RETROFIT
innovation
SUMMIT

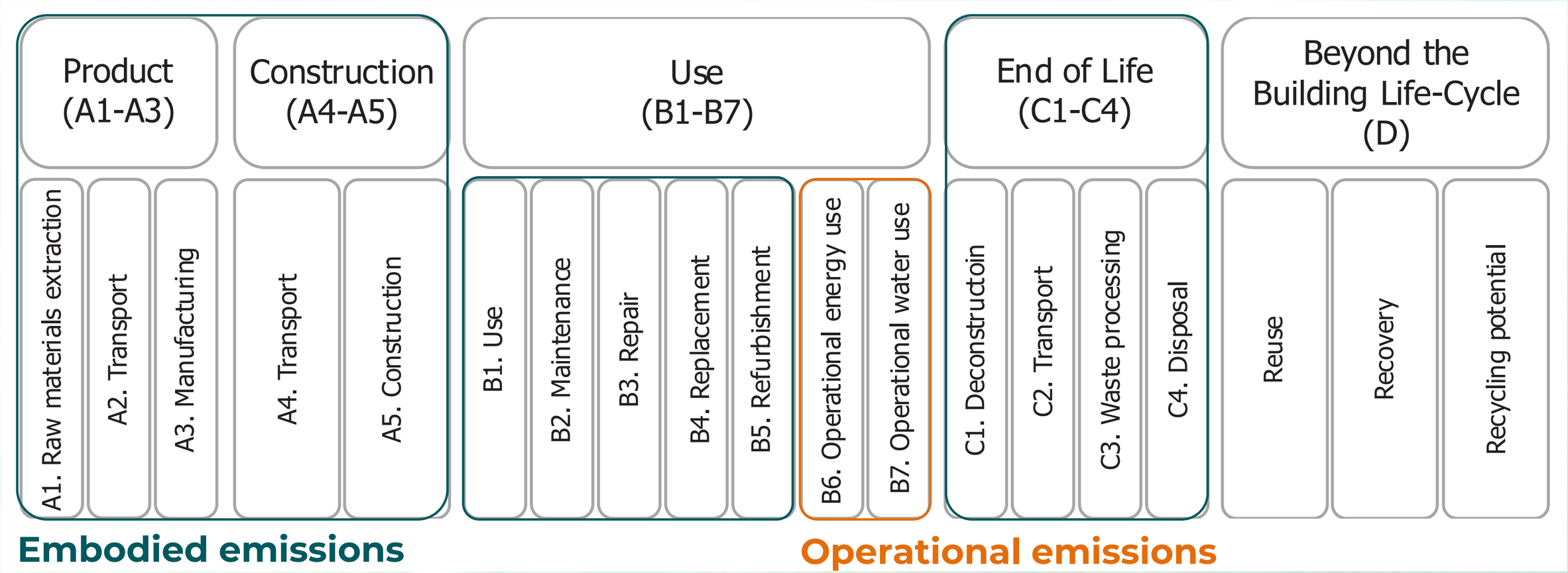
SESSION 3.2

Aurora Bertini – PhD student – University of Liège

Beyond Energy Efficiency:
Coupling Life Cycle Assessment and Building Performance Simulation for Whole-Life Carbon Analysis of Residential Renovations

Wallonie
Wallonie Relance
GREEN WIN CLEANTECH INNOVATION BOOSTER
renow
S3
Wallonia.be

Building Life-cycle stages (EN 15978)



