Pathways Towards Life Cycle Net-Zero Emissions in Australian Residential Buildings

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Abstract: The residential building sector is responsible for substantial amounts of energy use and greenhouse gas (GHG) emissions in Australia. To support a net-zero built environment, it is critical to evaluate both energy and financial requirements of energy-saving solutions and provide effective strategies for stakeholders of the built environment. The specific objectives of this project are: (a) identify and summarise the energy reduction strategies for residential buildings; (b) conduct a comprehensive life cycle energy and cost analysis of these strategies; and (c) provide the energy-efficient and cost-effective strategies for various decision-makers (e.g., building designers, contractors, occupants, urban planners, and policymakers). The expected outcomes will include detailed insights into the effectiveness of different energy reduction measures, balancing both environmental and economic considerations. This research will provide pathways to help Australian Residential buildings to achieve the life cycle net-zero emissions.

Keyword： Residential buildings, Life cycle energy, Life cycle cost, Energy reduction measures, Net-zero Emissions

1 Introduction

The Australian Government aims to reduce greenhouse gas (GHG) emissions by 26%-28% below 2005 levels by 2030 (Australian Government, 2020) and achieve net-zero emissions by 2050. In response, there are a growing number of energy efficient strategies are proposed by different stakeholders. As policy strategies and advancements in building technology drive reductions in operational energy (OE), the relative share of embodied energy (EE) in buildings is expected to increase (Chastas et al., 2016; Lausselet et al., 2021; Li et al., 2020; Li et al., 2022; Zeng & Chini, 2017). Previous studies have primarily focused on OE, seldomly considering the significant embodied environmental impacts (Röck et al., 2020; Wrålsen et al., 2018). This leads to underestimations in the overall energy and GHG emissions of residential buildings when assessed only from an operational perspective. Few research has comprehensively evaluated life cycle energy across various scales of the built environment. Most existing research has focused either on operational energy or embodied energy, with little attention given to the combined effects of both. Moreover, the financial implications of implementing energy reduction measures have often been overlooked. This gap in research limits the ability to identify cost-effective strategies that address both energy and financial feasibility. Therefore, this study aims to conduct a comprehensive analysis of the life cycle energy and cost associated with various energy reduction strategies in residential buildings.

2 Methodology

This research mainly includes three steps. Firstly, this study identifies and summarizes energy reduction measures analyses based on comprehensive literature review. Based on the identified measures, this study evaluates the life cycle energy and cost for energy reduction measures in residential buildings in Inner Melbourne Cities. Based on the analysis, it provides energy-efficient and cost-effective strategies for various building decision-makers (e.g., building designers, contractors, occupants, urban planners, and policymakers). The scope of the research includes the analysis of cost and energy of energy reduction measures at the construction and operational stages for residential buildings within a case study area, specifically Inner Melbourne Cities, Australia.

3 Results

Figure 1(a) reveals that the OE(Ahmed et al., 2020) savings for retrofitting detached and semi-detached houses can effectively offset the increase in EE in Inner Melbourne Cities. For improving the energy efficient of apartments, the EE increase is higher than the OE savings. Retrofitting residential buildings to enhance

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energy efficiency will lead to an initial increase in costs, particularly for upgrades such as insulation improvements, air conditioning systems, and double-glazed windows (Figure 1 (b)). However, the savings from reduced electricity and gas consumption will offset these expenses over time. Based on the life cycle cost analysis of residential buildings from Inner Melbourne Cities, the payback period for these energy reduction measures is estimated to be 7.6 years. This indicates that, despite the upfront investment, residents and stakeholders can expect financial returns in the medium term, as energy savings continue to accumulate beyond the payback period, making retrofitting a financially viable option in the long run.

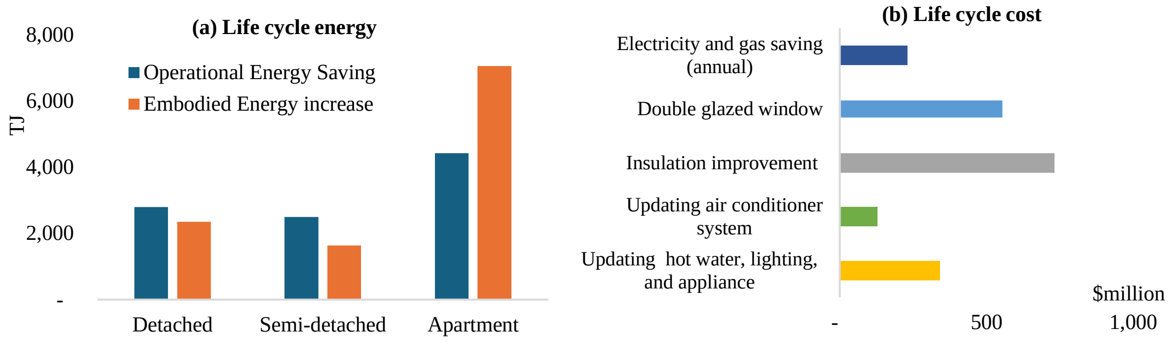

Figure 1. (a) Life cycle energy and (b) life cycle cost of energy reduction measures of residential buildings in Inner Melbourne Cities

The life cycle energy and cost analysis of residential buildings demonstrates that a combination of energy-efficient strategies can significantly reduce both OE and long-term costs. Early adoption of energy-efficient measures is important. Implementing retrofits or energy-saving upgrades during construction or early in a building's life cycle will increase long-term financial and environmental benefits. The following energy-efficient and cost-effective strategies are recommended for different decision-makers: (a) For Building Designers and Contractors: Integrating a combination of energy-efficient measures at the design and construction stages will reduce OE and operational costs, ensuring long-term savings and compliance with sustainability goals. (b) For Occupants: Regular maintenance and periodic upgrades to appliances, lighting, and HVAC systems will lead to reductions in energy bills contributing to lower household costs while supporting environmental goals. (c) For Urban Planners: Encouraging energy-efficient designs in new residential developments by incorporating mandatory energy performance standards into building codes and support retrofitting programs for existing buildings to drive energy savings at a broader urban scale. (d) For Policymakers: Developing and expanding financial incentives such as subsidies, tax credits, or low-interest loans to promote early adoption of energy-efficient technologies. These policies will drive widespread implementation and help accelerate the transition to a net-zero built environment.

4 Conclusion

This study provides a comprehensive life cycle energy and cost analysis of energy reduction measures in Australian residential buildings in Inner Melbourne Cities. The main findings show that while energy-efficient retrofitting increases EE and incurs initial costs, the OE savings more than compensate for these, making the retrofits economically and environmentally beneficial in the long term.

This study fills a research gap by integrating both EE and OE with life cycle cost analysis, providing a more holistic understanding of energy reduction strategies. This analysis provides a foundation for future research and guidelines development, contributing to the advancement of sustainable building practices and supporting Australia's net-zero emissions goals. The practical contribution of this study lies in the development of energy-efficient and cost-effective strategies for various stakeholders, including building designers, contractors, occupants, urban planners, and policymakers. These strategies, such as upgrading hot water systems, lighting, appliances, air conditioning systems, insulation, and windows, offer actionable insights to reduce life cycle energy and costs. Early adoption of these measures can accelerate progress toward Australia's net-zero emissions goals.

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