Affordable zero emission housing: Through life cost-benefit analysis to identify policy pathways for residential new-build in Melbourne, Australia

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From an energy efficiency perspective, recent housing policy in Australia has focused on setting minimum energy standards in order to reduce greenhouse gas emissions. Internationally, the UK and the USA have implemented definite policy targets of zero emission new housing by 2020. In Australia, the current minimum housing standard is ‘5 stars’, increasing to ‘6 stars’ by mid 2011. This policy direction has been strongly debated, and there remains uncertainty over the reliability of presented cost benefit data. A lack of empirical evidence has impeded the debate; particularly a lack of evidence on the through life costs and benefits of net zero and low emission housing options to private households and the costs and benefits of renewable energy technologies. This paper seeks to inform the present knowledge gap by applying cost benefit methods. AccuRate thermal simulation house modelling and lifecycle costing are applied to explore the costs and benefits across 50 year and 100 year time-horizons for net zero emission new house scenarios in Melbourne, Australia. Results show that net zero emission housing is economically viable at these time-horizons, with accumulated economic savings of a magnitude of 78% compared to a business as usual scenario over 50 years, with a 100% reduction of net energy emissions. Potential policy and regulatory pathways through which to achieve zero emission residential new-build based upon this empirical research are identified. This research provides empirical evidence to support stronger energy efficient housing standards and has significant implications for the future direction of housing standards in Australia. It argues that current housing standards policy is too narrow in focus, and that renewable energy aspects are presently overlooked.

Keywords: Zero emission housing, renewable energy, cost benefit analysis
1 Introduction
The imperative to reduce greenhouse gas (GHG) emissions, together with increased uncertainty regarding future energy prices, means that a shift to a low carbon economy is becoming increasingly critical from environmental, economic and social perspectives. The importance of the built environment in this context is widely recognised in the literature (Jones et al., 2007, Ortiz et al., 2009, Burnett, 2007, Ding, 2008, UNEP, 2007). While the residential sector is responsible for a significant amount of fossil fuel energy consumption (Swan and Ugursal, 2009), the sector also presents opportunities for significant energy savings at relatively low cost (Uihlein and Eder, 2010, Jakob, 2006).

In this respect, a more sustainable model of housing provision would incorporate energy demand reduction augmented with energy efficiency features (Joelsson and Gustavsson, 2009). The net ‘Zero Emission House’ (ZEH) as described by Torcellini et al (2006) and Hernandez and Kenny (2010) provides one such model. Benefits of ZEH include reduced energy demand, zero (net) energy emissions and protection from energy price increases. Other benefits include, protection from blackouts, more stable indoor air temperatures, improved indoor air quality and added resale value (Vale and Vale, 2000, Nevin and Watson, 1998).

However, a change from the current model of housing design, construction and use to a ZEH paradigm would require significant innovation and a change in both policy and practice (Smith, 2007). Such a departure from current practice presents significant challenges to actors and stakeholders in this sphere, including decision-makers, industry practitioners and consumers. As articulated by Bergman et al (2007) ‘there is much evidence that the mainstream building sector…has practices and a culture which are incompatible with sustainability on various levels, and that sustainability issues require not only a technological shift in the building industry, but a complete paradigm shift: changes in structure, communication, strategy and actors.’

To date in Australia, there has been is a lack of clear cost benefit research into the characteristics of low emission housing, in terms of both higher energy efficiency performance and renewable energy technologies. The lack of information is significant, not least because there is a wide body of published research on the subject of residential energy efficiency (Chwieduk, 2002, Morrissey et al., 2010, Zhu et al., 2009). A significant gap in analysis remains a lack of empirical research into the life-cycle cost implications of increased energy efficiency at the household level, and an interpretation of the wider implications of this analysis in terms of STT and sustainability theories.

This paper aims to investigate the lifetime economic and environmental costs and benefits of ZEH options, addressing aspects of design, energy efficiency and particularly the incorporation of renewable energy technology. Analysis is conducted for the cool temperate climate of Melbourne, Australia (See Australian Bureau of Meteorology for climate data recorded for Melbourne Climate Zone 60, Tullamarine Airport (BOM, 2010)).