RETROFIT innovation SUMMIT

From Zero Energy to Zero Emissions

2024 EPBD recast

Zero-emissions building requirements for new buildings and deep renovations

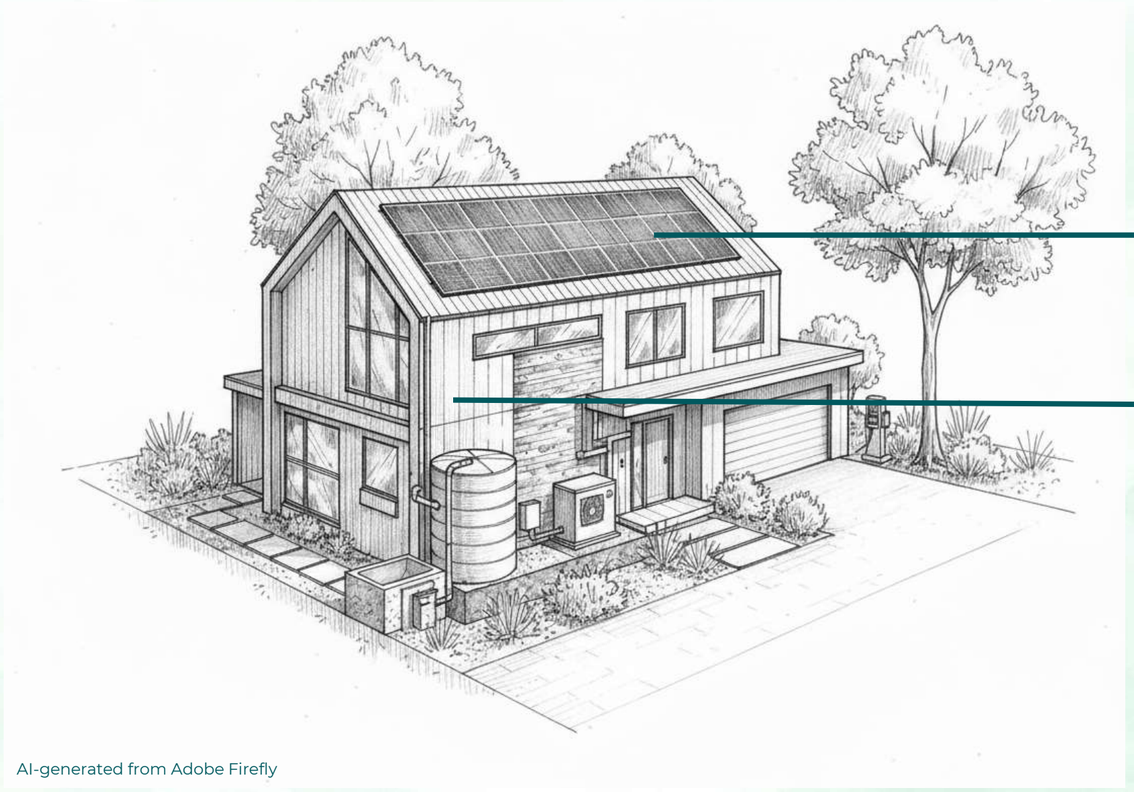
Buildings characterized by zero or very low energy consumption,
zero on-site carbon emissions from fossil fuels,
and zero or a very low amount of operational GHG emissions

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Embodied - Operational emissions trade-off



AI-generated from Adobe Firefly

→ Not always locally manufactured

→ More materials (e.g. thicker insulation)

M. Rock, M.R.M. Saade, M. Balouktsi, F.N. Rasmussen, H. Birgisdottir, R. Frischknecht, G. Habert, T. Lützkendorf, A. Passer, Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation, Appl. Energy 258 (2020) 114107, https://doi.org/10.1016/j.apenergy.2019.114107.

