilation	Gas boiler, air conditioning, mechanical ventilation	Heat pump, mechanical ventilation, photovoltaic, solar collector, district heating/cooling, geothermal network

Parameter	Value
COP heating	0.85
Fuel	Gas
Natural ventilation	Yes
Mechanical ventilation	No
PV surface	0 m^2

→

Parameter	Value
COP heating	4.5
Fuel	Electricity
Natural ventilation	Yes
Mechanical ventilation	Yes
PV surface	4 m^2

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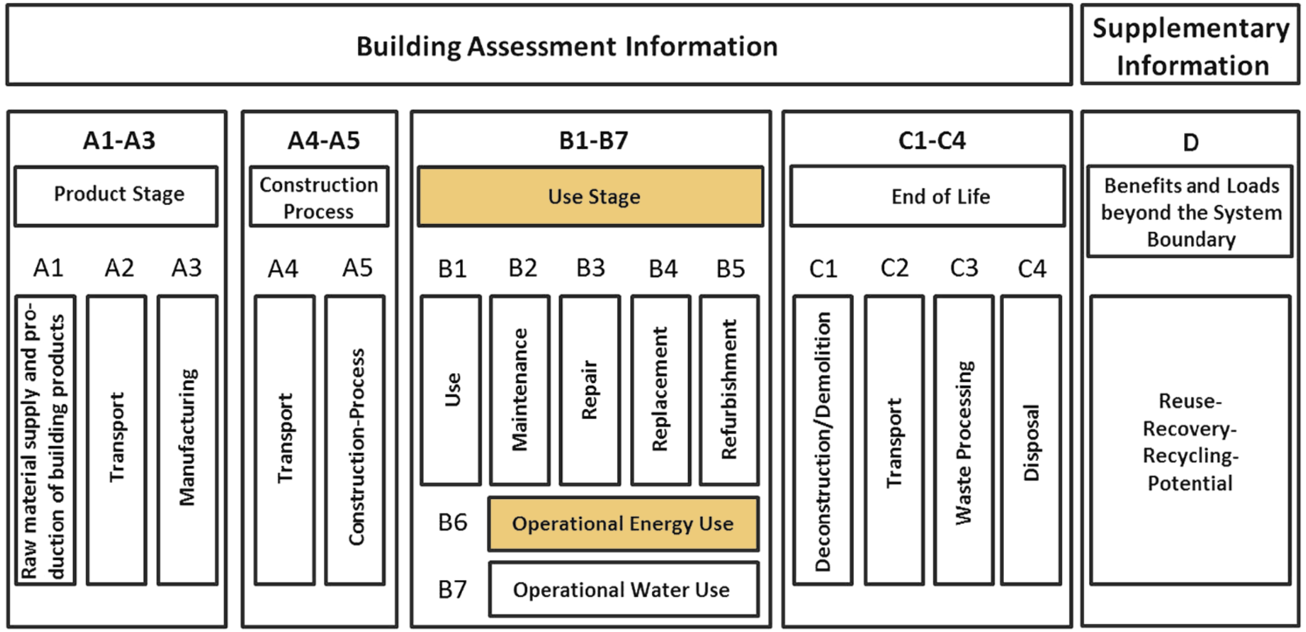
Step 5 – Operational GHG emissions calculations



Life Cycle Stages :
B6

Recommended source of data:

- Heating
- Cooling
- Mechanical ventilation
- Lighting
- Other (E.g., equipment, computers, …)

Step 6 - Storage

Water Tanks	PCM	Batteries & Fuel cells

Coupled with solar energy and heat pumps to produce hot water

Main parameters
Volume
Energy range
Hot water temperature
Tank insulation

Thermal storage to minimise variation in electrical energy consumption between day and night

Passive: gypsum wallboard, thermal energy storage concrete
Active: floor heating systems, PV panels