2 Methods
2.1 Cost Benefit Analysis of ZEH scenarios
Cost benefit analysis is one of the most commonly applied tools of economic evaluation in the public decision-making process (Simpson and Walker, 1987), despite shortcomings such as those discussed by Sáez & Requena (2007). The application of cost benefit analysis to inform Research to assess the costs and benefits of the government’s proposals to reduce the carbon footprint of new housing development (DCLG, 2008b) represents international best practice of research into the costs and benefits of ZEH. Analysis builds upon this approach as well as methods, data and assumptions from previous research into energy efficiency in the residential sector in Australia (Newton and Tucker, 2009, Constructive Concepts and Tony Isaacs Consulting, 2009) and internationally (DCLG, 2008a, Boardman et al., 2005, DCLG, 2008b).
2.2 Energy efficiency of housing in Australia

For the purposes of this analysis, zero emission housing is defined as a net balance of zero between renewable energy generation and total energy consumed by the occupying household across a year.

A series of ZEH scenarios is developed and a Lifecycle Costing assessment is conducted to empirically test the relationship between upfront investment costs for ZEH options and ongoing energy savings. Costs are analysed in terms of accumulated totals and discounted 2010 equivalent values.

To develop ZEH scenarios, two aspects were focused upon:

I. Improved thermal performance of the building envelope, through investment in material additions to construction (insulation, shading, glazing).

II. Investment in on-site renewable energy technology options.

Figure 1 provides a schematic overview of the applied approach.

Figure 1: Methodological flow map

The baseline for analysis is selected to be representative of new housing in Melbourne, Victoria in 2010. Selected on the basis of analysis of an initial sample of eighty volume build house plans, a baseline detached house scenario is developed. This baseline has a floor space of 246 m², consistent with ABS data on average new detached house size (ABS, 2010a). Building materials incorporated in simulation modelling are consistent with building practices in Melbourne in 2010, and include brick veneer outer wall construction and slab on ground base (ABS, 2008). It is assumed that the baseline house has no renewable energy technology. The Nationwide House Energy Rating Scheme (NatHERS) approved software AccuRate, is used to calculate annual energy requirements for heating and cooling purposes for this baseline design. In the NatHERS rating system, unique star-bands are set for each climate zone in Australia, taking into account the extremes of the local weather conditions. Simulations for this study are conducted for NatHERS climate zone 60. The star rating achieved, between 0 and 10 is based on the space heating and cooling demand in MJ/M², from a maximum at 0 stars to a minimum at 10 stars. AccuRate software has been validated through BESTEST (Delsante, 2004)
2.3 Improved thermal performance

To develop scenarios of improved thermal efficiency of the building envelope, material upgrades are applied systematically. These include improved ceiling insulation, infiltration control, shading, external wall insulation, window glazing and internal wall insulation. In this way, the ‘five stars’ rated baseline is adjusted to obtain higher performing thermal efficiency scenarios. Table 1 presents a summary of the costs of investment for higher efficiencies for this phase of analysis, compared with the baseline. Importantly, upgrade costs assumed no fundamental design changes to the developed model. Final costs, shown in Table 1, represent average values across the range of house sizes analysed.

<table>
<thead>
<tr>
<th>NatHERS Star rating</th>
<th>Annual energy requirement (heating and cooling)</th>
<th>Improvement in efficiency over mandatory requirement</th>
<th>Investment cost compared with ‘five stars’ baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘five stars’</td>
<td>182 MJ/M²</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>‘six stars’</td>
<td>138 MJ/M²</td>
<td>24%</td>
<td>$1,270</td>
</tr>
<tr>
<td>‘seven stars’</td>
<td>100 MJ/M²</td>
<td>45%</td>
<td>$4,226</td>
</tr>
<tr>
<td>‘eight stars’</td>
<td>64 MJ/M²</td>
<td>65%</td>
<td>$9,435</td>
</tr>
<tr>
<td>‘nine stars’</td>
<td>30 MJ/M²</td>
<td>83%</td>
<td>$26,486</td>
</tr>
<tr>
<td>‘ten stars’</td>
<td>2 MJ/M²</td>
<td>99%</td>
<td>$53,000</td>
</tr>
</tbody>
</table>

