



Centre for  
Urban Research

# Horsham Catalyst Research and Evaluation Final Report

Dr Trivess Moore  
Dr Yolande Strenger  
Dr Cecily Maller  
Dr Ian Ridley  
Dr Larissa Nicholls  
and Professor Ralph Horne



Final Report:  
**Horsham Catalyst Research  
and Evaluation**

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Authored by: Dr Trivess Moore, Dr Yolande Strengers, Dr  
Cecily Maller, Dr Ian Ridley, Dr Larissa Nicholls and Professor  
Ralph Horne

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# Horsham Catalyst Research and Evaluation Final Report

## About the Authors

Dr Trivess Moore is a Research Fellow at RMIT University working in the School of Global, Urban and Social Studies and the School of Property, Construction and Project Management.

Dr Yolande Strengers is a Senior Research Fellow in the Centre for Urban Research, where she co-leads the Beyond Behaviour Change research program.

Dr Cecily Maller is a Vice Chancellor's Senior Research Fellow in RMIT's Centre for Urban Research.

Dr Ian Ridley is an Associate Professor at RMIT University's School of Property, Construction and Project Management.

Dr Larissa Nicholls is a research fellow in RMIT's Centre for Urban Research.

Ralph Horne is the Deputy Pro Vice-Chancellor, Research and Innovation for the College of Design and Social Context at RMIT University and Director of the Cities Programme, the urban arm of the United Nations Global Compact Programme.

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# Preface

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The Department of Health and Human Services (DHHS) aims to provide homes across Victoria that better meet the changing needs of our clients, as well as managing our extensive property portfolio in a more sustainable way.

An increasingly sustainable approach means paying close attention to the social and environmental outcomes that result from the way our properties are designed, built and lived in.

Through projects such as the K2 apartments at Windsor and Carlton estates redevelopment, DHHS has shown its commitment to, and interest in, the benefits of environmentally sustainable design in public housing dwellings.

A number of Victorian Government strategies and policies drive DHHS to show leadership through integrating sustainable design. The department's environment policy 'recognises that disadvantaged and vulnerable groups are more likely to be affected by the negative effects of climate change'. The building project in Horsham, north-west Victoria, known as the Horsham Catalyst, demonstrates our quest to gain insights and experience in this field.

The Horsham buildings comprised four newly-built two-bedroom, single-storey units. The project set out to investigate what would result when leadership-level sustainability elements were added in lower-density public housing. We sought to identify what benefits could flow to our clients, and which sustainability elements delivered the best social, financial and environmental value.

The department is pleased to present this pioneering research, the *Horsham Catalyst Research and Evaluation– Final Report*, based on a three-year evaluation of these homes in Horsham, a region noted for its climate extremes.

For this study between April 2013 and October 2015, the RMIT University Beyond Behaviour Change research team interviewed Horsham householders in both the sustainable new units as well as recently-built 'standard' DHHS units.

The research team used typical cost-benefit analysis as well as non-traditional / life cycle methodology. The latter reveals financial and resource impacts over the project's life, rather than a simple focus on construction costs. This is a significant viewpoint in the context of public housing provision, when dwellings are commonly built, owned and managed by the department and house vulnerable people.

This report joins an emerging body of research into Australian sustainable, affordable housing developments. By documenting health, comfort, household finance and individual wellbeing impacts, the positive lessons here are relevant to government and housing organisations mandated to improve the circumstances of low-income people.

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# Key Definitions

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Catalyst houses – Four sustainable houses built by the department in Horsham, Victoria, and which are the focus of this research.

Control houses – Seven houses built to the department's minimum building requirements (Department Standard). These units were compared with the performance of the Catalyst houses in the research.

Cost-benefit analysis (CBA) – A systematic approach to evaluating and comparing the upfront and through life costs and benefits of different aspects. The analysis turns inputs and outputs into a common metric to allow comparison. Typically, this metric is expressed as value in present day dollar amounts. Increasingly CBA is attempting to include elements which have traditionally not been considered due to difficulties placing an economic value on them (e.g. the environment) to provide a more holistic analysis.

Department standard – The standard set by the department for all new detached residential construction. This goes beyond the minimum NatHERS requirement.

NatHERS – National House Energy Rating Scheme, the Scheme that sets thermal performance requirements for residential buildings. Rated on a scale of 0 (worst) – 10 (best) stars.

Passive solar – A design technique which uses the sun to naturally heat and cool a building or space.

Reverse brick veneer – A building technique where the bricks are on the inside and the cladding is on the outside.

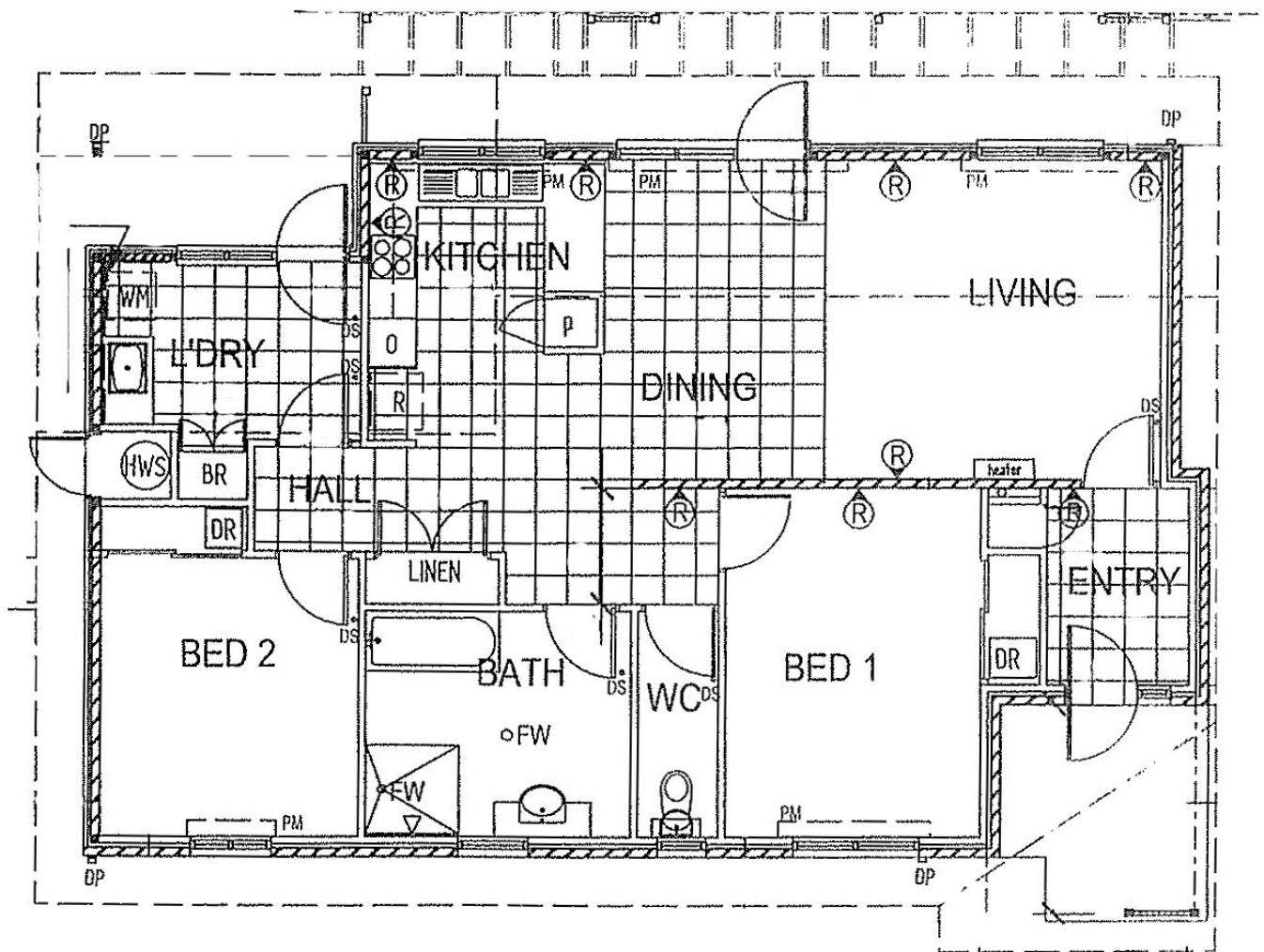
Standard Industry Practice (SIP) – A model of building performance and demand developed for the department by Organica Engineering to represent new residential building performance across Victoria. The SIP was created from regulation requirements, common industry practices and evidence of residential utility demand.

Stars – The NatHERS rating outcome, e.g. 9 Stars.

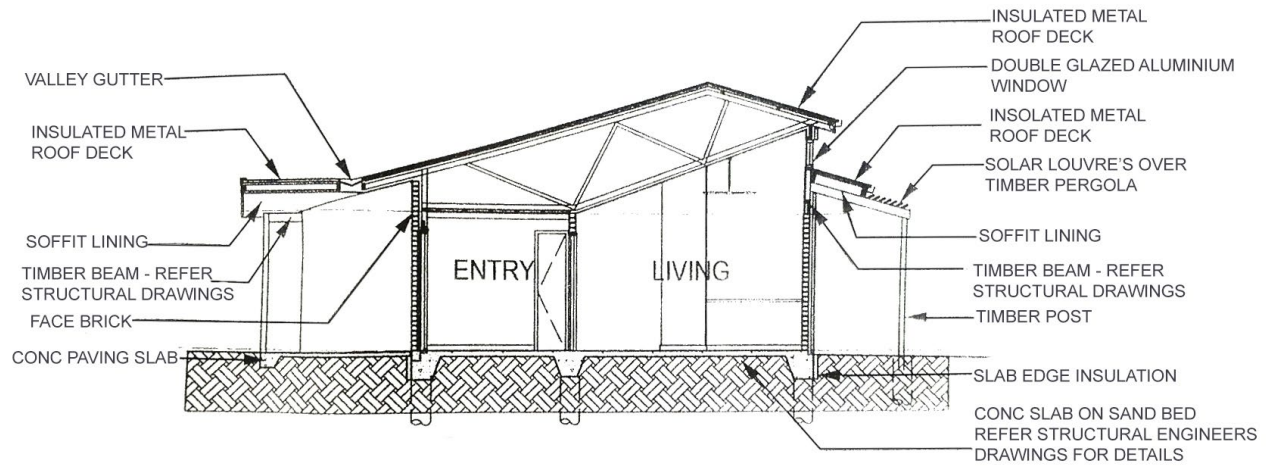
The department – The Department of Health and Human Services Victoria.

# Architectural Drawings

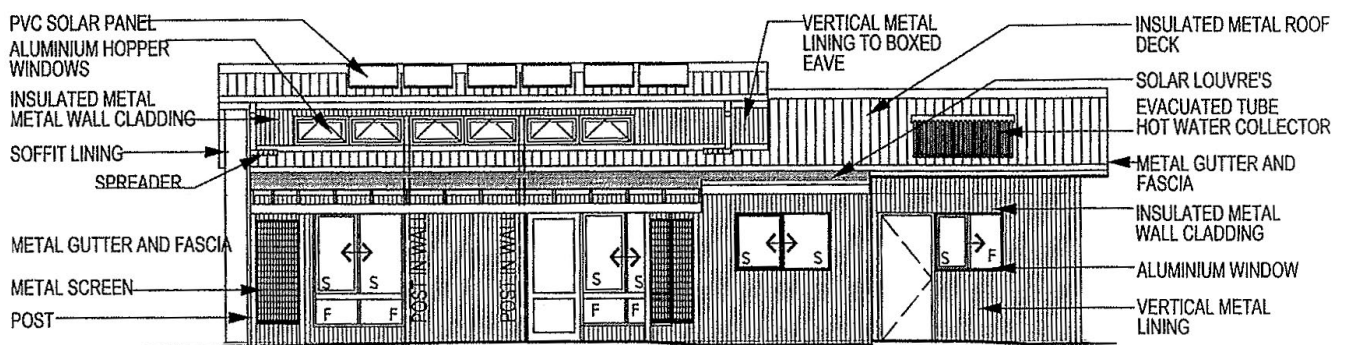
## PLAN OF ONE UNIT



## SECTION



## NORTH ELEVATION





# Executive Summary

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This Horsham Catalyst Research and Evaluation – Final Report presents outcomes from a three-year mixed-method evaluation of the Department of Health and Human Services' (herein the department) low-carbon housing in Horsham, Victoria. The aim of the project was to conduct a multi-year evaluation of four new two-bedroom, single-storey, sustainably designed units with a National House Energy Rating Scheme (NatHERS) rating of 8.9 stars (Catalyst houses, see Figure 1), in addition to seven one- and two-bedroom Control dwellings (located in Horsham). All dwellings were evaluated across a range of economic, social and environmental key performance indicators (KPIs) determined by the Department of Health and Human Services and revised by the RMIT University research team.

The research was conducted by the Beyond Behaviour Change Research Program within the Centre for Urban Research at RMIT University (RMIT research team) between April 2013 and October 2015. The evaluation included research with households living in the Catalyst dwellings and seven Control dwellings, as well as key stakeholders involved in the design, construction and occupation of the Catalyst houses. A comparative cost-benefit analysis (CBA) was also undertaken of the Catalyst and Control houses.

Specifically, the methods comprised:

- three separate rounds of in-home interviews with households across three years (see Section 3)
- two rounds of interviews with key stakeholders (years one and three) (see Section 5)
- a housing performance and CBA (see Section 6)
- a blower door test of dwellings (see Section 6)
- household home advisory tours conducted by a sustainability expert (see Section 4)
- the delivery of three key resources for the department to utilise in future projects, making future research more affordable. These were a literature review (see Section 2), interview guides (see Appendix 1 and Appendix 2) and a CBA model.

## Catalyst houses

The Catalyst houses utilised a number of sustainable housing (Ecologically Sustainable Development – ESD) principles to achieve an 8.9-star NatHERS rating including:

- passive solar design
- optimum orientation
- advanced roof design
- improved levels of ceiling, wall and floor insulation
- external window shading
- access to natural ventilation
- increased thermal mass
- reverse brick veneer construction on back section of dwellings (bricks on the inside, cladding on the outside)
- improved glazing.

The Catalyst households also had access to shared 5,000-litre rainwater tanks plumbed into the houses, individual 1.5 kW solar photovoltaics (PV) systems and solar hot water systems (gas boosted) to achieve their low-carbon, sustainable outcome.



**Figure 1: One of the Catalyst houses in 2012 (source: Trivess Moore).**

## Control houses

The Control houses were built to the department Standards requirement (the department Construction Standards (2011) for new build, low-density housing – herein referred to as the department Standards), a six-star NatHERS rating and included solar hot water. In addition to the department Standards requirements, the Control houses also included various sized rainwater tanks. These department Standards requirements were used by Organica Engineering to develop a department standard performance scenario assuming a two-person ‘average’ occupancy for a two-bedroom, new low-density dwelling with solar hot water but no other additional ESD technologies. This scenario was applied as a baseline for utility consumption for comparison to the 11 case study dwellings. The department Standards houses used in this evaluation were all located in Horsham, nearby to the location of the Catalyst houses.

The additional capital cost for the ESD elements of the Catalyst houses compared to the department Standards was \$75,700 per dwelling. When additional maintenance and technology replacement costs across a 40-year period are included, this results in a total additional cost per dwelling to the department of \$141,700.

## Catalyst household interview findings

Overall the research undertaken for the evaluation found that Catalyst households:

- had lower utility consumption and bills than they did in their previous dwellings
- were able to pay these bills more easily with reduced stress associated with utility usage and payments
- had savings available to spend on things that improved their quality of life that they used to struggle to afford, such as going on a holiday or buying clothes

- experienced an improvement in their thermal comfort and health during extreme weather (without requiring air conditioning), translating to fewer reported trips to the doctor or hospital
- demonstrated overall improvement in life circumstances, life satisfaction and wellbeing, including one household removing themselves from all CentreLink payments
- experienced improved neighbourhood satisfaction, perceptions of neighbourhood safety and relationships with the department regional office.

While all Catalyst households were highly satisfied with their houses, there were some suggestions for improvement, including:

- placing ceiling fans in bedrooms and an easier way to reverse fan direction

- improving lighting in parts of the house, including dimmable lights in some areas
- improving ceiling fan placement in bathrooms (place above shower)
- gap reduction around internal doors
- improving water tank access (individual water tanks)
- improving driveway layout (restrict access for cars to residents only)
- fixing cracked tiles (grouting), cracks in concrete and cracks in internal and external walls
- providing native grass and plants in the backyard
- changing the lock position on windows
- providing shade covering for the pergola.



**Figure 2: One of the shared rainwater tanks at the Catalyst houses (source: Trivess Moore).**



### Control household interview findings

Control households experienced limited improvements in comparison to their previous dwellings. Broadly, Control households reported:

- more issues paying utility bills on time (including two households that needed prepayment plans)
- lower satisfaction with thermal comfort and an over-reliance on mechanical cooling to stay cool in summer (which in turn impacted on electricity usage and costs)

- more neighbourhood amenity and safety concerns (in one cluster of three households that lived on the same street) minimal improvements in their life circumstances
- lower or similar satisfaction with their relationship with the department regional office.

The research found a clear relationship between Catalyst housing and improved financial, health, social and wellbeing outcomes for Catalyst households.



**Figure 3: One of the Control houses from the research project (source: Trivess Moore).**

## Stakeholder interview findings

The tradespeople who were interviewed for the project were satisfied with it and thought it worked well overall. However, they also reported no increase in ESD work because of their involvement in the project. The stakeholders identified key lessons from the development including the need to reduce delays between design and starting construction, which impacted on material and technology choices, which became quickly outdated in this rapidly changing area. There were also a high number of variances made to the design and construction of the Catalyst houses after the contract had been signed, which added time and costs to the project.

## Cost-benefit analysis findings

In terms of the monitored analysis, overall the Catalyst houses performed substantially better than the Control houses and the department Standards for overall utility consumption, environmental performance and thermal comfort. However, financial payback (of capital and through-life operation, maintenance and technology replacement costs) through a traditional CBA was problematic within 40 years.

Specifically:

- Catalyst households purchased 62 per cent less electricity compared to the department Standards and 45 per cent less electricity compared to the Control households.
- Catalyst households purchased three per cent less gas compared to the department Standards and 15 per cent less gas compared to the Control households.
- Catalyst households consumed 28 per cent less water compared to the department Standards and 22 per cent less water compared to the Control households.
- Catalyst houses had 50 per cent less CO<sub>2</sub>

environmental impact from power use compared to the department Standards, and 40 per cent less CO<sub>2</sub> environmental impact from power use compared to the Control houses.

- The Catalyst houses were comfortable 10 per cent more of the time for the living areas and seven per cent more of the time for the bedrooms compared to the Control houses (according to the European adaptive thermal comfort standard).
- The Catalyst houses were substantially more comfortable during extreme weather events (according to the European adaptive thermal comfort standard). For example, on the second consecutive day of temperatures above 41°C, the difference between the hottest Control house (which had air conditioning) and coolest Catalyst house was 16.6°C (without air conditioning) (see Figure 4).
- The same ESD performance and outcome of the Catalyst houses could have been achieved in 2011 for half the additional capital cost for ESD elements as evidenced in other low-carbon, sustainable housing projects in Australia and internationally.
- Only two of the Catalyst households will achieve a payback within 40 years at a high energy price future (and none at a low energy price future) using a traditional CBA approach.
- However, if the Catalyst houses were to be sold they could achieve an additional resale value of between \$15,000 – \$40,000, depending on the age of the sustainability technologies and current price of utilities.
- When analysing the individual sustainability elements, the most cost-effective option in the Catalyst houses was the inclusion of solar panels, followed by the rainwater tank plumbed into the house, with the building envelope improvement the least cost-effective element (see Figure 5).

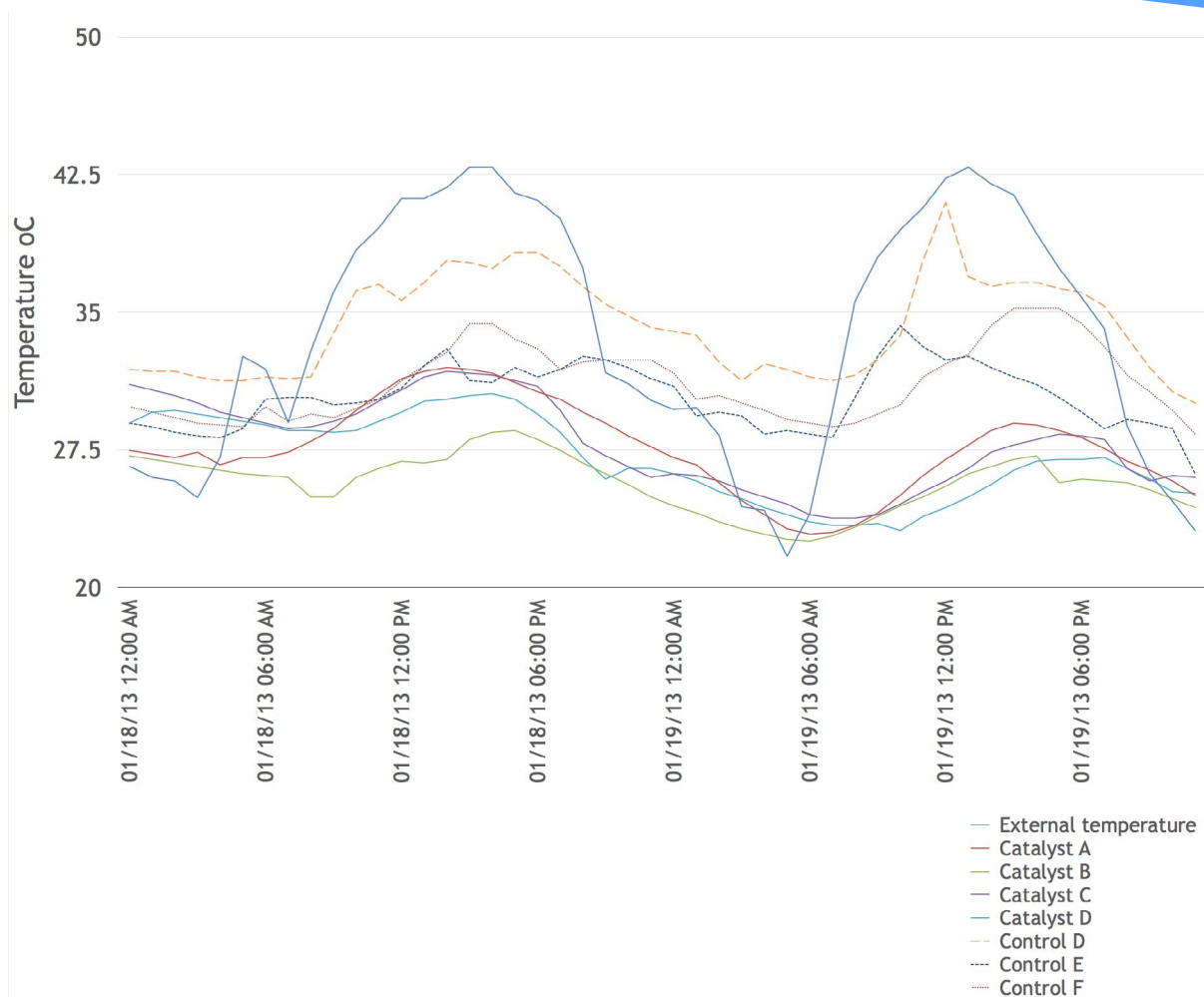


Figure 4: Temperature in the living rooms of monitored houses and external temperature for 18–19 January 2013.

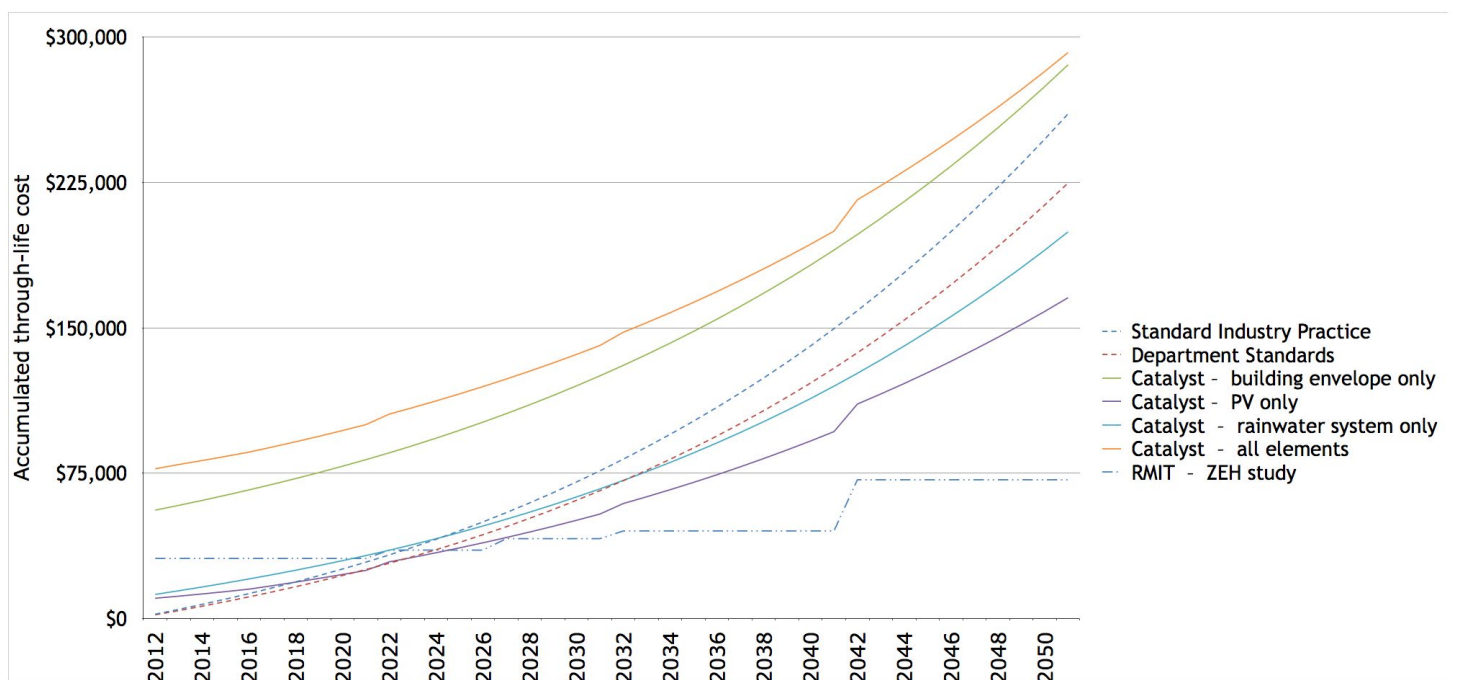


Figure 5: Accumulated costs for various sustainability elements within the Catalyst houses across time for a low energy price future.

## Key implications

Across the evaluation indicators and metrics the Catalyst houses and households performed significantly better than the Control houses and households, including against the department Standards. Catalyst houses and households had improved environmental performance, used less energy, had lower operating costs resulting in additional savings to be spent on non-essential activities and items, and had improved thermal comfort (especially in extreme weather conditions) without the requirement of an air conditioner. Tenants' overall life circumstances and wellbeing also reportedly improved. If the Catalyst housing design was replicated more widely across the department and general housing stock, there could be significant broader environmental, economic and social benefits.

However, the reported benefits are offset against the higher initial capital costs of the Catalyst houses. The research found that the additional capital costs for the sustainability elements of the Catalyst houses could be significantly less (at least 50 per cent less) if the development is repeated due to cost efficiencies in the design, materials and technologies. Economies of scale could also reduce these costs further if a larger development was constructed. This would significantly affect the issues of payback periods and make the development a more financially viable option.

Furthermore, there is a challenge regarding how much active engagement can reasonably be expected from tenants in order to maximise ESD outcomes. For example, the inclusion of solar PV 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 does need tenant involvement. The analysis found

that some Catalyst tenants were more willing or able to undertake the actions required to operate their dwellings as designed, while others were unable to or decided not to follow ESD processes. This can impact on the overall benefits to the tenants, the department and the environment, and prompts the question about how much of the design should be passive and not rely on tenants to direct outcomes and performance. Importantly, there is no simple division between 'design' and 'behaviour' that can be drawn here. Tenants engaged with their dwellings and its technologies in a range of ways (predictable and unpredictable) that both supported and undermined the sustainability objectives.

The research highlights the question of trade-offs and overall objectives. For example, if capital cost efficiency is important, a future development could be built to a slightly lower star rating (for instance, eight star) but include more solar panels, thus reducing living costs for tenants even further. However, reducing the thermal performance of the dwelling negates some of the tenant health and thermal comfort benefits both across the year and in extreme weather events. Further, an eight-star house would likely require some form of air conditioning, whereas the Catalyst houses demonstrated that at nine stars, air conditioning can for the most part be avoided.

Even more than three years post construction the Catalyst houses can still be regarded as one of Australia's leading sustainable housing developments. There has been the emergence of some other nine- and now 10-star developments, but this is still the exception with the majority of new construction being built in the six- to seven-star range. Additionally, there are few other examples of such low carbon, energy



and sustainable housing being developed by housing agencies such as the department, either in Australia or internationally.

The evaluation demonstrated 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 this multidisciplinary evaluation there is no way to understand what has worked and 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 increasing liveability costs are likely to cause mounting challenges for organisations such as the department and the tenants who live in its dwellings. The outcomes of this evaluation are critical not only for improving and guiding future the department housing stock decisions, but are also relevant to a global audience.

## Recommendations

The Catalyst houses have resulted in improved outcomes across a range of metrics for the department, the tenants, society and the environment. The following recommendations assume the following set of the departments objectives for new housing:

- durability and low maintenance of assets
- low construction costs
- improved tenant comfort
- minimised tenant vulnerability to energy and water costs (low operating costs)
- tenant safety in extreme weather.

With this in mind, the research team makes the following recommendations:

## Design and construction

1. The department Standards can be improved to benefit tenants and the environment using low-risk construction methods and technologies.
2. In the social housing context, best value for money is achieved with an eight-star building envelope (rather than nine stars) and reinvesting some of these capital cost savings into a larger solar panel system for each dwelling. This would reduce costs for the department while improving economic outcomes for tenants. An eight-star house would also reduce peak energy demand during hot spells compared to a standard dwelling.
3. The design of both new and retrofitted dwellings should consider providing smaller spaces for tenants to heat and cool during times of extreme weather so they don't have to heat and cool entire dwellings or large open spaces.
4. Ensure dwelling gardens contain climate-appropriate plants to encourage more tenants to participate in gardening activities.

## Maintenance

5. Develop a clear schedule of works for sustainability building elements and technologies, including maintenance and cleaning requirements, to ensure these elements can operate with maximum efficiency.
6. Consider installing remote monitoring of sustainability technologies to promote early detection of faults and maintenance needs.

## Tenant-department relationship

7. Engage tenants in home sustainability strategies through strong relationships with regional contacts and tailored in-person advice, rather than through generic call centres or extensive written information

(which is only likely to assist a limited number of literate and engaged tenants). Focus mainly on interested tenants.

8. Provide alternative cooling options to air conditioning for tenants during extreme heat events, such as low-cost retrofitting (for example, ceiling fans, secure screen windows and doors, external shading), provision of other accommodation, and cooled community facilities (for example, public libraries).
9. Use language for trial projects that is more engaging for tenants and media. For example, rather than 'Catalyst', name projects to reflect their comfort, health and liveability benefits.

#### **Evaluation, process improvement and data management**

10. Repeat holistic evaluations of new and existing housing developments so that a more detailed understanding of the costs and benefits, including observed and unmeasurable health and

wellbeing benefits, are captured and fed into the departments whole-of-life financials and policy development.

11. Develop a larger new build trial based on this evaluation to explore ways to improve capital costs for such projects across a range of department dwelling types. This would also address the limitation of this study, which is the small sample size.

It is important that these evaluations are mixed methods, as this evaluation has demonstrated that relying on quantitative or qualitative data alone would not have captured the complete story of how the Catalyst houses were performing.





# 1. Introduction

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## 1.1 Project description, aim and scope

This document reports on a study into the evaluation of a low-carbon public housing demonstration housing located in Horsham, Victoria. The Horsham Catalyst Research and Evaluation was funded by the Department of Health and Human Services (herein the department) and undertaken by the Beyond Behaviour Change Research Program in the Centre for Urban Research at RMIT University (RMIT research team). The evaluation was conducted from May 2012 to October 2015.

The evaluation brief was developed by the department (RFQ Reference Number – C2308). The aim of the evaluation, as detailed in the initial brief, was to conduct a multi-year evaluation of four new two-bedroom, single-storey units (Catalyst houses) on the site at 22–24 Pearl Street, Horsham, in addition to seven Control<sup>1</sup> dwellings (located in Horsham). All dwellings were evaluated across a range of economic, social and environmental key performance indicators (KPIs) (see Section 1.2). The evaluation brief included research with tenants living in the dwellings, as well as key stakeholders involved in the design, construction and ongoing management of the Catalyst houses. The RMIT research team proposed and delivered a mixed-method evaluation, involving the collection and analysis of both qualitative and quantitative data. In this way a more detailed and holistic analysis of the Catalyst houses could be undertaken.

The construction of the Catalyst houses was completed in April 2012 and the houses occupied in May 2012. The construction project was developed to demonstrate a new standard in sustainability in lower density public housing and to allow the department to gain a better understanding of what this means for its clients (households). The Horsham Catalyst Research and Evaluation (the analysis presented in this report) was part of a suite of research projects being undertaken by the Environmental Sustainability team at the department, which focused on gathering evidence of the costs and effects of environmental activities on the department, its clients and the environment.

The evaluation deliverables and timelines agreed between the department and the RMIT research team are presented in Table 1. A more extensive outline of each of the deliverables is provided in the RMIT research team's Evaluation Plan.

The research scope was limited to the evaluation of the 11 dwellings identified by the department. These households had already been approached to participate in the research prior to the engagement of RMIT University. In addition, the monitoring, collection and analysis of utility and temperature performance data was conducted by Organica Engineering, which provided this data to the RMIT research team, which subsequently conducted the CBA and other relevant analysis.

While the focus of this report is on the selected dwellings, much of the literature, analysis and discussion are relevant to the broader department housing stock.

