



International Conference on Improving Residential Energy Efficiency, IREE 2017

Benefits and challenges of energy efficient social housing.

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Abstract

This paper presents a multi-method (interviews, cost-benefit analysis, technical monitoring) longitudinal evaluation of ten social housing dwellings in Horsham (Victoria, Australia), including four low-energy and six control houses. Occupants of the low-energy houses purchased 45-62% less electricity, had lower utility bills resulting in financial savings of \$1,050/year, had improved thermal comfort, health and social outcomes. However, there were several challenges for the providing government department and tenants, including supporting tenants to use certain sustainability features of the house as designed. The paper concludes by providing discussion to help guide similar projects in the future to more sustainable outcomes.

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Peer-review under responsibility of the scientific committee of the International Conference on Improving Residential Energy Efficiency.

Keywords: Low-energy housing; low-income households; social housing; energy efficiency; thermal comfort; health and wellbeing; cost-benefit analysis; interviews.

1. Introduction

Rising energy costs are an increasing concern for households across Australia and many developed countries. In the 10 years to mid-2013, electricity prices in Australia rose by an average of 72% and gas prices rose by an average of 54% [1]. Some analysts predict that the costs for energy in Australia will continue to increase beyond the rate of general inflation although not at the rate seen over the past decade [2].

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Low-income households have been found to be most at risk from experiencing increasing energy prices [3-5]. There are three key reasons for why this is such a concern. Firstly, research has found that low-income households have greater difficulty in paying their energy bills, often resulting in involuntary disconnections when payments are not made one time [4, 6]. Secondly, to ensure payments can be made, some low-income households self-ration their energy consumption to an extent which compromises healthy thermal comfort levels [2, 6, 7]. For example, they may not use heating and cooling systems to maintain thermal comfort, which can lead to negative physical and mental health impacts during extreme weather conditions [8]. Thirdly, some low-income households trade off other things they require to be able to pay their energy bills [6]. For example, they may sacrifice healthcare, healthy food and education to pay energy bills.

The impact of rising energy costs on low-income households is often magnified by the fact that these households tend to have older and lower quality housing, less energy efficient heating and cooling equipment, other older appliances (e.g. fridge, TV), and are often unable to afford upgrading these appliances [3]. Improving the energy efficiency of dwellings can reduce reliance on mechanical heating and cooling, and improve financial and health outcomes for low-income households [7]. However, such improvements are often financially inaccessible to social housing tenants and there are several challenges for increasing energy efficiency in these households. These challenges include capital costs, split incentives and conflicting or complex information [3, 5].

The aim of this paper is to analyse the ways in which energy efficient housing can improve living conditions and thermal comfort for social housing tenants. In doing so it addresses the following research question:

What are the benefits and challenges of energy efficient social housing for tenants and providers?

The paper is organised as follows. In the following section, we briefly outline the methods employed for our evaluation of ten social housing dwellings. The next section provides the results of this evaluation, focusing on technical performance, thermal comfort, health, wellbeing, social outcomes and cost-benefit performance. We then discuss the benefits and challenges associated with this project for low-income tenants and housing providers, followed by conclusions for future social housing projects.

2. Methods

The Department of Health and Human Services (the department) engaged the research team to evaluate the costs and benefits of revising their minimum housing performance requirements for new low-income housing. The department decided to build four 9 Star NatHERS rated, low-energy houses (construction completed in 2012) and compare these to six control houses built to minimum department Standards (constructed from 2010-2012)[†]. All houses in the study were in climate zone 27[‡] as that climate experienced extremes in temperatures for both summer and winter allowing for improved testing and evaluation of the benefits and challenges of such housing design. The two-bedroom reverse brick veneer new detached low-energy houses were built to a higher building envelope thermal performance (predicted heating and cooling energy load of 25 MJ/m².annum) compared to their standard build (108 MJ/m².annum). All four of the low-energy houses had similar open plan modern designs and were built without the inclusion (or need) for air conditioning. The control houses were of similar size to the low-energy houses, but were built using only standard building materials. Additional key features of the low-energy housing include:

- passive solar design and optimum orientation
- advanced roof design (new material and improved design)
- improved levels of ceiling, wall and floor insulation
- external window shading
- natural ventilation and improved glazing

[†] The department Standards at the time of the research involved meeting the 6 star NatHERS minimum requirement and going beyond this with the inclusion of solar hot water and a rainwater tank (not plumbed into the house) where possible. These are the standards the control homes are built to, with department Standards theoretical model also used in the analysis based upon what these standards should mean for utility consumption.