Table 1: Upgrade costs for different star ratings for detached new brick veneer housing in Melbourne, additional to base house build cost

2.4 On-site renewable energy technology

On-site renewable energy options are considered, consistent with the approach reported in (DCLG, 2008b). For the purposes of this paper, onsite solar photovoltaic cells (SPV) are focused on. Government rebates and feed-in tariffs for renewable energy generation are included where appropriate, based on current government policy measures. The resale value of improved building thermal performance (Laquatra, 1986) and renewable energy technologies (Jackson et al., 2009) is included in the analysis. Upfront costs for renewable energy options ranged from $21,600 (10 stars with SHW) to $30,800 (5 stars).

Developed scenarios account for full electric heating and cooling options and gas heating, electric cooling combination options, together with gas, electric or solar hot water (SHW) options. Scenarios presented in this paper were selected on the basis of long term performance and practical feasibility. As a starting point for analysis, costs of SPV were obtained from local suppliers. Future energy prices were predicted based upon analysis conducted by Garnaut (2008) and Hatfield-Dodds and Denniss (2008). Equipment replacement costs are incorporated in the analysis where necessary. The final life cycle costs calculated therefore include upfront costs, through life costs and end of life residual value, and are presented as Net Present Value (NPV) figures, in 2010 equivalent Australian dollars.

3 Results

Over 300 scenarios are modelled in total, applying various combinations of improved thermal efficiency and renewable energy technology options. All scenarios are compared with a ‘business as usual’ (BAU) baseline scenario. This refers to a ‘five stars’ thermal performance of the building envelope, full electric heating and cooling equipment and no renewable energy technology. Table 1 presents results of scenario analysis, showing in rank of accumulated costs, the top 10 scenarios across 50 year and 100 year time-horizons.
3.1 Accumulated costs

The percentage cost reductions for the top 10 ZEH options presented in Table 2 against the 5 star BAU (electric) range from 45-53% (50 years) and 75-77% (100 years) for the low energy cost BAU option, and 77-80% (50 years) and 97-98% (100 years) for the high energy cost BAU option.

Figure 2 presents scenarios from Table 2 compared to a 'five stars' BAU projection, for low predicted future energy price. Results show that while the BAU scenario demonstrates the lowest costs over a 5 year time horizon, significant cost savings accumulate over extended time-horizons. A number of the scenarios fall below the BAU costs in 35 years or less, with some as low as 16 years.

<table>
<thead>
<tr>
<th>Star rating</th>
<th>SPV size (kW)</th>
<th>SHW* included</th>
<th>50-year time-horizon</th>
<th>Accumulated Costs</th>
<th>100-year time-horizon</th>
<th>Accumulated Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8 star</td>
<td>3</td>
<td>Yes</td>
<td>$91,677</td>
<td>9 star</td>
<td>2.5</td>
</tr>
<tr>
<td>2</td>
<td>7 star</td>
<td>3</td>
<td>Yes</td>
<td>$93,824</td>
<td>8 star</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>6 star</td>
<td>3.5</td>
<td>Yes</td>
<td>$96,163</td>
<td>9 star</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>8 star</td>
<td>4</td>
<td>No</td>
<td>$97,102</td>
<td>7 star</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>7 star</td>
<td>4</td>
<td>No</td>
<td>$99,829</td>
<td>7 star</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>7 star</td>
<td>3</td>
<td>Yes but no R/FIT**</td>
<td>$101,024</td>
<td>10 star</td>
<td>2.5</td>
</tr>
<tr>
<td>7</td>
<td>6 star</td>
<td>4.5</td>
<td>No</td>
<td>$102,167</td>
<td>8 star</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>5 star</td>
<td>3.5</td>
<td>Yes</td>
<td>$103,502</td>
<td>10 star</td>
<td>2.5</td>
</tr>
<tr>
<td>9</td>
<td>5 star</td>
<td>4.5</td>
<td>No</td>
<td>$104,602</td>
<td>9 star</td>
<td>3.5</td>
</tr>
<tr>
<td>10</td>
<td>8 star</td>
<td>3</td>
<td>Yes but no R/FIT**</td>
<td>$106,233</td>
<td>9 star</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*SHW – solar hot water
**R/FIT – rebate/feed-in tariff

Table 2: Top 10 ZEH options and accumulative costs after 50 years

The percentage cost reductions for the top 10 ZEH options presented in Table 2 against the 5 star BAU (electric) range from 45-53% (50 years) and 75-77% (100 years) for the low energy cost BAU option, and 77-80% (50 years) and 97-98% (100 years) for the high energy cost BAU option.