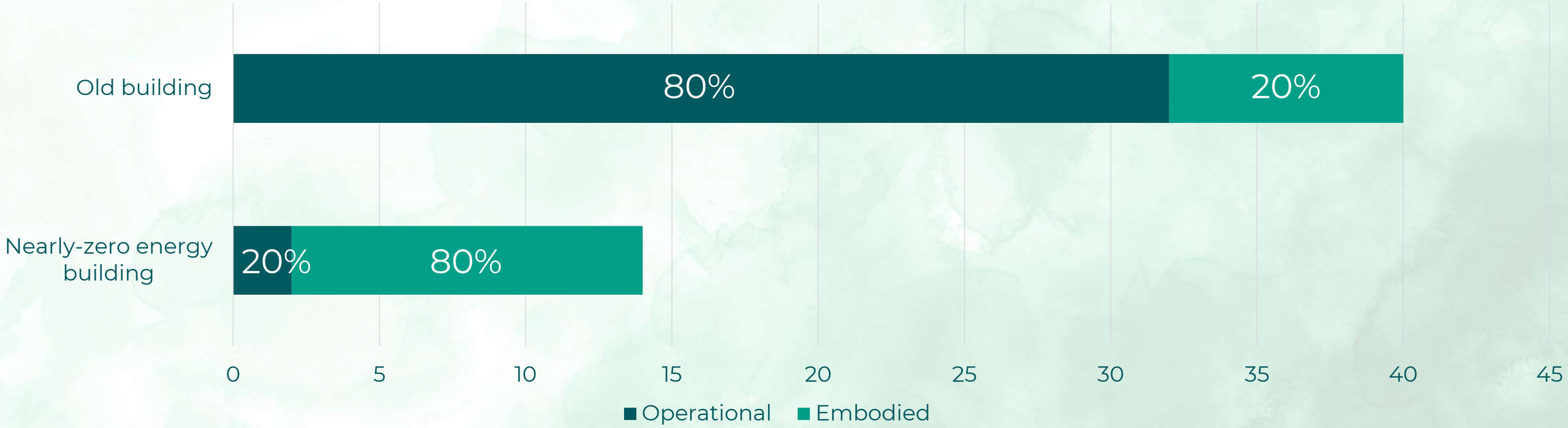
GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Embodied - Operational emissions trade-off

Total whole-life GHG emissions [$kgCO_2e/(m^2y)$]



Bertini, A., Al-Obaidy, M., Dasse, M., Amaripadath, D., Gobbo, E., & Attia, S. (2025). Parametrization of variables affecting the whole life carbon performance of nearly zero energy residential building renovation. Building and Environment, 278, 113013.

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

From Zero Operational to Zero Whole-Life

2024 EPBD recast

Life-cycle global warming potential (**GWP**) for new buildings

National roadmaps for the gradual introduction of GWP **limit values**
& set targets for new buildings from 2030

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Whole-life emissions calculation complexity

Life Cycle Assessment

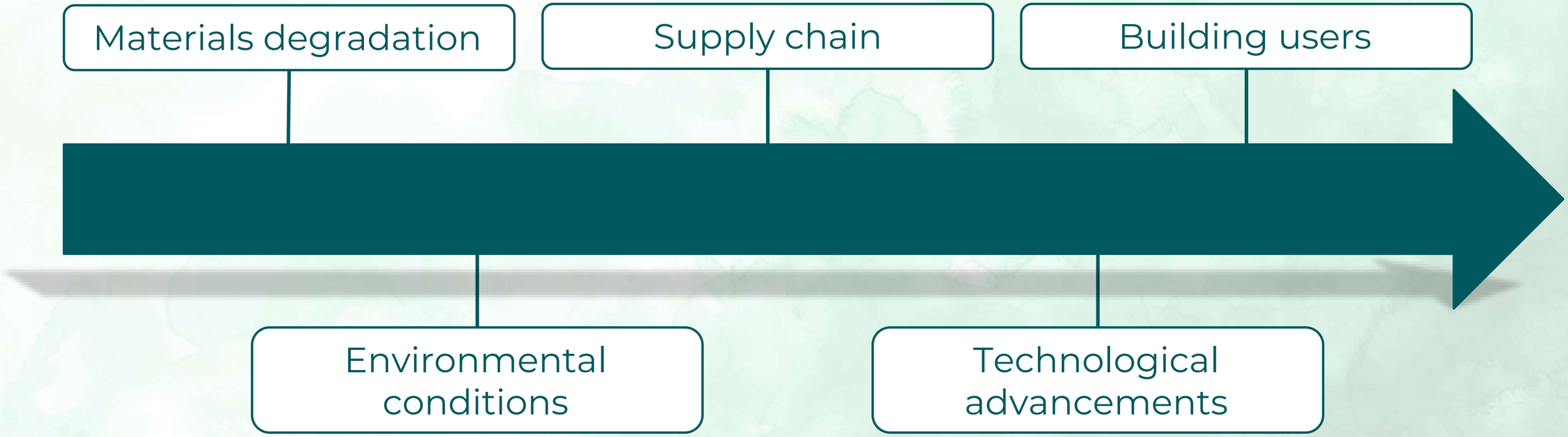
Building Performance Simulation

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Whole-life emissions calculation complexity



RETROFIT innovation SUMMIT

Whole-life carbon calculation complexity

Building scope

Finishes

Internal partitions

Envelope

Systems

Structure

Renewables

AI-generated from Adobe Firefly

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Research questions

How can embodied and operational emissions
be **dynamically coupled** in building retrofits?

