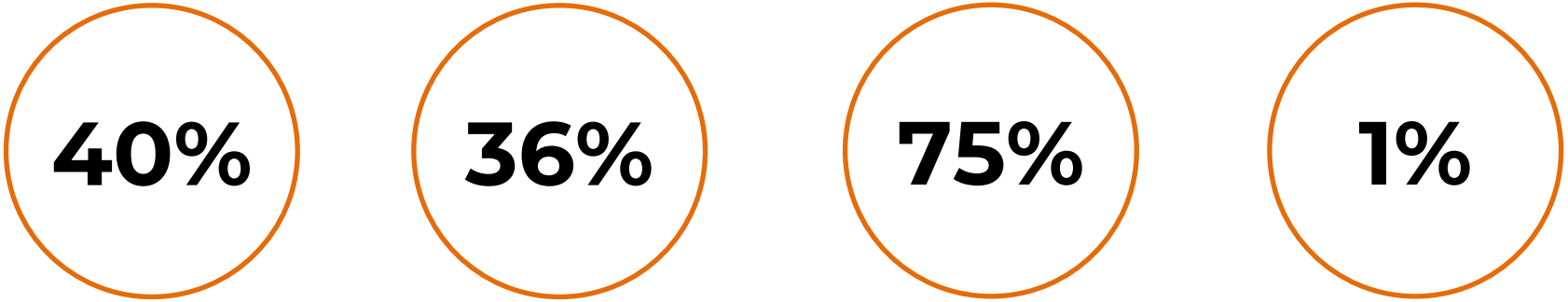
Towards climate neutrality in Belgium's residential building stock: Integrating technical, socio-economic, and environmental data for sustainable renovation strategies

Aurora Bertini, Guirec Ruellan, Shady Attia – University of Liège

Towards 2050 climate neutrality?