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<sup>1</sup> Standards 6 star dwellings with solar hot water and rainwater tanks but no other ESD technologies or design improvements.

**Table 1: Key deliverables and timeline for the evaluation.**

Deliverable	Deliverable Timing
<b>D1.</b> Methodology and evaluation management approach confirmed.	By 6 May 2013
<b>D2.</b> Develop interview guides and conduct, transcribe and analyse interviews with households and stakeholders.	By 17 June 2013
<b>D3.</b> Develop a cost-benefit energy model and undertake analysis for the case study houses, including developing a baseline scenario.	By 29 July 2013
<b>D4.</b> Revise interview guides and conduct, transcribe and analyse interviews with households.	By 31 March 2014
<b>D5.</b> Interim one-year report delivered in the form of a PowerPoint presentation with explanatory notes.	By 28 July 2014
<b>D6.</b> (Note this phase was altered to include the delivery of a home advisory tour and the evaluation was then conducted during D7.) Personalised home advisory tour with home sustainability assessor with each household. Short summary report to be submitted.	By 28 May 2015
<b>D7.</b> Revise interview guides and conduct, transcribe and analyse interviews with households and stakeholders.	By 24 September 2015
<b>D8.</b> Deliver final report, survey instrument templates and conduct final presentation to the department.	By 13 November 2015

## 1.2 Key performance indicators

The evaluation was framed around a set of benefits and KPIs developed by the department prior to the engagement of the RMIT research team. These were developed to help identify how successful the project was in meeting the project's investment goals. In summary, the original benefits and KPIs were as follows:

**Benefit 1:** Improved client health, finances and wellbeing.

**KPI 1:** Decreased relative utility bills (pre and post comparisons).

**KPI 2:** Reduced reported level of discomfort or negative health effects on extreme weather days.

**KPI 3:** Improved tenant engagement and experience in managing ESD and climate change-related aspects.

**Benefit 2:** Improved new housing standards and program that target available funds to client benefits.

**KPI 1:** Recommendations based on project evidence are submitted to appropriate program, policy or standards committee.

**Benefit 3:** Improved public perception and industry engagement.

**KPI 1:** Positive media articles and public profile.

**KPI 2:** Increased engagement with building and development industry sector.

After the first stage of household and stakeholder fieldwork (see Section 1.3.3), additional KPIs were identified by the RMIT research team that were relevant to the evaluation's aims and outcomes. In discussion with the department, the original KPIs were revised by the RMIT research team as follows (new or modified KPIs are in bold):

**Benefit 1:** Improved client health, finances and wellbeing.

**KPI 1:** Decreased relative utility bills.

**KPI 2:** Improved financial circumstances.

**KPI 3:** Improved level of thermal comfort.

**KPI 4:** Reduced reported level of discomfort on extreme weather days.

**KPI 5:** Improved occupant health and wellbeing.

**KPI 6:** Improved utility and mobility.

**KPI 7:** Improved tenant engagement and experience in managing ESD and climate change-related aspects.

**KPI 8:** Improved neighbourhood satisfaction and safety.

**KPI 9:** Improved life circumstances.

**KPI 10:** Improved relationship with the department.

**Benefit 2:** Improved public perception and industry engagement.

**KPI 11:** Positive media articles and public profile.

**KPI 12:** Improved business practices.

**KPI 13:** Improved process and governance (stakeholder perspective).

**KPI 14:** Improved benefits across all actors from increased ESD (stakeholder perspective).

**Benefit 3:** Improved new housing standards and program that targets available funds to client benefits.

**KPI 15:** Recommendations based on evaluation evidence are submitted to appropriate program, policy or standards committee.

The outcomes presented throughout the analysis section will be reported against these revised KPIs. Note that the research addresses each KPI except for Benefit 2's KPI 11 (positive media articles and public profile), which fell outside the scope of the evaluation. Further, there was no department resourcing or capabilities to complete this KPI.

### 1.3. Project methods

The department engaged the RMIT research team to conduct a multi-year study evaluating the low-carbon housing development and the lived experiences of the households compared to a group of Control houses and their households. The evaluation involved a mixed-methods approach, defined by at least one qualitative and one quantitative component conducted within a single research project [1]. The five main research activities undertaken to address the evaluation deliverables were (i) literature review; (ii) household interviews and tours with households living in the Catalyst and Control houses, and interviews with stakeholders involved in the design, construction and ongoing use of the dwellings; (iii) a CBA based upon the build costs and monitored consumption data from each house; (iv) a blower door test of dwellings; and (v) a home advisory tour designed to provide practical suggestions on how households could further reduce their use of energy and water resources. Each activity is detailed below, following an introduction to the demonstration project.

#### 1.3.1 Project summary

Four detached, low-carbon, two-bedroom demonstration houses were built in the regional town of Horsham in Victoria, Australia. The regional location was selected by the department due to the extremes in temperatures that occur across summer and winter, allowing for evaluation across a spectrum of climatic variances. The Catalyst demonstration houses utilised a number of sustainable housing principles including passive solar design, optimum orientation, advanced roof design, improved levels of ceiling, wall and floor insulation, external window shading, access to natural ventilation, increased thermal mass, reverse brick veneer construction, improved glazing, 5,000-litre rainwater tanks, 1.5 kW solar PV systems and solar hot water systems (gas boosted) to achieve the

low-carbon outcome. The houses averaged an 8.9 NatHERS star rating. They were completed in April 2012 and occupied in May 2012. In the context of these dwellings, low carbon refers to the predicted operational energy performance for heating and cooling being significantly less compared to the department Standards houses.

In addition to the four low-carbon houses, seven Control houses were also selected to participate in the evaluation. These houses had all been built within the three<sup>2</sup> years prior to the low-carbon houses and had an average NatHERS rating of six stars. Table 2 presents key information about each dwelling and household in the evaluation.

The households in the Catalyst and Control houses were selected through the departments standard processes. This involves the department receiving applications from low-income clients who are excluded from the private rental market due to their economic situation. Applications are assessed by the department and successful applicants matched to suitable housing. Potential households for the Catalyst houses were asked by the department if they would be willing to voluntarily participate in a research evaluation on the performance of the houses. Four consenting households were selected to live in the Catalyst houses and seven Control households were also organised by the department to be part of the evaluation. This was to allow some comparison between the two groups of households.

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<sup>2</sup> Note that some households and stakeholders did not participate in each round of interviews due to challenges organising suitable times for interviews or in the case of the final round of interviews, withdrawal from the project.



The department provided the households with an introductory sustainability training session on how to use the various sustainability elements of the houses. There was no additional introductory information

provided to the Control households beyond what typical department households would receive. The composition of the households is presented in Table 2.

**Table 2: Characteristics of each household and house.**

Household make-up and approximate age at first interview	Dwelling star rating	Thermal performance (heating and cooling MJ/m2 per annum)	Total internal area (m2)	Total internal area conditioned (m2)	Cooling technologies used in house	Solar hot water	Rain-water tank
Couple (early 20s) with two children (aged 3 and 6 months)	8.9	26	100	74	Two ceiling fans in the living area	Yes	Yes
Husband and wife (60+ years)	8.9	25	99	72	Two ceiling fans and split-system reverse cycle air conditioner in living area	Yes	Yes
Single woman (60+ years)	8.9	26	100	73	Two ceiling fans in living area	Yes	Yes
Single woman (55+ years)	8.7	33	99	74	Two ceiling fans in living area	Yes	Yes
Husband and wife (60+ years)	6.0	108	82	73	Split-system reverse cycle air conditioner	Yes	Yes
Husband and wife (55+ years)	6.0	108	82	73	Split-system reverse cycle air conditioner and pedestal fans	Yes	Yes

Household make-up and approximate age at first interview	Dwelling star rating	Thermal performance (heating and cooling MJ/m2 per annum)	Total internal area (m2)	Total internal area conditioned (m2)	Cooling technologies used in house	Solar hot water	Rain-water tank
Single mother (mid 20s) and child (three years old)	6.0	108	97	84	None	Yes	Yes
Single male (45 years)	6.4	98	52	40	Pedestal fans	Yes	Yes
Husband and wife (55+ years) and teenage child under their care	6.0	108	97	84	Portable air conditioner	Yes	Yes
Single mother (50+ years) and teenage child	6.0	110	88	75	Wall unit air conditioner	Yes	No
Husband and wife (65+ years)	6.0	108	85	76	Split-system reverse cycle air conditioner	Yes	Yes

The specific codes used to report householder findings are not provided in this table to ensure households remain anonymous.

### 1.3.2 Literature review

Four detached, low-carbon, two-bedroom demonstrationA detailed desktop literature analysis was undertaken on the key themes that emerged in the framing of this evaluation and from the analysis undertaken. These themes were transitioning to a low-carbon future, value of good design, sustainable housing and costs and benefits of sustainable housing. The international and Australian literature is presented in Section 2 of this report and builds on the information presented in the preceding background section.

### 1.3.3 Household interviews

The interviews with the households in the evaluation involved conducting three rounds of semi-structured

interviews; one interview with each household<sup>3</sup> was conducted each year of the evaluation (see Table 3). This allowed for follow-up questions that emerged from the initial interviews and analysis and the opportunity to identify changes in the lived experience associated with longer occupancy in the houses. The longitudinal qualitative component of the evaluation is not a common research approach, especially for evaluations relating to sustainable and affordable housing. This innovative approach arguably improves

<sup>3</sup> Note that some households and stakeholders did not participate in each round of interviews due to challenges organising suitable times for interviews or in the case of the final round of interviews, withdrawal from the project.

analysis and outcomes for the evaluation [2, 3].

The RMIT research team developed an initial semi-structured interview guide focusing on the evaluation's KPIs for both the Catalyst and Control households noting differences between questions where relevant to the different house types. The interview schedule was then reviewed by the department and changes incorporated into the final version. Appendix 1 contains the schedule for the first round of interviews. The schedule was revised for the second and third rounds of interviews based on information and analysis of the preceding interview round(s). Interview questions focused on assessing tenant health, finances and wellbeing, and included questions about utility bills, reported levels of comfort on extreme weather days and households overall lived experiences.

Interviews were conducted in tenants' houses in pairs by the researchers for the first two rounds of interviews, and by a sole researcher for the final round of interviews. In total 17 participants across the 10 households were interviewed, including one house that changed occupants between the first and second rounds of interviews (Control house A – ConA, with the second household known as ConA2). The interviews lasted an average of approximately 45 minutes. House tours were conducted at the end of each interview to visually explore the lived experiences of households and the ways in which they interacted with their house's features. Each household received a double movie pass as a recompense for each interview for the first and second rounds of interviews and an \$80 Coles-Myer gift card for the last round of interviews. The interviews and house tours were audio recorded and transcribed verbatim by a third party. The transcripts were thematically coded using the qualitative analysis software NVivo.

**Table 3: Household participation in interviews.**

Household	First round interview June 2013	Second round interview March 2014	Third round interview August 2015
CatA	✓	✓	x
CatB	✓	✓	✓
CatC	✓	✓	✓
CatD	✓	✓	✓
ConA	✓	x	x
ConA2	x	✓	✓
ConB	✓	✓	✓
ConC	✓	✓	x
ConD	x	✓	x
ConE	x	✓	x

As with all methods, qualitative research has a number of strengths and weaknesses. Strengths include the ability to study in greater detail the understandings, actions and practices of individuals or groups, particularly in regards to more complex situations; the ability to cover and account for contextual conditions and situations; and not being restricted to specific questions [4, 5]. Weaknesses include difficulties in ensuring consistency, researcher bias, self-reported action bias (participants providing answers they think the researcher wants to hear), difficulty in generalising wider outcomes from limited numbers of cases, and the time-consuming nature of data collection and analysis [4, 5]. Steps were implemented in this evaluation to reduce weaknesses in the interviews through techniques such as repeating key questions in different ways throughout the interviews, allowing the researchers to check answers. Furthermore, the multi-year nature of the interviews ensured that answers were cross-checked between the three rounds of interviews, allowing the researchers to account for 'new home' feelings and bias.

A limitation of the research is the small number of houses and households involved. The limitation was exacerbated by challenges in contacting households and arranging interviews. Some households did not have phones or answer them. Home visits by the department regional team were sometimes required to set up interviews with tenants. For the second round of interviews, the department regional office was unable to assist with recruitment, making this task particularly challenging for the Melbourne-based research team. Additionally, some tenants were not at home at the agreed time (despite reminders from the research team) or needed to pull out of the interview on the spot due to unforeseen circumstances.

While this is a small data set, valuable and detailed

information was obtained and can be used to inform future housing performance and social housing policy, both in Australia and internationally, even more so than if either approach was applied in isolation. As Ridley et al. [6] state about their detailed case study of only two low-carbon dwellings, such studies of limited numbers of houses and households allows for "quick feedback and performance data to the design, construction and regulatory community, developing and testing evaluation methodologies that can be later standardised and applied to the meta-analysis of larger data sets". This is one of the aims and KPIs of the project as set by the department.

#### 1.3.4 Stakeholder interviews

Semi-structured interviews were also conducted with five key stakeholders involved in the design, construction and operation of the Catalyst houses. Two rounds of interviews were conducted with the key stakeholders, the first at the start of the evaluation in 2013 and the second in September 2015. The stakeholders included two department employees, the architect, the builder and the electrician (see Table 4). As with the tenant interview schedule, the RMIT research team developed an initial semi-structured interview schedule on the evaluation's KPIs relating to the stakeholders. The interview schedule was then reviewed by the department and changes incorporated into the final version. Appendix 2 contains the first interview schedule for the stakeholders. The interview schedule was revised for the second round of interviews based on information and analysis of the preceding round of interviews and analysis of the tenant interviews.

Interviews were conducted in pairs by the RMIT researchers at the stakeholders' offices or via telephone for the first round of interviews, and by a sole researcher for the final round of interviews. In

total five key stakeholders were interviewed, with two stakeholders interviewed a second time. The interviews lasted an average of approximately 40 minutes. The interviews were audio recorded and

transcribed verbatim by a third party. The transcripts were thematically coded using the qualitative analysis software NVivo.

**Table 4: Stakeholder participation in interviews.**

Stakeholder code	First round interview June 2013	Second round interview September 2015
Stakeholder A	✓	x
Stakeholder B	✓	x
Stakeholder C	✓	✓
Stakeholder D	✓	x
Stakeholder E	✓	✓

### 1.3.5 Cost-benefit analysis

For this analysis four types of scenarios were developed: 1) a general business as usual scenario (the standard houses the department builds: six-star building envelope with solar hot water, ‘average’ household behaviour based on energy analysis from the Australian Government – known throughout at the department Standards [7]); 2) the scenario based on the Control houses in this evaluation; 3) the Catalyst house scenario; and 4) a Standards Industry Practice (SIP) scenario developed to reflect minimum general public housing performance outcomes. The analysis used data from the Catalyst and Control houses for scenarios two and three, making the outcomes of the CBA more rigorous than studies that are based on predictions and assumptions. The CBA (referred to as the CBA model) was undertaken building upon previous CBA performed by the research team [8].

Resource consumption for each demonstration house was provided by monitoring equipment for the first three years of occupancy (June 2012 to May 2015). Data was collected and provided by Organica Engineering, which was engaged by the department separately to the engagement of RMIT University. There were issues with this data collection relating to the utility companies not providing billing data despite relevant occupant consent being provided and in-home monitoring equipment going off-line for different periods of time (see Section 6). Future utility consumption was assumed to be consistent with the averaged data from the monitored period. The research team recognised that changes to household structures, circumstances, finances, climatic conditions and the number and use time of appliances and efficiencies of such appliances would alter utility

consumption. It is difficult to predict how households may change; therefore it was assumed households (and future households) would behave as they do currently. This is a limitation of the research.

The following table is a summary of assumptions applied in the CBA. A more detailed explanation of assumptions is provided in previous similar research undertaken by the research team [8].

**Table 5: Summary of data sources used for CBA assumptions.**

Assumption	Data Source
Upfront additional ESD building and technology costs	The department
Replacement costs	[8] and others
Maintenance costs	[8] and others
Inflation rate – 3%	RBA
Life of house – 40 years	Australian Building Codes Board
Net present value – 0%, 3% and 7%	[8] and others
Feed-in tariff – \$0.31/kWh	The department/consumer bills
Utility usage	Organica Engineering/ consumer bills
Solar and rainwater collection/generation	Organica Engineering/ consumer bills
Utility costs	Consumer bills (average)
Future utility costs	[8] and others
Solar hot water, rainwater tank (not plumbing or pump)	Same as per standard department build
Energy scenarios	[8]
Resale value	[8] and others
the department Standards and Standards Industry Practice (SIP) houses (baselines)	Organica Engineering

The analysis was undertaken across a 40-year period. This is the length of time used by the Australian Building Codes Board in its research for building standards [9].

It was assumed that the life of the solar PV system was 30 years, with the inverter requiring replacement every 10 years. This is in line with other low energy housing research. Furthermore, many solar PV systems

come with warranties for performance of between 20–30 years. There is no certainty within the literature about the future evolution of renewable energy technologies in terms of energy generation (efficiency and capacity) and new innovations. Therefore, when technologies were replaced at the end of their life throughout the CBA model, it was assumed that their energy generation performance would remain as it did in 2012 (the base year for the research). However,

improvements to existing technology and new technology innovation will likely result in changes to technology requirements in future years. By assuming these changes do not occur, the CBA modelling in effect presents a 'worst case' scenario.

The only assumption made to replacement technologies was that a learning curve of 18 per cent cost reduction for each doubling of production would be applied, as used by International Energy Authority modelling [10, 11]. This was calculated applying historical and current data regarding the supply and installation of solar PV systems as presented by the International Energy Agency [10, 11]. Predicted growth of solar PV systems globally was obtained from the International Energy Agency, which predicted that total installed PV capacity would increase at about 13 per cent per year between 2008–2035 [11]. This growth rate was assumed to continue throughout the CBA modelling time horizon due to the lack of any growth predictions beyond this time. This provided the basis for information on when the doubling of production of PV would occur. It was assumed that rainwater tanks, plumbing and the pump were products that had limited potential for design and cost-efficiency reductions. Therefore, only the inflation rate per year was added for the replacement costs to the original costs for these elements.

An operation and maintenance cost of one per cent of capital costs a year was added for all solar PV systems and inverters [11, 12]. The additional maintenance cost for the rainwater tank pump and plumbing was calculated using The cost-effectiveness of rainwater tanks in urban Australia [13]. From this report it was determined that there would be a maintenance cost of \$23 per dwelling in 2012. An inflation cost was added to all maintenance costs for future years. A rate of inflation of three per cent was applied

throughout the CBA modelling. This was calculated based on an average taken from Reserve Bank of Australia data from January 2001 to December 2010 (10 years) [14].

The discount rate is the rate applied to calculate the worth of future cash values in present values (net present value). Selecting the appropriate discount rate is an issue that is heavily contested, and the selection of a particular discount rate can significantly alter outcomes [15, 16]. The Australian Office of Best Practice recommends using a discount rate of seven per cent [17]. However, some researchers and economists discuss that for long-life modelling, such as in the case of housing, a lower discount rate should be applied [18, 19]. The UK Government uses a declining discount rate of 3.5 per cent for the first 30 years, falling to 3.0 per cent from 31 to 60 years, for example [19, 20].

Three discount scenarios were considered; one was a zero per cent discount rate, in essence reflecting the public good nature of the project; scenario two was applied in line with the real discount rates used in the UK listed above [19, 20]; with scenario three undertaken in line with the Australian Government's [17] real discount rate requirements listed above. A declining discount rate as used by the UK Government was applied for analysis of scenarios two and three between 31 to 40 years [20].

Utility usage, solar generation and rainwater collection and usage were taken from the monitoring data provided by Organica Engineering and cross-checked where possible with consumer bills. Where there was a significant difference (as there was for the gas usage for the Catalyst houses), the lower figure was used (generally the consumer bill).

The cost of utilities was taken from an average of the



consumer bills provided. The model provides data for different times of use for energy; however, in this report the anytime price data (same price no matter what time of day energy is used) is presented. The other scenarios can be found in the Excel model (provided to the department – not in this report). A feed-in tariff of \$0.31/kWh was applied. This figure was taken from the consumer bills. It should be noted that it is unlikely future projects would achieve this rate, with the current feed-in tariff in Victoria being \$0.08/kWh. For the start of the CBA in June 2012, the following utility prices were applied:

- solar feed-in tariff – \$0.310/kWh (net)
- electricity anytime usage – \$0.279/kWh
- gas anytime usage – \$0.017/MJ
- water – \$1.953/kL.

Two future energy price predictions were derived out to the year 2051 from Garnaut [18], Hatfield-Dodds and Denniss [21] and the Essential Services Commission [22]. High and low energy cost scenarios were calculated, in essence presenting a range of outcomes for the analysis. These will be identified throughout the presentation where appropriate. The prices exclude the Goods and Services Tax (10 per cent); and daily connection costs as these were assumed to be consistent across all housing scenarios as they all remained connected to the local energy and water infrastructure.

Past research has shown that improved housing energy performance adds to the resale value of a house. A report by the Department of the Environment, Water, Heritage and the Arts (DEWHA) [23] titled Energy efficiency rating and house price in the ACT found that for every one-star improvement to a house in the Australian Capital Territory, Australia, an added

economic resale value of almost AU\$9,000 was achieved. Another significant resale value study from the USA [24] found that for every dollar saved in energy bills, an added value of US\$20 resale value is added to the house. Both of these assumptions were applied in the evaluation's model to show the range of outcomes

Applying a standard depreciation approach has been identified within renewable energy technology literature as an appropriate method to calculate future worth of renewable energy technologies [25]. A declining balance depreciation method was used in this model as per Jackson et al. [26]. This method assumes a decrease in value that is more rapid at the start of the asset's life span.

The department construction standards for new build, low-density housing (the department Standards) and SIP houses are a baseline for utility use, which are the basis for comparison throughout this report. These scenarios are for a two-bedroom, two-occupant dwelling with solar hot water but no other ESD technologies. The predicted utility consumption of these two scenarios is presented in Table 11 in Section 6.2 and was developed from the initial baseline performance tool that was provided by Organica Engineering and contains assumptions about utility consumption for the two cohorts of 'occupants' – the general public across all housing types and the department tenants.

Additional capital cost data was provided by the department for the improved building envelope thermal performance, solar PV systems and the rainwater tank plumbed into the house (see Table 6). Maintenance and replacement costs of the additional sustainability technologies were applied in the analysis where appropriate. An additional resale value of the

demonstration houses was also calculated based upon DEWHA [23].

### 1.3.6 Blower door test

The blower door test is a standard method for measuring the air tightness or 'air leakiness' of a dwelling. Testing is carried out according to international standards and protocol, such as EN:13829 (2001) and ATTMA (the Air Tightness Testing and Measurement Association). The measurement of air tightness helps to investigate the energy performance of a dwelling, in terms of heating and cooling loads, and informs issues such as indoor air quality and dwelling ventilation rates. The test takes approximately one hour to set up and perform. A fan is fitted to the door of the dwelling using a dismountable frame and is used to blow air into and out of the building. A blower door test was conducted on all dwellings in the evaluation where the households gave consent.

### 1.3.7 Home advisory tour

A member of the RMIT research team conducted a home advisory tour with households participating in the evaluation. This activity replaced a proposed behaviour

change program due to issues identified in the first two rounds of interviews. In particular, it was found that any information-based behavioural change campaign would likely have a very small impact on these households due to low engagement with previous written materials provided by the department, and suspected low literacy in some households. Instead, a personalised assessment (or tour) was offered to each household participating in the research. All Catalyst and Control households were contacted to participate in the home advisory tour. Households were offered a double pass to the local cinema as encouragement to participate. In total seven households (four Catalyst and three Control households) agreed to participate in the home advisory tour. The home advisory tours were conducted during March 2015.

The expected advantages of the home advisory tours were to:

1. enable greater trust and household engagement through a face-to-face approach
2. take tenant understandings and circumstances into account when identifying energy and comfort advice (for example, presence of children in home, health issues)

Table 6: Cost for sustainability elements of each Catalyst house

Element	Additional cost per house
8.9-star building envelope	\$55,300
1.5 kW solar PV system	\$9,600
Plumbing of rainwater tank into house	\$10,800
<b>Total</b>	<b>\$75,700</b>

3. primarily provide verbal recommendations to tenants and use written information as a supporting strategy only
4. gain further insights into strengths and weaknesses of Catalyst home designs and any ways the Control homes could be modified to improve the project's KPIs.

The home advisory tours aimed to:

1. capture the households' current practices and engagement with the ESD features and/or available housing infrastructures and appliances
2. advise how thermal comfort and resource savings could be improved or done differently for the households.

The home advisor was a member of the RMIT research team who had not previously visited the homes (during interviews) and was unknown to the tenants. The advisor's approach was to present as an 'expert' but to conduct the home advisory tour in an informal manner. The advisor wore typical tradesperson work clothes and took a ladder to each house.

The advisor asked introductory questions about household health, utility bills and payment and experiences of hot weather in the home.

These discussions provided a basis for further recommendations. A room-based guide for the home advisory tour and energy and water topics was used (see Appendix 3), but the order and focus were adapted to suit tenant circumstances and interests. In the Catalyst homes, each of the ESD features were discussed to probe familiarity and use and help households understand how to get the most out of each feature. Energy and water efficiency, comfort and environmental ideas were discussed with the tenant during the home advisory tour. The responses to these

ideas were taken into account to formulate a short list of recommendations that were verbally revisited at the end of the home advisory tour and briefly summarised in a handwritten summary. The household summary included a 'Going Well' section to acknowledge tenants' energy and water efficient practices, and was designed to be a brief and visible 'at a glance' summary (see Appendix 3 for an example).

The advisor carried a range of potentially useful printed information (for example, websites with energy efficiency information, concession and energy hardship information and no interest loans scheme information) that could be given to tenants who indicated interest. However, other than one tenant at risk of electricity disconnection, tenants did not indicate interest in further information and some (including young tenants) did not have home computers to look at websites. This further confirms the limitations of providing formal written information and advice to these households. The evaluations of the home advisory tours can be found in Section 4.

## 1.4 Structure of the report

The outcomes of the research activities detailed above are presented across the remaining report as follows:

Section 2 presents an analysis of the literature concerning transitioning to a low-carbon future, value of good design, sustainable housing and costs and benefits of sustainable housing. This section establishes the broader international and Australian context within which this project sits in order to aid the understanding of the analysis outcomes and recommendations.

Section 3 presents the findings from interviews with households and the outcomes of the evaluations of

the home advisory tours. These are presented based on the relevant household KPIs. Outcomes from the first round of interviews are reported for each KPI, with changes identified in the second and third rounds of interviews noted at the end of each section. This is followed by the evaluation of the home advisory tours in Section 4.

Section 5 presents the findings from interviews with

stakeholders in relation to relevant KPIs. Information from the first round of interviews is presented, followed by any changes noted in the final (second) round of interviews with stakeholders.

Section 6 presents the dwelling performance and CBA. The key research outcomes are summarised in Section 7, with recommendations from the research presented in Section 8.





## 2. Literature Review

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### 2.1 Transitioning to a low-carbon future

This The way we (as a society) currently build and use housing in developed countries is unsustainable in respect to the widely acknowledged need to transition to a low-carbon future [27-29]. The environmental impact of housing is generally considered across two broad phases of the house: 1) design and construction; and 2) through-life use. With dwellings typically lasting 40 years or more, the through-life environmental impacts can be significant [8]. These impacts are created from the use of resources such as energy and water. For every new dwelling that is built and does not meet low-carbon outcomes, we continue to add to the problem of an unsustainable built environment. With a growing population, increasing numbers of dwellings and predictions of growing energy consumption, the challenge of transitioning to a low-carbon housing future is evident [7, 8].

The environmental performance of a dwelling is strongly dependent on two key factors. The first is how households use the space, for instance how many hours they are in the house, if they turn lights off after leaving rooms and how many appliances they have (and use) [30-32]. The second is the ongoing impact of the initial design and materials used during construction [33, 34]. For example, improvements to the building envelope (such as increasing insulation and window glazing performance) lower the need for heating and cooling technologies and, in turn, the energy required to power these. The environmental sustainability of housing in Australia has been found to be significantly behind that of comparable climate zones in the UK and USA [35].

The typical response from governments in developed countries when addressing the sustainability of housing has been the setting of minimum performance regulations [36]. These typically reduce heating and cooling energy requirements, although some more recent standards go beyond this to include all resources consumed in a dwelling and consider things such as onsite renewable energy generation and water collection and reuse [37].

While Australia has made progress towards improving the environmental performance of its housing stock through the introduction and incremental adjustment of such standards, the current requirement for new or renovated dwellings in Australia stills falls short of those standards required for a low-carbon future [38, 39]. In particular, in recent decades there have been significant increases in the use of energy for heating and cooling, especially during heatwaves or cold spells [40-42]. These increases have been driven in part by thermally poor housing, the falling purchase cost of air conditioning units and the rising expectations of thermal comfort levels all year round [43, 44]. The increasing use of heating and cooling technologies has raised overall energy demand and greenhouse gas emissions in countries such as Australia, and led to such pressure on energy networks, it has resulted in brownouts or blackouts [40, 45, 46].

The increasing use of energy and water has resulted in higher utility bills, causing financial stress for some households [41, 47]. Research has found that vulnerable households often cannot afford to install and use heating and cooling technologies, which impacts



their ability to maintain thermal comfort and personal health during extreme weather events. A rise of \$20 per month for utilities can be too much for some low-income households [41].

Various case studies demonstrate that knowledge, technology and skills are available to achieve low-carbon and low environmental impact housing, providing a model of what we should be striving to achieve [48, 49]. While there is an increasing number of housing professionals and households embracing sustainability globally, low-carbon and low-energy housing has yet to be replicated across the broader housing sector. A key challenge has been that the building industry has been slow to change and only done so when required by regulations or to make use of subsidies, rarely going beyond minimum requirements. This is partly because there is a perception that improved sustainability is unaffordable [50, 51].

## 2.2. Value of good design

Well designed, low-carbon and low-energy housing is not just about reducing environmental impacts. There is increasing literature on the wider value of good design (of which environmental performance forms a part), particularly from the UK and USA, across a range of building types, including housing [52-60]. These wider benefits (typically referred to as 'intangibles') include quality of life, health and wellbeing, a sense of place, satisfaction, liveability, equity, maintenance requirements, culture, mobility, improved thermal comfort, lower living costs, reduced environmental impacts, improved dwelling performance during peak weather conditions, and a lower (or no) requirement on mechanical heating and cooling [6, 30, 39, 48, 61-66]. Most of these benefits are directly experienced by the household, but some also impact on wider society (for example, fewer trips to the doctor because of

improved health due to more suitable thermal comfort). Researchers have been able to measure improvements to health, wellbeing, day-to-day finances and property resale value from improving residential design outcomes to include sustainability principles [67-70]. These benefits apply directly to the household and also the wider community. For example, if a vulnerable household is able to keep their utilities connected, this could reduce their impact on social services. Or if there is a local park, this can be used by the whole community to achieve health and wellbeing benefits. Research about the value of good design is limited in the Australian context, although there is some exploratory data about additional resale values of improved dwelling thermal performance [23].

Policymakers are also recognising the benefits of well-designed, sustainable dwellings. The City of Melbourne has released several reports in recent years that highlight its concerns that the rapid development of the Melbourne CBD is being done without due consideration of good design [71-73]. It fears that without intervention little will change, and that it will lock consumers of these properties into decades of poor housing value and use outcomes. This concern has also been expressed in other countries [74].

Achieving good design outcomes has largely been driven by housing performance standards (see Section 2.1). The challenge remains that few developers go beyond these minimum requirements and where they do, it tends to be at the higher end of the property market where they use this as a marketing tool to differentiate themselves from other products. The concern from the building industry is that there is a capital cost associated with achieving these improved designs, which it feels consumers will not want to pay for [75].

### 2.3. Sustainable housing

As mentioned in Section 2.1, over the last few decades there has been an increasing focus on improving the environmental performance and liveability of dwellings across their life cycle. The challenge for sustainable housing to become mainstream is related in part to a dearth of knowledge and skills and a building industry that is resistant to change. The current challenge is focused on the perceived additional capital costs to build sustainable housing, the through-life benefits of such housing, and to whom these benefits apply [8].

Around the world, there are an increasing number of innovative housing developments that have attempted to address housing quality, sustainability, affordability and social improvements as a way of promoting and advancing sustainable and liveable communities. While not always getting the outcomes right, these exemplar buildings are moving the policy, planning and research discussion forward. Noted examples include BedZED (London, UK), One Brighton (Brighton, UK), Printworks (London, UK), Adelaide Wharf (London, UK), Twelve West (Oregon, USA), zHome (Washington, USA), Josephine Commons Development (Colorado, USA), TaiGe Serviced Apartments (Shenzhen, China), K2 (Melbourne, Australia) and The Commons (Melbourne, Australia) [61, 76-80]. These developments typically have improved building envelope performance and passive design features, while including technology improvements (for example, LED lighting) and other sustainability technologies such as on-site renewable energy generation.

Thermal comfort is a major benefit of sustainable housing (particularly how it links to health and financial outcomes and a wider provision of energy). It is also becoming an increasing focus of housing policy as there are more frequent extreme weather events (for example, heatwaves). Many countries are exploring

a range of approaches to help reduce the negative impacts of thermal discomfort. As discussed in Section 2.1, there is an increasing use of air conditioning as a means of addressing tenant comfort and health within the built environment, particularly during heatwaves [40, 41]. Around the world policymakers are exploring ways to reduce reliance on air conditioning in response to changing expectations of thermal comfort and to address sustainability concerns [40, 41]. One model that has emerged is the adaptive model of comfort, which moves away from air conditioning as the answer to thermal comfort [70, 81]. This model argues that people can adapt to and, in many cases, prefer a much wider range of temperatures than previously suggested through engineering thermal comfort standards, such as those proposed by the American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) [70, 81].

For example, Indraganti [82] found that almost 100 per cent of households were comfortable in their case study in India at 30°C indoors. Eighty per cent were comfortable up to temperatures of 32.5°C. In Australia's southern states, Strengers and Maller [83] found a wide variation in the temperatures households felt comfortable at (up to 35°C in summer). For household occupants, adaptive thermal comfort activities in hot conditions commonly include opening and closing windows, adding or removing clothing, closing blinds, using wet towels, having cold showers and using a fan [70, 82, 84, 85]. Limited understanding about the complexity of how households' interactions with their houses contributes to realised dwelling performance, and thermal comfort has been identified as a barrier to achieving widespread low-carbon housing [86].

