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Lifecycle costing sensitivities for zero energy housing in Melbourne, Australia

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ABSTRACT

Minimum energy efficiency standards for new housing are typically informed by regulatory impact statements, underpinned by lifecycle costing (LCC) analysis. While LCC techniques are empirical and testable, such analysis is informed by considerable assumptions on key parameters. These assumptions are often heavily contested in the literature and by built environment stakeholders, but there is limited exploration of their implications within wider policy developments. This paper addresses this gap by analysing the impact of a number of assumptions and their implications within a LCC analysis of zero energy housing options in Victoria, Australia. The results show that changes to assumptions on key parameters have significant impact on LCC outcomes, with associated policy implications. Analysis shows that there is a requirement for a detailed review and debate of the assumptions applied within LCC analysis which is used to inform the development of minimum energy efficiency standards in Australia and internationally. In particular, as housing is a long-lived infrastructure, the issue regarding the use of assumptions based upon historical data or data based upon future predictions is critical to the development of policy and energy efficiency standards.

1. Introduction

Many countries have implemented minimum energy and environmental performance standards and regulations for new housing stock in order to address increasing energy consumption and associated greenhouse gas emissions from the residential sector [1]. Such standards invariably aim to address market failures preventing improved sustainability outcomes from new housing [2,3]. A number of jurisdictions, such as the United Kingdom (UK) and California, have set out policy reforms which mandate zero energy housing (ZEH) performance, or approaching zero energy performance, by the end of the decade [4,5]. Such standards remain elusive in Australian policy development, where the policy agenda remains focused on small incremental performance changes [1].

The development of ZEH standards, as with previous housing performance standards, has been informed by empirical evidence about predicted costs and benefits [5,6]. In this context, lifecycle costing (LCC) techniques have emerged as means of developing objective information on the likely costs and benefits of proposed policy measures and to counter claims of adverse effects on the economics of the residential sector. For example, in the UK, the Code for Sustainable Homes has been developed through application of LCC assessments informing a series of regulatory impact statements [6–9], whereby initial concerns regarding the affordability of improved housing energy performance standards were addressed [10].

Despite the applicability of LCC for policy development, there remains limited empirical research into the LCC implications of increased energy efficiency at the household level, particularly from the point of view of new build houses. Studies to date have tended to focus on state level policy implications [11–13], on the influence of particular envelope components on thermal performance [14–17], or produced findings of limited applicability to the wider housing stock [18]. Furthermore, LCC methods have themselves largely been omitted from the policy debate [19]. Consequently, there has been little discussion on the assumptions currently applied within the limited LCC undertaken; where efforts have been made to test revised assumptions, policy makers have received strong opposition, forcing them to revert to original assumptions [20].

For example, the last regulatory impact statement for proposed improvement to the minimum standards for new housing

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in Australia [20], attempted to make limited changes to assumptions compared to previous analysis (e.g. discount rates, building costs, future energy prices), arguably applying assumptions which were more in line with international best practice. Strong opposition from key actors to these changes meant that the original assumptions were applied in the final analysis [20]. The change to assumptions had a significant impact on the overall results. The change of discount rate from 5% to 7% meant that the overall benefits of the improvement of minimum standards from 5 star to 6 star (the star ratings are explained in Section 3.1) decreased from +$317 million with a benefit–cost ratio of 1.13 to −$277 million with a benefit–cost ratio of 0.88 (all costs presented in this paper are in US dollars. Conversion from Australian to US dollars where relevant was calculated for 30th June 2011 when US$1 = AUS$1.07 [21]). This example highlights that the selection of the input parameters and associated assumptions is critical in developing robust LCC data as building standards are improved to a ZEH standard, and debate increasingly focuses on the costs and benefits of new housing models. Such parameters are critical not only from the point of view of achieving optimal cost–benefit ratios, but also to establish the scope and targeting of effective policy instruments.