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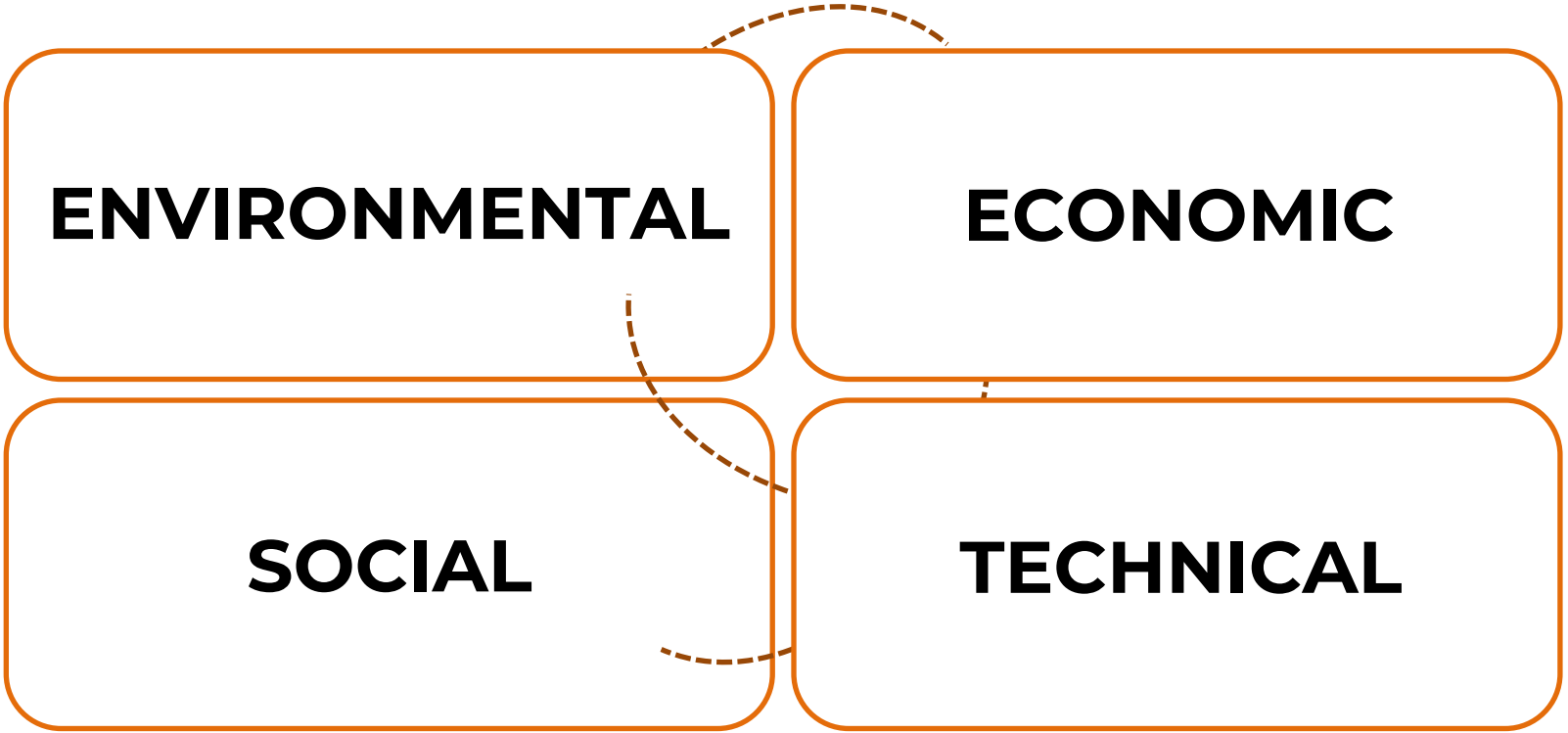
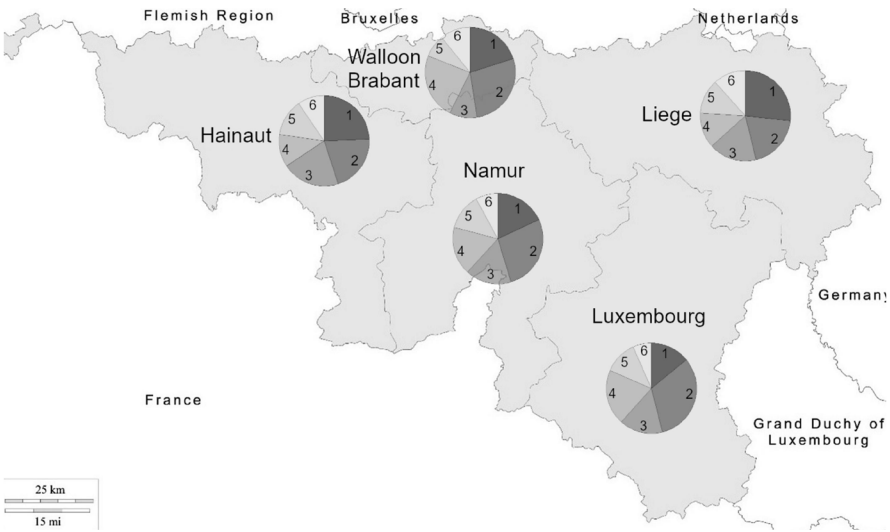
Energy Performance of Buildings Directive. (n.d.). https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/energy-performance-buildings-directive_en

Retrofit barriers



Case studies



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. https://doi.org/10.1016/j.enbuild.2021.111052

Ruellan, G., Attia, S., & Haesbroeck, G. (2025). Clustering of archetypal building-inhabitant pairs to improve energy efficiency: The case of the Walloon region in Belgium. Energy and Buildings, 335, 115549. https://doi.org/10.1016/j.enbuild.2025.115549