## 2.4. Costs and benefits of sustainable housing

In recent years there has been an increase in research and analysis that looks at the predicted costs and benefits of improving the minimum sustainability requirements of housing from a range of perspectives [38, 48, 87-90]. This research has found that achieving a zero carbon performance standard is likely to add between five per cent to 15 per cent to the cost of building a dwelling. However, this cost would achieve a payback for the owners within 10 years, making the proposition an attractive one over the 40-plus-year lifespan of a house. In fact, research has shown substantial economic benefits for households when just energy cost savings are factored in to payback periods (excluding wider social benefits) [38]. The challenge is to reposition discussions about housing affordability from those that are focused on upfront capital costs (or mortgage repayments) to those that are focused on through-life affordability.

Many researchers and governments have conducted detailed CBA in order to frame policy responses to housing sustainability. CBA is a tool for undertaking systematic analyses of total cost inputs against total expected outputs of various policy or program options compared to a business as usual approach in an attempt to identify economic efficiencies [91, 92]. CBA converts inputs and outputs into a common metric to allow for comparison between policy or program options. Typically this metric is expressed as value in present day dollar amounts.

The UK developed a 10-year policy approach to transition to net zero emission houses based upon initial CBA modelling, which found that it was financially

viable to improve minimum performance requirements<sup>4</sup> [87]. Benefits found included reduced utility bills, improved household comfort, improved household health, increased employment, industry innovation and reduced greenhouse gas emissions across the life of the house [93, 94]. As a result of progress for sustainable housing over the past decade, zero energy, carbon and emission housing is now international best practice.

While CBA is a useful tool, it is criticised for failing to adequately deal with placing a value on some social and environmental dimensions within analysis [8, 92, 95]. These include improved household health and comfort and improved living affordability [95, 96]. Golubchikov and Deda [95] believe that a case for policy approaches to improve housing sustainability performance can be made on these social benefits alone.

Studies that employ only CBA tend to overlook much of this social complexity, and leave policymakers with significant gaps regarding the qualitative dimensions of infrastructure investments. The dual use of qualitative and quantitative methods has been effectively employed across a range of policy arenas such as welfare [97], health care [98], fuel poverty [99] and climate change [100]. However, to date there has been limited research applying the two approaches in the evaluation of housing policy and environmental performance, both internationally [101] and in Australia [39].

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4 Note that while the UK sets a policy goal of requiring all new houses to meet a net zero emission standard from 2016, a recent change in policy has diluted these performance requirements. However, the broader EU has requirements that new dwellings must meet net zero emission standards from 2020.







# 3. Interviews with households

This section of the report presents the analysis of the household interviews repeated across three years. The section is structured around each KPI to address progress towards the evaluation objectives and indicators. The analysis presented focuses on change over time. Round one interview findings are first presented for both Catalyst and Control households against each indicator. These are followed by any changes noted during rounds two and three of the interviews. Where a household was not interviewed in round one, but was interviewed in round two (for instance, ConD, ConE and ConF), this round two data is presented in the round one interview analysis, with the third round interview data presented in the rounds two and three additional notes. Each KPI also contains a summary of key points for the Catalyst and Control houses. In some instances there was little evidence addressing specific indicators, and so only summary dot points are provided.

## 3.1. KPI 1: Decreased relative utility bills

**Objective: 1.** Reduce cost of utility bills

**Indicator: 1.** Perceived/self-reported and actual reduction of utility bills.

And

**Indicator: 2.** Changes in tenant attitude to utility billing, and concessions.

### Catalyst households

All of the Catalyst households reported paying less (in terms of the total bill) for gas and water when compared to their previous dwellings. Furthermore, three of the four Catalyst households were paying less for electricity, with the fourth (CatA) uncertain if they were or not. This was because they had come from

a share house and found it difficult to compare their previous bill with the Catalyst house bill, even though they said their gas and water bills were lower overall. The transition was challenging for this young couple, who were now solely responsible for their living costs. They were surprised at their large initial electricity bill (more than \$600), which they were still paying back when they participated in the first round of interviews.

Apart from the large first electricity bill for CatA, the other Catalyst households stated they had less difficulty paying their utility bills in comparison to their previous dwelling. CatB felt they were at least ‘\$250 per quarter’ better off even though they now had to pay for water, which they did not have to do in their previous house. In part they said this was due to the ‘very, very good, very economical’ heating system. The households in CatB used to live in two separate houses and so there may also have been some economic efficiency in moving in together as well as from the improved performance of the dwelling.

Three of the Catalyst households described how the solar panels on their dwellings had helped get their energy bills in credit at various times of the year, which had made a significant impact on their living costs and broader liveability of the dwellings.

CatC: ...I've saved so much money in the time I've been here because not paying, you know, so much electricity bills and stuff so my bank account's sort of got up a bit and it's like wow this is alright.

CatD: [It's] the first time ever I've been in credit on a power bill [laughs]

The Catalyst households indicated that there had been no change in the concessions they received. The tenants also appeared more relaxed about their utility bills. For example, the households in CatD stated:

CatD: ...It is easier...I don't have to stress that, "Oh my God, I'm going to have a power bill come in".

#### IN SUMMARY:

- Three of the four Catalyst households reported lower operating costs compared to their previous residences, particularly in regards to electricity and gas utilities.
- Three of the four Catalyst households were more positive regarding utility billing because their bills were lower than previous dwellings. They reported no change in any concessions they received. This could not be cross-checked with billing data due to difficulties in obtaining relevant information from the utility companies.

### Control households

Six of the seven Control households reported that their bills were no better off in comparison to their previous dwellings. Two households (ConB and ConC) had come from situations where they were not the ones responsible for paying the utilities in their previous dwellings, and therefore found it difficult to know how their current house was performing. However, the households in ConA said that their bills had reduced compared to where they previously lived, while acknowledging that they had become more frugal with their utility usage in recent years to ensure costs did not get too high. They stated:

ConA: Using the bottled gas up at [my previous residence] was very expensive whereas the natural gas here isn't as bad...and the same with the solar power for the hot water, it makes it cheaper.

Five of the Control households said they were able to pay their utilities on time. The two Control households who had not been responsible for paying for utilities in their previous dwellings both also faced challenges paying their utility bills, and had been placed on an automatic payment plan.

ConC: [My] power bill went from about \$140 to \$260 for that quarter...I had to make three payments on it but they [energy company] were good about it, they understood.

All Control households indicated that there had been no change to their concessions for utilities or otherwise since they had moved into their current houses. There was also little indication of any improvement or change regarding their attitudes towards utility billing.

#### IN SUMMARY:

- Only one Control household felt they were better off compared to their previous dwelling in terms of reduced utility consumption.
- Two Control households who had not been responsible for paying their utility bills in their previous households struggled to pay their utility bills.
- There were no significant positive changes with regards to the Control householders' attitudes towards utility billing, with two Control households reporting negative experiences with regards to utility billing.
- There were no changes to concessions.



### Additional findings from the second and third rounds of interviews

The Catalyst households continued to report lower utility bills and being in credit at times, and were grateful for this.

CatD: Look I haven't paid off my power bill in six months and I'm still in credit...\$882 [currently in credit]

This matches the technical data presented in Section 6, which showed that the Catalyst households had lower overall utility consumption and therefore reduced utility costs compared to the Control households.

For example the:

- CatB household estimated that their utility bills were halved because of the sustainability features
- CatA household was able to pay back the large initial electricity bill and then reported in the second round interview that they were now able to save and pay their utility bills on time.

CatB had a situation where someone turned off the solar connection after breaking into their power box. They only realised this had occurred after two bill cycles, but as it happened during winter the loss of solar did not significantly impact on this household's ability to pay their electricity bill. The household estimated they lost about \$200 in solar feed-in tariffs

In the second and third rounds of interviews, Control households reported that there were no improvements in utility consumption or concessions received. The Control households' bills fluctuated more than the Catalyst households' bills, and the Control households experienced more difficulty paying bills than the Catalyst households.

ConE: Oh, my daughter tried a fan heater last winter and...I got a \$700 electricity bill [up from an average of \$400].

For example, while the households in ConC had managed to stay on top of their utility bills due to the pre-paid automatic billing, the ConB household's situation had worsened by the third round of interviews to the point where they were regularly disconnected from their electricity and gas supply. This led to incredible stress for the household, who also had a young child (aged five at the last interview round). It was getting increasingly more difficult for this household to get their utilities reconnected, as evidenced by the requirement to seek external help (for example, from government services) with the reconnection. This situation appeared unlikely to change in the near future. However, the tenant did express some hope of reversing the situation when their child started school the following year (2016), freeing them up to seek employment.

ConB: I got up in the morning, I turned the TV on and it [the electricity] just went out and it was back on just after lunch. I had to ring up again and organise a new payment thing. And even now they'll cut me off again in the next couple of weeks and I'll have to do it all over again...I only owe them [the electricity company] like \$500...I owe [the] gas [company] over nearly a thousand [dollars].

There was also a situation where ConA2 had not received a water bill for their first 18 months in the dwelling as there was a mix up with the water meter and what address it was connected to. This caused significant anxiety for the households. The situation was resolved early in 2015, and the tenants did not have to pay for any previous usage. The tenants

indicated they would not have been able to afford to pay 18 months' worth of water if they had been charged for it.

**Objective: 2.** Less reliance on town water supply

**Indicator: 1.** Tenants self-reporting whether tank water has increased their gardening or other activities (particularly in drought conditions).

### Catalyst households

The presence of a rainwater tank was not reported to increase the gardening activities of Catalyst households. Only one of four Catalyst households indicated they were doing more gardening since moving into their Catalyst house. This household (CatB) took pride in their thriving front yard and ensured that it was regularly watered. The tenant of CatD was an avid gardener in their previous home and continued gardening in their new dwelling. However, they removed the plants that were in the original Catalyst garden and replaced them with native and drought tolerant plants. The other two Catalyst households did not describe themselves as gardeners. The inclusion of a water tank did not encourage them to develop an interest in gardening.

#### IN SUMMARY:

- The inclusion of rainwater tanks resulted in one of the four Catalyst households increasing their gardening activities. One Catalyst household also continued their passion for gardening.

The inclusion of a rainwater tank for the Control houses was not reported to increase the gardening activities of tenants. Households gave a number of reasons for this. For example, while the tenants of ConA had

previously enjoyed gardening, age and health issues meant they were unable to do much gardening in their current home. However, they did comment that they had mulched the garden to help reduce the requirement for watering. They had also replaced some of the plants so that they were more suitable for the soil and climate:

ConA: ...The plants that were in here weren't any suitable for the soil. So I've got ones that are suitable for the soil and they don't need much water.

The issue of plant suitability in the department houses was also raised by one of the Catalyst households. Ensuring that climate-appropriate plants are put into gardens may mean tenants are more likely to engage in gardening.

The households who replaced ConA (ConA2) were avid gardeners and improved the garden (see below). Their desire to create a 'sanctuary' of their own was motivated by their intention to try and improve the health of one of the households, who enjoyed sitting in the garden to get fresh air and relax. They did not indicate that this was enabled by having a rainwater tank; it is something they would have done regardless.

The tenants of ConB stated that they would like to do some gardening but found it was not possible. This was because they deemed it unsafe to be in the backyard due to issues with neighbours throwing things over the fence. When questioned about the water tank, the tenants of ConB said it was not used to water the garden, but it was used in summer to fill up an inflatable child's swimming pool, which they used to help keep their young child cool.



**Figure 6: ConA2's garden development in September 2015 (source: Trivess Moore).**

#### IN SUMMARY:

- Three of the Control households enjoyed gardening and made efforts to improve the garden provided to them. The other four households had little interest in gardening other than to keep the weeds down. There was no indication that the presence of a rainwater tank encouraged additional gardening activities.

#### **Additional findings from the second and third rounds of interviews**

There was no change to the above analysis from rounds two and three of interviews for any of the

Control or Catalyst households. However, ConA2 households continued to develop their garden and were encouraged by the department staff to enter it in the local gardening competition.

ConA2: The Housing Commission did yeah [recommend she enter the garden into the local competition]. I think they wanted to promote the fact that a commission house can be as good as the bloke next door or whatever you know and they can be.

### 3.2. KPI 2: Improved financial circumstance

**Objective: 2.** Improve overall economic wellbeing

**Indicator: 1.** Changes to amount of disposable income. Changes to level of financial stress experienced. What can/cannot now be afforded?

### Catalyst households

Three of the four Catalyst households reported having additional money to spend on non-essential items because of their lower utility bills (see Section 3.1). Similarly, the same households indicated they experienced less financial stress compared to their previous houses when it came to paying for the utilities (as reflected in their relaxed attitudes to utility bills).

For example, the additional money that the CatB household saved from lower utility bills was put towards a holiday to Queensland during their first year of residence. While the savings were not enough to pay for their entire trip, they felt that the savings provided a significant economic boost compared to their previous dwelling. The CatC household reported saving money for their funeral costs 'so the kids don't have to worry about it'. They added:

CatC: I always only had about \$XXXX [in my bank account]. I've got about [a little bit more] in my bank now so it's really good.

Furthermore, the CatC household was asked to loan money to one of their children now that they had these savings. This reflects a substantial change in their economic situation, although the additional \$XXXX in their account is more than the estimated savings of \$1,050 resulting from lowered utility bills (as calculated in Section 6).

The tenants of CatD reported that their utility bill savings allowed them to 'treat' themselves, and called the additional money 'play money'. They reported being able to buy DVDs, books and clothes.

CatD: I do go clothes shopping on occasion now instead of thinking, "Oh God, I have to go and layby that".

#### IN SUMMARY:

- Three of the four Catalyst households reported having additional money to save and spend on things such as a holiday, funeral planning, and personal items or to financially support other family members.

### Control households

While the tenants in ConA reported having lower bills in their current house compared to their previous house, the difference wasn't noticeable in terms of having additional money to spend on other things. They stated:

ConA: Well, I haven't got a lot of money to start with.

Other Control households provided similar responses; none indicated they had more money to spend on discretionary items after paying their utility bills compared to their previous dwelling. As stated earlier, two of the households were on payment plans to ensure they could (or attempt to) pay their utility bills on time. The tenant in ConC was one of those households and found that they had budgeted to pay around \$200 for electricity a quarter, but the bill was typically \$140 to \$160 per quarter. This surprised the tenant and left them with a credit that they said was used at Christmas to help offset the high cost of buying gifts and food. They stated:



ConC: Have I had money in? Yeah sometimes I've had like 200 dollars credit, like with power and if I sort of just keep it going all year and then at Christmas time I just take what I've got in credit...[to spend on] presents, food, just Christmas in general, you know what I mean?

#### IN SUMMARY:

- Control households did not report having additional money available after paying for utility bills.
- One household that was on a payment plan found their actual usage was slightly below their predicted usage, which provided some additional money at Christmas.

#### Additional findings from the second and third rounds of interviews

All Catalyst households continued to demonstrate improved financial outcomes (more discretionary spending) in comparison to their previous dwellings. Three Catalyst households reported that their financial savings increased the longer they lived in the dwellings, demonstrating that the initial savings they reported in the first round of interviews were not related to the 'new home' factor.

CatC: I'm spending money like mad by going away, which I wasn't doing before, I was never going away, staying places weekends...so yeah, I'm definitely better off money-wise.

CatB: A lot reckon they can't afford to buy food and all that thing. There's something wrong somewhere. We don't miss out on anything.

In addition, one of the Catalyst tenants no longer received any CentreLink benefits, which was a significant goal they had been working towards. This was achieved through a combination of reduced living costs and working more over the past year (2015).

CatD: And I no longer have to rely on any CentreLink benefits, anything like that...I don't like being dependent on a cheque coming in every fortnight.

When asked about how they would cope if they had to move into a standard department house, all Catalyst households interviewed in round three said they would be worse off financially and this would impact their ability to spend money on other things such as holidays or discretionary items.

The Control households did not report any further changes to their financial circumstances over the lifetime of the project.

### 3.3. KPI 3: Improved level of thermal comfort

**Objective: 1.** Improve thermal comfort throughout the year

**Indicator: 1.** Tenants' self-reporting of their own preferences with respect to comfort, and their thermal comfort in the houses (less hot in summer, less cold in winter, better ventilation, comfort of various rooms, etc.).

#### Catalyst households

All Catalyst households stated that their houses felt cool in summer and warm in winter. They were overwhelmingly happy with the thermal performance of their dwellings, with thermal performance matching

their preferences. Furthermore, three Catalyst households felt that the ventilation was better in the Catalyst houses compared to their previous dwellings. The bathroom was mentioned as an area that some tenants felt was too cold, especially for older residents. Two households also mentioned that their spare bedroom was too cold in winter on occasions. However, overall they were comfortable in the house.

CatA: ...The way it's built is pretty good like keeping the heat in. So the heater's pretty good.

CatB: They're nice and comfortable, heat wise they are very good. They don't use much gas for the heater. It's very economical.

#### IN SUMMARY:

- Catalyst households were very happy with the thermal performance of their dwellings and were mostly comfortable in the house.
- Some households reported minor issues about the bathroom and spare bedroom being too cold on occasions.

### Control households

Four of the Control households had different thermal comfort preferences to how their dwellings were performing. This was largely due to health issues, which are discussed in Section 3.5. They were most uncomfortable during extreme weather events. For example:

ConA: No, his condition [her husband], his blood is lower than a normal persons because of what he's had done. So he doesn't feel the heat and I'm sitting here perspiring and I've got to have a fan or something on the same as in the bedroom when he's as warm as toast, and he doesn't mind that, but I can't stand it.

All Control households were satisfied with the ventilation, although at least two Control households reported having a window and/or door open either to allow fresh air in or for pets (most of the households had dogs) to come in and out. This was observed on a cold day in winter when the first round of interviews took place.

#### IN SUMMARY:

- Control households were less satisfied with the thermal performance of their dwellings.

### Additional findings from the second and third rounds of interviews

There were no significant changes to tenant preferences for thermal comfort in either housing group. Catalyst households continued to enjoy an improved level of thermal comfort.

CatB: You could feel, yourself, we've only been home half an hour, I just put the heater on, it's not on very high, the place is nice and warm, so it's pretty good.

**Indicator: 2.** Tenants' self-reporting of improvements in thermal comfort between current and previous houses

### Catalyst households

Three of the four households stated that their houses were performing better thermally than their previous houses (warmer in winter, cooler in summer) and particularly during more extreme weather periods (as discussed in Section 3.4). In some cases improved thermal comfort had a major impact on the wellbeing of tenants. For example, in their previous house, the tenants of CatD would often leave the house in



summer and go to the shopping centre where it was cooler, but in their current house they were able to stay at home as it was more comfortable.

CatD: I would be forever going out because I was so depressed in that house around there...and in summer I would sit down at the supermarket, you know, because it was cool... [Now] I can stay home and veg out.

#### IN SUMMARY:

- All Catalyst households stated that the thermal performance of the Catalyst dwellings was significantly better than their previous dwellings.

#### Control household

Most of the Control households said they felt the thermal performance was 'much the same' as their last house. However, the tenants of ConB said that it was colder in winter but easier to keep cool in summer compared to their previous dwelling. They found it difficult in winter to heat only certain areas of the house due to poor design (for instance, no door on the hallway to keep the heat contained), resulting in the tenants running heaters at both ends of the house to keep the living area warm.

#### IN SUMMARY:

- Most of the Control households reported that the thermal performance in their current dwellings was similar to that of their previous dwellings.

#### Additional findings from the second and third rounds of interviews

Catalyst households continued to enjoy improved

thermal comfort across each season compared to their previous dwellings. Several Control households believed their overall thermal comfort had declined, although this was most likely due to the impact of extreme weather events discussed below. The 2015 winter was reported to be colder than previous years, which may have impacted on reported thermal comfort.

ConF: I think it's been the coldest winter we've had for a long time.

### 3.4. KPI 4: Reduced reported level of discomfort on extreme weather days

**Objective: 1.** Lessen the risk of harmful effects of extreme weather days

**Indicator: 1.** Tenants' self-reporting on their ease/difficulty of temperature management on extreme weather days.

#### Catalyst households

Despite the perceived improved thermal performance of Catalyst houses, tenants reported some issues associated with extreme weather conditions. The tenants in CatB installed an air conditioner using their own money so they could have more control over the indoor temperature in summer. They requested that the department reimburse them for this expense, which was agreed to. Another Catalyst household reported wanting an air conditioner, although they had not done anything to purchase or install one or to request this from the department. The other two Catalyst households were satisfied with ceiling fans and the high electric windows on very hot days in summer.

CatB: Well, we both feel the heat pretty well but when it was 42 degrees outside, it only got to 29 in here...when it was three degrees below zero this was 15 degrees inside on that morning, that's without any heaters being on, 15 degrees. So that's good.

CatD: Well, like I said, not totally uncomfortably so...I managed.

CatA: I think ages ago it was really, really hot. So that's why we brought the hose out the back [to help cool down]... It was probably when we did wish for an air con.

On extreme cold days in winter, Catalyst households reported increasing the temperature on their heater. One household mentioned that they sometimes also used a blanket to keep warm and closed the doors to the bedrooms to contain the heat in the living area. However, the other three Catalyst households did not report taking any additional action to stay warm on extreme cold days.

CatA: ...The way it is built is pretty good like keeping the heat in [laughs]. It was, actually it was quite easy.

CatB: It's a beautiful heater that one. I've got it set on 20 degrees at the moment, that's all I set on and it is 20...but when she cools off tonight we might put it up to 22, 23 at the most.

CatD: I run the heater on low and close off the rooms other than my bedroom that I'm not using. But like I said, I don't even put a doona on; I've just got two little lightweight covers and no electric blanket now, because it's nice and warm [laughs]... The coldest I think I've had this, I've come home from being away and I've come in and it's been on at about 16 degrees and that's with no heater.

#### IN SUMMARY:

- Extreme hot days made it more difficult for two Catalyst households to maintain thermal comfort. In response, one of these households installed an air conditioner and

the other expressed a desire to install one.

- Two Catalyst households reported managing on extreme hot days with a fan and high electric windows. They did not think they needed air conditioning.
- All households managed to stay comfortable on extreme cold days by adjusting the temperature setting on the heater and/or using a blanket to keep warm.

#### Control households

All Control households stated that in extreme weather they found it difficult to manage the thermal performance of their house, particularly during extreme hot weather. In extreme heat, three households reported leaving the house due to unbearable conditions. The tenants in ConA said they had to leave the house despite having mobility and health issues:

ConA: ...Just go outside or go down the river for a walk with the dog because I can't stand it, I get too hot.

ConA households, and other Control households, reported trying to use blinds to manage extreme heat as much as possible, but this was not enough to maintain comfort. The tenants in ConB tried to shut the house up as much as possible and often took cold showers to cool themselves and their young child down. Those in ConC reported having the most difficulty dealing with extreme heat. They reported leaving the house for prolonged periods of time (up to two weeks) to stay at friends' houses until a heatwave passed. The tenant explained how extreme heat could create health issues due to a lack of sleep.

ConC: ...Or if you're expecting a week of 40s... most of all my friends have got air conditioning so I normally sleep there for a, when it's like, like that...I pack up pretty much, get a bag and, because sometimes you might get a whole week of 40s in Horsham, January and that, so just come and check on the place. So, which is a bit of a bummer, but you can't have everything.

I can even do like low 30s. You get through a day of it, that's cool. But, again, once you get near 40, well you can't literally sit in the place without... And then you start losing sleep and you end up getting, people are cranky enough when it's really hot without going, you know.

Those in ConE reported turning off their air conditioner at certain times of the day because of cost concerns, highlighting an added challenge for low-income households to maintain thermal comfort during heatwaves.

ConE: We were getting 40, over 40 to reach 43, 44 and 45. That was on every day from morning till night. I had to turn [the air conditioner] off at night time because my electricity bill would have gone through the roof.

On extreme cold weather days Control households undertook adaptive thermal comfort activities such as putting on more clothes and sitting under blankets. The use of heaters was a prevalent way to stay warm, although there were cost concerns about using the heater from one Control household. The ConB household needed to put on both heaters on extreme cold days to maintain the preferred level of thermal comfort. They did this despite stating they were concerned with how much it cost to run both heaters. They felt there was nothing else they could do due to the poor design of the house. However, other Control households found that they were able to manage comfort with the use of their heaters.

ConC: No, I don't turn it on till five o'clock...I just turn it on and, as I said, it takes hardly any time at all and just heats the whole house up.

#### IN SUMMARY:

- Control households found it difficult to maintain thermal comfort during extreme heat events, but were more able to manage during extreme cold events.
- During extreme heat events, some Control households had to leave their house for periods of time (including sleeping elsewhere).
- Control households were concerned about the cost of running air conditioners and heaters during extreme weather days, and sometimes turned them off during these times.

#### Additional findings from the second and third rounds of interviews

Catalyst households continued to report thermal satisfaction with their dwellings during extreme weather events, even though they had experienced a significantly colder (self-reported) winter (2015) than during previous years (2013–14).

CatB: Well, the first winter we were here, it never got below 15 degrees [Celsius] inside... This winter's been that cold, we've had it down to 11, that's the lowest, but that's still good, because when you can walk out and see the gazebo at nine o'clock in the morning, still covered in frost, it's bloody cold.

The CatC household had reduced their use of the heater during winter and no longer ran the heater overnight as reported during the first round of

interviews. They had also bought a small portable air conditioner for extreme hot weather days, but had not yet felt the need to set it up or use it. They spent \$400 on it second hand, but found ways to stay cool without using it.

Several of the Control households reported that their thermal discomfort during heatwaves had worsened. ConC was still leaving their house during extreme heatwaves and staying at friends' houses. They discussed how this was impacting on their wellbeing and ability to do things.

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 ConF household described how their heater was not able to warm all rooms, making maintaining thermal comfort during the coldest days in winter challenging.

ConF: Cold – the other end of the house is cold, yeah. We've got a little oil heater there, we put in the shower, you know, just to take the chill off to have a shower, otherwise you'd freeze.

Across both groups of households, extreme cold days were easier to manage than extreme hot days.

**Indicator: 2.** Tenants' self-reporting of their incidence of health issues on or from extreme weather days (for example, heatwaves).

### Catalyst households

One Catalyst household (CatA) did not report suffering any health issues during extreme weather conditions.

However, three Catalyst households had health issues that either were or could have been exacerbated by extreme weather conditions. These households agreed that the Catalyst houses had improved their climate-related health issues significantly. For example, the CatB households were concerned about potentially getting sick at their elderly age and stated:

CatB: Oh, if we're home I put it on most of the time [the heater], very economical... Both [my partner] and I have had pneumonia and I've had it three times and she's had it twice, [we] can't afford to get it again, not at our age.

The tenant in CatC had suffered from severe leg cramps in cold conditions in their previous house. They reported often sleeping in the living area of their previous home in front of a small bar heater to try and help the problem. In the Catalyst house they had not had these issues and could sleep in their bedroom.

CatC: Yeah, look I used to wake up in [my] street and oh, I'd be nearly crying with the pains right down the side of my legs and you'd try to stand up to try and start moving around and you could hardly walk and I haven't had that in here... [here] I get hot. I end up throwing my doona back for a while and cool off, yeah, so it's pretty good.

The tenant in CatD regularly suffered from bronchitis. They thought this condition had improved since living in the Catalyst house because of a more stable indoor thermal temperature.

CatD: Oh, look, I have bronchitis every winter, regardless of where I live. I'm just getting over a small dose of it now, but not as bad; I don't get as chesty because I don't go from extreme hot, you know, the other house I would have the lounge room warm but the rest of the house.

The CatD health improvements had a flow-on benefit

to the health sector. While the tenant had previously been hospitalised several times with bronchitis, this had not occurred since living in the Catalyst house. Similarly, the tenants in CatB had not suffered further episodes of pneumonia, reducing the need to engage with the healthcare sector. And while the tenant in CatC had not sought medical assistance for their severe cramps, this had reportedly led to improved mental wellbeing, given that they no longer needed to worry about or manage the issue.

#### IN SUMMARY:

- Three of the four Catalyst households reported improved health due to the dwellings, inadvertently resulting in reduced hospital admissions, trips to the doctors and improved mental wellbeing.
- The fourth household did not report any health issues.

#### Control households

Only one Control household indicated they suffered any additional health issues during extreme weather conditions. The tenant in ConC had bad arthritis in their hands, which became very painful when it was extremely cold. They had to take medication to keep the pain under control at times.

ConC: I've got bad arthritis. In the ends you see those fingers are a bit bung. That's from footy, I broke them badly playing footy and since I've got older they've gone all weird on me. So I don't, winter's probably not the great, because arthritis and any of that sort of stuff plays up in the winter when it gets colder... I take tablets and that for it and when it gets real, well it gets that bad that I get scripts like for Oxycontin, so you got to be sort of out there a bit with pain for them to give you that.

#### IN SUMMARY:

- Only one Control household reported that they had health issues relating to temperature.
- They were not able to effectively manage their condition through thermal dwelling performance.

#### Additional findings from the second and third rounds of interviews

There was no change to tenants' health during extreme weather events for either housing group.

**Indicator: 3.** Tenants' self-reporting on the level of comfort/amenity in the house if there is a blackout (for example, in heatwaves).

#### Catalyst households

#### IN SUMMARY:

- None of the Catalyst households reported experiencing any blackouts during their first year of occupancy.

#### Control households

#### IN SUMMARY:

- None of the Catalyst households reported experiencing any blackouts during their first year of occupancy.

#### Additional findings from the second and third rounds of interviews

Only one Catalyst household and one Control household reported experiencing blackouts during

the three-year evaluation. None of these events lasted more than several hours, and they did not occur during extreme weather conditions. Tenants did not report any adverse effects on their level of comfort or amenity during these short blackouts.

**Indicator: 4.** Number of extreme weather days in the period

This data was not provided as part of the evaluation.

### 3.5. KPI 5: Improved occupant health and wellbeing

**Objective: 1.** Improve tenant health outcomes

**Indicator: 1.** Tenants' self-reporting of trips to the doctor, physical or mental health services, days spent in hospital and number of days too unwell to carry out normal activities.

#### Catalyst households

None of the tenants indicated that they had been hospitalised since living in the houses. Beyond the health issues presented in Section 3.4, there was no discussion of wider health outcomes. At least two of the three Catalyst households who had health issues that were exacerbated by extreme weather sought less medical care or intervention. Three of the four Catalyst households reported being less stressed about paying utility bills, reflecting improved mental health.

#### IN SUMMARY:

- Three of the four Catalyst households reported improved health due to the dwellings, inadvertently resulting in reduced hospital admissions, trips to the doctors and improved mental wellbeing.
- The fourth household did not report any health issues.

#### Control households

None of the Control households indicated that their trips to the doctor or similar had changed compared to their previous dwelling. The ConA household had a carer who came to their home daily, which began when they moved into their current house. This was due to ongoing health issues that the elderly couple had suffered from prior to moving into their current house.

#### IN SUMMARY:

None of the Control households reported any changes to accessing health services in their current dwelling in comparison to their previous dwelling.

#### Additional findings from the second and third rounds of interviews

While two of the Catalyst households stated they had improved health outcomes across the research evaluation, one household had experienced deteriorating health from round two to round three interviews, which reduced their overall wellbeing although this was not related to the dwelling. There had been improved health outcomes for two of the Control households, but three households had experienced deteriorating health across the final year of the evaluation (2015).

**Indicator: 2.** Self-reported improvements in tenant health, not related to thermal comfort, since moving into current dwelling.

#### Catalyst households

#### IN SUMMARY:

Apart from the already-mentioned reduction in stress levels around paying utility bills by three of the Catalyst households, there was little evidence of further non-comfort related health benefits.



## Control households

Two of the Control households (ConA2 and ConC) reported an improvement in their overall health and a reduction in number of hospital visits since moving into their current dwelling. The tenant in ConC had issues with alcohol previously. They were working in a family run motel in a rural area and found that their health went downhill.

Having private accommodation was playing a key role in their ability to reduce their dependency on alcohol.

ConC: Like it was a no-win situation for years. And, you know, it was job, it was family and it just deteriorated severely, so I got a lot of time in hospital and stuff like that... I was on the Flying Doctors more than I'd like to know.

The other Control household that reported that their health had improved in their current dwelling was the tenants of ConA2. One of the tenants had been struggling with ongoing health issues for a number of years. These health challenges meant that the tenant needed to quit a high-paying job, which drastically altered the lifestyle of the tenants. The help and financial assistance provided by the department afforded them the opportunity to recover, both financially and physically.

### IN SUMMARY:

- Two Control households reported improved health from having stable housing provided by the department.

## Additional findings from the second and third rounds of interviews

Catalyst households did not report any additional improvements to health and wellbeing since the first round of interviews; however, they reported reduced

stress and anxiety around paying their utility bills. One Catalyst household (CatB) reported deteriorating health between the first and third rounds of interviews. This was due to their advanced age.

Four Control households' health and wellbeing had worsened. For example, ConC's tenant's health had worsened since the first round of interviews; however, their lifestyle had improved. One of the tenants in ConA2 had experienced deteriorating health due to a degenerative illness; however, both tenants' wellbeing improved due to security of tenure. ConB's tenants had also experienced serious health issues between the round two and round three interviews, some of which were still unresolved. Three Control households reported improvements in their health and wellbeing. The health of ConD's tenant had improved since moving in as they had addressed long-standing issues.

## Objective: 2. Improve tenant wellbeing outcomes

**Indicator: 1.** Overall life satisfaction, subjective feeling of wellbeing.

## Catalyst households

All Catalyst households described having higher life satisfaction and an improved feeling of wellbeing when compared to their previous living arrangements. This was in part due to the improved design and sustainability of Catalyst houses, improved thermal comfort (see Section 3.3), and lower utility bills (see Section 3.1).

However, some of this improvement can be attributed to changes in life circumstances. For example, the tenants of CatA were previously living in a shared household and were more satisfied being in their own newly built home, although this was countered by the challenges of living on their own with a young child

for the first time (for example, the shock of a high first electricity bill). Furthermore, they had recently had a second child and so their family had expanded, which had again changed the dynamics of their life. The tenants of CatB had been living in separate units previously but had wanted to live together and had recently married, which improved their life satisfaction.