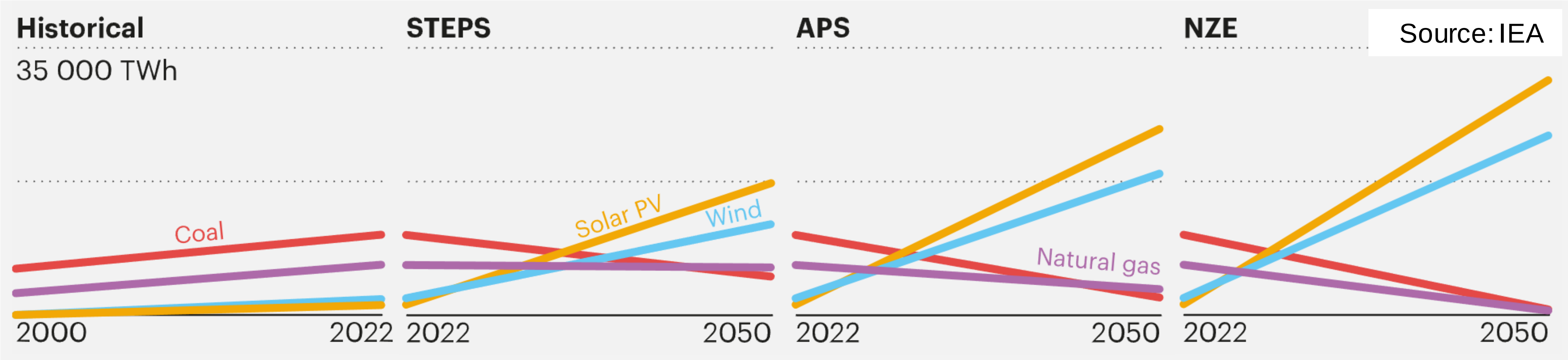
Hydrogen for long-term energy storage
Battery for short-term energy storage

Coupled with PV panels power to produce hydrogen in Summer, and generate electricity in Winter when battery storage is not available

Step 7 - Energy mix

Energy Mix Scenarios

Carbon Factors



Changes in the electricity mix → Impact on the operational GHG emissions

Step 8 – Additional parameters

Carbon Tax

Carbon threshold (e.g., 2.5 $kgCO_2eq/m^2/year$)

European Union Emissions Trading System (EU ETS)

A market mechanism that gives CO2 a price and creates incentives to reduce emissions.

The EU sets a cap on how much CO2 can be emitted (which decreases each year) and companies need to have a European Emission Allowance for every tonne of CO2 they emit within one calendar year.

Before 2027: power generation and energy-intensive industries
From 2027: fuel distribution for road transport, **buildings**, and additional industrial sectors