[‡] Refer to <http://apps.nowwhere.com.au/DCCEE/climatezonemaps> for further information about the NatHERS climate zones.

- increased thermal mass (internal)
- reverse brick veneer construction on back section of dwellings
- 1.5kW solar system
- 5,000 litre rainwater tanks plumbed into the toilet and laundry (shared between two houses)
- solar hot water system (the control houses also had this).

The tenants in the low-energy houses received a two-hour site tour and tutorial with representatives from the department and the design team to inform them about the features of the houses and how to use them to maximize performance. They also received a written user manual for the house, which included manuals for various technologies.

A multi-method evaluation was undertaken of the ten dwellings by the authors of this paper during 2012-15. The methods involved a cost-benefit analysis of the housing, a technical performance evaluation (energy and water consumption, renewable energy generation, adaptive thermal comfort), three rounds of one hour, in-person householder semi-structured interviews about how tenants experienced living in the home (e.g., health and wellbeing, impacts on their finances, liveability, lessons learnt (engagement and from the house design and performance), engagement with the department and other key stakeholders), and an evaluation of a home advisor tour for each household which was conducted with an energy efficiency expert (different to the two-hour site tour and tutorial when the occupants moved in).

Two rounds of semi-structured interviews were also undertaken with key housing provider stakeholders involved in the design, construction and management of the houses (once at the start of the research project and once at the end of the research project – addressing their role in delivering the housing, the processes and governance experienced throughout, engagement with other stakeholders, the households and the broader housing industry and lessons learnt). The results of the stakeholder interviews are reported elsewhere [9].

All interviews were thematically coded using NVivo. The cost-benefit analysis used the actual data from the housing as provided by the department (e.g. build costs) and the monitored data as collected by the research team. A more detailed presentation of the methods applied (including assumption used in the cost-benefit analysis) can be found [9]. This paper discusses the three-year longitudinal evaluation of the low-energy dwellings compared to the control houses against key indicators including resource consumption, thermal performance, financial outcomes and health/wellbeing outcomes to explore the benefits and challenges of such housing for low-income households and the housing provider.

3. Evaluation

The below analysis presents key outcomes from the evaluation undertaken, starting with the technical performance, social outcomes and followed by the cost-benefit analysis. The economic and technical data is supplemented with anonymous interview excerpts from the households. Quotes are identified by the household type (Control (Con) or low-energy (LEH) household) and alphabetical codes for example ConA, ConB, etc. More detailed analysis and discussion about the performance and use of the houses can be found elsewhere [9].

3.1. Technical performance

The low-energy houses were found to perform significantly better in terms of utility consumption compared to the control houses. Tenants in the low-energy houses purchased 62% less electricity compared to the department Standard and 45% less electricity compared to the control households. When accounting for number of occupants the low-energy households purchased 53% less electricity compared to the department Standard and 29% less than the control households. Furthermore, the 1.5kW solar system provided between 46-56% of total electricity consumed in the low-energy houses, reflecting that both increased energy efficiency and renewable energy technologies contributed to lowering purchased and consumed energy. The low-energy households also purchased 3% less gas compared to the department Standard and 15% less gas compared to the control households, although were higher on a per occupant basis. For water, the low-energy households consumed 28% less water compared to the department Standard and 22% less water compared to the control households. Overall, the low-energy houses

had 50% less environmental impact (CO₂-e) compared to the department Standard and 40% less environmental impact compared to the control houses.