What **variables** affect the whole-life environmental performance of building renovation?

How do **climate change** and **electricity mix** influence the transition
from Zero Energy to Zero Carbon buildings?

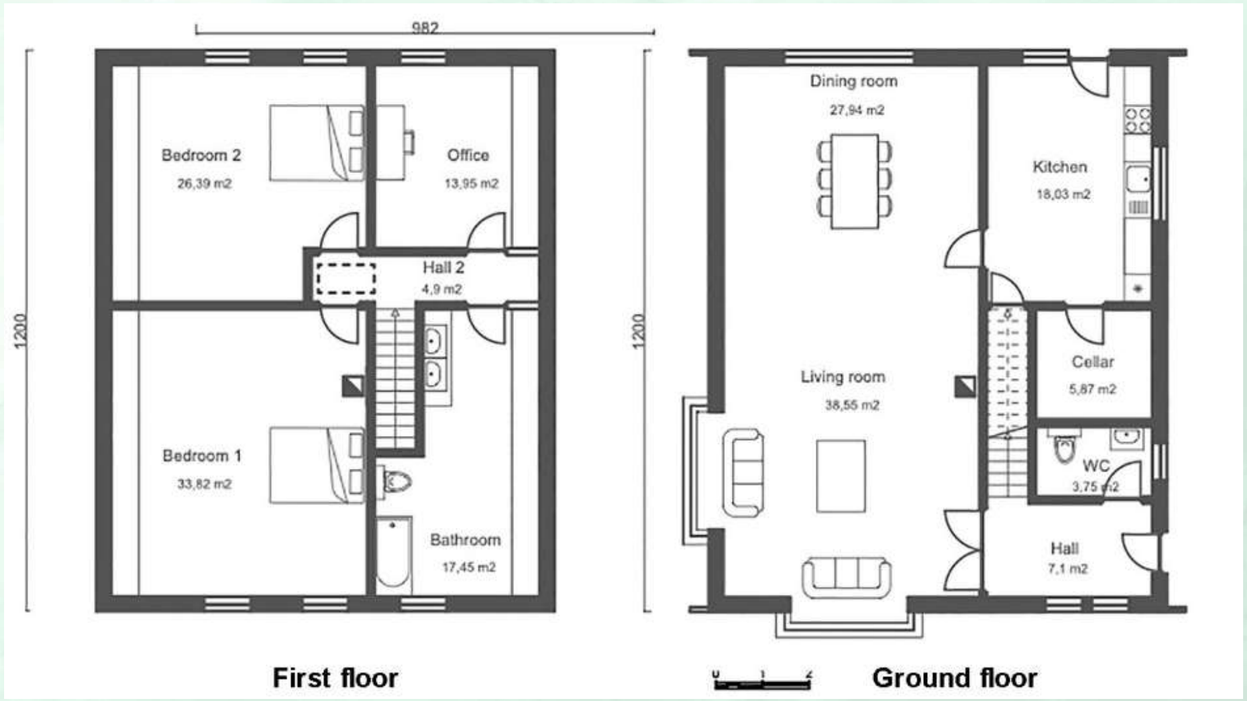
GREEN W!N CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Methodology

Case study



Attia, S., Mustafa, A., Giry, N., Popineau, M., Cuchet, M., & Gulirmak, N. (2021). Developing two benchmark models for post-world war II residential buildings. Energy and Buildings, 244, 111052.