Figure 2 presents scenarios from Table 2 compared to a 'five stars' BAU projection, for low predicted future energy price. Results show that while the BAU scenario demonstrates the lowest costs over a 5 year time horizon, significant cost savings accumulate over extended time-horizons. A number of the scenarios fall below the BAU costs in 35 years or less, with some as low as 16 years.
The cost-optimal combination of thermal efficiency measures with renewable energy technology options is dependent on the time-horizon of analysis. Figure 3 provides a summary, showing the cost-optimal star rating (presented in MJ/M2) across a 100 year time-horizon. It is clear that high thermal efficiencies become significantly more cost-effective as the time-horizon expands. A ‘six stars’ rating is optimal below 20 years for example. At 20 years ‘seven stars’ becomes cost-optimal. At 50 years time-horizon, an ‘eight stars’ house is cost-optimal and beyond 75 years, a ‘ten stars’ rating is the most cost-effective option.
In order to achieve a ZEH system, consisting of energy efficiency building envelope and renewable energy technology, a decreasing SPV system size is required as the building envelope energy efficiency increases (Figure 4).

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Figure 3: Optimal star rating (cost-efficiency) by energy requirement across time

Figure 4: Cost-Optimal ZEH configuration (Solar photovoltaic system size requirement combined with energy efficiency ratings)
3.2 Discounted cash flows

In conjunction with analysis on accumulated costs, analysis is conducted to calculate energy savings in 2010 equivalent dollars. For this analysis, the Net Present Value (NPV) of the investment necessary for each developed ZEH scenario is calculated. For the purposes of this paper, the real discount rate of 3.5% is applied for the first 30 years of analysis, which is then reduced by 0.5% for the 30-75 years period. This approach is consistent with the declining discount rates approach of the UK Government (HM Treasury, 2003). Analysis is conducted in nominal terms, using an average inflation rate of 3.32% (ABS, 2009).