The reduced energy consumption translated to reduced utility costs for tenants in the low-energy homes. Three of the low-energy households mentioned that their energy bills were in credit at various times of the year and one said 'look I haven't paid any off my power bill in six months and I'm still in credit...\$882 [currently in credit]' (LEH-D).

Tenants in the low-energy units attributed this to the feed-in tariff they received from having a small solar system on their houses and substantially lower operating costs than their previous dwelling. In contrast, most of the control households had high energy bills and/or reported difficulty paying their energy bills. One control household (ConB) had been disconnected for non-payment and was still in debt to their energy retailers:

ConB: I got up in the morning, I turned the TV on and it [the electricity] just went out...I had to ring up again and organise a new payment thing...I only owe them [the electricity company] like \$500...I owe [the] gas [company] over nearly a thousand [dollars].

There were also some challenges identified in terms of how households were using the dwellings. For the low-energy households there was an ongoing challenge about how to get tenants to use sustainability features of the house in the ways they were intended or designed. For example, the houses were designed with clerestory windows to be opened (electronically) to help vent hot air during summer in conjunction with using ceiling fans. However, one of the low-energy households was adamant that this was a design flaw and in fact exacerbated overheating in summer by drawing hot air in. No amount of discussion with the department, the research team or the architects could convince them otherwise. There were also other challenges which were common across both dwelling types such as leaving doors open for pets to come in and out of the dwelling even when heating or cooling was being used. These challenges meant that dwellings were not always being used as efficiently as designed.

3.2. Thermal comfort

The low-energy houses were built without air conditioning[§]. These dwellings were found to have better thermal comfort across the year compared to the control households and particularly during extreme weather. The average temperatures between the low-energy houses (23.8°C) and control houses (24.0°C) were similar for the living area, but the low-energy houses had an average mean temperature of 1.2°C lower for the bedrooms. The average maximum temperature in the living areas of the control houses was significantly higher (2.7°C) compared with the low-energy houses. The assessment of the adaptive comfort criteria [7] shows that the low-energy houses were comfortable for 10% more of the time for the living areas and 7% more of the time for the bedrooms compared with the control houses. The biggest benefit for thermal comfort was during extreme weather conditions such as heatwaves^{**}, when the low-energy houses were significantly cooler than the control houses which were using air conditioning^{††}, reflecting the improved design and thermal performance of the dwellings. Figure 1 shows that the best low-energy house was 16.6°C cooler on the second day of a heatwave compared to the worst control house (which used air conditioning, which can be seen that it was turned on around midday on the second day). At least one of the control households (without fixed air conditioning) found it too hot to stay in their dwelling during heatwaves, and spoke about the negative impact of having to find other places to stay during such periods.

ConC: One of my friends had a device and walked in here one day and it was like 51 degrees... They [his friends] couldn't come over, we couldn't watch the cricket and have a beer or do stuff like that 'cause you couldn't sit in here.

The low-energy houses were also found to perform significantly better during winter, with one occupant reflecting:

LEH-B: [W]e've had four to five degrees below [zero outside] and it's never been below 15 degrees when we've got up in the morning.

[§] One of the low-energy houses installed air conditioning during the evaluation period due to perceived health issues (they believed they were more susceptible to pneumonia due to their age and previous health issues). The monitored data before they installed the air conditioning suggested the dwelling remained comfortable over summer.

^{**} Three or more days of unusually high maximum and minimum temperatures as defined by the Bureau of Meteorology.

^{††} Four of the control houses had some form of air conditioning installed, with the other two using portable air conditioning systems.