#### IN SUMMARY:

- All Catalyst households reported improved life satisfaction and wellbeing outcomes since moving into the Catalyst houses.
- This was partly due to the improved design and sustainability of the dwellings, in addition to broader changes in life circumstances.

### Control households

Three of the Control households were reportedly more satisfied with their lives compared to living in their previous houses. This was mainly due to having stable tenure. For example, the tenants in ConB had had their young child removed by social services. The child was returned to them when they moved into their current house. They would not elaborate as to why their child was taken away, but it may have been related to the tenant not having stable living arrangements. This tenant felt more satisfied with life because they were living with their child. Similarly the tenant in ConC described moving away from a living situation that had led to him becoming an alcoholic. In doing so, and by securing private housing, they had improved their physical and mental health. Their overall life satisfaction had improved significantly. The tenants in ConA2 reported no longer having to stress about where to live and how to stay on top of paying rent. They had suffered significant financial challenges since one of the

tenants had become seriously unwell (see Section 3.2). Having department support meant that their quality of life and wellbeing had improved.

However, three Control households did not report any improvement in their quality of life in comparison to their previous dwelling. This was largely because at least one occupant in each of the dwellings had deteriorating health, which, while not related to the house, was reducing their quality of life.

#### IN SUMMARY:

- Three of the Control households reported improved quality of life, mainly relating to having secure and private tenure rather than the quality, design or performance of their house.
- Four Control households had deteriorating health, which meant their quality of life was not improving.

### Additional findings from the second and third rounds of interviews

Two of the Catalyst households continued to report improvements in overall life satisfaction, and were engaging in more social activities since the first round of interviews. One Catalyst household tenant reported a decrease in overall life satisfaction and wellbeing because they had lost the remaining sight in one of their eyes over the preceding 12 months.

CatB: Yeah, that [loss of remaining eyesight] pulls me down a bit, I do get down on that one.

Despite the tenants of ConB struggling to keep their utilities connected and having significant health issues and safety issues in their neighbourhood, they reported

being hopeful about the future. They believed that once their child started school in 2016 they would be able to get a job and improve their financial circumstances. They talked positively about the prospect of a holiday to the Gold Coast and Sydney. Another Control household said their overall life satisfaction had declined due to health challenges, while the other five Control households' levels of life satisfaction remained consistent from the first interview to the last interview.

### 3.6. KPI 6: Improved utility and mobility

**Objective: 1.** Improve tenant ability to operate the house

**Indicator: 1.** Tenants' self-reporting of ability to operate their current house.

#### Catalyst households

All households reported being familiar with how to operate 'the basics' of their Catalyst house. They knew how to use the fans and how to (and when to) operate the high electric windows. One tenant in household CatB was more knowledgeable than the other tenants. This tenant pointed out all of the sustainability features of the house on the tour, including things that were not visible or obvious. For example, they said things like:

CatB: Oh, well this place here is so well insulated, even up in the roof, the roof itself they tell me is very thickly insulated. The ceiling here is thickly insulated. That wall there and that wall there are solid brick, and on the outside of it it's got like refrigeration insulation and also up in the ceiling, they tell me when it gets to 35 degrees there's a fan automatically starts up and opens a louver up there and blows all the hot air out. That's their idea of trying to keep this cool.

The other three Catalyst households gave less detail about the sustainability features during the house tour and were confused when asked about some specific features during the interview. They acknowledged

they had received an information pack about their Catalyst house when they moved in, however, they did not seem aware of where it was or having read it. For example:

CatA: I'm pretty sure they did [give us an information pack about how to use the house] but I'm just a bit forgetful what...I've just got to sit down and read that then I'll know [if I am uncertain about anything].

Similarly, CatC's tenant was confused about how to use the heater in the most energy-efficient way. In this instance they had taken advice from their sister rather than any information provided by the department or the builder.

CatC: Oh, they [the department] just said to run [the heater] on about 22 [degrees Celsius]... Just leave it running on about 22. So my sister said she leaves hers on all the time, she never ever turns hers completely off. Because they reckon once you turn them off it costs so much more to try and, it really uses the power trying to boost it up to where you had it before. So you're using more there than if you just leave it running at the same temperature.

#### IN SUMMARY:

- All Catalyst households were vaguely familiar with the basic sustainability elements of the Catalyst houses and how to use them.
- Only one tenant was very knowledgeable about the sustainability elements of the Catalyst houses.
- All Catalyst households remembered being provided with an information pack about how to operate the houses, but had not looked at this information recently and/or were unsure where it was.
- One Catalyst household reported issues with using the reverse direction feature on the ceiling fans.





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## Control households

Two Control households did not report having any issues with the operation of their houses (ConC, ConA2). The remaining Control households either said there were issues or issues were identified by the interviewers during the house tour. For instance, the tenants in ConB said that they had significant issues keeping the heat in the living area, and used multiple heaters to warm the room (see Section 3.3).

ConA's tenants indicated that the location of window locks on the tops of the windows made it impossible for them to lock or unlock the windows, as they were both elderly and disabled and could not safely reach them.

None of the Control households had received any information or training on how to use their houses. All stated they would have liked some information, if only to be shown how to use things such as the heater.

ConA: I had to get one of the carers to put the heater on and show me how to use it... I would have liked somebody to show me how to use it... The heater and that and plus I didn't know that the windows had locks on them at the top and, I mean, a lot of that is rather silly because you get an elderly disabled that the home's designed for, and the locks on the windows are right up the top. I mean, to me, that's very unpractical.

### IN SUMMARY:

- Most Control houses reported challenges operating their dwellings or operational challenges were identified by the interview team.
- Most tenants would have liked to receive some basic information (for example, a demonstration) about how to use the features of their house, such as the heating and cooling systems.

## Additional findings from the second and third rounds of interviews

There were no reported changes across the rounds of interview from the households about how they were able to use or operate their dwelling.

**Indicator: 2.** Tenant's self-reporting on ability to access and make use of spaces within the house.

## Catalyst households

### IN SUMMARY:

- There were limited reports from the Catalyst households on any difficulty to access and make use of the space within the Catalyst houses.
- The only issue flagged by one household was that the disability bars for the bath had been put in the wrong place, making it difficult to use the bath.

## Control households

Two of the Control households raised significant issues concerning access and use of space in their houses, while the others did not report any major issues. The tenants in ConA lacked adequate storage space. They reported having three wheelchairs that required storage and said that they often filled the spare bedroom with a years' worth of incontinence pads, as this is how they were provided to them. The living room was an important room for this household; however, they felt it was far too small. They wanted to get a sofa in the living room but couldn't.

ConA: Well, where are you going to put it, you tell me, you can't... We can't even entertain properly.



The subsequent tenants who moved into this house during the study also raised the issue of the living room, and specifically the placement of the air conditioner in the room, which they felt was not an effective location.

The ConB household only used about half of their house and did not use their backyard at all due to safety concerns with the neighbours. They had a major mice infestation in the back bedroom. The tenants described how the mice had taken over the room and done significant damage to the room. It was unsafe for the tenant's child to use it as a bedroom, so it was not used at all. The mice infestation was caused by a large rubbish pile in their neighbour's yard. The tenant had sought help from the department in dealing with the mice, but had been told it was a tenant issue. They had tried putting down bait, but this had not helped.

#### IN SUMMARY:

- Three Control households had significant issues with access and use of space, mainly concerning sufficient storage space, location of air conditioning and heaters and their ability to use outdoor space.

### Additional findings from the second and third rounds of interviews

The tenants in CatB had some external works undertaken between the second and third rounds of interviews to remove an external step down to the carport. One of the tenants had a fall on this step so the department regional office organised for the step to be removed and a ramp installed in its place. The tenants were very pleased with the quick response to their request and the final changes made.

During the third interview, the tenants in ConA2

reported requesting an external door to be changed to a sliding door to improve the function of their house. This change was made by the department and the tenants were very happy with the improvements to their dwelling. They reported using their outdoor area more frequently as a result of this change.

ConA2: I'm out there every morning of every day. That's my morning cup of tea and in the afternoon when X is having a sleep I'll make a cup of tea and I'll sit out – I do all my thinking out there. It's like another room and it's an extension to the house, its fantastic isn't it? A peacefulness was what I was trying to create.

**Indicator: 3.** Features most liked about their current house.

### Catalyst households

Catalyst households all reported a number of features that they liked about their current houses. These included the open plan layout, ability to zone off areas for heating and cooling, double-glazed windows, solar panels, rainwater tanks, toilets with inbuilt hand basin, size of the bedrooms and bathrooms, built-in storage, sensor lights, solar lights down the driveway and the yard and carport area. Three of the Catalyst households took great pride in their dwellings and two referred to their houses as 'palaces'. All spoke very positively about the design.

CatA: Yeah, it's new. It's bigger. It's a lot better... It's pretty spacious the way it's all built together

CatC: The design's great. People walk in and they're like, "Oh my God, I can't believe this. This is commission, no it can't be commission, you know like..." And I'm like, yeah it is. I love the way it's set out and it's just, it's roomy, it's not over big, but it's still roomy enough, you know what I mean. The bedrooms are good sizes.



Tenants also liked the airlock, windows and locks on the windows. A key feature was that the windows could be left open a little bit while remaining locked.

CatD: Whereas here I can throw everything open and I love that little airlock [laughs]. That works so well, because I notice the difference when I come home, you know, if it's been cold, it's still nice and, it's cold out there but once you get in here it's lovely and warm.

Bathroom size was also highlighted as a positive feature by several households.

CatC: I'm like, wow that's going to be good when I get a wheelchair one day. I'll be able to get into that shower.

The water-saving toilet with inbuilt hand basin was also a key feature:

CatD: I must admit, there's one thing that I do like, is the water-saving toilet. You can actually wash your hands.

#### IN SUMMARY:

- Catalyst households all spoke positively about a number of features in their current houses.

### Control households

There were several features mentioned by Control households that they liked (and disliked) about their current houses. For example, while one household said they disliked the lack of living room space, another said the space was a real bonus compared to where they previously lived.

Other positive features noted by Control household tenants were having a house all on one level with no

steps, the feeling of the house being of good solid construction, having their own privacy and having a house that is easy to maintain.

ConA: There was no steps here, it's lovely...I feel really at home here.

ConA2: It's just home.

All Control households appreciated the large size and layout of the bathrooms:

ConC: Everyone laughs about it (the size of the bathroom). They reckon they got the lounge room mixed up with the bathroom.

#### IN SUMMARY:

- Control households did like some elements of their dwellings, although they did not speak as positively about their houses as the Catalyst households did.
- Positive features for Control households mainly related to having their own space and something that was easy to maintain.

### Additional findings from the second and third rounds of interviews

The features that households liked most about their dwellings remained consistent throughout the interviews across both groups of households. It remained clear that the Catalyst households liked their dwellings more than the Control households did.

**Indicator: 4.** Lessons, improvements and suggestions (features disliked) for design of future department houses.

## Catalyst households

While all Catalyst households liked their houses, there were some suggestions for improvement. These include improving:

- cooling options (for example, installing ceiling fans in the bedrooms and an easier way to reverse the fan direction)
- lighting in parts of the house, including dimmable lights in some areas
- ceiling fan placement in the bathroom (placed above shower)
- gap reduction around internal doors
- water tank access (individual water tanks)
- driveway layout (restrict access for cars to residents only)
- cracked tiles (grouting), cracks in concrete and cracks in internal and external walls
- grass and plants in the backyard
- lock positions on windows
- shade covering for the pergola.

Providing improved cooling options was the most significant issue raised (see Section 3.4). While tenants stated that the houses stayed cooler in summer than their previous dwellings, one household had an air conditioner installed, with another stating they would like one. In addition, one household mentioned that ceiling fans in the bedrooms would help during extreme heatwaves.

CatB: Well, see this isn't insulated here [bedroom] like that other room [living room] is and very often you, we could leave the air conditioning going but a lot of the time you don't need an air conditioner. But if you're laying in bed it can still get a bit hot...and we just got these, just little pedestal fan that, we've only had to use them a couple of times and this is the other one.

One tenant also pointed out that the fans in the

living area were multi-directional – to make use of both summer and winter conditions. However, the switch that needed to be changed from summer to winter mode was on top of the ceiling fan. This meant that tenants needed to contact the department maintenance to do it, and they could take up to two weeks to respond, by which time the weather conditions may have changed. This tenant suggested that a remote switch could be set up for this. Given that the other Catalyst households did not mention this, it is likely that they were not aware about the seasonal use of the fan.

Lighting was a concern for two of the Catalyst households. One did not use the ceiling fan lights, saying they did not like the 'orangey yellow colour'.

CatA: It doesn't light up the room so much. So I don't see the point of turning it on.

The other household said that as one of the tenants was legally blind but had a slight amount of vision, the low brightness of the lights was not acceptable for them. They had tried to replace a few light bulbs, but this had not helped. In this instance it was more a concern for their situation than necessarily something that should be considered for future department houses.

The placement of the ceiling fan in the bathroom was raised by two Catalyst households. It was not over the shower but in the middle of the room, making it mostly ineffective. The tenants reported having to open the window to ensure that the steam could escape.

CatC: So all the steam, it runs all down the wall and it's high to get, you have to get up on a chair to try and wipe it and it's a bit, yeah I don't like getting up on high things you know to have to clean. So they were going to see about putting a fan, but I haven't heard nothing more about it...

The sharing of rainwater tanks was also raised as a significant issue by three of the Catalyst households. Some tenants felt they were not getting the full benefit of the rainwater tank because they were sharing it with another household, which used more than their 'share' of the water.

CatD: So that and perhaps maybe the rainwater tank, which sounds silly, but because we share the tank I've got, so I think [CatC] has the same problem; the two bigger units, sort of they use most of the rainwater, sounds a little bit, but because they've all got gardens whereas [Cat-C] and I don't, so it would have been probably more practical for us to share a rainwater tank.

The carport and driveway layout caused issues for one tenant, who found it difficult to enter and exit their parking space at times. This seemed to be due to non-residents parking in the driveway when visiting their friends. This is something that could easily be fixed by making access to the driveway for residents only.

Gaps around internal doors were mentioned as an issue that could unnecessarily cool bedrooms.

CatA: ...Sometimes I think under the doors a bit of cold air comes under make it a little bit cold after a while.

One household (CatB) said that the placement of the high electric windows were on the wrong side of the house and that a designer with local knowledge should have known that during summer the hot wind would just blow straight in, rather than venting warm air out as intended.

#### IN SUMMARY:

- Catalyst households suggested a number of improvements for future department designs.

#### Control households

Control households also made several suggestions for improvement, including making sure there were appropriate drought-tolerant plants in the garden, providing a larger living area, providing locks on windows at an appropriate and accessible height, providing heaters in the bathroom, providing a door in the hallway and providing air conditioning.

#### Additional findings from the second and third rounds of interviews

During the third round of interviews, one of the Catalyst households suggested improvements to the bedroom windows, in particular the way they open. The fact that it was a sliding window rather than an awning window meant the window could not be left open if it was raining. This was only a minor concern for the tenants.

CatB: The only trouble is, if it's raining at all, you can't open these up, the rain comes straight in.

During the third round of interviews another Catalyst household discussed the issues regarding the reverse direction switch located on the ceiling fans. Their solution was to get one of their children to change the direction switch when they visited.

### 3.7 KPI 7: Improved tenant engagement and experience in managing ESD and climate change-related aspects

**Objective: 1.** Increase tenants' stated capability and confidence in making positive behavioural decisions regarding their utility bills costs, energy consumption management and environmental footprint

**Indicator: 1.** Tenants' self-reporting if they can monitor and impact their consumption and bill expenditure. Empowerment.

## Catalyst households

All Catalyst households reported monitoring their utility consumption and costs across the first year of occupation in the houses. For three of the Catalyst households this stemmed from their appreciation of having such low bills. There was no evidence of a rebound effect where they had become lax in how they used resources; they were still keen to be as efficient as possible and capture maximum economic savings. The fourth household (CatA) had moved out on their own for the first time and received a large initial electricity bill. From that point forward they monitored their usage more carefully to ensure that this situation did not happen again. As discussed previously, Catalyst households became more relaxed about receiving their utility bills over time, as the tenants knew the bills would be low, if not in credit.

### IN SUMMARY:

- All Catalyst households reported monitoring their utility consumption and costs across the first year of occupation and continued to try and ensure they used resources efficiently where possible

## Control households

All Control households reported ‘keeping an eye’ on their utility consumption and bills. Most Control households also said they tried to be efficient with their utility consumption to keep bills low. For example, the tenants in ConA said they did not use the ceiling fans in the summer if they thought their usage was getting too high (even though this is a very economical way to keep cool). Overall, Control households reported using energy sparingly for most things (although not in terms of TV use).

ConA: Yes, I try to do without the fans and things as I say in the summer, if I think it's going up too high.

ConC: Pretty much. Because I'm on a disability pension, I get 30 dollars taken out every fortnight for electricity and 20 dollars every fortnight for gas.

### IN SUMMARY:

- Control households reported ‘keeping an eye’ on their utility usage and bills.
- Control households appeared to take more actions to reduce their utility usage if they felt their bills were getting too high, in comparison to Catalyst households

## Additional findings from the second and third rounds of interviews

Catalyst households still reported keeping an eye on their utility usage, although they had become more relaxed about this over time as they realised they had low utility bills. This did not translate to an increase in utility consumption, as shown in Section 6. Control households had a similar level of monitoring and engagement with reducing their utility consumption throughout the research. The technical data shows that most households (across both housing groups) were using less than the average and the department Standards, meaning there were less opportunities for additional savings.

**Indicator: 2.** Typical use of appliances, showers, heaters, coolers, hot water, lighting, etc.

## Catalyst households

Three of the four Catalyst households had brought most of their appliances from their previous houses. One household had to buy everything when they moved in and did this over a period of time. Households did not report any changes in how they watched television, did the laundry or took showers

since moving into a Catalyst house. However, there were changes in lighting use and the use of heating and cooling. Most households (apart from CatB, with a blind tenant) said they used the lights less during daylight hours, as there was more natural light compared to their previous dwellings.

CatD: Yeah, you don't have to have your lights [on] most days. They are that little bit sunnier and I've put these ones up. It's really nice in here. Just really light.

As discussed in Sections 3.3 and 3.4, the tenants were generally happy with the thermal comfort of the dwellings in both summer and winter. In winter, tenants spoke about not needing to use the heater for as long to warm the house up, and when warm the house stayed comfortable for longer in comparison to their previous house. In addition, they were able to keep cool without air conditioning, although the tenants in CatB had installed an air conditioner for extreme hot days.

CatA: I'll just turn the heater on for a couple of hours and then turn it off.

CatD: Like [the heater's] on today on low; I'll sort of run it on low during the day and then sort of, I don't know, after tea if it's still nice and warm I'll turn it off for a while.

#### IN SUMMARY:

- Catalyst households reported a reduced need for daytime lighting and heating and cooling.
- Households' television use, laundering and showering remained consistent in comparison to their previous dwelling.

## Control households

The tenants in Control households reported using appliances in much the same way they had previously. The tenants in ConB and ConC had to source all appliances (either new or second hand) when they moved in, as they did not own any due to previous living situations. The other households brought many appliances from their previous dwellings, although some did buy new or second-hand appliances after they moved in. For example, tenants in ConA bought a new glass oven to make cooking and cleaning it easier. The two households that bought all their appliances recognised that some of the second-hand appliances they acquired may not have been the most energy efficient. However, these households were also the same two that were on payment plans for their utilities, and therefore could not afford new appliances.

As shown in Table 2, only the tenants in ConB had no form of mechanical cooling (either an air conditioner or ceiling or pedestal fans). Four of the Control households stated they would like to improve the cooling appliances they had.

ConC: I think me fridge is the actual power killer because I was fridgeless and no one could believe it because I bought a TV before the fridge, they were a bit, that was a bit of a joke. And then me friend rang up and one of his friends had a fridge he wanted to give away so we went and got it and took about eight men to lift it so I think it juices up, it's pretty historic I think.

ConA's tenants were not able to use the clothes line due to it being too high for them to use (elderly couple), and because their washing requirements had more than doubled due to recent health changes (one of the tenants suffered from incontinence). They used the washing machine and a clothes dryer a lot more than they had in their previous dwelling.



ConA: I have trouble hanging them on the line. So I generally put them in the dryer... Sometimes I do three [loads] in one day... They've lowered it [the clothes line] but it broke once because I had so much washing to put out you see with him because sometimes he might have four changes during one day and everything's got to be washed. You can't leave it laying around the house because of the infection.

Showering practices were reportedly similar to previous dwellings in terms of frequency and length for those without health issues. For example, the tenants in ConB took long showers, up to 20 minutes, but this was something they had always done. However, the tenants in ConA took more efficient showers due to them requiring carers to help them shower.

ConA: [Showers take] only a few minutes. They're very efficient... Now it's winter we're in and out quickly... You do not linger in the shower because they [carers] only have half an hour and they got to go to the next person.

The tenants in ConA had experienced a significant increase in their use of the TV. This was because recent health issues meant that the tenants were less mobile and therefore spent more time watching TV. The other Control households used the TVs as they had in their previous houses.

ConA: Well, since my incapacity I'd have it [the TV] on all day, otherwise there's nothing else to do for me... Before my illness I was very active, now I'm not, the reverse.

#### IN SUMMARY:

- Control households' use of appliances was similar to their previous dwellings, except where tenants experienced changes to their health.

### Additional findings the second and third rounds of interviews

Tenants across all households did not report any significant changes to the way they used appliances since moving into their houses, except for those in ConB, who now were now washing clothes on a cold wash cycle after the home advisory tour visit by the research team in early 2015.

**Indicator: 3.** Tenants' use of composting and food production.

### Catalyst households

#### IN SUMMARY:

- None of the Catalyst households engaged in composting or growing their own food, although the tenants in CatA did express a desire to grow some basic vegetables.

### Control households

#### IN SUMMARY:

- None of the Control households grew any of their own fruit or vegetables or did any composting.
- The tenants in ConB said they were thinking about setting up a compost bin, but were not sure how to go about it. They thought they might ask the council what to do. The tenants in ConA said they disposed of most of their scrap food by giving it to their dog or their carer for her chooks.

### Additional findings from the second and third rounds of interviews

None of the households were growing their own food

or undertaking any composting. The one household that did undertake some form of composting in round one, ConA, moved out of the home during the study.

**Indicator: 4.** Tenants' interest in their environmental footprint. Change in attitude towards environmental issues. Beliefs with respect to achieving energy and water conservation.

### Catalyst households

#### IN SUMMARY:

- Catalyst households reported trying to reduce their utility consumption where possible. They indicated this was partly due to broader environmental considerations, but like Control households, they were more concerned with reducing their living costs.
- There was no evidence that living in a Catalyst house had raised the tenants' environmental awareness or concern for energy or water conservation.

### Control households

Most Control households said they do try to do things for the environment where possible. For example, they said they try to use their heater less, turn off lights when not required and recycle their waste through the recycle bin. The tenants in ConA had put woodchip mulch on their garden and replaced the plants with native drought-tolerant plants to reduce water consumption. Those in ConA2 had expanded the drought-tolerant garden since moving into this house. In addition, the ConA household had purchased a small glass oven to reduce energy consumption and because they were easier to clean:

ConA: One of those round glass ovens that I use because I find that saves energy because it cooks a lot quicker and it's easier for me to wash than having to do a whole oven.

The tenants in ConC said they did not use the rainwater tank for the garden, but liked to use it for drinking water. They did this because they said it tasted better, rather than for any environmental reasons.

ConC: Sometimes like I get a jug of water and that out of it (the water tank)...To drink...Tastes better actually.

It was not evident that any Control households' attitudes to the environment had changed because of the houses. They were more concerned with lowering their living costs, which had an indirect environmental benefit.

#### IN SUMMARY:

- Most Control households said they tried to reduce their impact on the environment, although this was likely to be more about controlling living costs than broader environmental concerns.
- The Control houses had not significantly changed these households' attitudes towards the environment.

### Additional findings from the second and third rounds of interviews

Engagement with environmental concerns remained similar throughout the research for the Catalyst households, although the tenants in CatA became less engaged with the sustainability features of their dwelling. This may be in part due to the fact they were busy with two young children.

Control households became less engaged with environmental considerations across the research period, primarily because they were more concerned with maintaining comfort and being able to pay their utilities.

**Objective: 2.** Use of composting

**Indicator: 1.** Volumes of waste to landfill, recycling and compost, as self-reported by tenants.

### Catalyst households

#### IN SUMMARY:

- None of the Catalyst households engaged in composting activities.
- There was no evidence that Catalyst households had reduced the amount of waste they sent to landfill or to be recycled.

### Control households

#### IN SUMMARY:

- None of the Control households engaged in composting activities, although one household did feed food scraps to their dog or their carer's chooks.
- There was no evidence of a reduction of general waste or recycling in comparison to their previous dwellings.
- Two households had significant issues with their bins being collected on a regular basis.

### Additional findings from the second and third rounds of interviews

There was no evidence of any changes to any households across the research period. There were no further mentions about issues with rubbish being collected by the two Control households.

## KPI 8: Improved neighbourhood satisfaction and safety

**Objective: 1.** Improve satisfaction and perception of safety levels of current neighbourhood compared to previous

**Indicator: 1.** Tenants' self-reporting on satisfaction with the neighbourhood compared to their previous place.

### Catalyst households

Two Catalyst households spoke directly about their satisfaction with the neighbourhood.

Both were similarly or more satisfied with their current neighbourhood than with their previous neighbourhood, apart from issues with one specific neighbour. The tenants in CatB stated that:

CatB: Well we've had no worries at all. It's very quiet...Very quiet here but with all the insulation and that you don't hear anything anyway...

The tenants in CatC were more satisfied with their new neighbourhood. When asked about their previous house they said:

CatC: The house was okay but the area was like wow terrible [laughing]...If the house had of been anywhere else it would have been fine, yeah...I had a guy murdered out the front of my place.

#### IN SUMMARY:

- Two of the Catalyst tenants reported an improved local neighbourhood in comparison to their previous dwelling location.

### Control households

Three Control households (ConB, ConC and ConD) had issues with their neighbourhood satisfaction and were all located near each other. The tenants in ConB were reluctant to talk about the street, but revealed they had issues with their neighbour dumping rubbish in their own and their neighbours' yards. When they sought help from the department they were told that

‘you can’t tell someone how to live in their own home’. This tenant put in a request to move. They also had issues with their bin not being collected for several months. They didn’t know why this happened, but assumed it was because they were not putting the right things in the right bins. However, they had not received any information on what they had done wrong or how the issue could be resolved.

There was also a lot of late night activity in the street, which meant it was difficult for the tenant in ConC to get to sleep early. They would often sit watching TV in the evenings with all the lights off so that no one would approach the house, as there had been several incidents where neighbours had tried to engage the tenant late at night. This tenant also reported an issue where children from the neighbourhood had jumped over the fence and turned the gas off (affecting the hot water supply). It took almost two weeks for someone from the department maintenance to come to the property and identify the problem was (the tenant did not know that the gas had been turned off).

ConC: There’s a lot of sort of drug deals that go on here later at night, so there’s always cars going up and down from pretty hectic, from probably 11 [pm] to one, two [am]...this is the gun street.

The other Control households were positive about their neighbourhoods.

ConA: Well it’s close to the shops. The river is only 5 minutes away so that is ideal for us. We go for walks in the afternoon.

#### IN SUMMARY:

- Three Control households live in a street which is reported to be noisy and untidy.
- The other Control households are all relatively satisfied with their neighbourhoods.

### Additional findings from the second and third rounds of interviews

Catalyst households reported continued satisfaction with the neighbourhood during the research period. This satisfaction increased when a challenging neighbour moved out and when a ‘drug dealer’s’ house across the road burnt down earlier in 2015.

The Control households that had initially raised amenity and safety concerns regarding their neighbourhood repeated these throughout the interviews, while households that reported a satisfactory neighbourhood continued to report the same. The tenants in ConA2 had stated in their first interview that they had no intention of getting to know their neighbours, but by the third round of interviews they started talking positively about knowing their neighbours and had swapped phone numbers in case anyone needed help.

**Indicator: 2.** Tenants’ self-reporting on safety in the neighbourhood compared to their previous place.

### Catalyst households

Catalyst households were mostly satisfied with their perception of safety in their current neighbourhood. However, this was negated by three of the Catalyst households having a safety issue with one of the Catalyst households. This household was reported to play loud music until 3.00 or 4.00 am, and would often only stop when the police were called. One of the tenants of that household had physically destroyed one of the other household’s doors after they had said they were going to call the police because of the noise.

#### IN SUMMARY:

- Catalyst households felt safer in their current neighbourhood compared to their previous dwellings.
- There was a safety concern with one Catalyst

household creating excessive noise and threatening violence.

### Control households

The same cluster of households (ConB, ConC and ConD) raised concerns with safety in the neighbourhood. The tenants in ConB and ConD felt the need to always lock everything. They often woke up to hear screaming or fighting in the street. The tenant in ConC stayed up late watching TV to drown out the noise from the street. In addition to the screaming and fighting, they said noisy cars and drug deals were a significant issue. While they said they had lived in more 'wild places', they still had concerns regarding the safety of the street.

ConC:...there's probably 50, 60 police cars a day going past...Sometimes it gets a bit intimidating...a bloke just up the road went mad with them (the police), with a samurai sword about three months ago so that didn't help. So they're [the police] not happy campers.

#### IN SUMMARY:

- There are a cluster of households who experience ongoing safety concerns in their neighbourhood.

### Additional findings from the second and third rounds of interviews

Once the tenants of the Catalyst household who had caused safety issues for the other three Catalyst households had moved out, perceived levels of safety improved.

CatD: I don't like to hang it on the neighbours up the front there, but you know sometimes you can be a little bit nervous here. But then I have good door locks too.

The cluster of Control households that had concerns about safety in their neighbourhood repeatedly raised these issues during the subsequent interviews.

ConC: If you've got the light on you've always got some clown around you knocking at your door wanting something...They're normally off their head or full of something and they're asking for cigarettes or money or stuff.

ConD: You notice people have been in your house, because they leave fingerprints or muddy feet, have slid down the manhole and tried to open the door.

ConB: My son doesn't ever sleep in his room because they'll [people trying to break in] be coming through my back [entrance], through the back and I felt a little bit uncomfortable. He's, you know, a little boy, you know what I mean? Now his been in my room for about three years because I don't feel safe having him down in his own room.

## 3.9 KPI 9: Improved life circumstances

**Objective: 1.** Positive changes in tenants' life circumstances

**Indicator: 1.** Tenants' self-reporting on changes to their life circumstances since moving into current dwelling.

### Catalyst households

All four Catalyst households experienced changes to their life circumstances since or because of moving into the Catalyst houses. The tenants in CatA were living in their own home for the first time, having shared their previous house with friends. They had one child when they moved in, and their second child was born



just prior to the first round of interviews. The tenants in CatB had been living in separate places but had wanted to move in together, which is why they were offered the Catalyst house. They have since married. The tenant in CatC started studying with the aim of getting a qualification to help them find work. The tenant in CatD had been able to move away from a neighbourhood they felt unsafe in, therefore improving their life circumstances.

These changes were in part enabled by the houses, although may have occurred in any form of stable tenure. However, the other social, financial and health benefits experienced by Catalyst households due to their unique dwelling assisted in improving their life circumstances.

#### IN SUMMARY:

- Each Catalyst household experienced positive life changes since moving into the Catalyst house, including having a second child, getting married, starting studying, gaining more hours of employment and moving away from an unsafe neighbourhood.

#### Control households

Three of the Control households experienced positive changes to their life circumstances since moving into their current dwellings. The tenants in ConA2 reported an improved quality of life because they had moved away from a deteriorating health and financial situation and were now able to concentrate on improving other health outcomes.

After gaining ongoing tenancy, the main tenant in ConB was reunited with their child, who had been taken away for a period of time by social services. The tenant described this as a 'good day'.

The tenant in ConC had turned their life around by gaining a private and permanent place to live. Before moving into their current dwelling, this tenant was a self-described alcoholic struggling to overcome their addiction. They reported now being on top of this condition, and believed that this was largely down to having a roof over their head.

ConC: Yeah, it has [improved]. I've been pretty good with, can't say I've given up alcohol, but it's decreased like major, majorly...Because I've got me own space...[it's a] big change to what I was doing.

#### IN SUMMARY:

- Three of the Control households reported experiencing positive changes to their life circumstances in their current dwellings. These included being reunited with a child and helping to address health issues.

#### Additional findings from the second and third rounds of interviews

Three of the Catalyst households continued to experience positive changes in their life circumstances, although this was tempered by the tenants in one of these dwellings suffering deteriorating health, and another tenant's ex-husband and pet passing away. Due to deteriorating health, the tenants in CatB had started to change things that they regularly did to fit better around their changing health. For example, instead of going to Queensland for a holiday, they had started taking holidays closer to home.

The Catalyst tenant who had started studying postponed their studies part way through because an opportunity for more work came up. This increased work led to a reduction in benefits they received from the department, and made them more independent

and financially secure. One Catalyst household had started engaging in more social activities, including rock 'n' roll dancing (including participation in competitions), and was finding the increased exercise beneficial for their health. They also bought some pet birds (in addition to already having a cat and two dogs). Two of the Control households continued to experience positive changes to their life circumstances since moving into the Control houses, mainly resulting from improved health outcomes coupled with security of housing. Other Control households either had no change or negative changes as explored previously in this report (see Section 3.5).

One Control household reported several deaths in the wider family between round two and round three of the interviews, which negatively affected their life circumstances.

The types of improvement differed between the two groups. The Control groups' circumstances related to their basic needs, such as housing security and medical attention. The Catalyst groups' circumstances represented improvements to their lifestyle and wellbeing.

### 3.10 KPI 10: Improved relationship with the department

**Objective: 1.** Positive changes in the relationship tenants have with the department (housing)

**Indicator: 1.** Tenants' self-reporting on changes to their relationship with the department (housing) since moving into their current dwelling.

And

**Indicator: 2.** Tenants' self-reporting on changes in their ease and ability to contact the department about questions or issues since moving into their current dwelling.