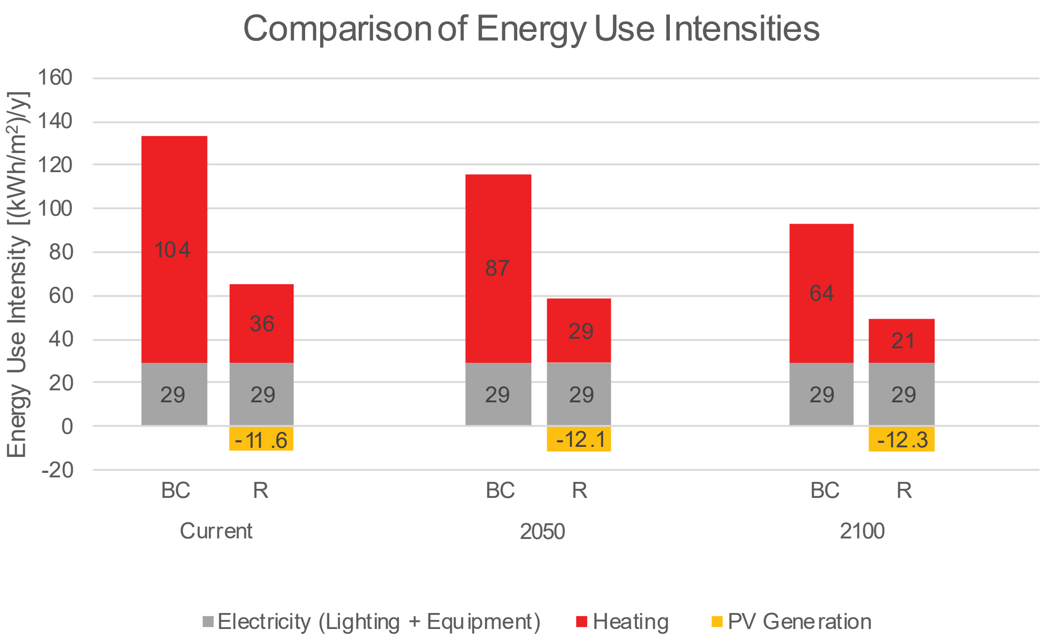
RE2020

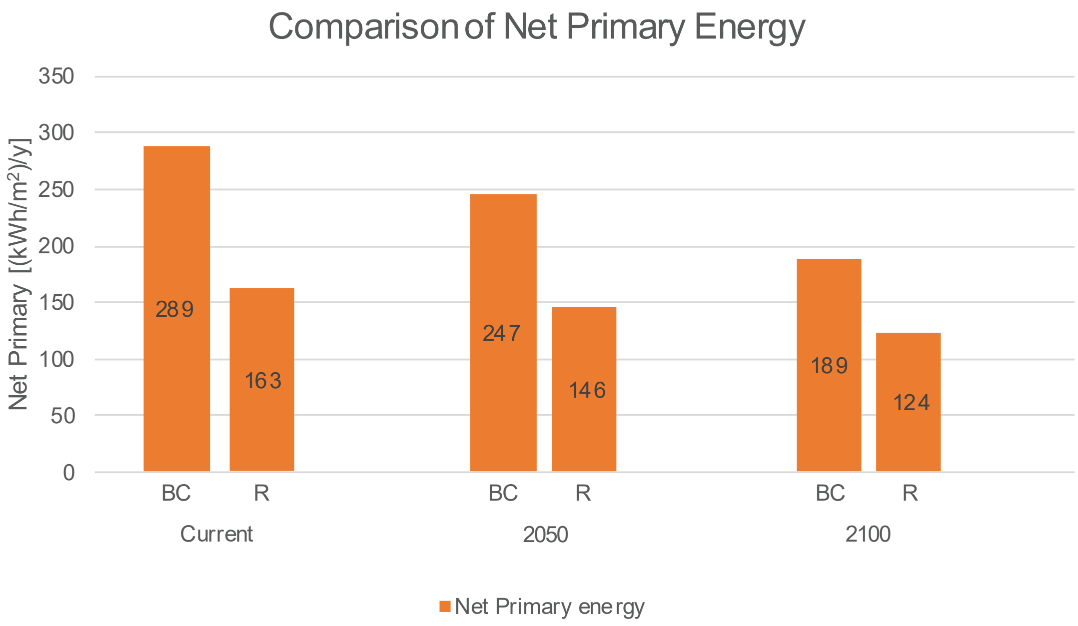
The regulation sets a maximum threshold for GHG emissions from energy consumption:

- 4 kg $CO_2/m^2/year$ for new single-family homes. Fossil fuels are to be completely phased out by 2025.
- 14 kg $CO_2/m^2/year$ for apartment buildings, to be reduced to 6.5 kg $CO_2/m^2/year$ in 2025.
- 8 kg $CO_2/m^2/year$ for apartment buildings already connected to district heating, to be reduced to 6.5 kg $CO_2/m^2/year$ from 2028 onward.

Step 9 – Evaluation Scenarios and Functional Units

Operational Energy [(kWh/m²)/year]	GHG emissions (E+O) [(kgCO$_2$eq/m²)/year]	Cost [€/m²]