GREEN WIN CLEANTECH INNOVATION BOOSTER

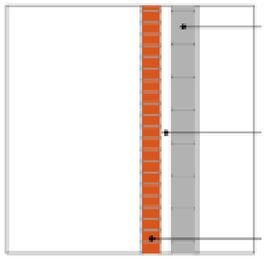
fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Methodology

Renovation strategies

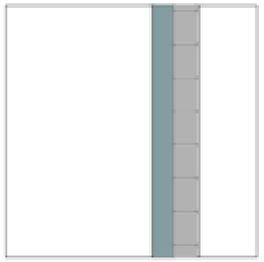
Base case



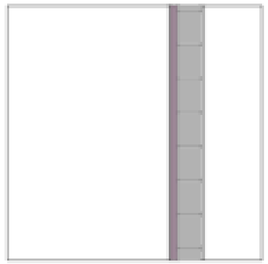
U = 1.72

Gas boiler, No cooling
Natural ventilation
No on-site renewables

Low-Energy retrofit



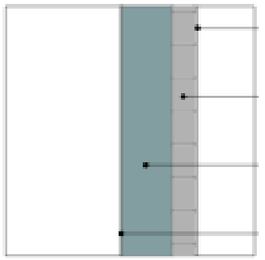
U = 0.80



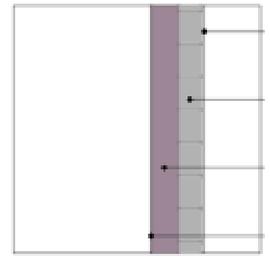
U = 0.80

Reversible heat pump
Mechanical ventilation (C/D)
PV panels + Battery

UltraLow-Energy retrofit



U = 0.15



U = 0.15

Reversible heat pump
Mechanical ventilation (D)
PV panels + Battery
Solar collectors

RETROFIT innovation SUMMIT

Methodology

Coupling

Materials inventory

↓

Materials quantities

↓

Environmental impact

↓

Embodied GHG emissions
[$kgCO_2e/(m^2y)$]

Whole-life GHG emissions
[$kgCO_2e/(m^2y)$]

+

Energy model

↓

Building energy use

↓

Carbon Factor

↓

Operational GHG emissions
[$kgCO_2e/(m^2y)$]

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Methodology

Sensitivity analysis

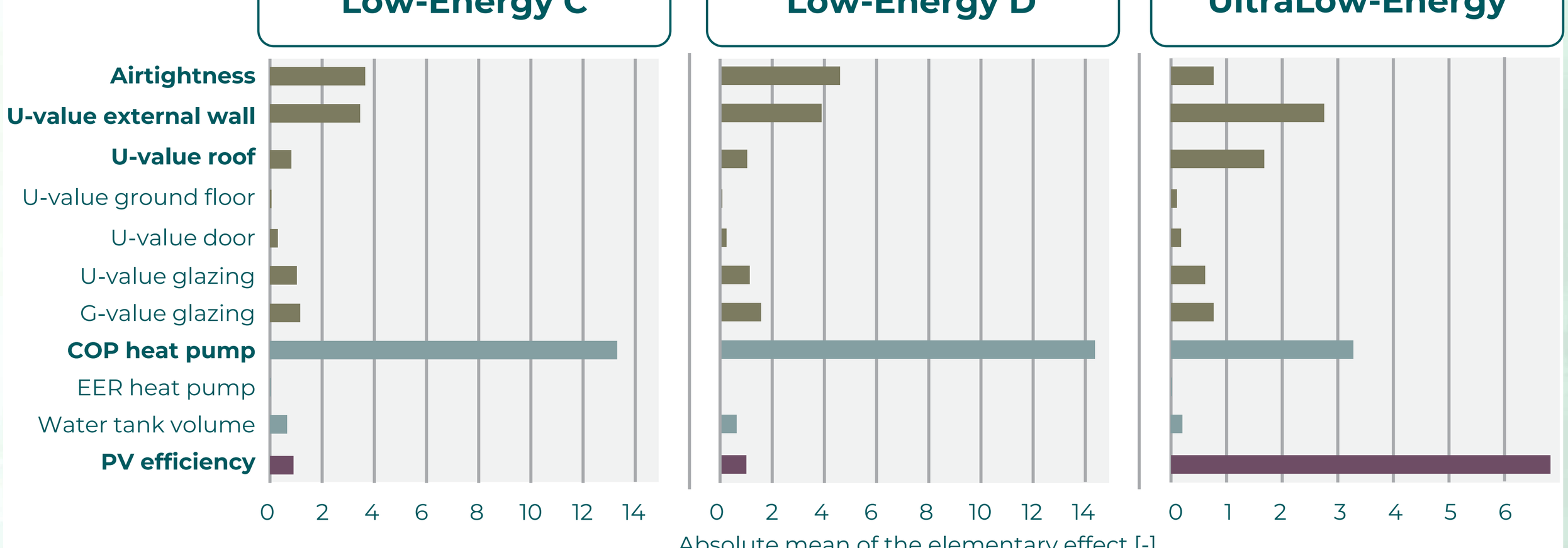
Envelope	Systems	Indicators
Airtightness	COP heat pump	Embodied GHG emissions [$kgCO_2e/(m^2y)$]
U-value external wall	EER heat pump	Operational GHG emissions [$kgCO_2e/(m^2y)$]
U-value roof	Water tank volume	Whole-life GHG emissions [$kgCO_2e/(m^2y)$]
U-value ground floor	PV efficiency	
U-value door		
U-value glazing		
G-value glazing		