### Catalyst households

Two of the Catalyst households (CatB and CatD) spoke of their relationship with the department regional office in a positive light. They felt comfortable either calling the office or attending in person to discuss any issues they had. They knew the staff by first name, and were happy with the level of service and response they received from the regional staff. The tenants in CatC said they had not had to engage with the department since they moved in, and had some initial issues with the solar panels addressed. The tenants in CatA had a very limited relationship with the department. This may have been because they were a young household and had little experience living in social housing and were unclear about what they could or could not engage the department staff about. There were a number of comments about little elements around the house (for example, wanting grass in the backyard) and they said they knew they should speak with the department, but had not done so.

### Control households

#### IN SUMMARY:

- Two of the Catalyst households had improved relationships with the DHHS regional office.
- Three of the Catalyst households reported that they were comfortable to contact the DHHS regional office if they required anything at all.
- One of the Catalyst households was not comfortable to contact the DHHS regional office as they did not want to cause any issues.

The majority of Control households did not describe their relationship with the department regional office in the same way as the Catalyst households. They were less positive about their engagements and tended to contact the department regional office with complaints

or requests. They were often unsatisfied about the response. For example, the tenants in ConA had to contact the department about modifying the shower for mobility requirements. The glass shower door was removed and a strip placed at the bottom of the shower to stop the water leaking onto the bathroom floor. However, the water still leaked and the tenants were advised that the department thinks the existing solution was sufficient. While this did not appear to negatively affect the tenants' relationship with the department, it did not improve it.

Much like the tenants in CatA, several Control households did not want to cause any 'issues' or draw attention to themselves. For example, the tenants in ConB seemed reluctant to report anything to the department or push the issue about the mice infestation after being told it was their responsibility. This tenant appeared to be cautious about 'causing trouble' in case they were removed from the house or faced having their child taken away again.

Those in ConC similarly did not want to cause any non-essential issues with the department in case they were removed from their house. However, the tenant did chase up with maintenance several times to get their gas connection looked at. This tenant was repeatedly told that the person would be there by the end of the next business day. However, on several occasions the person never showed up. This meant that the tenant, who had stayed home to make sure they were there when the maintenance person arrived, missed three appointments with their drug and alcohol councillor. This was flagged as a significant issue. Furthermore, after stating an air conditioner would be great so they could stay in their own home during heatwaves, when asked if they had contacted the department to request one be installed the tenant said:

Not all experiences or interactions with the department

ConC: No, you sort of try not to rustle any feathers or anything like that. Got four walls and a roof and that's, it's pretty hard to get accommodation in Horsham at the moment, believe it or not.

were like this. Two of the households (ConA2 and ConF) were happy with their engagement with the department and the response they received to any issues. For example, the tenants in ConA2 spoke of how they were allowed to repaint the interior of the house before they moved in, which meant they could make it feel more like their own place.

ConA2: When I approached the Housing Commission they were absolutely fantastic. They treated us with a great deal of respect and understanding and consideration which I thought was amazing.

#### IN SUMMARY:

- Four of the Control households reported having either negative relationships with the department regional office or were cautious not to engage with them too much in case they 'rustled any feathers'. This had some tangible impacts on their ability to live in their dwellings in some cases.
- Two of the Control households reported positive relationships with the department and were comfortable engaging with the department regional office if and when required.
- Four of the Control households had concerns about contacting the department regional office about any issues they had. They felt that they did not want to cause any issues in case they jeopardised being able to stay in their house.

### Additional findings from the second and third rounds of interviews

The Catalyst households continued their mainly positive engagement with the the department regional office. The tenants in CatA became more comfortable engaging with the department regional office after the first round of interviews, and described their interactions with the department regional office as improving.

The Control households continued to experienced mixed relationships with the department regional office over the lifetime of the project. Four of the Control households reported that they were not comfortable contacting the department regional office if they needed anything, as there was a perception that they may risk their accommodation if they were seen to be complaining.

**Indicator: 3.** Tenants' self-reporting on changes in the services and privileges provided or afforded to them from the department since moving into their current dwelling.

### Catalyst households

#### IN SUMMARY:

- Only one of the Catalyst tenants (CatB) reported being afforded any privileges since moving into their Catalyst house. This was when they paid for the installation of an air conditioner and were subsequently reimbursed by the department.

### Control households

#### IN SUMMARY:

- There did not appear to be any additional services or privileges provided to any of these

- households, although one house (ConA/A2) had an air conditioner, while the other Control houses did not. It was not clear why this was the case.

### Additional findings from the second and third rounds of interviews

One Control household (ConB) had been struggling to get safety screens installed on their windows and had found the department regional office to be unreceptive to this request, which became an increasing safety concern for the tenants.

## 3.11 Household summary

ConB: Like, I asked them [the department regional office] to change them security screens and they said they can't...[so] I got my mate to bring a drill in. Every single window in this house is screwed in. So they can't, like that one I've got just there so I can open it a little bit. But the rest of them, they can't open at all. And that's pretty bad because I was talking to my mate about it the other day, if there's a fire inside the house, me and Cody are stuffed and that shouldn't be the case, when they should be doing their jobs properly.

In summary, there were some clear differences between the Catalyst and Control households. Some of these were due to the dwelling (for example, improved thermal comfort), while other elements were related to personal circumstances (for example, health). Overall the Catalyst households were found to address more of the KPIs compared to the Control households (see Table 7). Some key findings from the Catalyst households were that they:

- experienced lower utility consumption and significantly lower utility costs
- were able to pay utility bills more easily with reduced stress
- had additional money available for discretionary items and experiences, such as going on a holiday or buying clothes

- demonstrated an improvement in their thermal comfort and health during extreme weather events compared to their previous dwelling, translating to fewer trips to the doctor or hospital
- were better able to adapt during extreme heat without the use of an air conditioner, including being able to stay at home during such events
- reported overall improvement in life circumstances, life satisfaction and wellbeing
- experienced improved neighbourhood satisfaction, perception of neighbourhood safety and relationships with the department regional office.
- In comparison, Control households reported limited and less consistent improvements across the KPIs in comparison to their previous dwellings. In comparison to Catalyst households, Control households:
  - had more issues paying their utility bills on time
  - reported lower satisfaction with thermal comfort and demonstrated an over-reliance on mechanical cooling (air conditioning) to stay cool in summer, including one household that had to vacate their house during prolonged periods of heat
  - reported significant neighbourhood issues and safety concerns in one cluster of three households living on the same street
  - experienced ad hoc changes to improved life circumstances unrelated to their dwelling (but related to the provision of secure tenure)
  - experienced lower satisfaction with their relationship with the department regional office.
- reported lower satisfaction with thermal comfort and demonstrated an over-reliance on mechanical cooling (air conditioning) to stay cool in summer, including one household that had to vacate their house during prolonged periods of heat
- reported significant neighbourhood issues and safety concerns in one cluster of three households living on the same street
- experienced ad hoc changes to improved life circumstances unrelated to their dwelling (but related to the provision of secure tenure)
- experienced lower satisfaction with their relationship with the department regional office.

In comparison, Control households reported limited and less consistent improvements across the KPIs in comparison to their previous dwellings. In comparison to Catalyst households, Control households:

- had more issues paying their utility bills on time



**Table 7: Summary of household findings against evaluation KPIs across each round of interviews.**

Project KPIs	First round Catalyst	First round Control	Second round Catalyst	Second round Control	Third round Catalyst	Third round Control
Number of households per round	4*	3	4	6	3	3
KPI 1: Decreased relative utility bills	3	1	3	0	3	0
KPI 2: Improved financial circumstances	3	1	4	0	3	0
KPI 3: Improved level of thermal comfort	4	1	4	0	3	0
KPI 4: Reduced reported level of discomfort on extreme weather days	4	0	4	0	3	0
KPI 5: Improved occupant health and wellbeing	4	1	4	1	2	1
KPI 6: Improved utility and mobility	4	1	4	2	3	1
KPI 7: Improved tenant engagement and experience in managing ESD and climate change-related aspects	1	0	2	0	1	0
KPI 8: Improved neighbourhood satisfaction and safety	3	1	3	2	3	2
KPI 9: Improved life circumstances	4	2	4	0	2	1
KPI 10: Improved relationship with the department	3	0	2	1	3	2

\* Note the number of households recorded against each KPI is based on the number of households available for interviews in each round.



## 4. Evaluation of home advisory tour

During the third round of interviews, households that had participated in the home advisory tours were asked to evaluate these tours. The home advisory tours were well received by all households that participated. The households appreciated having someone come in and walk them through how they use, or do not use, their houses. They felt the home advisory tours were personalised and comprehensive and were able to understand what the advisor was doing and asking about.

However, there were limited opportunities for households to make changes. Very few households made many changes at all as they felt they were already doing most things they could, or because the suggested changes had a cost associated with the action, which the household could not afford (for example, buying a more energy-efficient fridge). The tenants in CatD summarised the feedback from most households that participated in the home advisory tours as follows:

CatD: She just said I was doing most things right, other than the fact I should turn my TVs off. They're always on standby. The minimal [energy] that they use, really. Other than that, no, we just basically said I'm still doing the same old thing.

I: And did you start to turn the TVs off at the [wall]?

CatD: No. [Laughing]

I: And the reason for that?

CatD: I just never have. If I go away for a couple of days I will, but other than that I think the tiny little bit of power that uses it's not going to worry me too much.

I: Do you think if you weren't in credit on your energy bill that...?

CatD: No, I still wouldn't.

However, two households did indicate they had made some changes. The tenants in CatC, previously left

the gas heater on when they were out of the home as they had been told by a friend that turning the heater on and off used more energy than leaving it on all the time. Once the home advisory tour expert explained that this was not the case, they began turning the heater off properly when they left the house, although only if they left for more than a few hours (so there is still room for improvement). They were not sure if this had resulted in any change to their utility bills or not. This was similar to one of the Control households (ConB), which had made the switch from washing clothes in warm water to cold water based on the advisor's feedback. They were also unsure if this had impacted on overall utility bills.

ConB: We were just talking about the power and how to, like, yeah, about the laundry, to put it on cold instead of like, because I do my washing on warm. So she reckons that, because that uses up gas as well when you put it on hot or warm or something. Yeah.

I: Okay. And...

ConB: That was a good tip, because I didn't even know that the washing machine actually used some of the gas.

I: Yeah, so you've changed that now? Do you wash in cold?

Con B: Yeah.

I: And have you noticed any differences in your gas bills or your electricity bills?

ConB: I'm not too sure, I haven't really looked at them. I don't know.

### IN SUMMARY:

The home advisory tours were well received, but achieved little in changing energy or water consumption. The findings suggested that interventions needed to be further tailored for particular groups of households, such as those in social housing. While the personalised and tailored delivery of advice was well received (and well suited as a future format for social housing tenants), further interventions are more likely to achieve positive sustainability outcomes if they are supported by financial incentives, rebates or the provision of equipment.

## 5. Interviews with stakeholders

This section presents the analysis of two rounds of interviews with key stakeholders involved in the design, management, construction and occupation of the Catalyst houses.

### 5.1 Stakeholders

Five key stakeholders were interviewed for the analysis: the builder, electrician, architect, the department Project Manager and the department regional representative (see Table 8). All stakeholders participated in the first round of interviews. However,

only two stakeholders participated in the second round of interviews. This was due to a range of issues with the other stakeholders.

- The builder had left the company and there was no suitable person to interview within the company.
- The electrician did not respond to repeated requests for a follow-up interview.
- The department Project Manager had retired by the time of the first interview and was not approached for a follow-up interview.

**Table 8: Stakeholders interviewed as part of the evaluation.**

Role/relationship to Catalyst houses	Analysis code	First round interview	Second round interview
Builder	Stakeholder A	✓	X
Electrician	Stakeholder B	✓	X
Architect	Stakeholder C	✓	✓
The department Project Manager	Stakeholder D	✓	X
The department regional representative	Stakeholder E	✓	✓

### 5.2 KPI 11: Increased engagement with building and development industry sector

**Objective: 1.** Support ESD up-skilling of regional builders, contractors and trades

**Indicator: 1.** Builders, contractors and trades getting increased ESD work stemming from their experience in

the Catalyst project, as self-reported by them.

While all stakeholders were happy to be involved in an innovative sustainable development, their involvement had not led to an increase in ESD work, even three years after completion of the project. Three key

reasons identified by the stakeholders for this were:

- there was no local promotion of the project
- changes by Federal and State Governments to solar panel rebates and feed-in tariffs meant incentives for this technology reduced
- stakeholders needed to build and demonstrate a portfolio of similar work before gaining further projects.

The following quotes reflect these challenges:

Stakeholder B: At that stage it was pretty strong anyway, the solar, in itself. It's definitely dropped off. But that's – that seems probably caused by the government, to be quite honest, because the feed-in tariff was originally 66 cents and it went down to 30-odd cents, now it's down to eight cents, so supply and demand is not there as what it was. So to me that's the government.

Stakeholder C: No it's, so you get sustainability clients by getting a reputation in sustainability. Now we don't have a reputation in sustainability so we get the clients that we can get.

Only one of these reasons (no local promotion) was within the control of the department, although it appears there was little self-promotion undertaken by any of the stakeholders. The stakeholders were unclear

#### IN SUMMARY:

There has been no increase in ESD work for stakeholders involved in the Catalyst project.

as whose role it was to drive local promotion.

**Indicator: 2.** Other feedback from builders, contractors and trades on implications stemming from project involvement.

The tradespeople (builder, electrician) interviewed felt that the project had run relatively well in terms of engagement with the department, processes

and outcomes. However, there were a few points of feedback, mainly concerning design of the development, which could be considered for future projects. In summary, these related to:

- the design and choice of some materials and technologies
- significant periods of delay at the start of the project
- higher than normal variances after the contracts were signed.

For example, the size and sharing of the water tanks between two households was identified as a design learning:

Stakeholder D: I think they're 5,000 [litres] from memory. So 5,000 isn't really a lot of water... But if you've got it for [a] toilet and laundry, then I think it probably has to hold a substantial amount more because Horsham, for example, will only rain at a certain time of the year and it's not like you're going to be able to top it up getting a lot of rain during summer. So you're probably going to run out of tank water fairly quickly once you get into the dry period. But the, the joining the two together yeah, I think I'd probably say that now in hindsight that probably wasn't a good idea because you want people to be able to manage it themselves, just manage their own tank and keep it to a certain level and know what they've got and don't have to worry about somebody else maybe using more or using their water, you know.

Stakeholder C felt that there were periods of significant delay between design, engagement of trades and beginning of work. This led to a risk that technologies or materials may have been superseded or supply of those changed, creating inefficiencies in work practices. It was recognised that some of this delay was typical of working with any government department.



In addition to the delays in starting the project, there were challenges resulting from the higher than normal number of variances to the project after the contract had been signed. While some of these variances were the result of the project being innovative, Stakeholder A thought that a lot of the variances could have been avoided with more careful planning. For example, the placement of power boxes and monitoring equipment had to be moved after initial installation. Furthermore, the laying of additional power requirements down the driveway was unexpected and almost became a bigger issue as it was only flagged days before the driveway was due to be sealed.

Stakeholder A: We had issues with that trying to batten it out onto the brickwork, which was, yeah, bit of a challenge. If they did it again they should have a false wall in the brickwork that's already straight rather than try and batten the brickwork to the spacings to put the cladding on because the brickwork's in and out the backs of bricks are everywhere. Yeah, they should have a maybe a three-inch wall on the back of it or something like that on the back of the brickwork so you can fix your cladding straight to it, be miles quicker.

Stakeholder A continued, saying:

Stakeholder A: Well, I suppose a job like that that's a little bit different you'd expect some [variations]. Some of them were minor, but they had to be documented for our company to get paid for them because it might've been only change of a product that maybe wasn't quite suitable that they'd at a later date, well, we need a variation before we're entitled to order it and get paid for it.

While the design and choice of materials were not raised as major concerns for the builder, one element was flagged as something that could be changed for next time, and also proved to be a learning outcome.

Another lesson was that the carports should have been redesigned, and that the use of metal cladding meant that it sometimes became hot to touch (stated as a minor issue). The cost of the carports was an issue raised in the CBA (see Section 6).

Stakeholder C: What would I have done differently? Well I suppose I would have designed the carports differently to the way I did at the end...I discovered that the metal, we used the Fischer insulation wall panels and when the sun shines on them they get hot.

#### IN SUMMARY:

The stakeholders reported a number of learnings to improve future projects around de-sign, material and technology choices, reducing delays and variances to contracts.

**Indicator: 3.** What worked well about the project, as self-reported by the trades and the department.

Overall feedback about the project and outcomes was exceedingly positive from all stakeholders. The way all the trades and key department stakeholders worked together was flagged as very successful. Some innovative design and technology elements, such as future-proofing the department housing for both a changing climate and ageing population, were also considered a success. The monitored data supports stakeholder claims that a more sustainable and liveable product was delivered (see Section 6). Feedback from the tenants also indicates their overall satisfaction with the end product, as discussed in Section 3.

Stakeholder D: So it was a project wanting to lead in that area [sustainability] and I think it achieved that result and achieved the accommodation that we were seeking, that is when it was completed and you walked in you knew that the money spent was well spent, that we got what we wanted...well it's better than private accommodation. You know it actually wasn't that expensive for the outcome. I'm very pleased. [We] had a good team, good architects and good builders.

Stakeholder E: ...From what sort of the feedback I've got from the tenants so far and my experience with managing those actual properties, everything seemed to be doing what it was supposed to be doing and meeting the aims of the projects that I'm aware of. I guess the longer term will perhaps, we'll know more as to what improvements could have been made and changes that could be made. But for now I think it's doing really well.

#### IN SUMMARY:

The stakeholders reported a number of things that worked well about the project, including a good working relationship with other key stakeholders and the innovative nature and outcome of the development.

### 5.3 KPI 12: Improved business practices

**Objective: 1.** Improve business practices across trades resulting from work on Catalyst houses

**Indicator: 1.** Builders', contractors' and trades' changes to business practices as self-reported by them.

Only one stakeholder had changed their business practices as a result of working on the Catalyst project. There were other possible reasons for this, including changing Federal and State Government policies, reduced support for sustainability in general and specifically less renewable energy rebates and feed-in tariffs. Furthermore, Stakeholder A reported that their company was trying to deliver products that they believed the market wanted, and stated that improved sustainability was not what the market was demanding. Unfortunately this stakeholder was not able to be interviewed a second time, as there has been recent research suggesting a subtle shift in the housing market, with consumers more aware of improved design and sustainability [102].

For the one stakeholder who had changed their practices, the Catalyst project fed into a wider strategic decision for them to engage more with sustainable developments, and this project was a way for them to demonstrate their capabilities.

However the other two tradespeople interviewed indicated that it was business as usual for them.

Stakeholder C: Well, I think we've always been 'green' in inverted commas... unfortunately we don't market ourselves very well and because of our tendency always to fly below the radar, it works to our disadvantage unfortunately... And every project is an evolution from your past experience, so yes we do learn and I'm currently doing six houses at the moment in Middle Park where we're using the Tri Deck, we're using the solar panels, we're using well the reverse, not quite the reverse brickwork in a way yes that's, that concept is working through. The sun shading control is working though, orientation is, so yes you can't go backwards...

Stakeholder B: Mostly, we've got our procedures of how we run our jobs...We make sure obviously when we price the job, we run the job, we buy the material, material so for that day to do that day's work...we've got so many hours, we quote the job to win the job, that we're hopefully counting in that time. If it doesn't come in that time, there's got to be reasons why.

Stakeholder A: It's no different to normal building really.

#### IN SUMMARY:

Only one of the three trades made changes to their business practices based on their involvement in the Catalyst project.

### 5.4 KPI 13: Improved process and governance (stakeholder perspective)

**Objective: 1.** Improved process and governance due to the project

**Indicator: 1.** Builder, contractor, trades and the department improved process and governance as self-reported by them.

There were significant learnings around process and governance reported by the department and the architect. This was largely because of the innovative nature of the project for both the department and the architect, but more broadly also for the wider building industry. At the time the project was being designed, there would have been few nine-star affordable housing developments with which to reference. While the department has been an early adopter of some housing sustainability elements (for example, solar hot

water, rainwater tanks for gardens), the Catalyst project represented a significant sustainability improvement for the department housing stock, with little wider guidance to draw upon.

Furthermore the project did not start out as a strategic goal to push sustainability outcomes, but emerged after the architect had already been engaged to develop some standard department housing for the site. Through proactive discussions between the architect and the department it was determined that if funding could be acquired they would aim to test what was possible and build some low energy, sustainable dwellings. Implementing such a significant performance improvement compared to standard department housing required a process of learning by doing and testing. For example, there was a requirement to provide households with information about how to use the sustainability elements of the house, which was something that had not been provided previously. There was a strong working relationship between the architect and the the department, which allowed this approach to work, although as mentioned earlier, there were challenges resulting from the high number of design variations.

Stakeholder C: The initial development was actually a conventional department development both in terms of planning and in terms of the housing that we were putting there... So we started off this project in a similar fashion and I think we had somewhere between five and six stars when we first got the energy rating and the energy rating was actually done in-house here... Then we were approached by the department and in particular to see what we can do to those existing houses that would make them more energy efficient and be more, I suppose, user friendly and see what can be done that we can, or the department can, demonstrate a responsibility to the community as well, and demonstrate that public housing can play its part in terms of providing better housing, a higher quality of housing. And in turn it would also help us ascertain how good the existing housing is versus what is it that we actually can do... we had an opportunity to see what we can do and what the potential is and see what is available. And then we learned from that and I'm hoping after the three-year period we set up a new set of standards for the housing and I hope to be part of that process.

In the second round of interviews with Stakeholder E, they indicated that they felt that recent new department buildings around Horsham had improved, perhaps not in terms of significant sustainability, but certainly through improved design and layouts.

Stakeholder E: They seem to be, last few lots of units that we've had handed over, there seems to have been a lot more thought put into the layout of the units, which is good.

The builder and electrician, however, did not provide any evidence that their own processes or governance structures had improved or changed due to being involved in the Catalyst project. Part of the issue may be that for the regional area, there was already a lot of building work occurring due to recent Federal Government stimulus funding, which limited the tradespeople available to work or reflect on the project.

Stakeholder D: So there was a very limited number of builders actually available and we did tender twice. The first time we tendered it far exceeded budget, so we just stepped back from it then we redesigned to bring it down, the price down, so then we went back out again... Doing schools and police stations and all that sort of thing. So time wise it probably wasn't a good time to do it.

#### IN SUMMARY:

- There were some learnings for all stakeholders in relation to improvements for governance of such a project.
- Specifically the main learnings related to having now undertaken such an innovative project (which still remains innovative three years post construction), and so stakeholders have a better understanding of what to expect if the project was to be repeated.

### 5.5 KPI 14: Improved benefits across all actors from increased ESD (stakeholder perspective)

**Objective: 1.** Improve benefits across trades, the department and households from increased ESD of new housing stock

**Indicator: 1.** Builder, contractor, trades and the department increased benefits as self-reported by them.

The stakeholders identified a number of benefits for the trades involved, to the department and to the households.

#### *Trade benefits*

The Catalyst project presented an opportunity for the trades to be involved in a leading ESD construction. The trades reported being satisfied to have been involved, but to date they did not feel it had led to any ongoing ESD-type work. One stakeholder was unclear of what the longer-term benefits were. The stakeholders were hopeful that if the quality of the project was high, then it might lead to additional work with the department in the future. In contrast, a department stakeholder felt there were substantial benefits for the trades, in that they had an opportunity to learn about doing enhanced sustainability in developments.

Stakeholder D: For the building industry I thought it was extremely good for [them] to have that opportunity to, you know, it's a fairly low risk thing, it's not like their money, they're having the opportunity to just see how you can achieve a good energy rating, an extremely good energy rating. How it's done and how things work and the same with the tradespeople that were involved with the builder. So I think they can learn a lot from that.

Stakeholder B: Oh, obviously we've got work, and hopefully ongoing work. And hopefully if we did a good job, future work. So that's why we try and do our best possible way in that to get ongoing work.

Stakeholder A: Well [sigh] we haven't got any benefits at this stage.

#### *Department benefits*

The benefits identified for the department included being an industry leader that was driving cutting-edge ESD; developing properties that were more liveable, particularly for elderly people in a changing climate (peak weather conditions); reduced utility bills for tenants; and lower maintenance and less engagement with tenants in the Catalyst houses (as they were happier and had fewer issues). As identified in the household interviews, the Catalyst houses delivered on the improved liveability outcome (Section 3).

Stakeholder D: For the department I think the department has got an ageing population in its tenant profile and if we are going to continue to have drawn out summers and long periods of hot weather in summer the department's going to face using air conditioning, you know using mechanical means to keep older people cool and being able to live in those conditions. I think that the project demonstrated you don't actually have to go down the mechanical path, you can look at passive design and some simple technologies to help provide a fairly liveable or balanced thermal outcome for tenants. So I think the department has to look at the long term how it's going to accommodate its older population...I should say that the department met two things and it was, it showed liveability, that high liveability is achievable without throwing too much money at it, and also you can protect the environment without having to spend a lot of money. So I think that's something you've got to keep in mind that we have a benefit for the environment as well. But with the community, well it showed a commitment to the environment...it demonstrated to community that, yeah, the department is a, like when I was saying like an authority or a leader in design.

Stakeholder E: All government departments have obviously got that environmentally friendly in the back of their mind with everything that we do these days. I mean the policies that we've got even here, we're not allowed to buy non-recycled paper, just for example... But yes, specifically for our clients it is the financial benefits for them.

Stakeholder E: I'd say probably less [maintenance]. Whether that has to do with they were well built or whether it has to do with the tenants that we selected to go in there. Perhaps it's a combination of those two...I would say that overall there have been less.

However, two stakeholders questioned whether the department had achieved the most efficient outcome for its money (see Section 6.5).

Stakeholder C: ...That's still something that I think needs further discussion because I can't see, unless there's something, the research actually reveals something really positive and of real advantage, I can't see the amount of money that's being spent on the PV panels and versus, what the cost penalty to the department for the solar panels versus the benefit to, and think from the department there isn't a benefit other than a community responsible benefit, do you know what I mean?

Stakeholder A: The benefit? I don't think there is any benefit to be honest with you, for those type of people. I mean you're probably going to get good tenants but for the bad, for the tenants that don't look after it, it's a crying shame waste of good money.

### *Household benefits*

The benefits identified for households included living in a new house, reduced utility bills, helping the environment and flow-on benefits to visitors. These benefits were confirmed through the housing performance and CBA (see Section 6). One stakeholder also raised the issue of the quality of the tenants being placed in the sustainable houses and if the full benefits were being, or could be, realised.

Stakeholder E: I've been in there in during our really hot summers and they've actually been quite pleasant in there, which is part of the purpose of it. Yeah, I think...and they're big and spacious and they have like your built-in robes, the carports – there's things that they have that aren't standard for our other properties so they're actually really nice units and they have remained so. Like given their age now, you would expect to have seen some sort of, well I guess, more than average wear and tear, but they've actually remained in pretty much their original condition.

Stakeholder E continued to summarise the benefits for households, three years post construction:

Stakeholder E: With healthier, happier tenants, I guess if tenants are in a better frame of mind, one of the ideas that has been sort of bandied around is to encourage tenants to use it more as a stepping stone. So, "You're in this situation now, you need the assistance but maybe if you can manage to get full-time work then you can look to purchasing your own home". So I guess if the tenant is happier and

healthier, they're more likely to be able to make those steps out of public housing, which that turnover would benefit. The financial benefits for the tenants as well, like, as you say, some of them are in credit in their power bills because simply the solar panels makes that difference. So I think it's that overall it all plays a part with if you've got a healthier and happier tenant, one, if they're able to they're more likely to move on and two, if they're not able to, you're more likely to have a successful lengthy tenancy as in they're going to pay their rent on time, they're going to be in a better position to look after the property. So the long-term maintenance on the property will be less than otherwise as well.

### **IN SUMMARY:**

- The stakeholders did not feel that many wider or additional benefits had eventuated for the trades involved.
- Many benefits were identified for the department around having happier, healthier tenants who were in more liveable and affordable housing.
- Similarly the tenants in the Catalyst houses were the ones who were realising the improvement to health, comfort, liveability and affordability.

## **5.6 Stakeholder summary**

In summary, there was overwhelming opinion from stakeholders that the project was a success. The relationship between external stakeholders and the department worked well for the most part. There were some learnings around design and process (for example, the delayed start and a high number of variations), which proved challenging. While the tradespeople saw the project as a gateway to more work with the department and also towards more sustainability projects, that had not eventuated at the time of the first round or round two interviews. There were a number of factors that contributed to this, some of which were outside the direct control of the stakeholders (for example, changes to environmental



policy and support by Federal and State Governments), but the lack of local promotion of the project was raised as something that could have helped the stakeholders to build on the success of the Catalyst houses. In addition, there were a number of benefits for the department, the tradespeople and households

raised from the interviews. While the stakeholders were positive about the project and what it achieved, Table 9 shows that against the department KPIs, the project did not meet its objectives for the stakeholders involved.

**Table 9: Summary of stakeholder KPIs and if they were addressed.**

<b>KPI list</b>	<b>Number of stakeholders (not including the department) (out of three)</b>
KPI 11: Increased engagement with building and development industry sector	0
KPI 12: Improved business practices	1
KPI 13: Improved process and governance (stakeholder perspective)	0
KPI14: Improved benefits across all actors from increased ESD (stakeholder perspective)	3 (but not directly to them)

## 6. Housing performance and cost-benefit analysis

The following section presents the analysis of the performance of the dwellings from June 2012 to May 2015. The section first outlines the data that was collected, noting where data was not available and what occurred in these situations. The performance of household utility consumption and renewable energy generation are then presented, followed by analysis of thermal performance of dwellings, blower door performance, the outcomes of the CBA and the environmental performance.

As described in the methods section (see Section 1.35), Organica Engineering provided monitored

and collected data for this analysis. Ian Adams from Organica Engineering contributed to the analysis of utility performance presented below. Any tables or graphs provided directly by Ian Adams are acknowledged as such

### 6.1. Data collected

Table 10 shows the availability of either monitored or collected (utility bill) data for each dwelling across electricity, gas and water consumption for each year of analysis. There are data gaps, particularly around gas consumption for all Control houses for 2013–15, and electricity for three of the Control houses for

**Table 10: Monitored or collected (utility bill) data available for each year and utility.**

Dwelling	Electricity data (including solar)			Gas data			Water data (including rain-water tanks)		
	2012–13	2013–14	2014–15	2012–13	2013–14	2014–15	2012–13	2013–14	2014–15
CatA	✓	✓	✓	✓	✓	✓	✓	✓	✓
CatB	✓	✓	✓	✓	✓	✓	✓	✓	✓
CatC	✓	✓	✓	✓	✓	✓	✓	✓	✓
CatD	✓	✓	✓	✓	✓	✓	✓	✓	✓
ConA/A2	✓			✓			✓	✓	✓
ConB	✓	✓	✓	✓			✓	✓	✓
ConC	✓			✓			✓	✓	✓
ConD	✓	✓	✓	✓			✓	✓	✓
ConE	✓	✓	✓	✓			✓	✓	✓
ConF	✓	✓	✓	✓			✓	✓	✓
ConG	✓		✓	✓			✓	✓	✓

2013–15. There are several reasons for this. Due to project budget constraints, Organica Engineering did not have monitoring equipment in three of the Control houses (ConC, ConA/A2 and ConG), which meant electricity data for these dwellings was reliant on utility bills, and Organica Engineering did not have monitoring equipment for gas consumption in any of the Control houses. Despite receiving all necessary permissions from households for collecting initial data in 2012–13, the electricity and gas providers did not provide further bill data after this point in time due to issues of household permission. Organica Engineering spent time following this up with the utility providers, but a solution was not found. This issue was raised at the Deliverable 5 interim presentation with the department. Where there were data gaps for whole years, data was assumed to remain consistent from the available data collected for that dwelling.

There were also some periodic issues with the monitoring equipment for electricity and gas in the houses where monitoring equipment was installed. This meant that the equipment failed to monitor data in specific dwellings for periods of one to three months at a time.

Where this occurred, data from the corresponding months the previous year or following year were used to fill gaps in the data to ensure seasonal differences of consumption were captured. Note that the Organica Engineering data presented in parts applied a slightly different method whereby data gaps were removed and averages across the remaining data set calculated. This did not make a significant difference between the RMIT team and Organica Engineering data.

## 6.2. Utility performance

The average annual data for electricity consumption, renewable energy generation, gas consumption and water consumption for each dwelling in the study is presented in Table 11. This data will be explored in more detail in the following sections. Further data is presented in Appendix 4, as compiled by Ian Adams from Organica Engineering.