Table 3 and Figure 5 present the outputs of this analysis. A number of scenarios demonstrate negative NPV of investment across the early years of the building life-span. However around 25 years many of these scenarios become positive.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>5 years</th>
<th>10 years</th>
<th>25 years</th>
<th>50 years</th>
<th>75 years</th>
<th>100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 star ZEH (with SHW)</td>
<td>$4,516</td>
<td>$3,765</td>
<td>$3,467</td>
<td>$16,546</td>
<td>$27,140</td>
<td>$53,906</td>
</tr>
<tr>
<td>6 star ZEH (with SHW)</td>
<td>$5,747</td>
<td>$5,724</td>
<td>$7,145</td>
<td>$20,387</td>
<td>$31,115</td>
<td>$57,902</td>
</tr>
<tr>
<td>6 star ZEH</td>
<td>$4,754</td>
<td>$4,629</td>
<td>$3,381</td>
<td>$14,878</td>
<td>$31,840</td>
<td>$61,332</td>
</tr>
<tr>
<td>7 star ZEH (with SHW but with no R/FIT)</td>
<td>-$2,057</td>
<td>-$2,485</td>
<td>-$902</td>
<td>$12,411</td>
<td>$21,898</td>
<td>$45,735</td>
</tr>
<tr>
<td>7 star ZEH (with SHW)</td>
<td>$3,755</td>
<td>$3,703</td>
<td>$5,597</td>
<td>$18,911</td>
<td>$28,398</td>
<td>$52,234</td>
</tr>
<tr>
<td>7 star ZEH</td>
<td>$2,762</td>
<td>$2,607</td>
<td>$1,833</td>
<td>$13,401</td>
<td>$29,123</td>
<td>$55,664</td>
</tr>
<tr>
<td>8 star ZEH (with SHW)</td>
<td>$2,618</td>
<td>$2,996</td>
<td>$6,619</td>
<td>$20,343</td>
<td>$29,718</td>
<td>$53,407</td>
</tr>
<tr>
<td>8 star ZEH (with SHW but no R/FIT)</td>
<td>-$6,051</td>
<td>-$6,479</td>
<td>-$4,896</td>
<td>$8,417</td>
<td>$17,904</td>
<td>$41,741</td>
</tr>
<tr>
<td>8 star ZEH (with SHW)</td>
<td>$593</td>
<td>$1,136</td>
<td>$4,262</td>
<td>$17,829</td>
<td>$27,316</td>
<td>$51,153</td>
</tr>
<tr>
<td>8 star ZEH</td>
<td>-$400</td>
<td>$40</td>
<td>$876</td>
<td>$12,607</td>
<td>$28,462</td>
<td>$55,025</td>
</tr>
<tr>
<td>9 star ZEH (no R/FIT)</td>
<td>-$25,543</td>
<td>-$25,252</td>
<td>-$21,812</td>
<td>-$9,099</td>
<td>-$1,236</td>
<td>$19,688</td>
</tr>
<tr>
<td>9 star ZEH (SHW but with no R/FIT)</td>
<td>-$20,928</td>
<td>-$20,637</td>
<td>-$17,959</td>
<td>-$4,575</td>
<td>$3,671</td>
<td>$24,557</td>
</tr>
<tr>
<td>9 star ZEH (with SHW)</td>
<td>-$15,688</td>
<td>-$15,240</td>
<td>-$12,432</td>
<td>$952</td>
<td>$9,198</td>
<td>$30,084</td>
</tr>
<tr>
<td>9 star ZEH</td>
<td>-$16,714</td>
<td>-$16,369</td>
<td>-$15,114</td>
<td>-$3,312</td>
<td>$11,302</td>
<td>$34,914</td>
</tr>
<tr>
<td>10 star ZEH (with SHW but no R/FIT)</td>
<td>-$46,497</td>
<td>-$46,206</td>
<td>-$42,413</td>
<td>-$28,865</td>
<td>-$20,486</td>
<td>$422</td>
</tr>
<tr>
<td>10 star ZEH (with SHW)</td>
<td>-$45,628</td>
<td>-$44,718</td>
<td>-$40,410</td>
<td>-$26,863</td>
<td>-$18,483</td>
<td>$2,425</td>
</tr>
</tbody>
</table>

Table 3: Net Present Value across time for scenarios from Table 2

Figure 5: Net Present Value across time for scenarios from Table 3
4 Discussion

Pressures from climate change and energy security/future cost issues together with the empirical evidence on ZEH presented in this paper suggests that a significant change in current housing practice in Australia is economically viable and environmentally and socially prudent. The current conditions are characteristic of future policy development; favourable economics for ZEH, significant energy related pressures/issues and alternative technologies/actors ready to be incorporated into mainstream housing practices if given a window of opportunity and adequate government support.

Policy development to lower emission housing has been underway in Australia since the early 1990’s when policy makers became notably active in this space. In 1991, minimum requirements for insulation were introduced for new housing (Greene and Pears, 2003). Following this, the NatHERS scheme, which is now used by most states in Australia, was introduced in late 1997 (CSIRO, 1997). This scheme has resulted in a progressive strengthening of minimum performance standards. In July 2005 the minimum requirement for new housing in Victoria was raised from approx 2 stars, to 5 stars and in May 2011 this will be revised to a 6 star minimum (Building Commission, 2009). These policy initiatives have resulted in significant changes in housing performance in Australia over the past two decades.

However there is still a lack of any meaningful discussion regarding the inclusion of renewable energy technology in housing requirements (SOGEE, 2010), or a consideration of the wider implications of the adoption of ZEH across society. As discussed in the literature, housing is important because it provides not only a place to stay but amongst other things, security and confidence for households (DHS, 2006, ACF and VCOSS, 2008). The energy performance of housing in particular has social justice and equity implications (ACF and VCOSS, 2008).