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

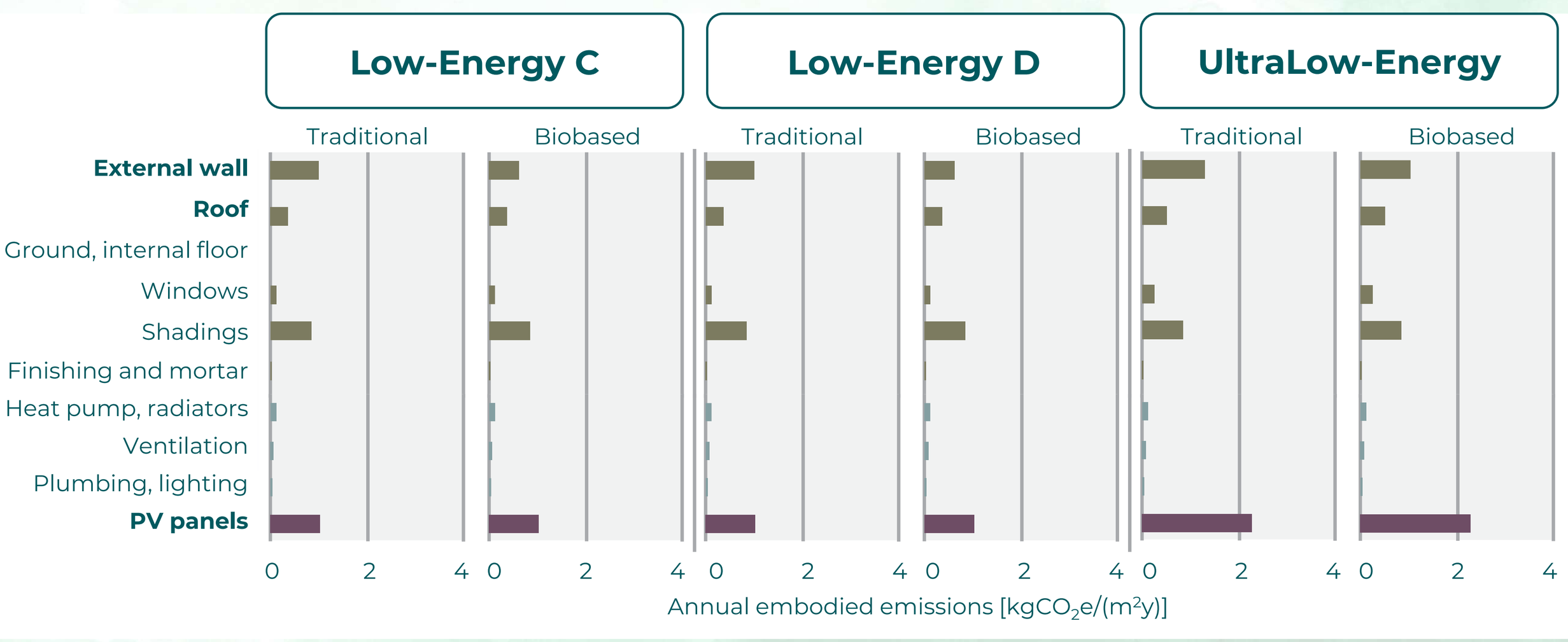
Sensitivity analysis – Operational emissions



Bertini, A., Al-Obaidy, M., Dasse, M., Amaripadath, D., Gobbo, E., & Attia, S. (2025). Parametrization of variables affecting the whole life carbon performance of nearly zero energy residential building renovation. Building and Environment, 278, 113013.