2024 EPBD recast

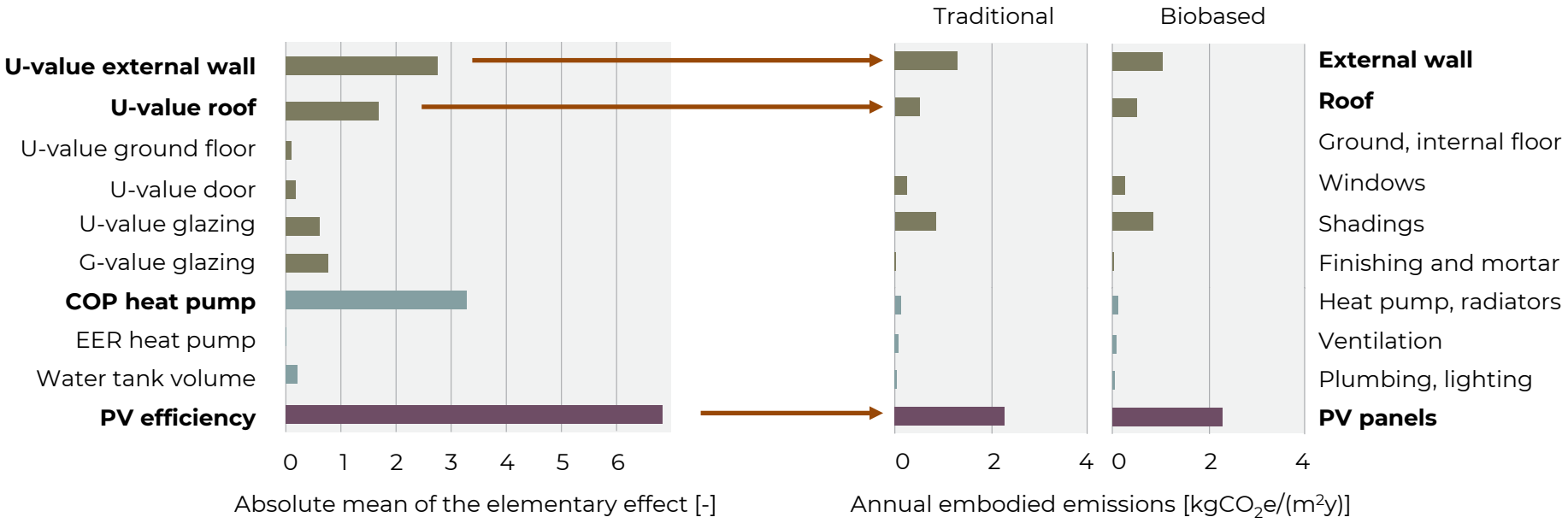
From Zero Energy to Zero Emissions

Zero-emissions building requirements for new buildings and deep renovations

Buildings must be 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**

Embodied – Operational emissions trade-off

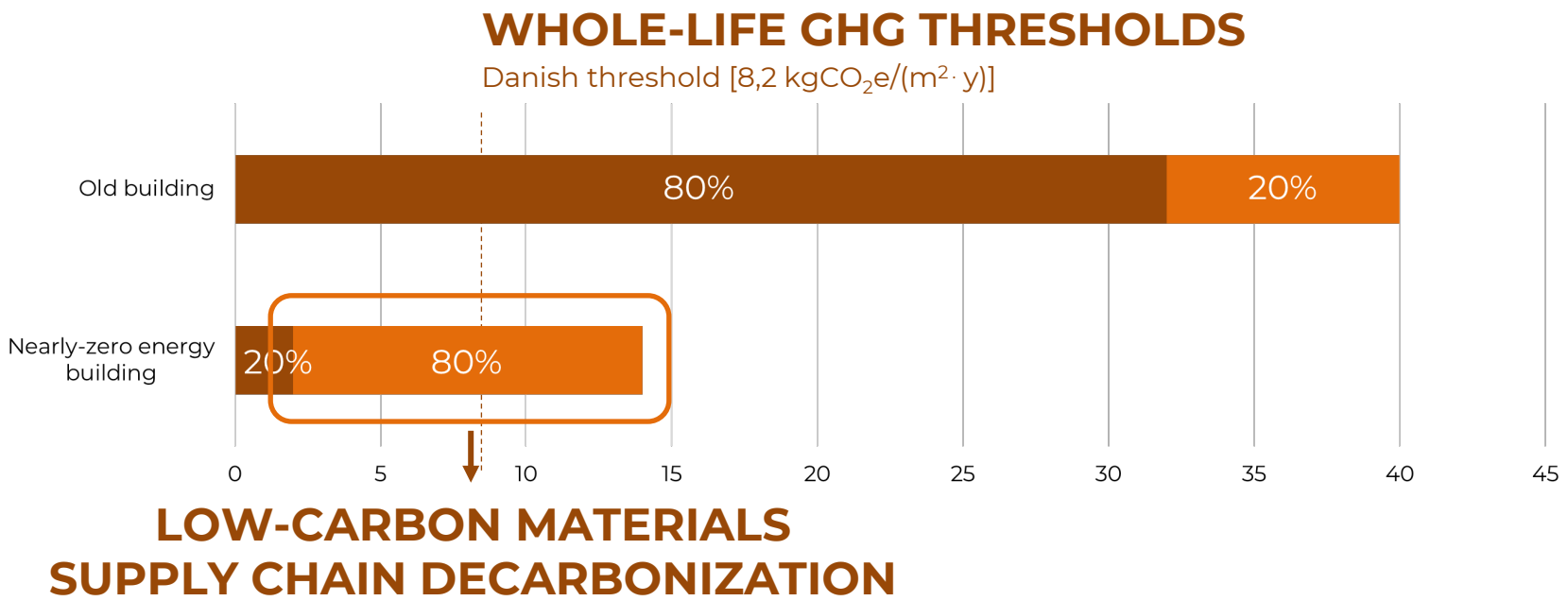
Operational emissions - Embodied emissions



