Travail de fin d'études / Projet de fin d'études : Developing a building energy model for a nearly zero-energy semi-detached home

Auteur : Khoshroo, Seyedehmarziyeh
Promoteur(s) : Attia, Shady; 26424
Faculté : Faculté des Sciences appliquées
Diplôme : Master en ingénieur civil architecte, à finalité spécialisée en ingénierie architecturale et urbaine
Année académique : 2024-2025
URI/URL : http://hdl.handle.net/2268.2/24923

Université de Liège
Faculté des Sciences Appliquées

Developing a building energy model for a nearly zero-energy semi-detached home

Final year project submitted in order to obtain the Master's degree in Civil Engineering and Architecture by

KHOSHROO Seyedehmarziyeh

Academic Year:
2024–2025

Supervisor: Prof. ATTIA Shady - SBD Lab
CoSupervisor :Dr. Amaripadath Deepak

Thesis Summary

As part of the European Union's ambitious carbon neutrality targets by 2050, the building sector represents a critical area for focused reduction of energy consumption and CO_2 emissions (European Commission, 2024). This study addresses a key challenge in this domain: the fundamental mismatch between a building's static energy performance metrics and the dynamic, time-varying carbon intensity of the national electricity grid. The research directly tackles this problem by developing a comprehensive, calibrated building energy model of a representative Belgian Nearly Zero Energy Building (NZEB) and integrating it with real-time grid data to accurately quantify operational carbon emissions. This work is a crucial extension of previous research, building upon the work of (Attia et al., 2021), who developed a benchmark model and calibration methodology, and the work of (Amaripadath, D. et al., 2025), which focused on the application of statistical and dynamic carbon accounting to building energy systems.

The research highlights a significant knowledge gap in the existing literature, revealing that relying on static, annual average emission factors is highly insufficient and can lead to a considerable underestimation of a building's true environmental impact. The study positions itself by strongly advocating for a more granular, hourly approach to carbon accounting, arguing that the timing of a building's energy consumption is as important as the total amount consumed. The study's most crucial component is the rigorous calibration of the building energy model against four years of detailed, real-world monitored data from the Sustainable Building Design (SBD) Lab, ensuring the model's predictive accuracy.

The most important finding is that using annual average carbon factors can underestimate operational emissions by a significant margin between 25–50% when compared to high-resolution, hourly calculations. This finding underscores the study's central argument that a Net Zero Energy (NZE) building is not automatically a Net Zero Carbon building. The results demonstrate that the addition of a battery storage system is key for achieving up to a 91% reduction in emissions by actively time-shifting electricity demand to periods when the grid's carbon intensity is low. This highlights the critical role of on-site storage in a decarbonizing grid.

In conclusion, this thesis contributes by applying a dynamic, hourly carbon intensity dataset to a calibrated residential building model. The results show that achieving near-zero operational carbon is technically feasible for the Belgian housing sector, provided that attention shifts from overall energy consumption to the timing of that consumption. These findings support the case for policymakers to adopt more time-sensitive performance standards and for practitioners to incorporate on-site generation and storage into their design strategies, thereby extending existing work on benchmark models and dynamic carbon accounting to a practical case study.

Keywords: Semi-detached building, 3D modelling, 3D printing, Energy efficiency, Energy Use Intensity, Energy mix, Operational carbon emissions, Renewable energy integration, Nearly Zero Carbon Buildings, Nearly Zero Energy Building.