RETROFIT innovation SUMMIT

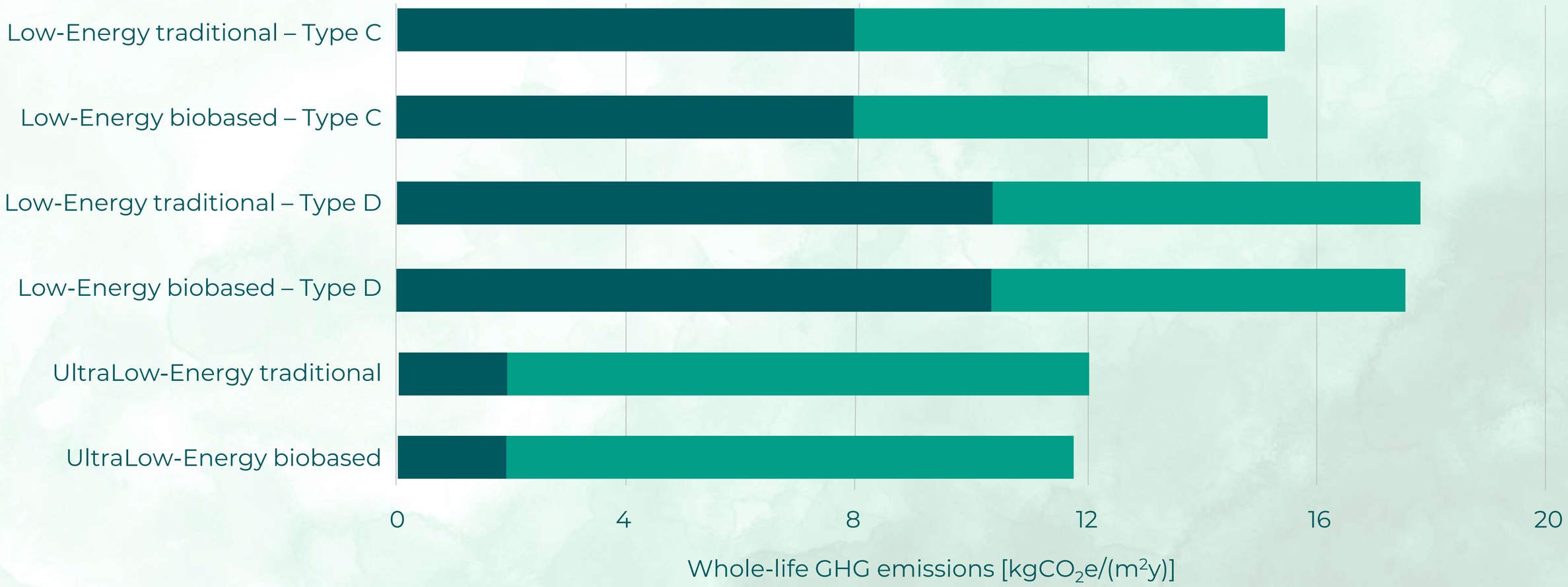
Sensitivity analysis – Embodied emissions



Bertini, A., Al-Obaidy, M., Dasse, M., Amaripadath, D., Gobbo, E., & Attia, S. (2025). Parametrization of variables affecting the whole life carbon performance of nearly zero energy residential building renovation. Building and Environment, 278, 113013.