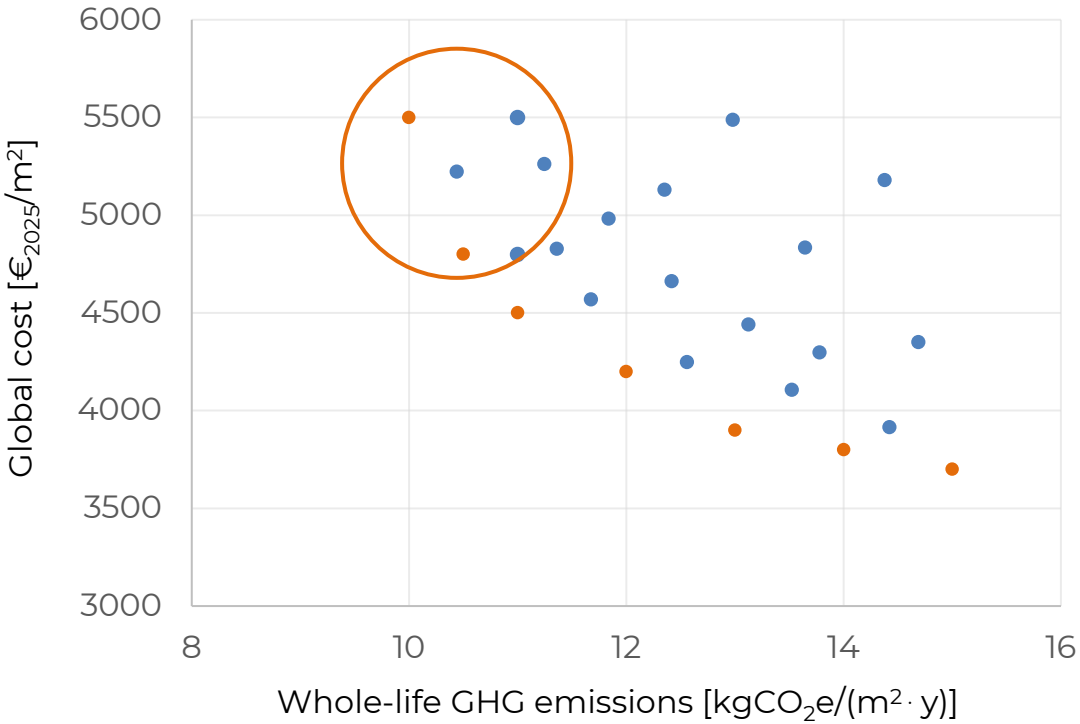
Adapted from Figures 10 and 11 in: Bertini, A., Al-Obaidy, M., Dasse, M., Amaripadath, D., Gobbo, E., & Attia, S. (2025). Parametrization of variables affecting the whole life carbon performance of nearly zero energy residential building renovation. Building and Environment, 278, 113013. https://doi.org/10.1016/j.buildenv.2025.113013