Primary Energy Factors
Electricity = 2.5
Natural gas = 1

Source: European Commission database, EIA

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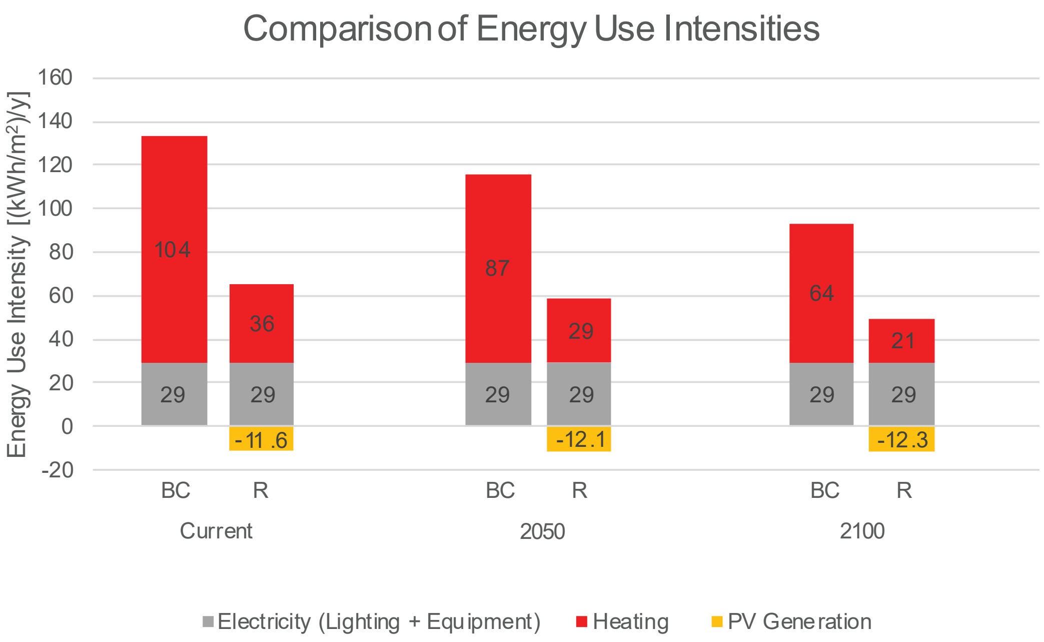
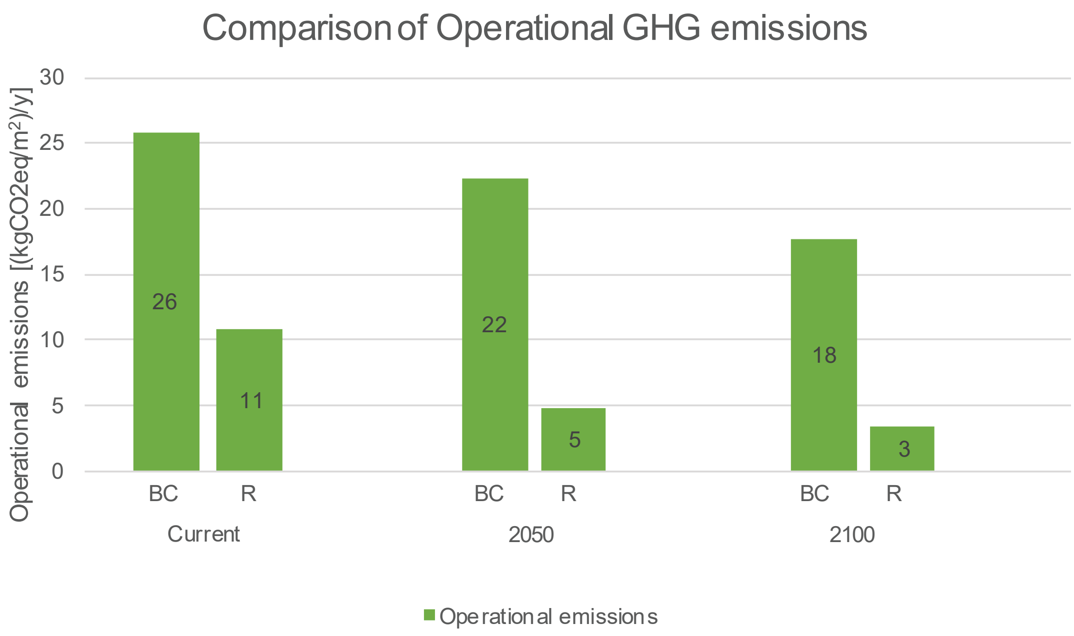
Step 9 – Evaluation Scenarios and Functional Units

Operational Energy [(kWh/m²)/year]	GHG emissions (E+O) [($kgCO_2eq/m^2$)/year]	Cost [€/m²]





Emission Factors (Belgian energy mix)