The combination of renewable energy technologies and star ratings is critical, not only from an economic, cost optimisation perspective, but also for energy security and greenhouse gas emission reduction perspectives. A 10 star rated house for example, will only reduce GHG emissions by 45-50% (DEWHA, 2008), when compared with a 5 stars baseline. ZEH strategies require a combination of improved building envelope thermal efficiency combined with renewable energy technologies, as demonstrated by results of cost-benefit scenario analysis.

Across a 50 year time-horizon, an 8 stars thermal performance of the building envelope standard with 3kW of SPV and a solar hot water system provides cost-optimal outcomes. The environmental savings of this ZEH scenario are significant when compared with a business as usual ‘five stars’ design. The ZEH building would save 6,250 kWh of fossil fuel energy per year equivalent to 8,375kg of GHG emissions (ESAA, 2010). If the 39,000 new detached housing approvals for 2009-10 (ABS, 2010) in Victoria were built to a ZEH standard, the environmental savings would equate to 243,750,000 kWh per year of avoided fossil fuel energy and 326,625 tonnes of avoided GHG emissions equivalent. Over a building life span of 50 years, this amounts to 16,331,250 tonnes of avoided GHG emissions equivalent for houses built in 2010.

These figures present a strong empirical case for ZEH in place of current practices, under both economic and environmental criteria. These modelling results are sensitive to a number of factors, including future energy price applied, the time-horizon of analysis and the ratio of investment in thermal efficiency to renewable energy technology. For example if the higher future energy cost predictions are to eventuate, the modelling supports higher star ratings at shorter time horizons. The modelling results should be considered as conservative as in reality, the housing industry and consumers will find ways to reduce costs. Bulk buying of renewable energy technologies is one example for cost reduction and has been shown to be successful in a number of Australian case studies (Manningham City Council, 2009).
As well as the environmental considerations, wider social aspects such as housing affordability must also be considered. As discussed by Garnaut (2008), energy prices are expected to rise significantly in Australia over the coming years. This will place added strain on households who are already under financial stress due to rapidly increasing house prices (ACF and VCOSS, 2008). Current housing policy, however, views housing affordability as an upfront cost issue. A shift to ZEH would necessitate a shift in thinking to incorporate affordability considerations across the building lifespan, as well as considering the costs of energy from household welfare and security perspectives. While there significant upfront capital costs associated the ZEH scenarios included in this analysis, ongoing savings in energy mean that ZEH options are economically more cost-effective across the full term of the building life-span. The UK has recognised the increased upfront costs of ZEH as a significant challenge for any potential housing transition and has implemented a number of financial programs to help assist with the provision of accessible funds for such investment.

Analysis has shown that current policy directions for housing performance are sub-optimal in terms of long term environmental and economic considerations. Despite this, policy development in this space has been contested at each stage of incremental improvement in standards. Further study is required to explore the nature of these past contentions. In particular, a characterisation of the conditions which would facilitate efficient and effective change is required. The authors aim to apply theories of innovation as one means of exploring of these issues. One relatively new theory in this body of knowledge is ‘Socio-Technical Transitions’ which argues for longer term policy development which looks beyond technical aspects of change to include wider social aspects (Geels, 2002, Rip and Kemp, 1998). Key aspects of transitions theory including visioning, goal setting, scenario development and reflexive learning will be incorporated into analysis. While these aspects are critical in the charting and characterisation of ongoing transitions, they have been notably missing from housing policy in the Australian context.

5 Conclusion

Policies for zero or low emission new housing have been adopted by several countries as a target to achieve by 2020. However, Australia is currently lagging behind in the development of new housing performance policy. Housing policy is still focused primarily on heating and cooling loads while ignoring the integration of renewable energy technologies. The discussion needs to be broadened beyond the benefits and costs of star ratings to include longer term indicators of housing performance, including renewable energy technologies. Intervention by the Australian or Victorian governments to develop policy which is more inclusive of sustainability aspects would help to facilitate ZEH in a timely, efficient and effective manner. This research is part of a larger PhD thesis. The next phase of the study will analyse in further depth the reported lifecycle costing analysis and investigate implications for policy direction, applying aspects of innovation theory. Recommendations for policy directions will be developed for decision makers to help inform more comprehensive and effective future housing performance.
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