Embodied – Operational emissions trade-off

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



Emissions - cost trade-off

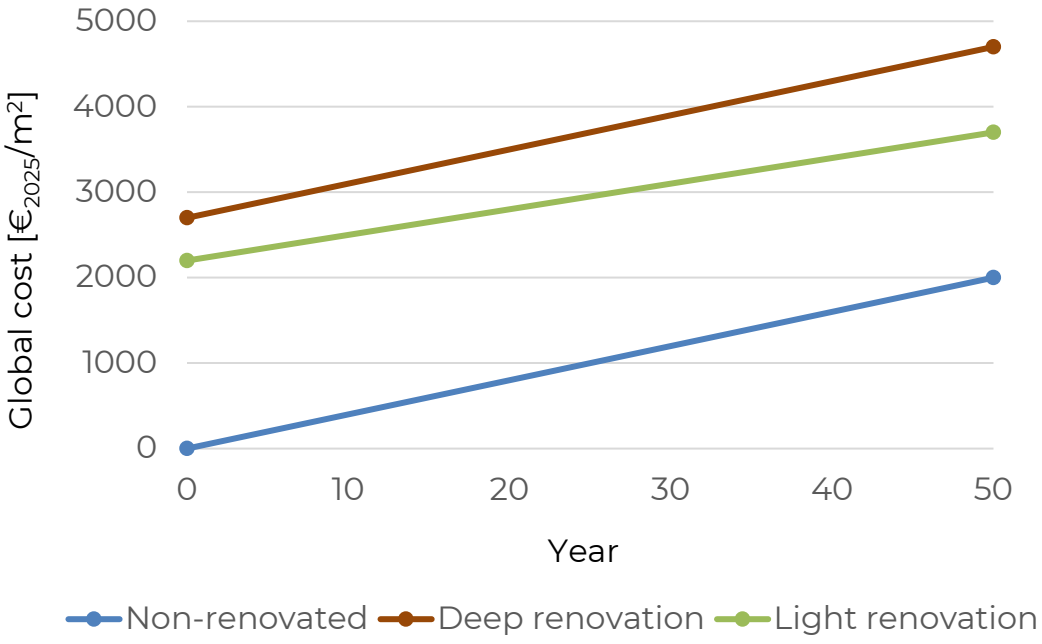


Whole-life GHG emissions

Global cost

Upfront investment (CAPEX)

Economic payback period



1. Low carbon taxation
2. Gas price < Electricity price

↓

a. Investment not recovered

b. Light > deep retrofits

↓

CHANGE OF PARADIGM & TARGETED SUBSIDIES

Targeted interventions

Owners' income

Low-income people

17 % of residential buildings in Wallonia (**EPC F and G**)

↓

Energy poverty & health risks

↓

Priority in renovation policies

High-income people

Houses with average energy use of **704 kWh/(m²·y)**

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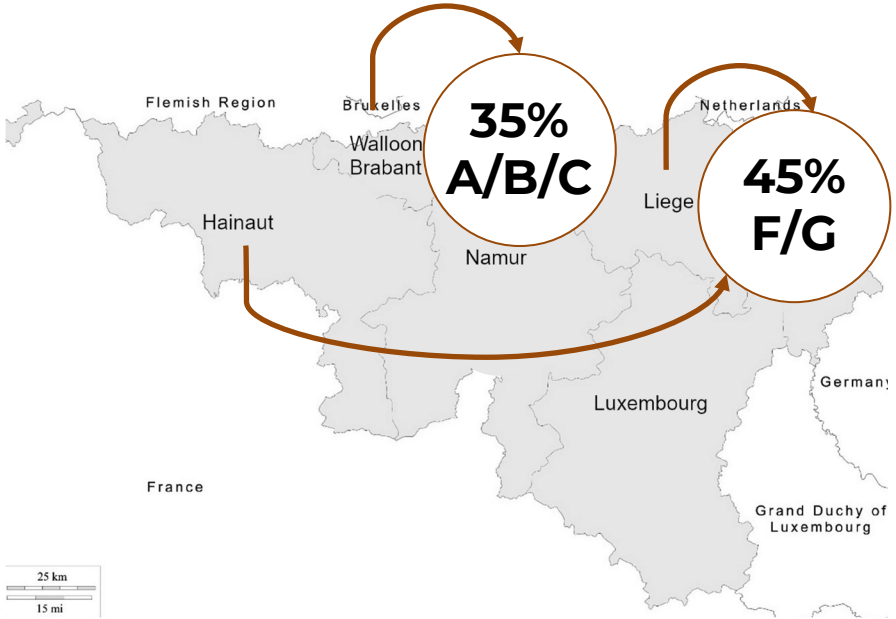
New reforms and regulations (High taxation on GHG emissions)

Targeted interventions

Location & granularity



Heterogeneity of building energy efficiency among municipalities

More efficient dwellings: Apartments
Less efficient dwellings: Semi-detached

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Strategies implemented
on the **city** and **municipal level**

Lessons learnt

Need for a **systemic** approach to achieve **sustainable** and **fair** carbon neutrality

References

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. https://doi.org/10.1016/j.enbuild.2021.111052

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