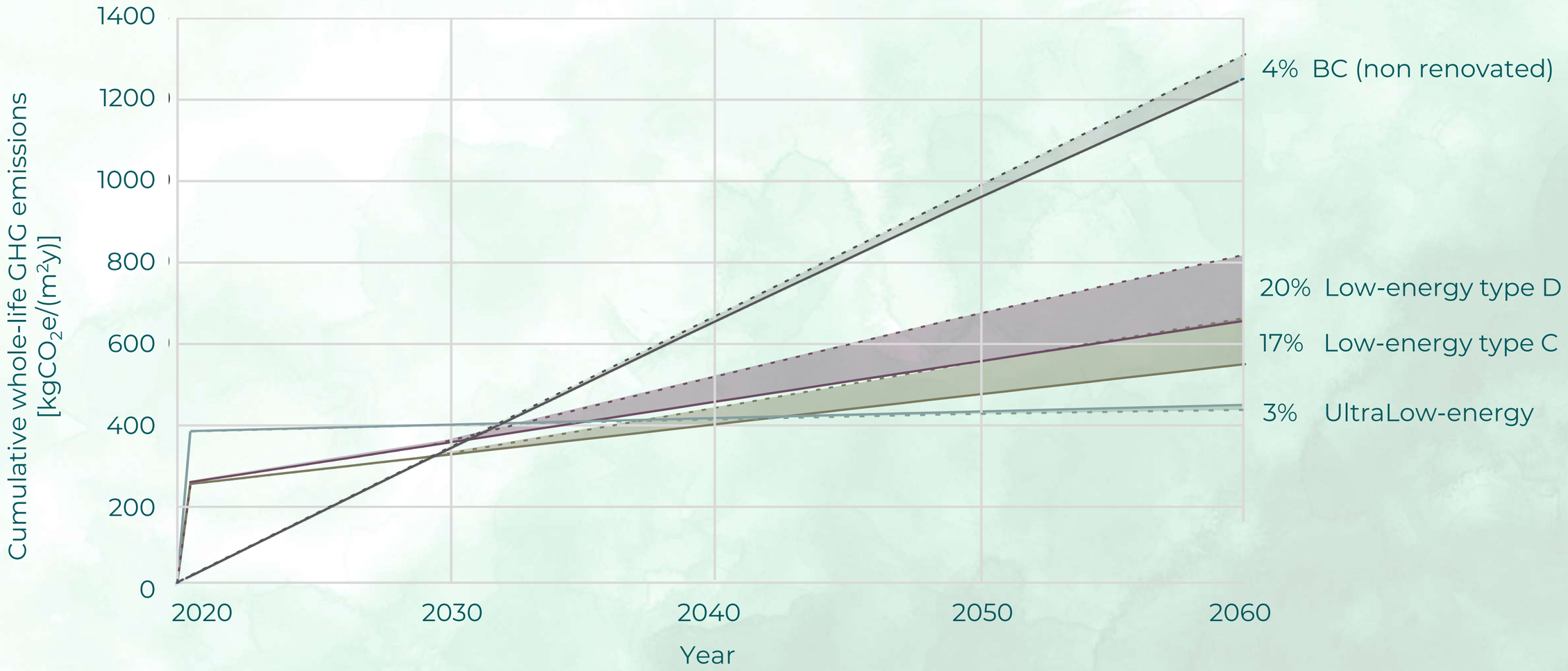
RETROFIT innovation SUMMIT

Sensitivity analysis – Whole-life emissions



RETROFIT innovation SUMMIT

Dynamic vs Static assessment



Bertini, A., Al-Obaidy, M., Dasse, M., Amaripadath, D., Gobbo, E., & Attia, S. (2025). Parametrization of variables affecting the whole life carbon performance of nearly zero energy residential building renovation. Building and Environment, 278, 113013.

RETROFIT innovation SUMMIT

Lessons learnt

Embodied/operational emissions trade-off

↓

Zero-emissions building requirements are **not** sufficient to achieve carbon neutrality

↓

Whole-life GHG emissions requirements

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Lessons learnt

Prioritize heat pump, PV panels and biobased insulation (UltraLow-Energy requirement)

↓

Whole-life zero GHG emissions is not achieved

↓

Need for a systemic approach

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Lessons learnt

Building life may exceed 50 years

↓

Climate change and electricity mix may change the results up to 20%

↓

Need for dynamic calculations

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT innovation SUMMIT

Challenges and future research

Cost analysis

Emissions estimation

Long-term uncertainties

GREEN WIN CLEANTECH INNOVATION BOOSTER

fnrs LIÈGE université SBD Lab

RETROFIT
innovation
SUMMIT

THANK YOU FOR YOUR ATTENTION

Full paper here

Aurora Bertini – University of Liège
aurora.bertini@uliege.be