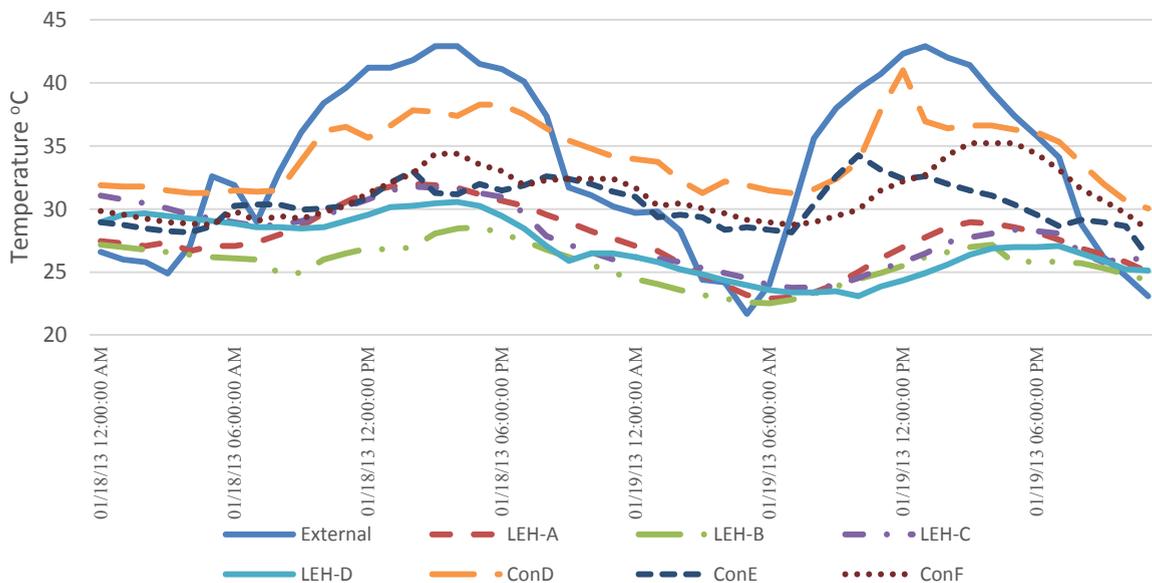


Fig. 1. Temperature in living rooms of monitored houses and external temperature for 18 – 19 January 2013.

3.3. Health, wellbeing and social outcomes

The low-energy households all self-reported improved health, wellbeing and social outcomes. Health and wellbeing outcomes included less stress due to relieved pressure on finances and less health impacts from extreme temperatures (e.g. including existing conditions such as bronchitis and other conditions exacerbated by heat and cold changes).

CatD: Oh, look, I have bronchitis every winter, regardless of where I live...I don't get as chesty [in the low-energy house] because I don't go from extreme hot [to cold]...the other house I would have the lounge room warm but the rest of the house [was cold].

Low-energy households experienced improved livability through reduced utility costs (with an average direct financial benefit of \$1,050 a year from reduced consumption and accounting for feed-in tariff across the four low-energy households). These reduced utility costs had resulted in low-energy households experiencing less stress paying their utility bills and having additional money available (compared to their previous dwelling) which they spent on 'luxuries' such as short holidays, buying Christmas presents and being able to eat out periodically. These experiences were a stark contrast to the control households, who reported struggling with living costs and did not have additional money for such discretionary items. Two of the control households were on payment plans for their utility bills and had experienced disconnection previously. They were finding it increasingly difficult to pay their utility bills on time. While some of this financial challenge can be attributed to the different life circumstances each household was in, there was a clear link to improved finances relating the housing as discussed above.

Low-energy households also reported fewer trips to health professionals and hospital compared to the health issues these tenants experienced in their previous dwellings. Conversely, the control households did not report much improvement in their health and social outcomes, except for two households who had previously been homeless and benefited from having permanent housing.

3.4. Cost-benefit analysis

The additional costs for building the low-energy housing compared to the department Standard build were calculated to be \$75,700 per dwelling. When additional maintenance and technology replacement costs across a 40-year period were added, this resulted in a total additional cost per dwelling to the department of \$141,700 (includes initial additional capital costs) compared to the control houses. Based upon the use and performance of the low-energy houses across the first three years of their operation, the houses would not achieve a payback within a 40-

year life of the dwellings for a low-energy price future^{**}, and only two of the low-energy houses would achieve a payback within a 40-year life for a high-energy price future. However, it was calculated that the occupants are at least \$1,050 a year/household better off compared to the control houses due to lower energy and water consumption and through the generation of renewable energy (feed-in tariffs). This financial benefit would be higher if other benefits suggested below are monetized. Figure 2 shows the costs and benefits of the low-energy houses (average) for the different sustainability elements across time in comparison to a previous zero energy housing study [10].