Electricity = 0.165

Natural gas = 0.202

Source: IPCC EFDB, IEA

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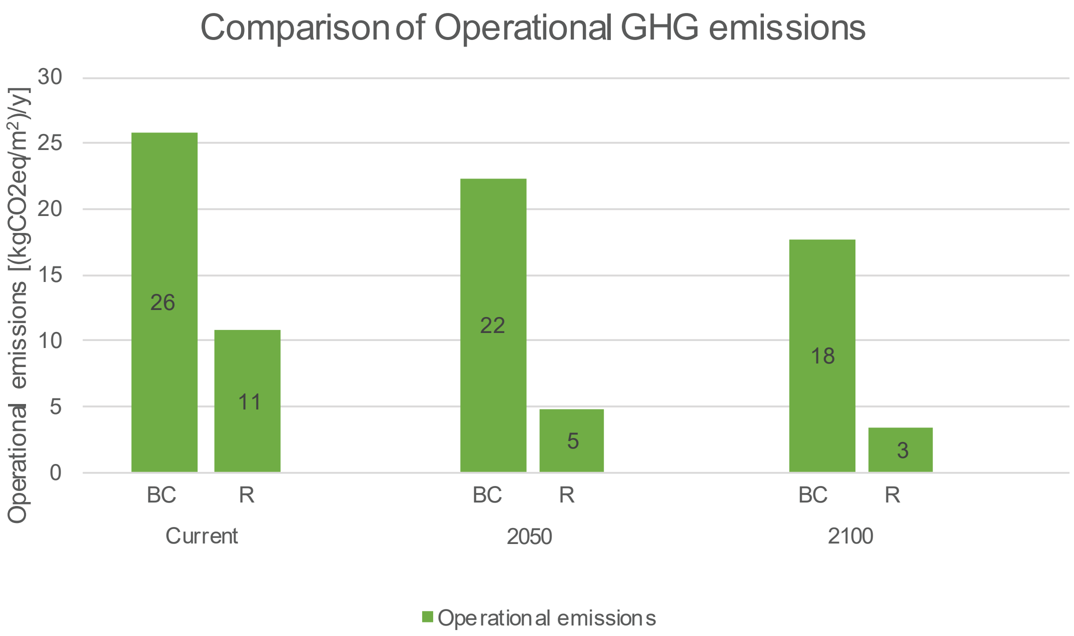
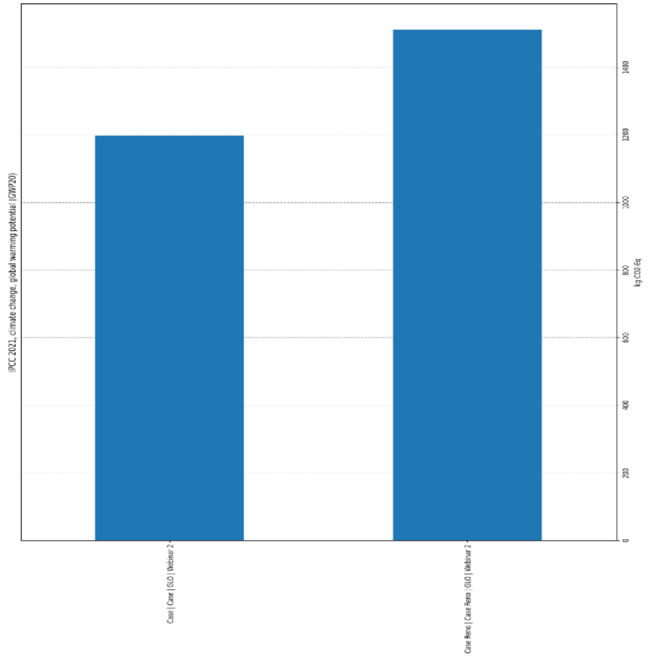
Step 9 – Evaluation Scenarios and Functional Units

Operational Energy [(kWh/m²)/year]	GHG emissions (E+O) [(kgCO_2eq/m²)/year]	Cost [€/m²]





Step 9 – Evaluation Scenarios and Functional Units

Sensitivity Analysis & Uncertainty Analysis

Sensitivity analysis
to test the sensitivity of the results to the different parameters and identify critical parameters

Uncertainty analysis
to evaluate the robustness of the results by analysing the impact on results of parameters considered less reliable
(e.g., emission factors, …)

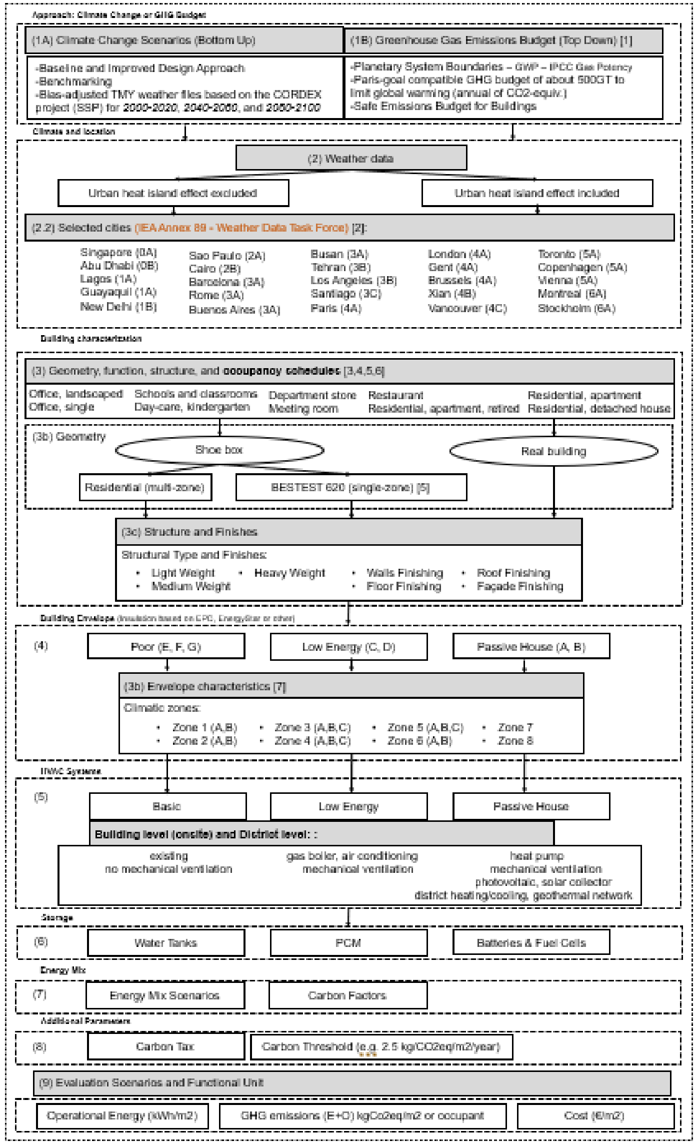
DynamicRenowave - Life Cycle Assessment and Energy Simulation of Building Renovation Strategies