**Table 11: Summary of average annual utilities consumed/generated from each dwelling.**

	Annual average from monitored/collected data from June 2012 – May 2015									
	Electricity consumed (kWh)	Electricity bought (kWh)	Renewable energy generated (kWh)	Gas consumed (MJ)	Total energy consumed (kWh)	Total energy bought (kWh)	Mains water consumed (KL)	Rainwater consumed (KL)	Total water consumed (KL)	Number of occupants
Standards Industry Practice	6,468	6,468	0	8,777	8,906	8,906	147	0	147	2
Department Standards	4,587	4,587	0	8,777	10,639	10,639	143	0	143	2
CatA	3,305	1,605	2,916	13,977	7,188	5,488	108	32	140	3
CatB	3,495	1,890	2,497	26,044	10,140	9,124	194	30	224	2
CatC	3,978	1,756	3,257	16,614	8,593	6,371	109	25	134	1
CatD	3,285	1,604	2,853	27,463	10,914	9,233	77	17	94	1.5
ConA/A2	4,584	4,584	0	32,776	13,688	13,688	138	0	138	2
ConA/A2	2,259	2,259	0	55,864	17,777	17,777	121	0	121	2
ConC	1,510	1,510	0	14,827	5,629	5,629	131	0	131	1
ConD	5,860	5,860	0	32,776	14,964	14,964	110	0	110	3
ConE	2,223	2,223	0	30,491	10,693	10,693	177	0	177	2
ConF	2,172	2,172	0	24,618	9,010	9,010	126	0	126	2
ConG	3,118	3,118	0	14,008	7,009	7,009	118	0	118	2

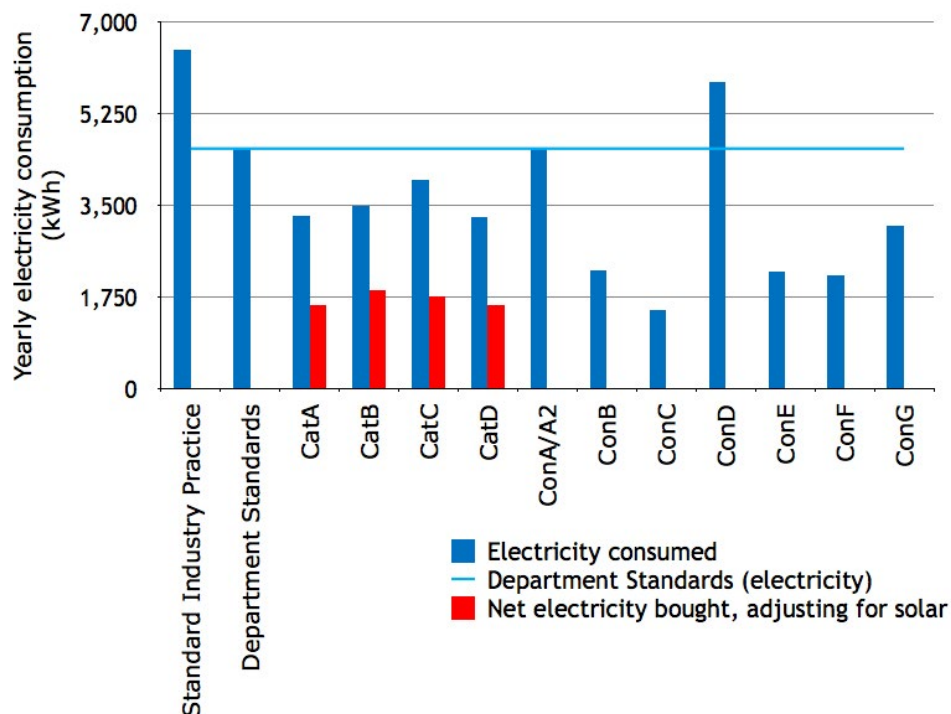
### 6.2.1. Electricity

Overall the Control households consumed less electricity (an average of 3,104 kWh) when compared to the Catalyst households (an average of 3,516 kWh). This is due to differences in household practices (for example, heating and cooling) and Control households appearing to have less electricity-consuming appliances and devices (based on researcher observations). However, once solar generation is factored in, the Catalyst households purchased less electricity overall (an average of 1,714 kWh). Only one Control household (ConD) consumed more electricity

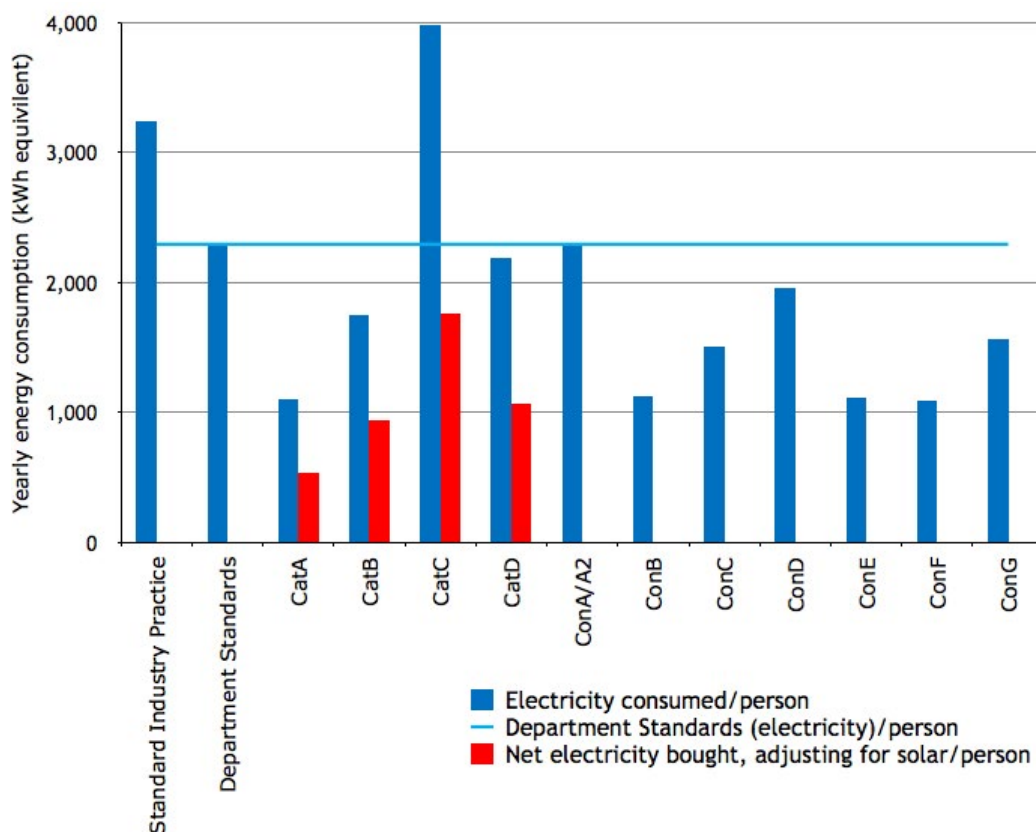
than the department Standards (see Figure 7). When looking at the electricity consumption data from a per person perspective (see Figure 8), the ConD household falls below the department Standards, while the CatC household is above this Standards, although this household falls below the department Standards once the solar generation is considered. On a per person basis, when solar generation is factored in the Catalyst households purchased 77 per cent less electricity compared to the SIP household, 53 per cent less electricity compared to the department Standards,

and 30 per cent less electricity compared to the Control households. On a per dwelling basis, when solar generation is factored in the Catalyst households purchased 73 per cent less electricity compared to the

SIP household, 62 per cent less electricity compared to the department Standards, and 45 per cent less electricity compared to the Control households.



**Figure 7: Average annual electricity consumption and adjustments for solar energy for all dwellings in comparison to the SIP household and the department Standards.**



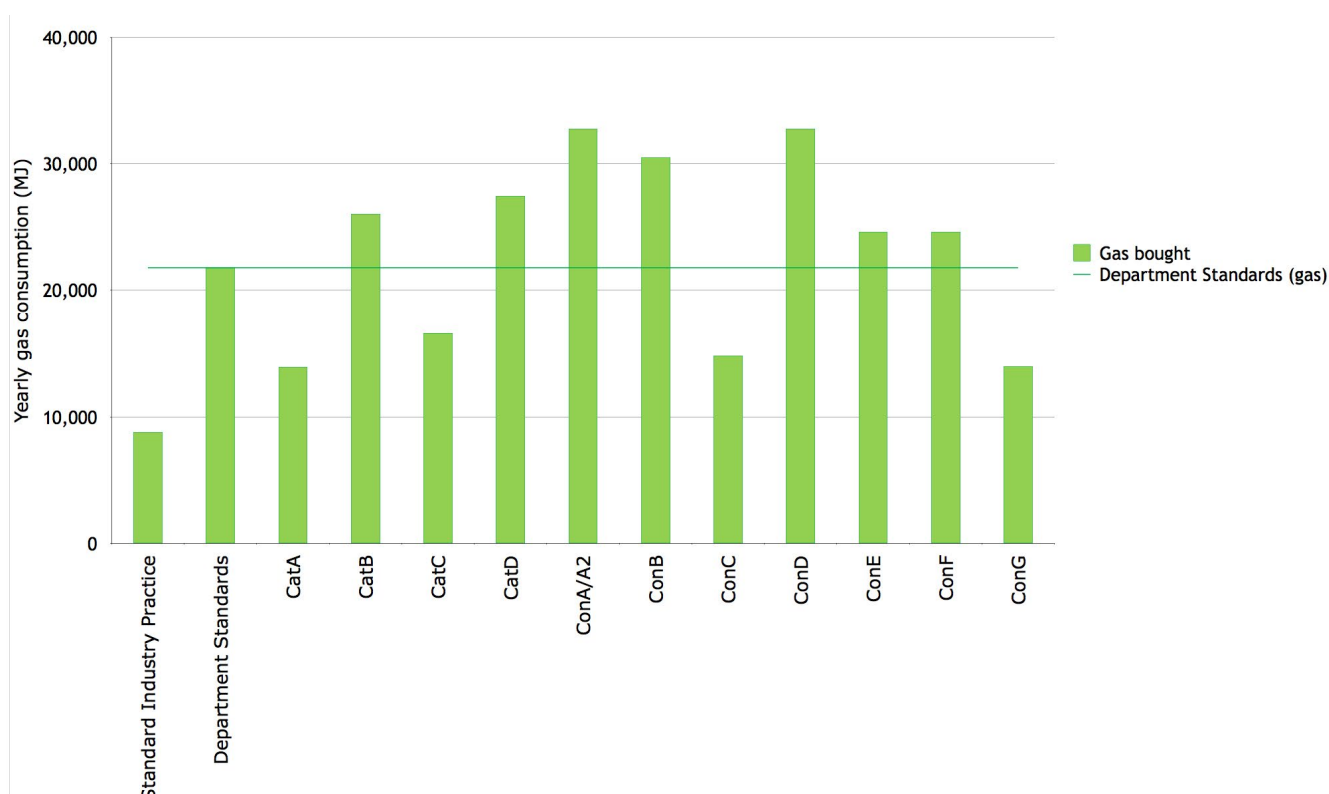
**Figure 8: Average annual electricity consumption and adjustments for solar energy for all dwellings/persons in comparison to the SIP household and the department Standards.**



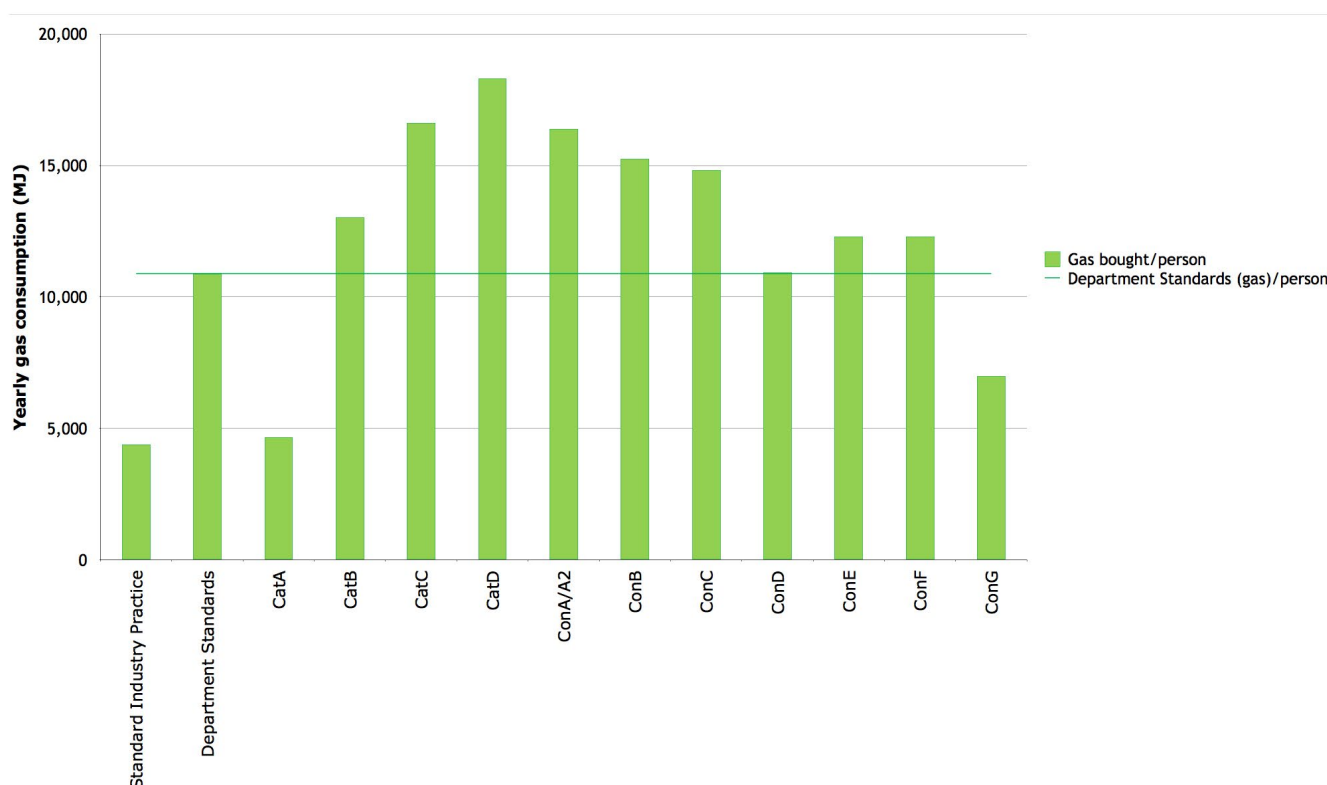
## 6.2.2 Gas

The Catalyst households consumed 15 per cent less gas (average of 21,000 MJ) when compared to the Control households (average of 24,900 MJ). While overall the Catalyst households used almost three per cent less gas than the department Standards (21,786 MJ), only two of the individual Catalyst households used less than the department Standards. Further, only two of the seven Control households consumed less gas than the department Standards. In comparison to the SIP household, the Catalyst households consumed 239 per cent more gas. When looking at the gas consumption data from a per person perspective, only one Catalyst household (CatA)

and one Control household (ConG) were below the department Standards. On a per person basis, the Catalyst households consumed 300 per cent more gas compared to the SIP household, 20 per cent more gas compared to the department Standards, and three per cent more gas compared to the Control households. The high use of gas for the heating of the Catalyst houses compared to the SIP household was caused by differences in thermal comfort practices (for example, leaving doors open while the heater was on so pets could come in and out, or leaving windows open to vent cigarette smoke). These variations, common in other household research, are not factored into the SIP household assumptions of behaviour.



**Figure 9: Average annual gas consumption for all dwellings in comparison to the SIP household and the department Standards.**

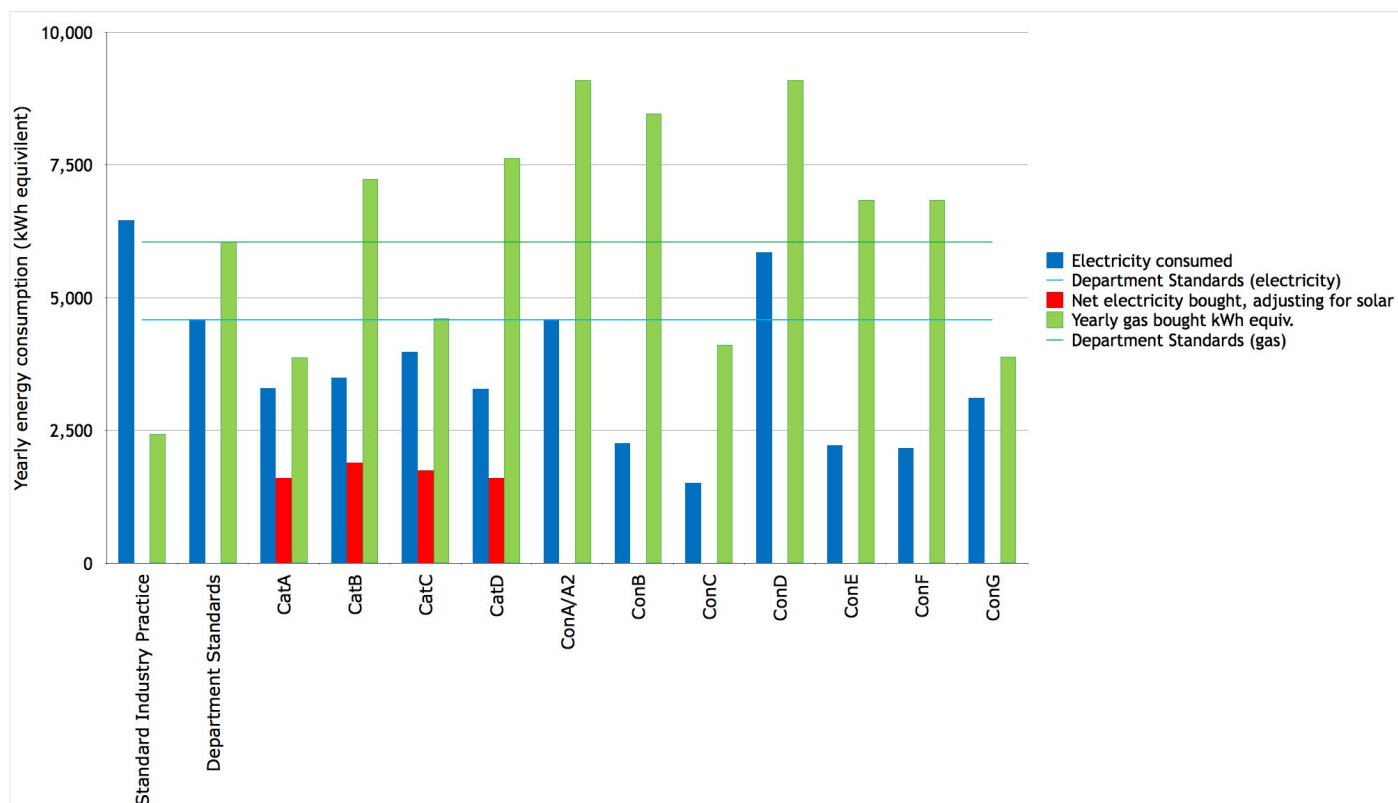


**Figure 10: Average annual gas consumption for all dwellings/persons in comparison to the SIP household and the department Standards.**

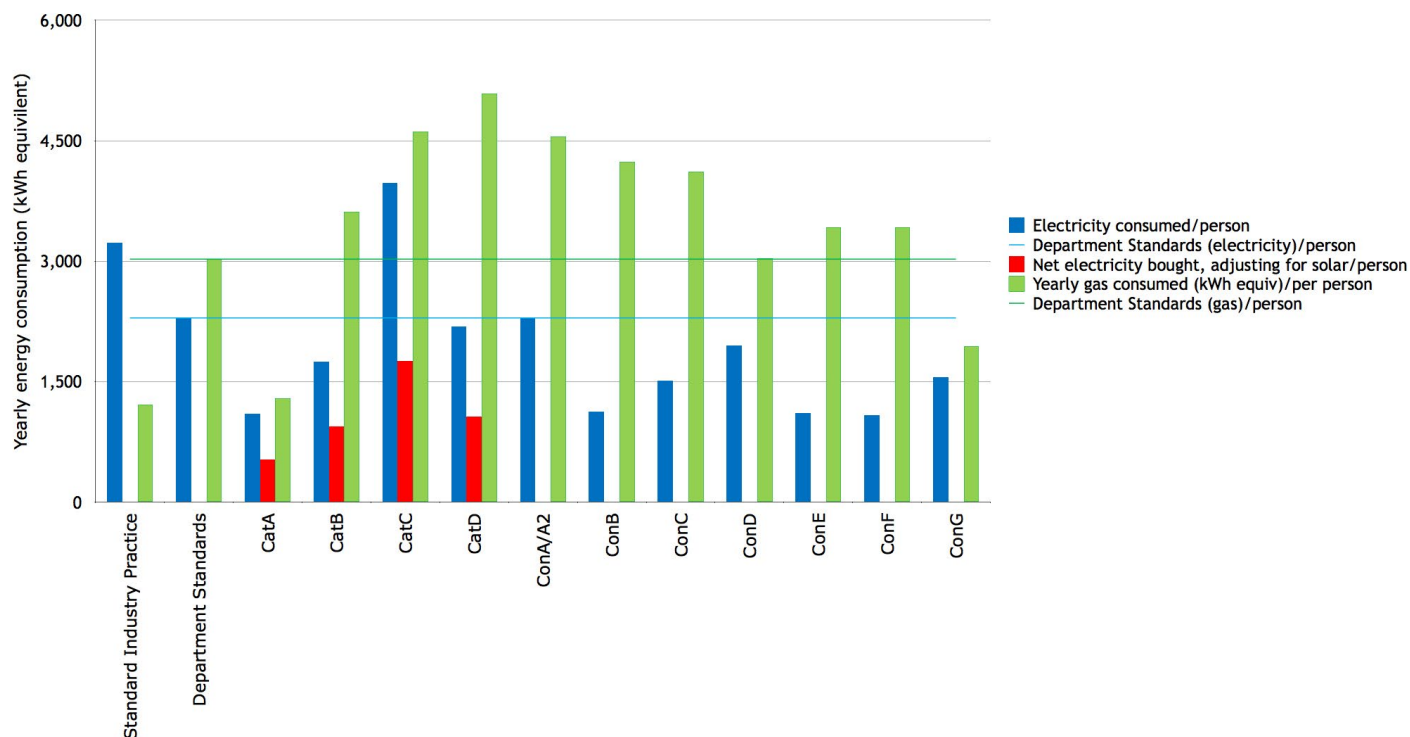
### 6.2.3. Energy total

Figure 11 and Figure 12 present the preceding electricity and gas data in a single graph (for dwelling and per person) for comparison. What these graphs show is that while the Control houses consumed less electricity overall, they also consumed more gas. The electricity and gas consumption data is combined into a single total per house and per person in Figure 13 and Figure 14. For both per dwelling and per person analyses, there are three Control households that have a higher consumption of energy in comparison to the department Standards. There are two Catalyst

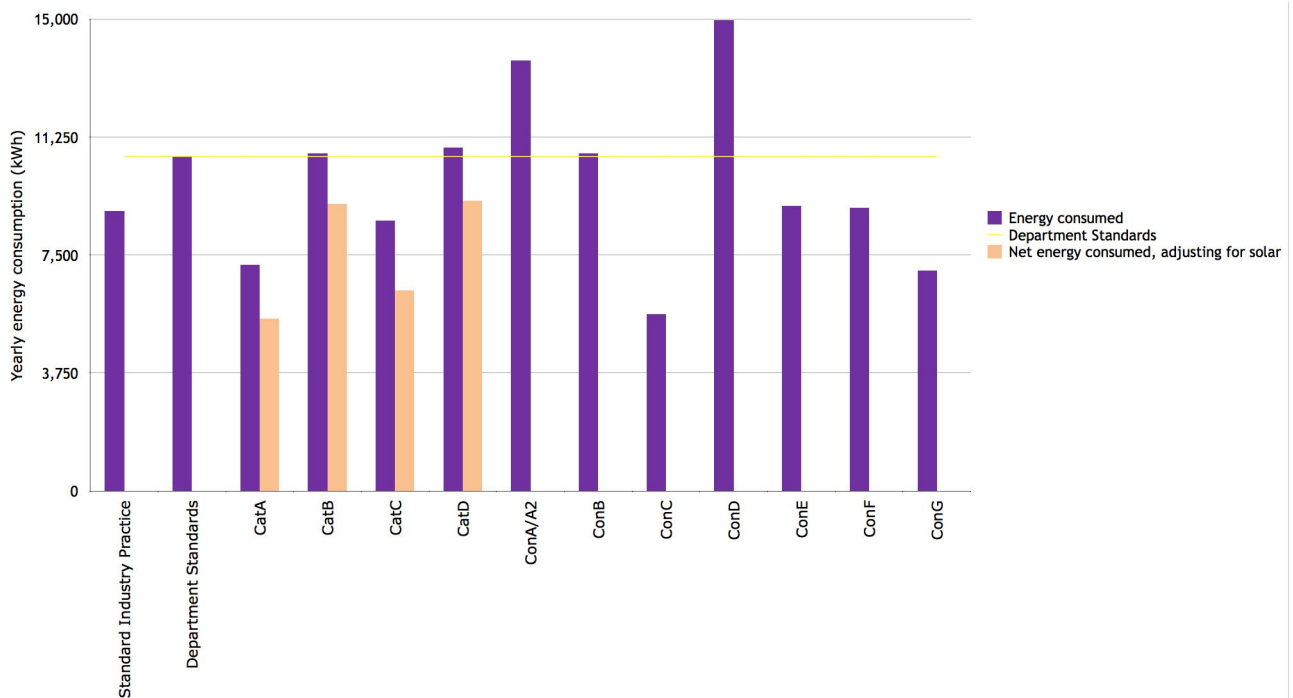
households above this Standards for the per dwelling data, and three households above this Standards for the per person data. Overall, the Catalyst houses used 12 per cent less energy (gas and electricity) than the department Standards, seven per cent less energy than the Control households, and five per cent more than the SIP household. When solar generation is factored in, overall the Catalyst houses used 29 per cent less energy (gas and electricity including solar generation) than the department Standards, 24 per cent less energy than the Control households, and 15 per cent more than the SIP household.



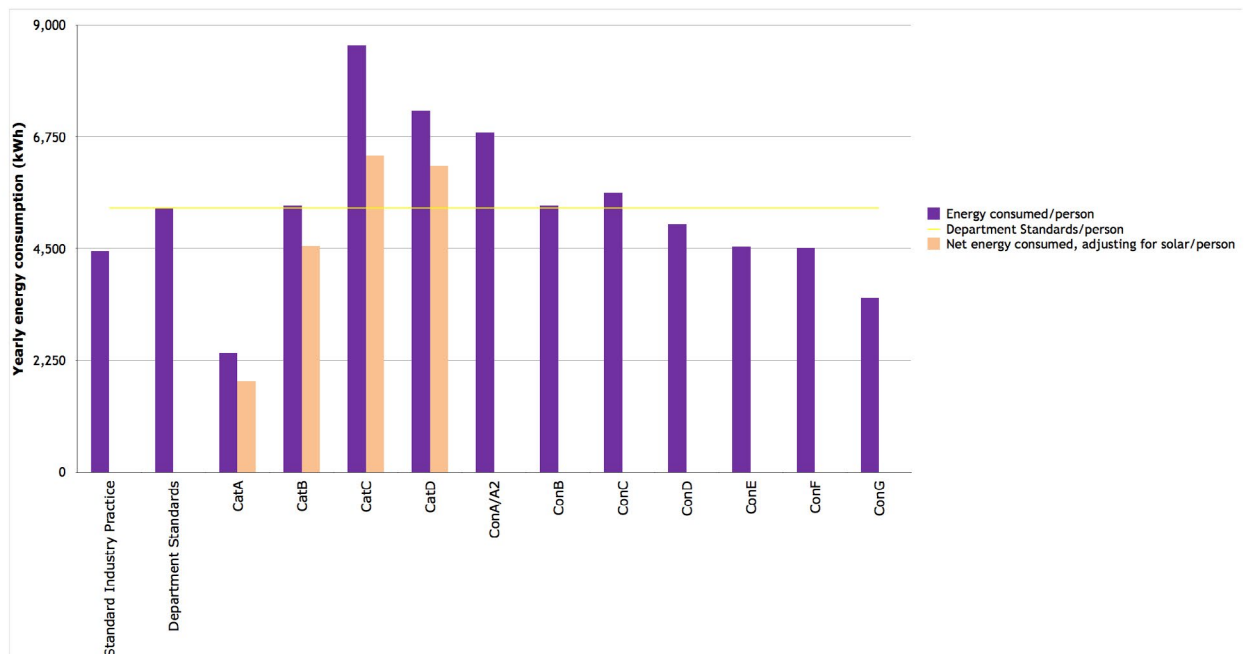
**Figure 11: Average annual electricity and gas consumption for all dwellings in comparison to the SIP household and the department Standards.**



**Figure 12: Average annual electricity and gas consumption for all dwellings/persons in comparison to the SIP household and the department Standards.**



**Figure 13: Average annual energy consumption for all dwellings in comparison to the SIP household and the department Standards.**

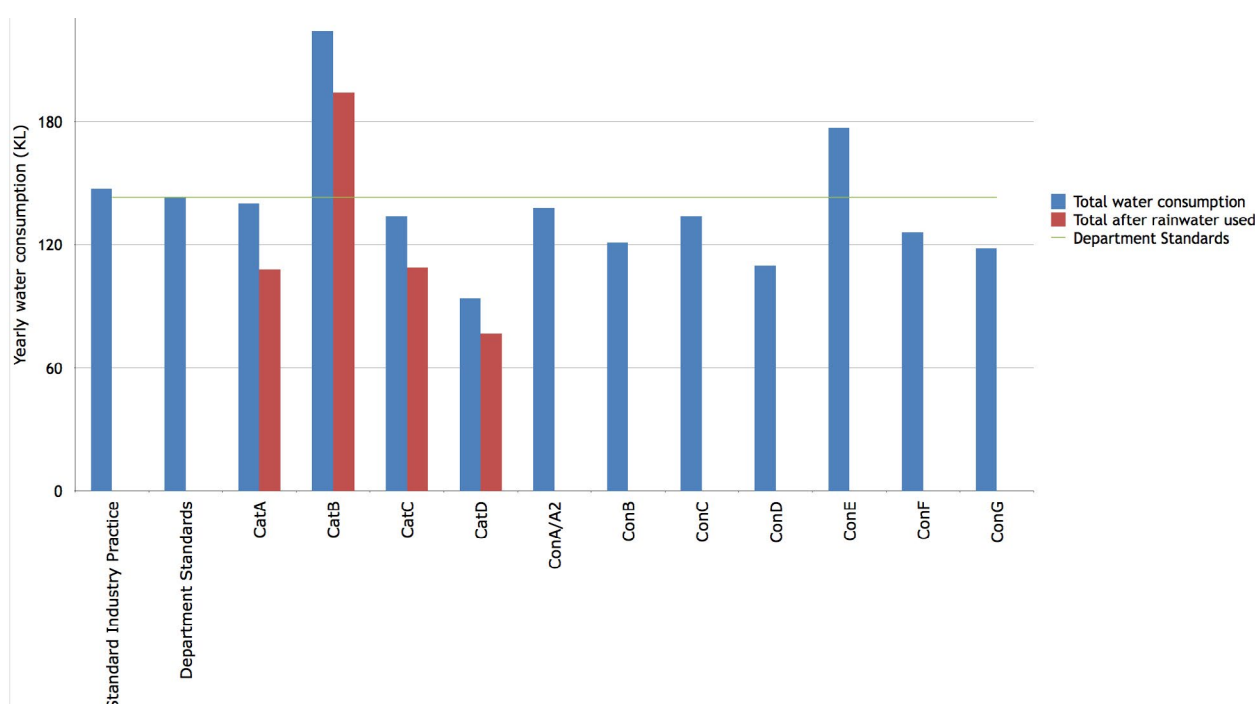


**Figure 14: Average annual energy consumption for all dwellings/persons in comparison to the SIP household and the department Standards.**

## 6.2.4. Water

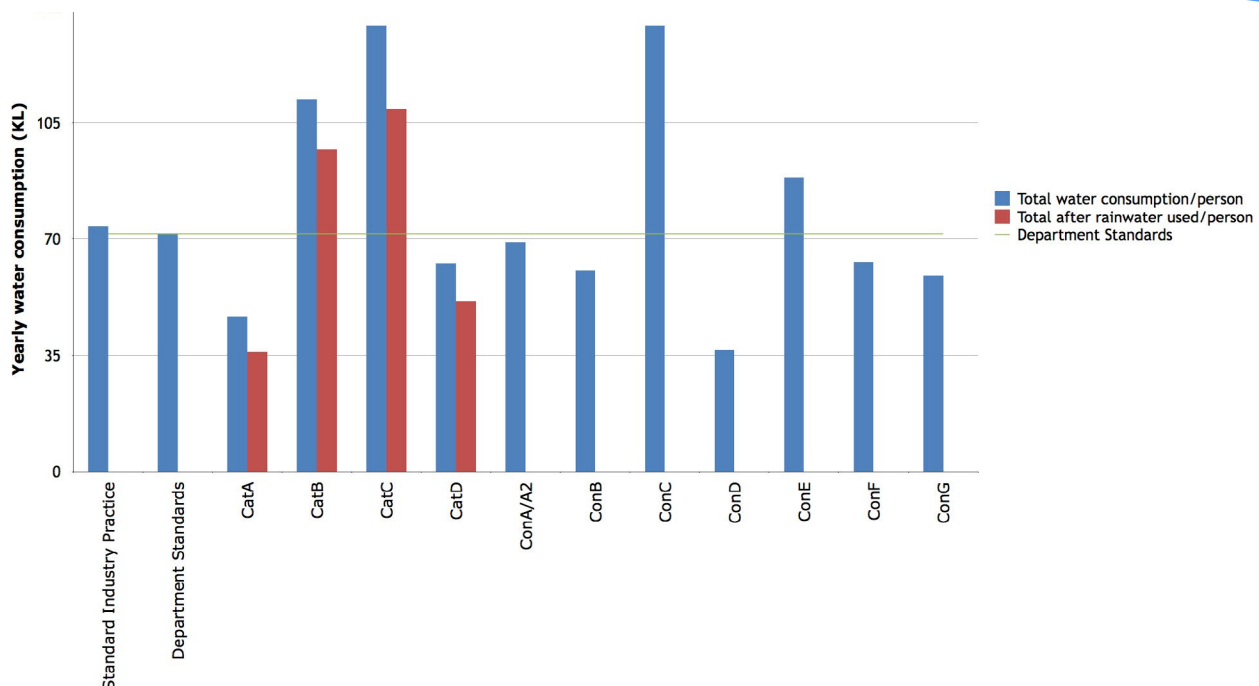
In terms of water consumption, only one Catalyst household (CatB) and one Control household (ConE) were above the department Standards. In the case of the CatB household, a portion of this high usage is attributed to a water leak that went undetected for several months. The data after the water leak was fixed indicates consumption similar to the department Standards (see Figure 15). Adjusting for the water leak data, both sets of households consumed a

similar amount of water (Catalyst household average 129 KL, Control household average 131 KL). When rainwater use was included, the Catalyst household average dropped to 103 KL or 22 per cent lower than the Control households, 28 per cent lower than the department Standards, and 30 per cent lower than the SIP household. On a per person basis, there are two Catalyst households and two Control households whose water consumption was above the department Standards (see Figure 16).



**Figure 15: Average annual water consumption for all dwellings in comparison to the SIP household and the department Standards.**





**Figure 16: Average annual water consumption for all dwellings/persons in comparison to the SiP household and the department Standards.**

### 6.3. Thermal performance

Summertime thermal comfort analysis was undertaken for the period October 2012 to March 2013 and October 2013 to March 2014 via three key adaptive thermal comfort criterion. Analysis based upon these criterion has been used in recent thermal performance research, (see [68]).