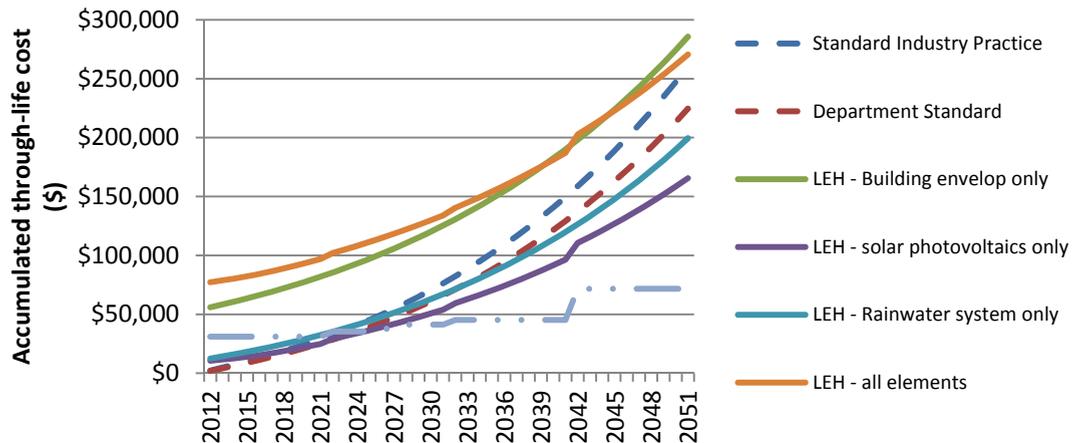


Fig. 2. Breakdown of LEH capital costs and benefits across time.

4. Discussion

4.1. Discussion of benefits

As the above findings show there are clear benefits from low-income households living in energy efficient housing which included improved thermal comfort without the aid of air conditioning (a benefit which is magnified in extreme weather conditions), improved health and wellbeing outcomes, as well as other social benefits. These benefits were not just experienced directly by the low-income households in our study, but also permeate through the department and broader society. For instance, the department could have happier, healthier and more financially secure households, resulting in less complaints and time spent dealing with tenant issues. In fact, one of the low-energy households turned their financial situation around so significantly due to reduced living costs and an improvement in health, resulting in them removing themselves from all Centrelink (government welfare provider) payments. The technical performance of the low-income houses also demonstrated significant reductions in the use of energy and water, and associated greenhouse gas emissions, contributing to the state government's climate change and renewable energy generation targets. If these benefits could be replicated across all 84,000 dwellings in the department's management, the cumulative outcomes could be substantial. Furthermore, there was no evidence that the low-energy households were facing any of the key challenges highlighted in the introduction (e.g. energy rationing, disconnection, going without other essential things), whereas this was evident amongst some of the control households.

In addition, the fact that the low-energy households had a better connection to their dwellings (e.g. keeping the dwellings in better condition compared to the control houses). Their connection to the houses points towards additional benefits such as greater care taken by tenants when occupying social housing. This could reduce ongoing maintenance and churn costs for the department if implemented on a wider scale.

^{**} A high and low energy price scenario was used to test a range of future outcomes and sensitivities as is typically undertaken in other cost-benefit analysis.

4.2. Discussion of Challenges

While there were numerous benefits for both the low-energy households and the department, there were also several challenges for both, particularly relating to occupants using the dwellings as they were designed. Similar challenges where households are not using sustainability features as intended have been found in other studies [11]. Trying to address for established occupant practices within more complex sustainable housing design is difficult. This raises questions about whether low-energy houses should provide automated features or support design features that actively engage occupants in creating sustainable outcomes to improve performance and liveability of sustainable dwellings. Evidence from this study reported elsewhere [7] shows that the low-energy households were more active in how they managed their thermal comfort in the absence of air conditioning during summer.