Carbon Emissions Modeling

Objective 1: Define common thermal conditions to assess different decarbonization pathways
Objective 2: Publish the (Liege-Aarhus) framework by June 2024
Objective 3: Define a common benchmark

Performance Evaluation

Step 1: Identify LCA *database* and potential inventory
Step 2: Identify GHG emissions for *acceptable carbon targets* under possible *foreseeable decarbonization pathways*.
Step 3: Quantify the *KPI margin violation* and the *severity of foreseeable emissions*
Step 4: Calculate the *GHG emissions following the two approaches*



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Thanks for your attention

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Q & A

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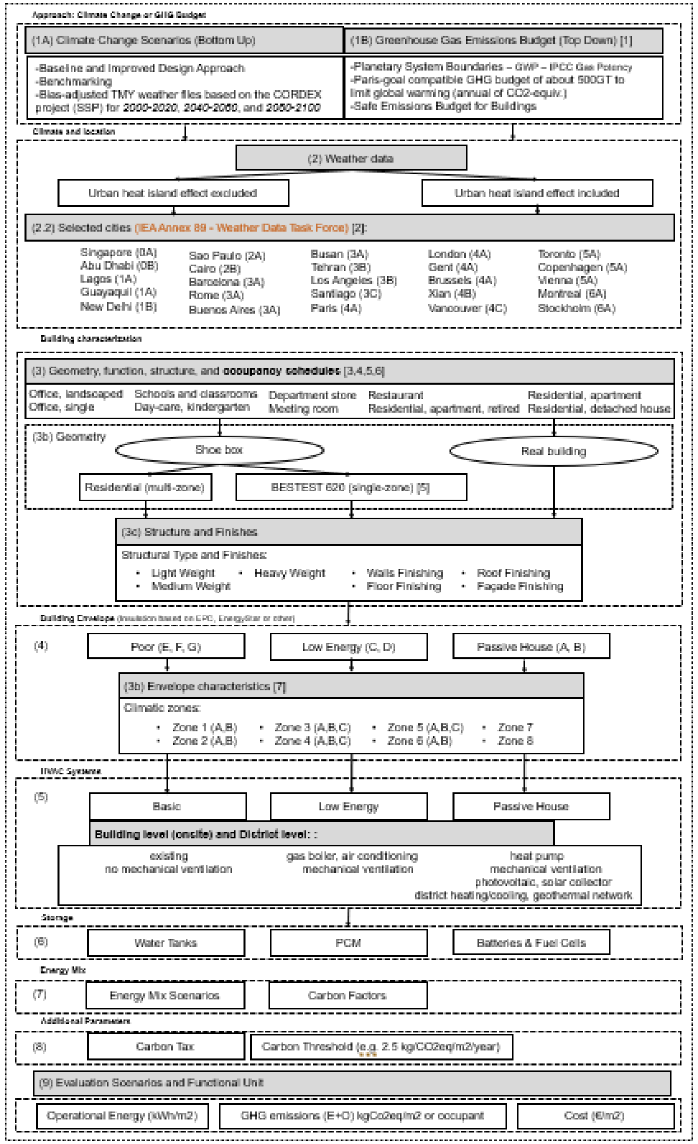
GHG Emissions Modeling

Questions and Answers



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DynamicRenowave - Building Carbon Emissions Modeling Framework \ References

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