The European thermal adaptive comfort standard, BS EN 15251 (BSI, 2007), was used in the analysis as there is currently no Australian standard. The standard, although essentially a blunt technical instrument, allows for a wider range of indoor temperatures to calculate thermal comfort, with the temperature midpoint changing based on the average temperatures experienced across the previous month.

The standard calculates the comfort temperature ( $T_{comf}$ ) in a free running building according to the running mean of the outdoor temperature ( $T_{rm}$ ), using the formula  $T_{comf} = 0.33 \cdot T_{rm} + 18.8$ . For new buildings and renovations (category II buildings),

the allowable maximum difference between this comfort temperature and the actual indoor operative temperature is  $\pm 3^\circ\text{C}$ . The standard provides three additional criteria to measure the severity of overheating beyond this temperature range:

Criterion 1 – Hours of Exceedance ( $H_e$ ): The number of hours the measured operative temperature ( $T_{op}$ ) exceeds the upper limit of the acceptable comfort temperatures range ( $T_{comf} \pm 3^\circ\text{C}$ ) by  $1^\circ\text{C}$  or more should not exceed three per cent of the total occupied hours or 40 hours, during summer months.  $T_{max} = T_{comf} + 4$ .

Criterion 2 – Weighted Exceedance ( $W_e$ ): For each day the sum of the weighted exceedance for each degree Celsius above  $T_{max}$  the allowable maximum should be less than 10; where  $W_e = \sum H_e \cdot (\Delta T)^2$  and  $\Delta T = (T_{op} - T_{max})$ , rounded to a whole number.

Criterion 3 – Threshold/Upper Limit Temperature ( $T_{upp}$ ): The measured operative temperature should

not exceed the  $T_{max}$  by  $3^{\circ}\text{C}$  or more at any time.  $T_{upp} = T_{comf} + 7^{\circ}\text{C}$ .

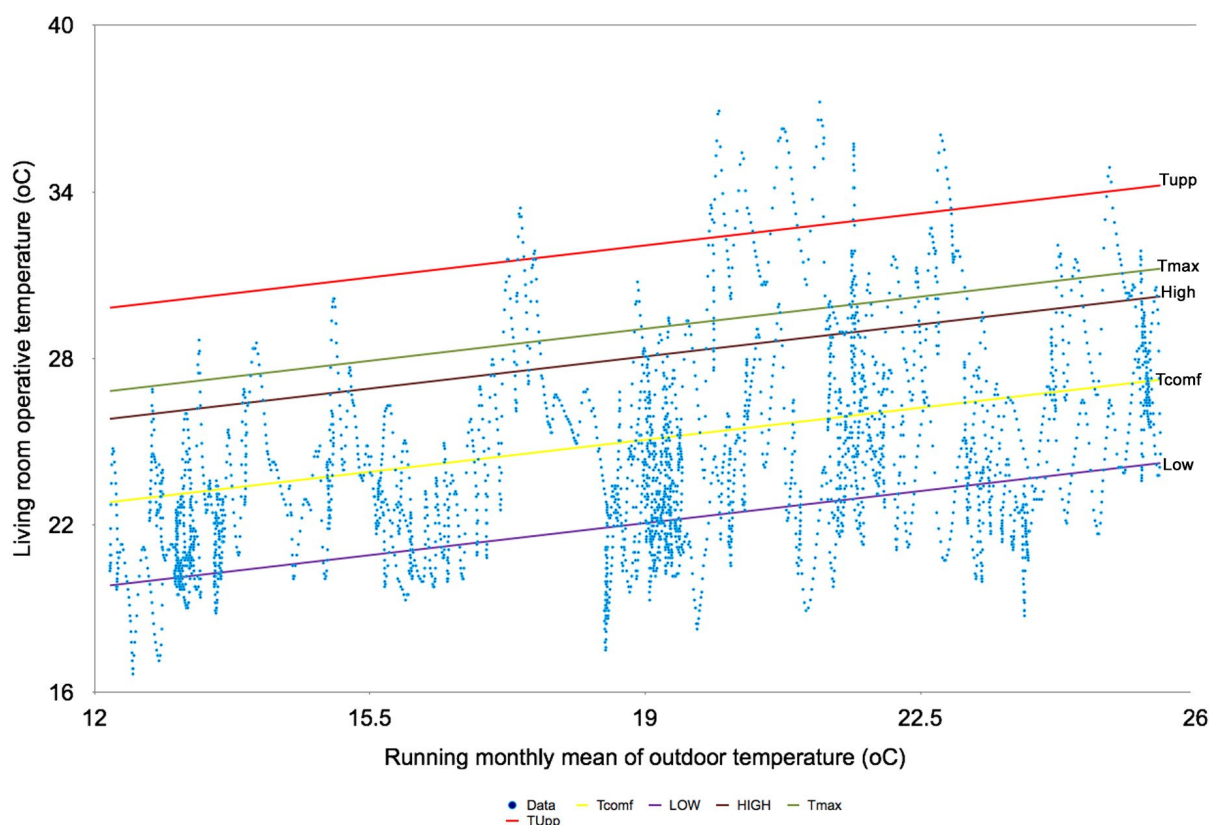
A building is judged to have an unacceptable level of overheating if any two criteria are exceeded.

The analysis also includes mean, minimum and maximum temperatures recorded for each house, as well as an average internal temperature when the external temperature is  $30^{\circ}\text{C}$  and  $40^{\circ}\text{C}$ . The temperature data at these two temperature points is also presented after being standardised by regressing internal temperature against external temperature allowing comparison between different periods of time and different locations if they were exposed to the same 'standard' external temperature conditions. It is of course stressed that adaptive thermal comfort criteria can only be used to examine if the households are likely to find conditions comfortable in buildings that are not air conditioned. To allow a comparison of the

temperature conditions across the dwellings, adaptive thermal comfort criteria have been calculated for all houses, not as a metric to assess if the tenants would be considered thermally comfortable, but as a means to evaluate overheating.

The operative indoor temperatures for the living rooms and bedrooms were analysed through the three criteria described above for each house with available data.

Figure 17 is presented as an example of the raw data analysis using data from the living room of CatD. Each dot represents temperature data collected in 30-minute intervals compared to the average temperature across the previous month. Based upon the European adaptive comfort standard, the aim across the summer months is for the operative temperature to be between the Low and High temperature lines. It is clear that the temperature is above the Criteria 1 and 3 limits for a significant period of time.



**Figure 17: Example of adaptive comfort measurements undertaken in analysis for the periods October 2012 – March 2013 and October 2013 – March 2014.**

Table 12 and Table 13 present the temperature analysis for all houses. The mean temperatures between the Catalyst houses (23.8°C) and Control houses (24.0°C) were similar for the living areas, but Catalyst houses had an average mean temperature of 1.2°C difference for the bedrooms. The average maximum temperature in the living areas of the Control houses was significantly higher (2.7°C) compared to the Catalyst houses. When the data is standardised, the Control houses are warmer than the Catalyst houses at both 30°C and 40°C and for both the living areas and bedrooms.

When looking at the adaptive comfort criteria, the Catalyst houses were comfortable 10 per cent more of the time for the living areas, and seven per cent more of the time for the bedrooms compared to the Control houses.

This is not unexpected due to the improved passive design and increased thermal mass in the Catalyst houses. Using the averaged data, both types of houses failed all of the three overheating criteria, and would be considered to be unacceptably hot on several occasions during summer (for example, heatwave days where the averaged daily maximum and minimum temperatures were above 30°C). The suitability of using BS EN 15251 to assess overheating risk in dwellings needs to be investigated further as it still seems to present a narrow indicator of comfort.

Table 13 presents the individual analysis for each of the Catalyst houses and the Control houses for the living areas. The lowest mean temperature was 22.6°C for ConE, and the highest mean temperature was 25.4°C for ConD. The lowest maximum temperature was 31.8°C for CatB, while the highest maximum

temperature was 43.0°C for ConD. It should be noted that CatB was the only Catalyst house that had air conditioning installed. The use of the air conditioner in CatB is reflected in the analysis, with the dwelling recording the lowest maximum temperature. As a result, CatB had the highest percentage of time where it was calculated to be comfortable (76 per cent) across the summer. The house with the lowest percentage of time where it was calculated to be comfortable was CatA (53 per cent). Apart from CatB, which had air conditioning, the Catalyst houses were physically and technically similar, indicating that differences in calculated time in comfort were likely due to the different activities households participated in to achieve thermal comfort. As with the averaged data, all houses failed the overheating criteria.

Figure 18 shows the monitored temperature data for the Catalyst and Control houses during two days of extreme weather in January 2013. The external temperature reached 42.9°C on both days and only dropped to 21.7°C overnight. The figure clearly shows that the Control houses were significantly warmer compared to the Catalyst houses. The difference is more pronounced on the second day due to the Control houses not cooling down as much as the Catalyst houses overnight, with a difference of 16.6°C from the hottest Control house to the coolest Catalyst house.

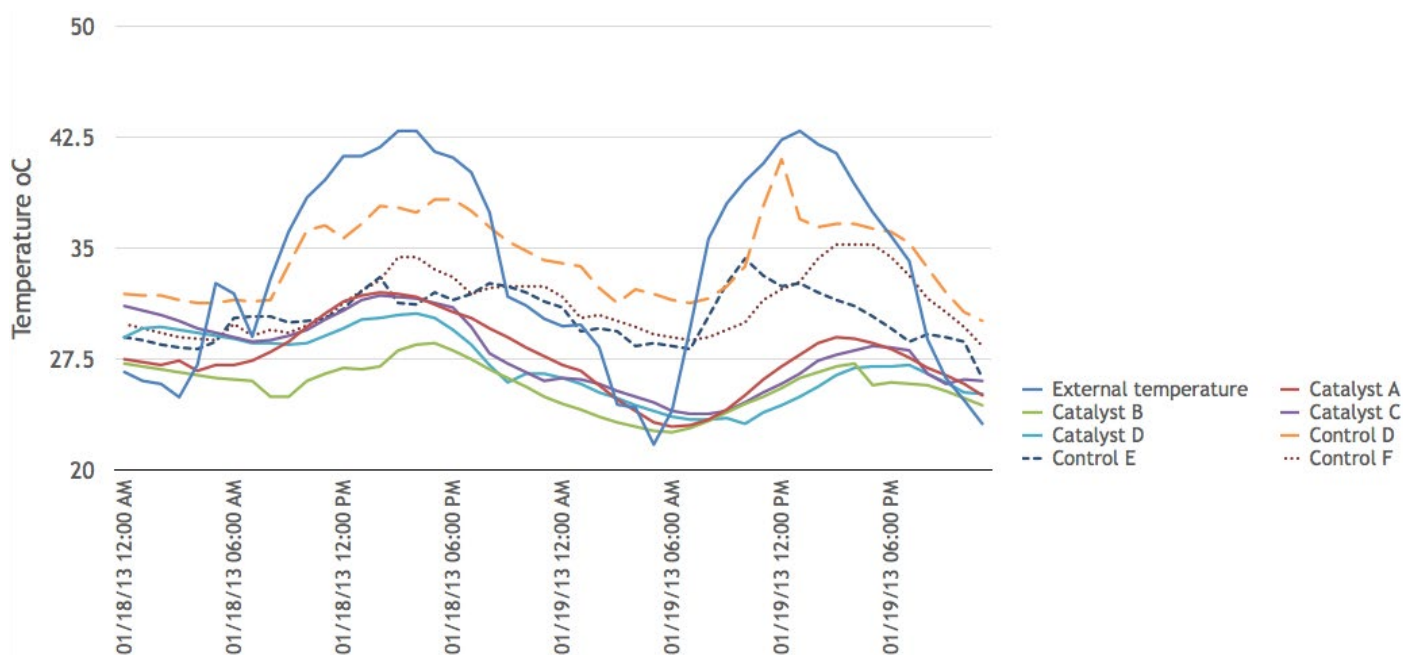
The analysis of the monitored temperature data is supported by households' reported satisfaction with the Catalyst houses – they were generally happier with the thermal comfort of the dwellings across summer than those in the Control houses, as was explored in Section 3.4.

**Table 12: Summary of measured performance from both groups of houses – summer data.**

Room	House	Internal temperature			Standardised internal temperature when external temperature is 30°C and 40°C		% of hours above certain temperatures		European adaptive comfort standard criteria				
		Mean (°C)	Min. (°C)	Max. (°C)	T@30°C (°C)	T@40°C (°C)	>25	>28	% of time comfortable	Hours above Criterion 1	Days	Hours above Criterion 3	T-Tcomf
Living rooms	Catalyst	23.8	14.9	34.4	28.6	30.9	42.6	13.8	64.9	280.8	22.5	37.8	-0.6
	Control	24	13.7	37.1	28.8	33.8	38.5	16.5	59.7	509.3	58	102.7	0.3
Bed-rooms	Catalyst	22.6	13.3	33.4	28.5	32.8	33.8	9.8	54.7	183.5	18	16	-1.6
	Control	21.4	12.6	34	30.8	36.2	18.3	7.1	52.6	335	40	55.5	-1.1

**Table 13: Measured performance from the living areas of each dwelling – summer data.**

House	Internal temperature			Standardised internal temperature when external temperature is 30°C and 40°C		% of hours above certain temperatures		European adaptive comfort standard criteria				
	Mean (°C)	Min. (°C)	Max. (°C)	T@30°C (°C)	T@40°C (°C)	>25	>28	% of time comfortable	Hours above Criterion 1	Days above Criterion 2	Hours above Criterion 3	T-Tcomf
CatA	23.1	14	35	26.7	31.3	36.3	14.6	53.2	312	25	45	-1.2
CatB	23.9	15.1	31.8	29.1	33.7	47.3	7	76.1	106	8	6	-0.6
CatC	23.7	15	35.7	26.9	31	38.7	14.6	62.2	294	25	41	-0.6
CatD	24.6	15.4	35.2	31.9	27.8	48	19	67.9	411	32	59	0.2
ConD	25.4	15.2	43	30.3	35.8	51.2	26.8	59.1	794	68	267	1.5
ConE	22.6	11.6	35	29.4	36.3	27.6	10.4	54.7	484	80	38	-0.4



**Figure 18: Temperature in the living rooms of monitored houses and external temperature for 18–19 January 2013.**

## 6.4 Blower door performance

During the second round of interviews, a blower door test was conducted where the households gave consent. This was an additional data collection method delivered by the RMIT research team, which was not included in the original evaluation design. The blower door test is a standard method for measuring the air tightness or ‘air leakiness’ of a dwelling. Testing is carried out according to international standards and protocol, such as EN:13829 (2001) and ATTMA (the Air Tightness Testing and Measurement Association). The measurement of air tightness helps to investigate the energy performance of a dwelling, in terms of heating and cooling loads, and informs issues such as indoor air quality and dwelling ventilation rates. The test takes approximately one hour to set up and perform. A fan is fitted to the door of the dwelling using a dismountable frame and is used to blow air into and out of the building (see Figure 19).



**Figure 19: Blower door test once set up (source: Trivess Moore)**



In the UK, new housing achieves a result of approximately 10 air changes per hour at 50 pascals. Wider evidence from Australia shows that existing housing achieves between 20–30 air changes per hour, with some at 30-plus changes per hour. Newer housing in Australia could be expected to be in the 10–20 air changes per hour range. An evaluation of housing in Canberra for another evaluation has found results as low as six air changes per hour. When the air changes are too low (below 10 air changes per hour), there is a requirement for other forms of mechanical air exchange to prevent mould.

Table 14 presents the outcomes of the blower door test. The Catalyst houses performed better than the Control houses, although one Control house (ConA/A2) had similar results to three of the Catalyst houses. We believe that there was an issue with the testing

of CatC, likely to be a vent or window left open. This would explain why that house recorded a significantly higher number of air changes in comparison to the other Catalyst houses. This issue was not picked up at the time of testing, partly due to time constraints of the household. The data also shows that apart from ConE, the other Control houses performed within the range for existing housing, although given their relatively new age, a lower number would have been expected. The star rating of the dwelling contributes to the number of air changes, in that higher star ratings require improved thermal performance (for example, reducing gaps around doors and windows). However, even houses that meet minimum standards should be able to achieve 15–20 air changes per hour if the houses are well built (for instance, if the builder takes care to build to specification).

**Table 14: Results from the blower door test**

	Address	Star rating	Air changes per hour @50 pascals
Catalyst	CatA	8.9	14.1
	CatB	8.9	14.3
	CatC	8.9	22.1
	CatD	8.7	13.2
Control	ConA/A2	6	13.5
	ConB	6	Not tested
	ConC	6.4	20.2
	ConD	6	22.6
	ConE	6	32.8
	ConF	6	Not tested
	ConG	6.5	Not tested

## 6.5. Cost-benefit analysis

The additional upfront cost for the Catalyst houses was calculated to be \$75,780 per dwelling (see Table 15). The majority of this cost was for the improved thermal performance of the building envelope. This additional upfront cost is critical for any analysis of costs and benefits, as presented below. In comparison to other low and zero energy developments and research in Australia and internationally, the additional upfront cost for the Catalyst houses is high (see Figure 20). For example, the Cape Patterson EcoVillage in Victoria calculated that in 2011 the additional cost for their dwellings (minimum of 7.5 stars with minimum 2.5 kW

solar PV system, solar hot water and a 10,000-litre rainwater tank plumbed into the house) to be only \$32,500 – less than half the cost of the Catalyst houses. While this is also a regional case study in Victoria, the EcoVillage is proposing 219 dwellings so there may be cost efficiencies considered in their modelling that were not available in the Catalyst evaluation. Furthermore, the authors only modelled two designs, so there could be further cost efficiencies when the development considers a wider range of house designs.

**Table 15: Additional upfront costs per Catalyst house compared to a standard department house**

Element	Cost per unit (does not include locational efficiency)
Building envelope	\$55,322
Solar PV system	\$9,625
Rainwater tank plumbing and pump	\$10,833
<b>Total</b>	<b>\$75,780</b>

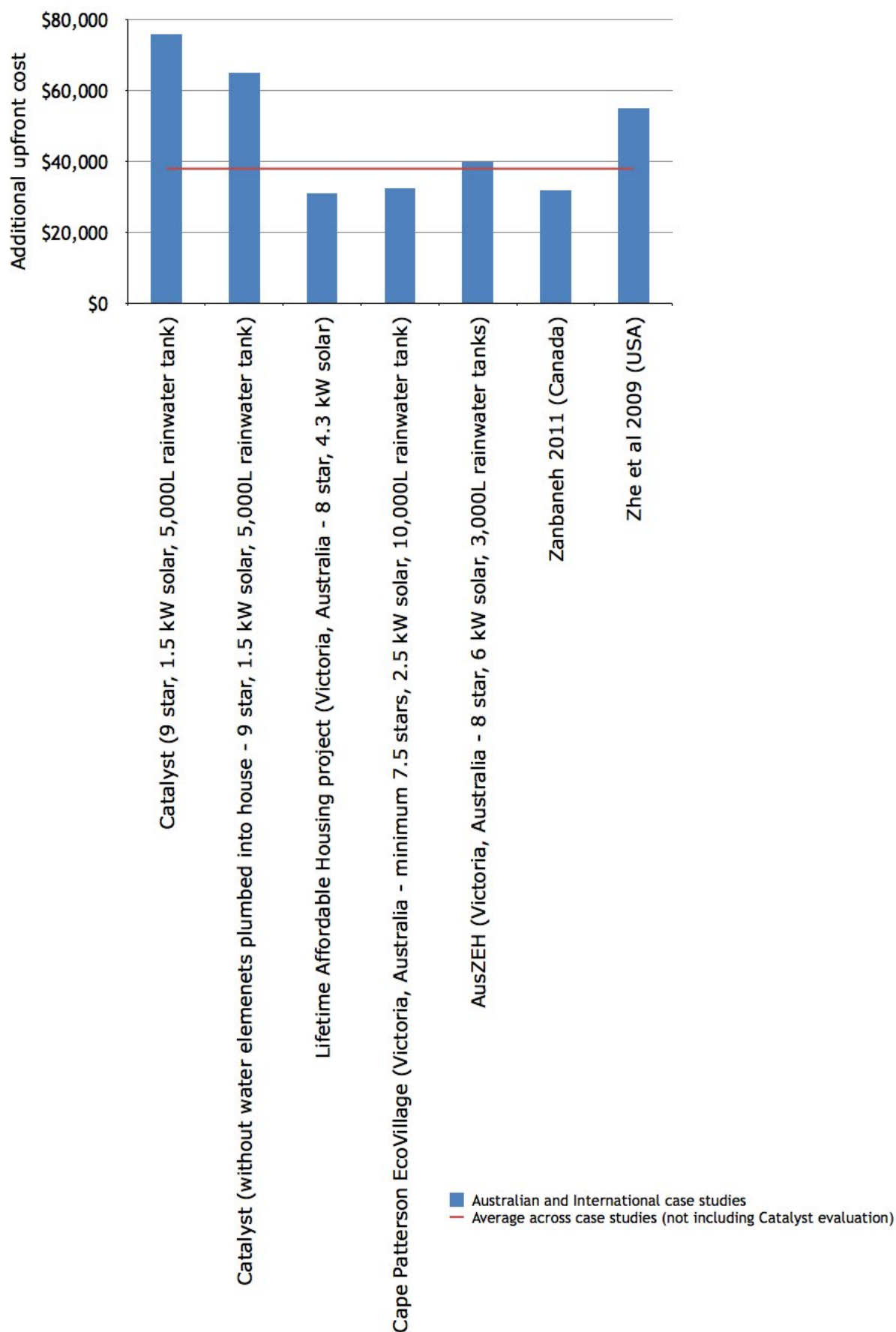


Figure 20: Comparison of additional capital costs to achieve a low or zero energy house from a range of projects and research.

Three key elements in the design and cost of the Catalyst houses were evident in terms of being able to reduce the capital costs for future projects. The first is that the 1.5 kW solar PV system was at least twice as expensive as comparable systems available at that time for an individual dwelling [8]. Secondly, the rainwater tank plumbing and pumps were felt to be more expensive than other options available in the (regional) market at the time, especially as this cost does not include the rainwater tank as they were also standard for other department Control houses in the study.

However, the main concern regarding where additional costs were spent relates to the carport specification, which featured an innovative material for its construction. While understanding that the project aimed to contribute to design and construction innovation, this

Three key elements in the design and cost of the Catalyst houses were evident in terms of being able to reduce the capital costs for future projects. The first is that the 1.5 kW solar PV system was at least twice as expensive as comparable systems available at that time for an individual dwelling [8]. Secondly, the rainwater tank plumbing and pumps were felt to be more

is one immediate area where future costs could be reduced by reverting to a more traditional construction material. In addition, the additional costs for the solar PV systems and rainwater tank plumbing cannot be explained by the regional location or lack of scale of efficiencies. Both these elements were overpriced based on sustainable housing cost research undertaken by the research team at a similar point in time.

Further, research has found that the optimal result for building performance in Melbourne for 2012 was eight stars not nine stars, as with the Catalyst houses. It should be feasible to reduce capital costs for future projects by modifying the building envelope performance (for example, reducing from nine stars to eight stars) and selecting more economical technology options, although this would negate some benefits to expensive than other options available in the (regional) market at the time, especially as this cost does not include the rainwater tank as they were also standard for other department Control houses in the study.

However, the main concern regarding where additional costs were spent relates to the carport specification,

**Table 16: Through-life maintenance costs per Catalyst house compared to a standard department house**

<b>Maintenance costs</b>	<b>Additional cost per year per unit (\$) without inflation</b>
Building envelope	\$553
Solar PV system/inverter	\$96
Rainwater tank and associated plumbing	\$23
<b>Total</b>	<b>\$672</b>

**Table 17: Technology replacement costs**

<b>Technology replacement costs</b>	<b>Total cost for the replacement of solar PV system and rainwater tank across 40 years (includes inflation)</b>
Solar PV system/inverter	\$13,531
Rainwater tank pump replacement	\$1,673
<b>Total</b>	<b>\$15,204</b>

The accumulated costs (upfront and through-life operating and maintenance costs to both the department and the household) of the Catalyst houses compared to the department Standards and SIP house are presented in Table 18. Data is presented for using an anytime energy pricing model (where energy costs the same no matter what hour of the day it is used or how much is used). There is a high upfront cost

associated with the Catalyst houses that impacts on the financial viability of the dwellings after five years. None of the Catalyst houses have a lower through-life cost when compared to the department Standards at five years for the low or high energy price future. After 40 years for the low energy price future, none of the Catalyst houses have a lower accumulated through-life cost lower than the department Standards, but two



**Table 18: Upfront and through-life operational costs after five and 40 years for a low and high energy price future**

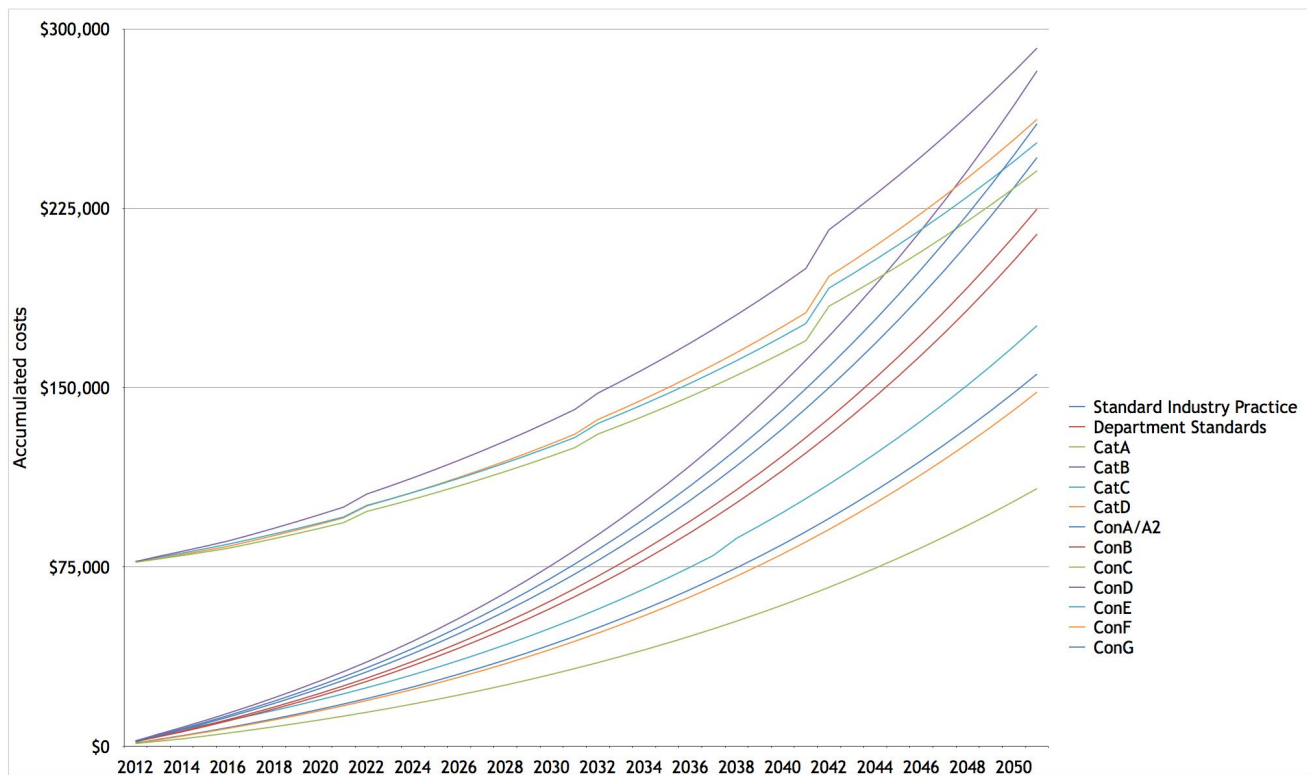
	Accumulated through-life costs (anytime energy pricing, low energy price future)		Accumulated through-life costs (anytime energy pricing, high energy price future)	
	5 years	40 years	5 years	40 years
Standards Industry Practice	\$15,848	\$260,342	\$18,106	\$350,721
Department Standards	\$13,784	\$224,657	\$15,497	\$296,765
CatA	\$84,815	\$240,659	\$85,465	\$269,168
CatB	\$88,497	\$291,955	\$89,337	\$330,467
CatC	\$86,651	\$252,432	\$87,375	\$284,307
CatD	\$85,851	\$262,178	\$86,597	\$297,617

have lower costs than the SIP house: CatC (three per cent lower) and CatA (eight per cent lower). Overall, after 40 years against a low energy future, the four Catalyst houses are predicted to have a slightly higher through-life cost compared to the SIP house of 0.5 per cent.

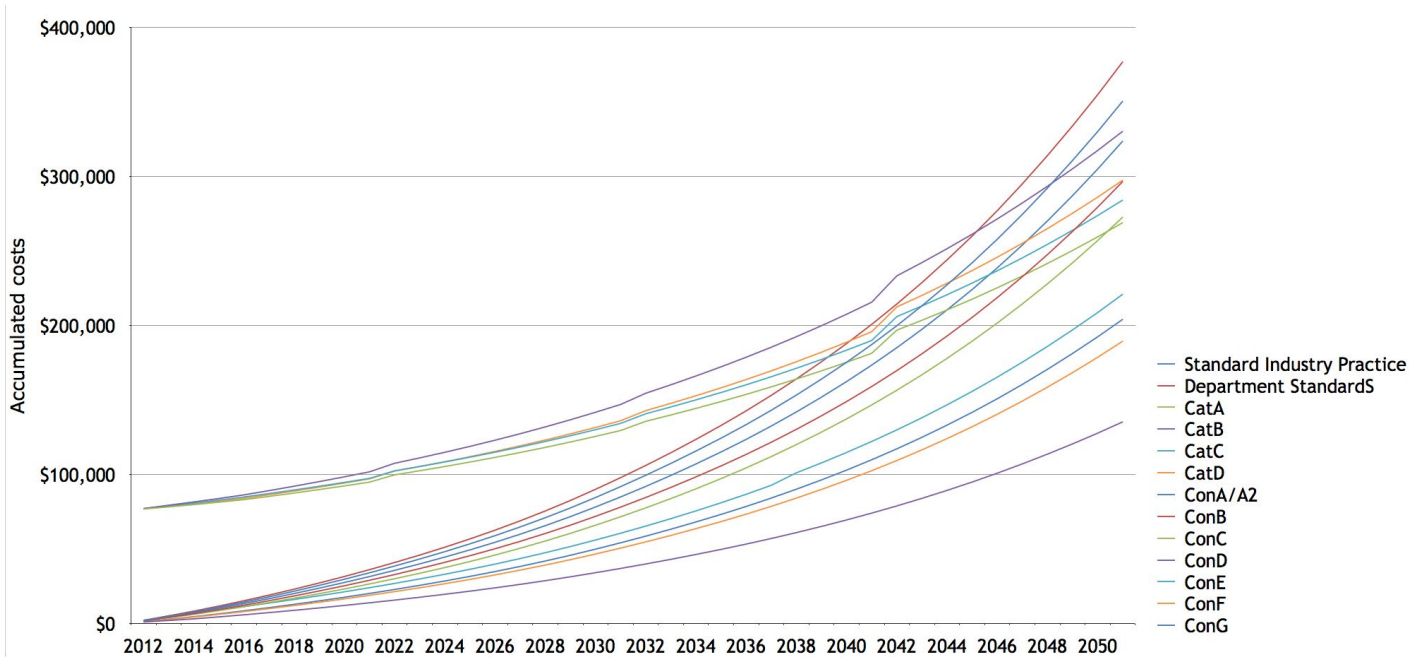
For a high energy price future, there are also no Catalyst houses that have a lower accumulated through-life cost after five years compared to the department Standards or SIP houses. When compared to the department Standards after 40 years, two Catalyst houses have lower accumulated through-

life costs: CatC (four per cent lower) and CatA (nine per cent lower). Compared to the SIP house, all four Catalyst houses have lower accumulated through-life costs: CatB (six per cent lower), CatD (15 per cent lower), CatC (19 per cent lower) and CatA (23 per cent lower).

Figure 21 and Figure 22 depict the above information. As shown, the Control houses have a lower accumulated through-life cost for both the low and high energy price scenario for at least 25 years.