This paper firstly explores LCC techniques and discusses a number of central assumptions within LCC, which are typically applied for costing of energy efficiency and renewable energy technologies in new housing. Following this, a method to test a number of identified assumptions in the LCC of ZEH is described. Outcomes of LCC analysis are presented, and the implications of results for policy makers are addressed together with insights to wider debates about sustainable housing and LCC methods. Specifically this paper asks the following research questions:

1. What impact do changes to key assumptions have on the outcome of LCC analysis for ZEH in the temperate climate of Melbourne, Australia?
2. What implications arise from the analysis of research question 1 with regards to selection of appropriate assumptions, LCC analysis and housing standards?

For this research ZEH is defined as housing which has the capacity to generate all energy consumed in the dwelling across a calendar year through renewable energy technologies [1].

2. Lifecycle costing techniques

LCC is a type of investment calculus used to rank different investment alternatives [22]. The development of LCC has its origin in normative neoclassical economic theory which states that organisations seek to maximise profits by always operating with full knowledge [23]. The main difference with traditional investment calculus is that the LCC approach has an expanded lifecycle perspective, and thus considers not only investment costs, but also operating costs during the product's estimated lifetime [22]. LCC analysis should cover a defined list of costs over the physical, technical, economic or functional life of a constructed asset, over a defined period of analysis [24]. LCC thereby seeks to optimise the cost of acquiring, owning and operating physical assets over their useful life by attempting to identify and quantify all of the significant costs involved in that life, using the present value technique. LCC methods enable the quantification of alternative investment scenarios so as to ensure the adoption of the optimum asset configuration, across materials configuration, use and replacement phases [25]. In terms of building thermal performance calculations, LCC analysis should identify the optimum materials investment, operating energy cost, cost saving and pay-back period which minimise the total cost over the building's lifecycle [26]. The scope, form, level and period of analysis together with an anticipated level of uncertainty and risks relating to the LCC analysis and reporting should all be explicitly defined [24].

Despite methodological advances, the use of LCC remains contested. Authors such as Pearce [27], have been critical of the concept of placing a monetary value on non-market goods and services, such as on natural resources and ecological services. Another issue raised is that LCC outcomes lead to a determination of the 'feasibility' of the options considered in analysis from a costs perspective [28]. However, outcomes of LCC do not determine if the most feasible option from a technical and costs perspective is in fact the most appropriate policy approach [29,30]. Outcomes of LCC must therefore be integrated into wider decision-making processes.

2.1. LCC of housing thermal performance measures – critical parameters

The parameters of the LCC analysis depend on the purpose and use of the intended results. The validity and relevance of the analysis can depend on the parameters selected [24]. While the literature raises a number of concerns about the use of LCC, there are steps which can be taken to minimise limitations. The undertaking of sensitivity analysis on results, for example, can help to mitigate limitations of LCC by testing the impact of variations in key assumptions on reported outcomes [31]. However this testing is often limited or for the most part overlooked in the publication of LCC derived analysis.

This represents a critical oversight, particularly as the sensitivities in question can result in differences in results of several orders of magnitude as described in Section 1. The International Organisation for Standardisation Standard *ISO 15686–5. Buildings and constructed assets – Service-life planning – Part 5: Life-cycle costing* describes a number of critical factors to be considered in defining the scope and form of an LCC analysis of buildings. These include lifecycle and time-horizon parameters, operation maintenance and repair cost variables, discount rates, energy and utilities costs and taxes and subsidies [24]. In the case of housing energy and environmental performance LCC analysis, the literature further highlights a number of these parameters. For the purposes of testing the sensitivities of LCC analysis of energy efficiency measures, key assumptions are typically made with regards to the following parameters [8,20]:

- Discount rates,
- Cost of upgrades (materials, construction and design),
- Future prices of energy,
- House size,
- Occupant behaviour and use patterns,
- Lifespan of building,
- Occupancy rates,
- Frequency of the maintenance factor, and
- Variation of the asset's utilisation or operating time.

Some assumptions are based on supporting evidence, but this is not always the case. Assumptions which once may have been appropriate can become out-dated as new research, information or trends emerge. For example, average floor area per new house has increased in Australia in recent years while the average number of occupants has decreased in the same period [32,33]. If assumptions are not revised on a regular basis, there is a danger that outcomes of analysis may no longer be representative of current or future conditions and could result in the development of ineffective or misdirected policy approaches. The following presents a summary of current challenges and debates on a number of key assumptions