A major challenge for social housing providers to build more energy efficient housing is the higher initial capital costs. They have key responsibilities for providing as much housing as their budgets will allow, meaning that any additional costs beyond minimum building standards will impact on this responsibility. However, as shown above there are significant benefits for social housing tenants in low-energy houses which then flow back to the department (and reduce costs in other associated departments) and broader society. This research found that these additional costs to achieve the low-energy outcome could be reduced by at least 50% if these low-energy houses were to be repeated [9], due to cost efficiencies in the design, materials, technologies and learnings from the process. Economies of scale could also reduce these costs further if a larger development was constructed [9]. This would address issues of payback periods significantly and make building low-energy houses a more financially viable option, while still providing many of the benefits for the low-income housing tenants. It would also facilitate providing more social housing tenants access to energy efficient housing.

5. Conclusions

More than three years' post construction, the low-energy houses can still be regarded as one of Australia's leading sustainable housing developments, especially in terms of social housing provision. Across multiple indicators the low-energy houses and households performed significantly better than the control houses and households, including against department Standards. However, social housing providers must find ways to achieve such housing with lower capital costs if this type of housing is to be economically viable within traditional cost-benefit framings. The inclusion of improved monetizing of broader social benefits would help this.

Our analysis also identified a key challenge for future low-energy housing developments regarding how much active engagement to reasonably expect from tenants to maximise sustainability outcomes. For example, the inclusion of solar panels does not require the tenant to do anything to receive the benefit; whereas the requirement to reverse the ceiling fan direction and open the celestial windows to vent warm air requires tenant involvement. The analysis found that some tenants were more willing, or able, to undertake the actions required to operate their dwellings as designed, while others were unable, or decided not to, follow processes. Importantly, there is no simple division between 'design' and 'behaviour' which can be drawn here. Tenants engaged with their dwellings and its design features in a range of ways (predictable and unpredictable) that both supported and undermined sustainability objectives. With more complex and advanced low-energy housing, the department may need to provide some sort of ongoing checks or training to ensure that the houses are being used as intended. Training for tenants could be rolled into the house visits schedule, which is already conducted to check on tenant's welfare and the condition of properties and could be used alongside other financial incentives to improve tenant energy efficiency engagement.

Another implication of the research is how households who have lived in the low-energy houses will adjust if they have to move back into a 'standard' house. While the movement of tenants in social housing is not common without a compelling reason, there was one young family in our initial cohort who moved towards the end of the research as their family had expanded and they no longer met the occupant/bedroom ration guide set by the department. The research team identified concerns with this young family as they had not lived on their own previously, and had only experienced the low-energy house with solar panels and feed-in-tariff supporting their payment of bills for high energy consumption. Future research needs to understand the challenges for tenants who move 'backwards' in terms of housing quality and sustainability.

This analysis demonstrates the benefits of monitoring and analysing real performance and occupancy data from a sustainable housing development. There is limited ‘real world’ research available for sustainable housing, particularly in the affordable housing sector. Without multidisciplinary and longitudinal evaluations such as the one discussed here, there is no way to fully understand what has worked, what has been problematic and therefore what the lessons are. This research is particularly critical in a transition to a more sustainable future where the risk of a changing climate and increased costs to liveability are likely to generate increasing challenges for organisations such as the department and tenants who live in their dwellings. The outcomes of this project are critical for not only improving and guiding future social housing stock decisions, but are also relevant globally. The research design presented is also useful to inform other housing evaluations.

Acknowledgements

The construction, research and evaluation of this project was funded by the Director of Housing, Victoria and is reproduced with permission of the Director of Housing. The authors thank the research participants who generously gave their time to this project and for the feedback provided on earlier versions of the paper from colleagues at RMIT University. The authors also thank the contribution of Ian Ridley and Shae Hunter to the research project.

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