**Figure 21: Accumulated costs for each dwelling in the research across time for a low energy price future.**



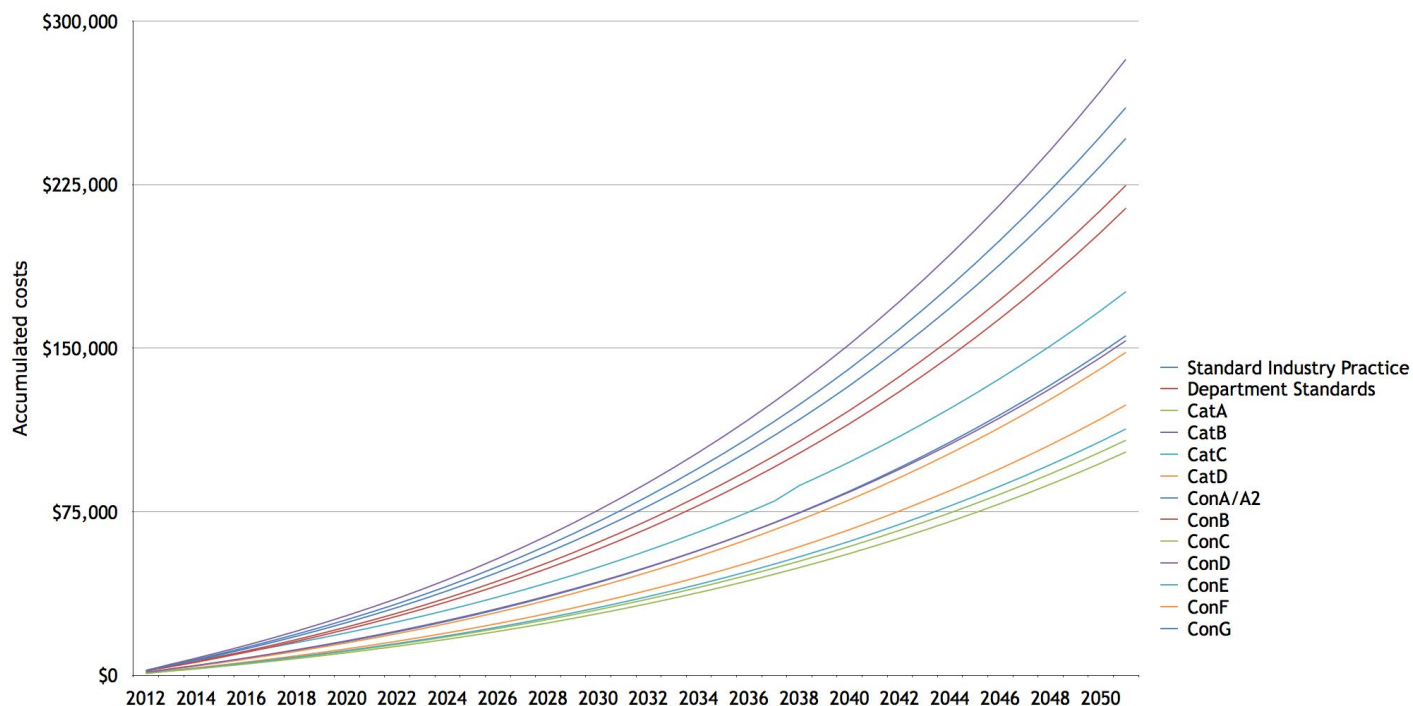
**Figure 22: Accumulated costs for each dwelling in the research across time for a high energy price future.**

Table 19 provides a summary of the initial and accumulated costs after five and 40 years for the department compared to a standard department house. While there are substantial costs to the department over 40 years (\$141,689), there are benefits to the households as explored in Sections 2 and 3. However, the Catalyst households saved an average of \$1,050 per household from the improved design, although this did not necessarily translate to lower operating costs (see Figure 23

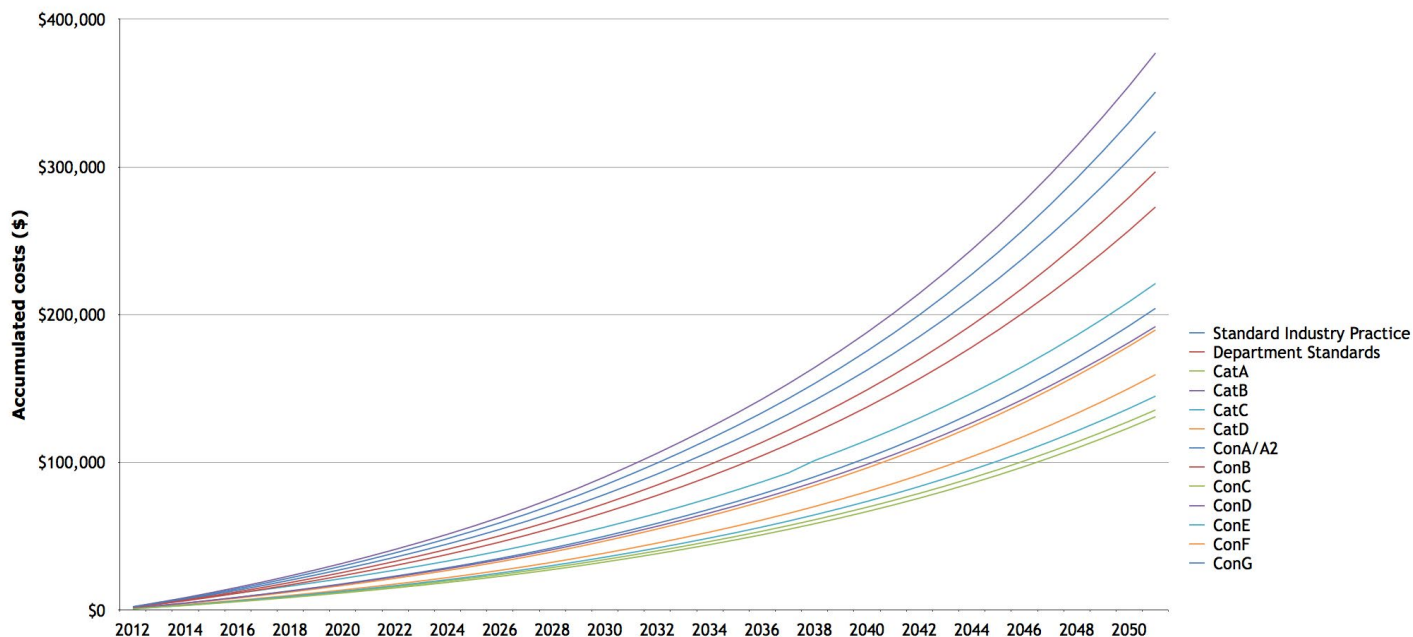
and Figure 24). They also deliver significant contributions to sustainability and comfort that are uncoded in this study. This had a tangible effect on the households as discussed previously, and significant carbon savings for the planet. In addition, the houses, due to improved design and sustainability, are predicted to achieve an increased asset value of \$9,300 – \$40,000 over different future times depending on the future price of energy.

**Table 19: Summary of additional costs to the department**

<b>Element</b>	<b>Initial cost</b>	<b>Accumulated cost after five years</b>	<b>Accumulated cost after 40 years</b>
Additional building envelope, solar PV system, rainwater tank plumbed into house	\$75,780	N/A	N/A
Additional maintenance	N/A	\$3,570	\$50,705
Additional solar and rainwater tank elements' replacement	N/A	N/A	\$15,204
Change to rent received	\$0	\$0	\$0
Total additional cost to the department	\$75,780	\$79,350	\$141,689



**Figure 23: Accumulated costs for each household (without the department capital and maintenance and replacement costs) in the research across time for a low energy price future.**



**Figure 24: Accumulated costs for each household (without the department capital and maintenance and replacement costs) in the research across time for a high energy price future.**

Based on the additional capital cost and through-life data of the Catalyst houses presented above, a net present value analysis was undertaken in comparison to the department Standards scenario. Only for a 0.0 per cent real discount rate for a high energy price

future did the Catalyst houses achieve a positive net present value by 40 years (see Table 20). Otherwise, for all other scenarios the Catalyst houses did not achieve a positive net present value.

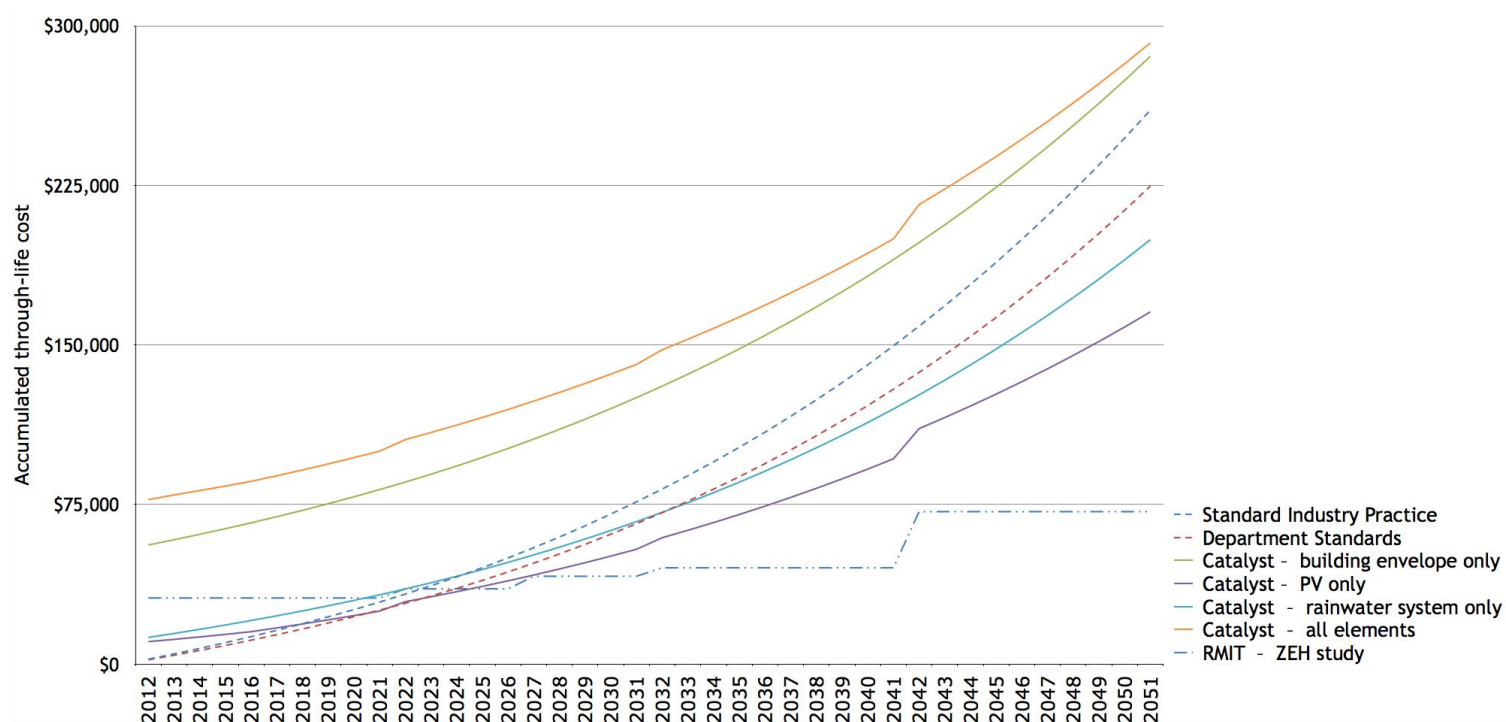
**Table 20: Net present value analysis of Catalyst houses after five and 40 years.**

Scenario	Real discount rate	Five years	40 years
Catalyst – low energy price future	0.0%	-\$73,014	-\$37,149
	3.5%	-\$73,348	-\$66,111
	7.0%	-\$73,498	-\$69,948
Catalyst – high energy price future	0.0%	-\$72,307	\$1,376
	3.5%	-\$72,760	-\$58,064
	7.0%	-\$72,964	-\$65,831

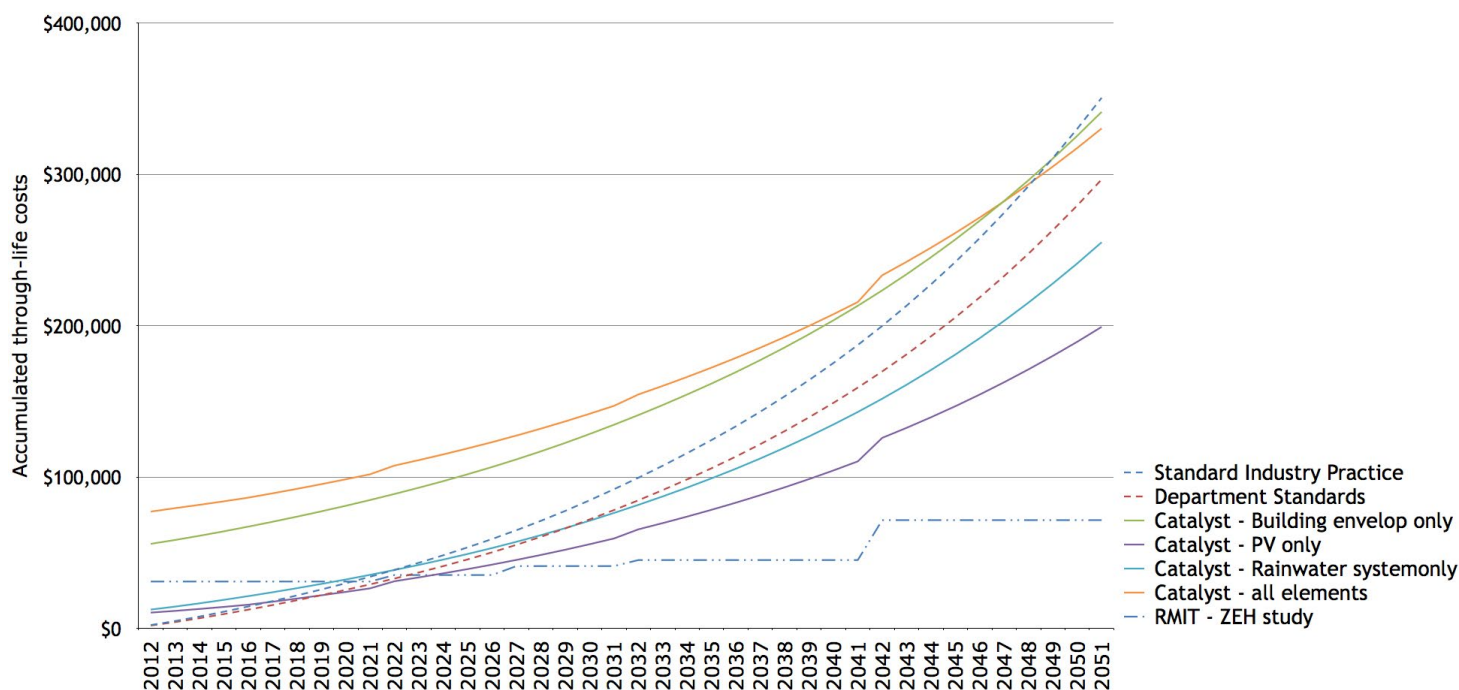
If the development was to be repeated, there would be expected cost efficiencies that could be found that would significantly improve the CBA and payback periods (see Figure 20). For example, payback periods of seven to 25 years have been found in Australian and international research [8, 48, 66, 103] indicating the scope for improvements in capital costs for the department. In addition, extending the life of the building to 60 to 80 years would see a payback achieved across more scenarios, improving the financial proposition of the development. A well-built house should last more than 40 years if it is maintained [104]. Furthermore, the dwellings are calculated to achieve an additional resale value of between \$15,000 to \$40,000 per dwelling depending on the age of the sustainability technologies in the dwellings and the price of utilities at the time of selling (see Section 1.3.5), which would be a direct benefit to the department.

If the additional upfront costs are broken down to their individual elements, there is a change to the results (see Figure 25 and Figure 26). What can clearly be seen is that for both a low and high energy price future, the solar PV system is the most cost-effective element, followed by the rainwater system plumbed into the house. The solar PV system has a payback period of 10 to 13 years and the rainwater tank plumbed into the house has a payback period of 17 to 21 years. Only for the high energy price future does the building envelope only or the whole Catalyst house achieve a payback (36 years) compared to the SIP household, and neither of these options achieve payback within the 40-year model against the department Standards. This indicates that it is more economical for the solar PV and water elements than it is for the building envelope.





**Figure 25: Accumulated costs for various sustainability elements within the Catalyst houses across time for a low energy price future.**



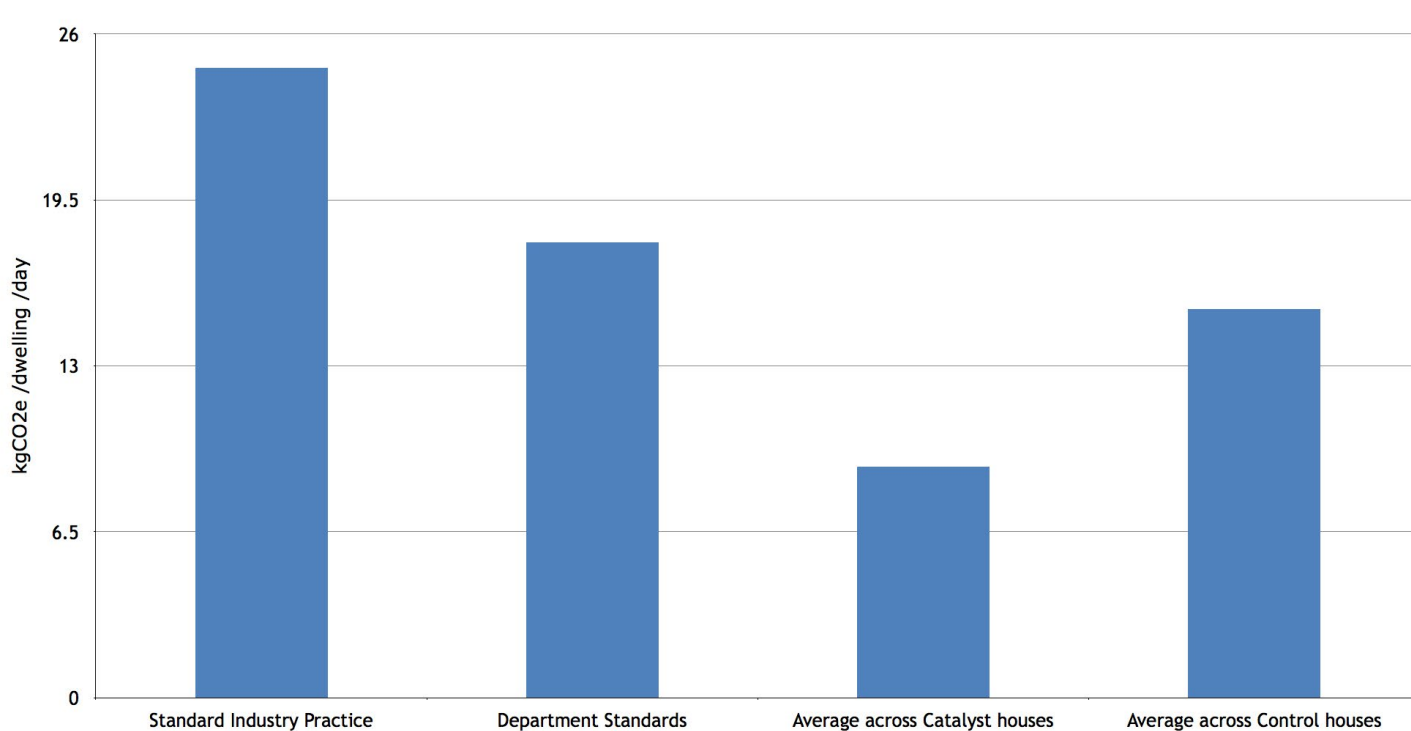
**Figure 26: Accumulated costs for various sustainability elements within the Catalyst houses across time for a high energy price future.**

## 6.6. Environmental performance

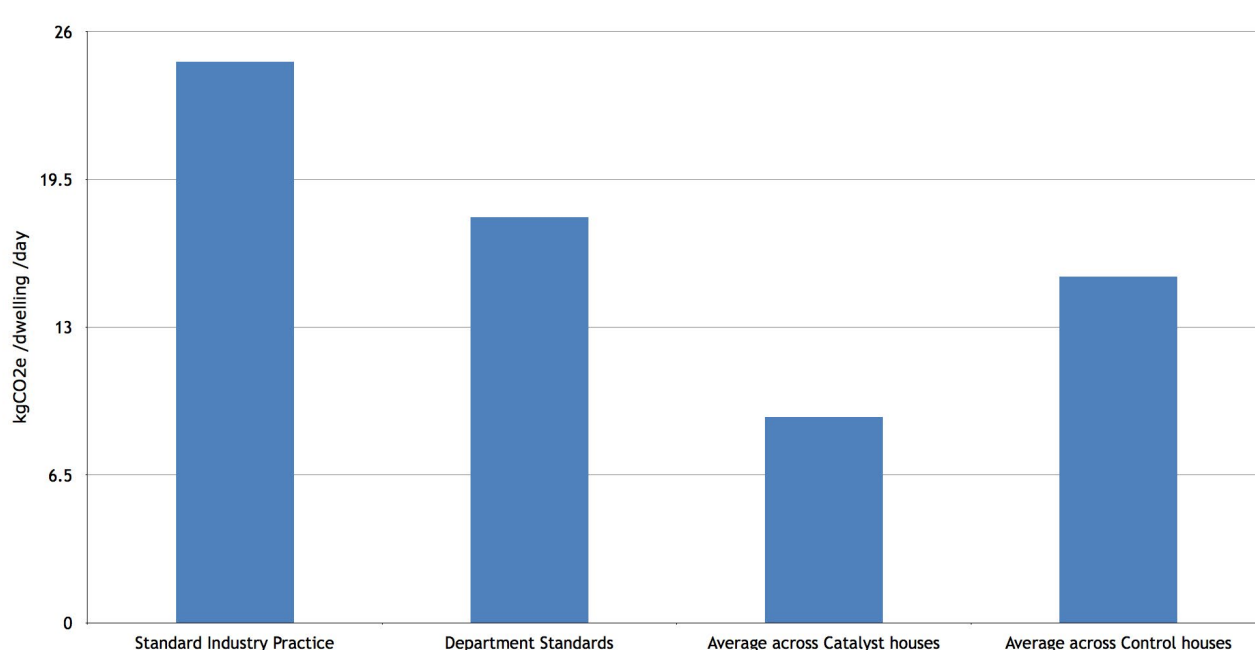
The following presents analysis of the environmental performance of the dwellings based on the monitored utility data from June 2012 to May 2015.

Using the figures provided by Organica Engineering to calculate environmental impacts in terms of kgCO<sub>2</sub>e/dwelling/day, it can be seen in Figure 27 that the Catalyst houses had less environmental impacts from their (energy) operation than the Control houses (40 per cent less), the department Standards (50 per

cent less) and the SIP house (63 per cent less). The improved performance of the Catalyst houses is also reflected when looking at per person environmental impact, using the real household occupancy numbers from the project (see Figure 28). On a per person basis, the Catalyst houses had less environmental impacts from their (energy) operation than the Control houses (25 per cent less), the department Standards (36 per cent less) and the SIP house (54 per cent less).



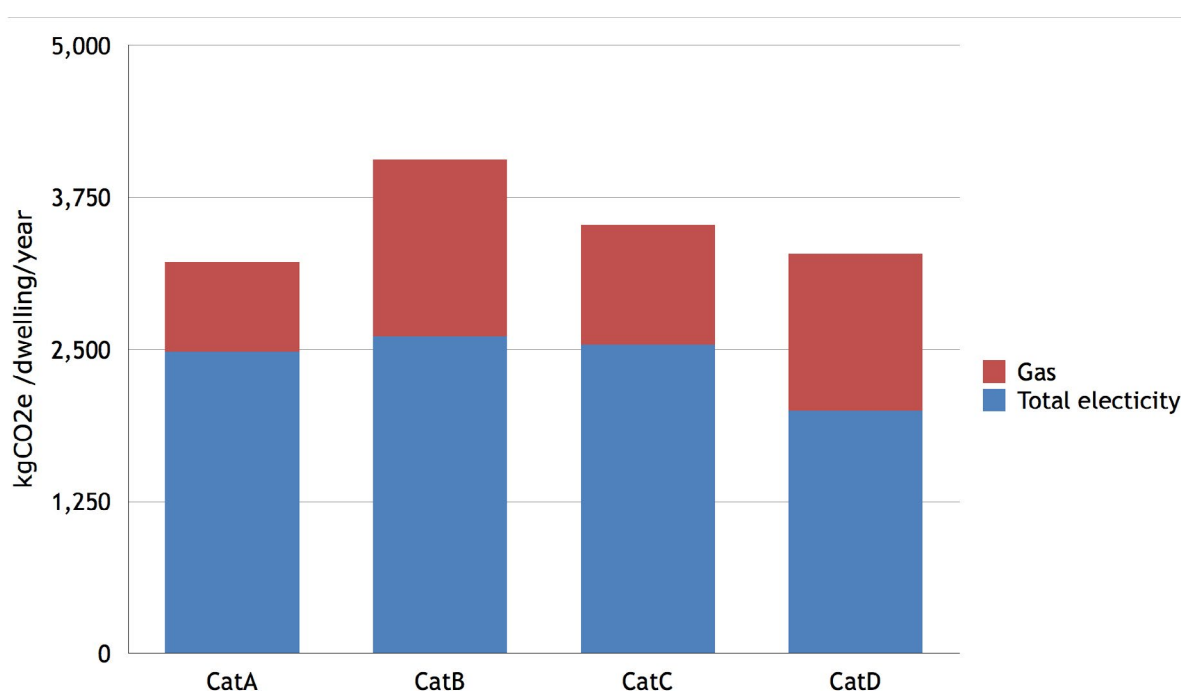
**Figure 27: Environmental performance of dwellings in comparison to the SIP household and the department Standards.**



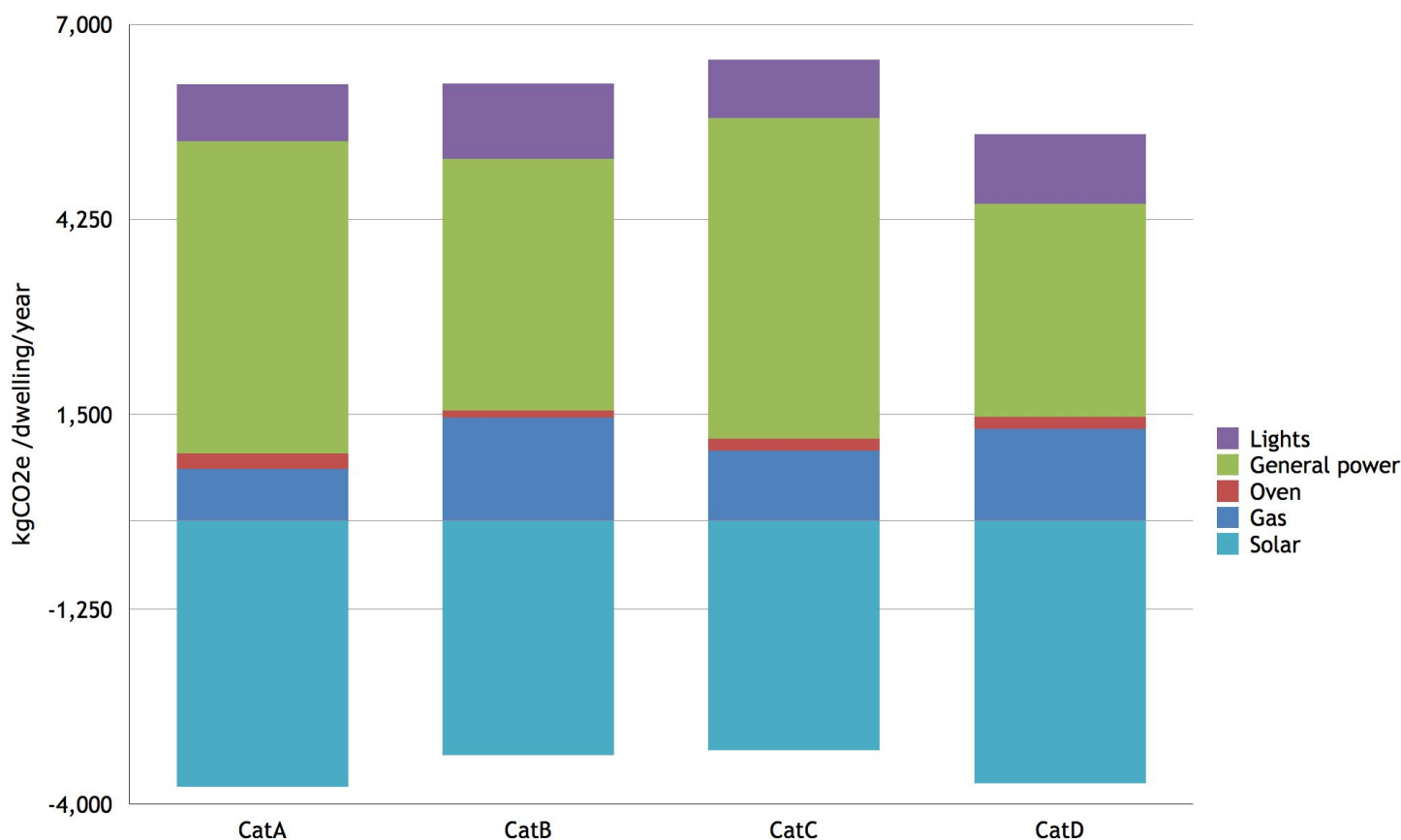
**Figure 28: Environmental performance per number of occupants of dwellings in comparison to the SIP household and the department Standards.**

Looking at the houses in more detail, Figure 29 presents the contribution for each Catalyst house of gas and electricity consumption, with Figure 30 breaking this down further to the various electrical

elements monitored. There is a 26 per cent difference between the highest (CatB) and the lowest (CatA) consumption.



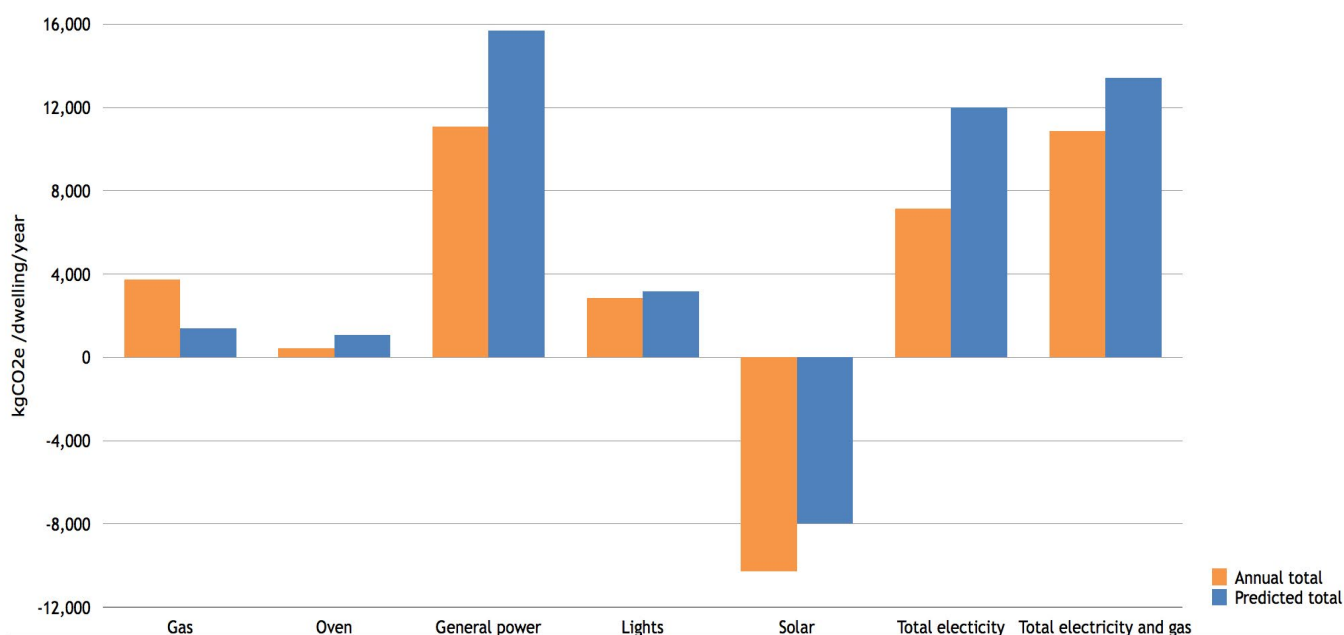
**Figure 29: Contribution of gas and electricity to annual CO2e from Catalyst houses (source: Ian Adams – Organica Engineering).**



**Figure 30: Contribution of gas and individual elements of electricity (including negative solar contribution) to annual CO2e from Catalyst houses (source: Ian Adams – Organica Engineering).**

When the actual performance of the Catalyst houses is compared to the predicted performance by Organica Engineering (see Figure 31), overall the Catalyst houses performed only five per cent higher than predicted. In looking at the individual consumption elements, the usage of gas was significantly higher than predicted (317 per cent), usage of electricity for lights was higher (15 per cent), and the generation of solar was higher than predicted (176 per cent). The usage for oven (64

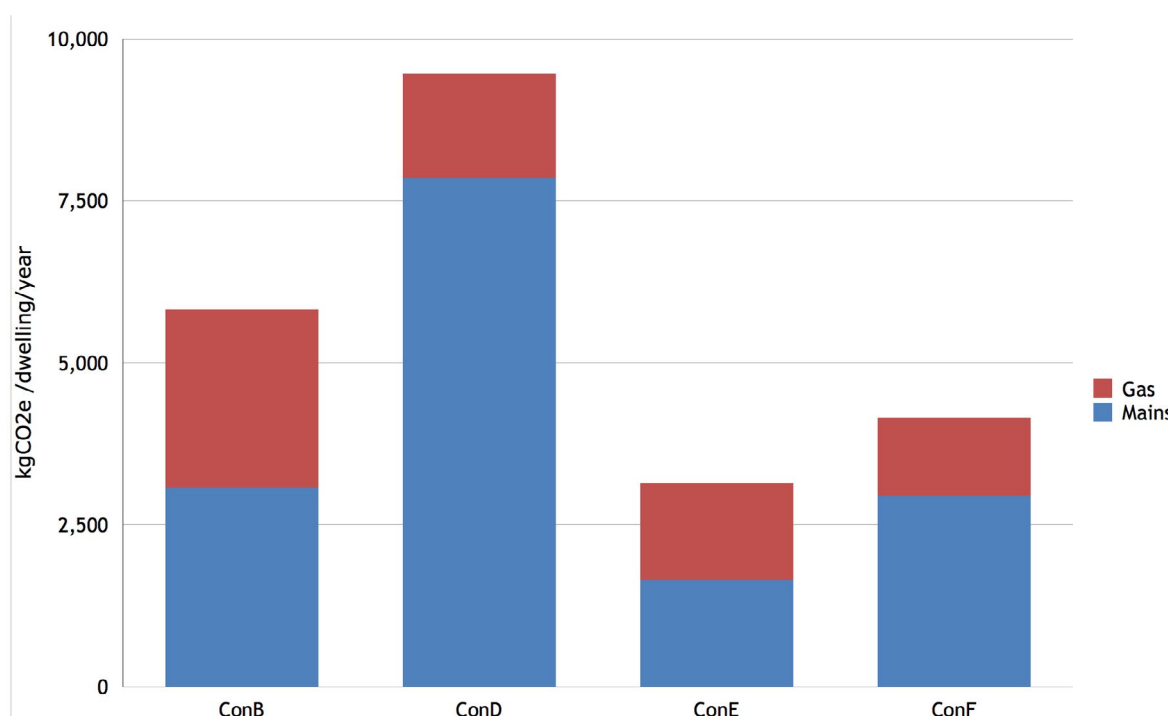
per cent), general power (one per cent) and total electricity (25 per cent) were all lower. The high usage of gas indicates that the Catalyst households were using more gas to heat their dwellings during winter than predicted. This in part was driven by at least one colder than average winter during the research period, and likely that the households were setting their temperatures higher than estimated in initial predictions.



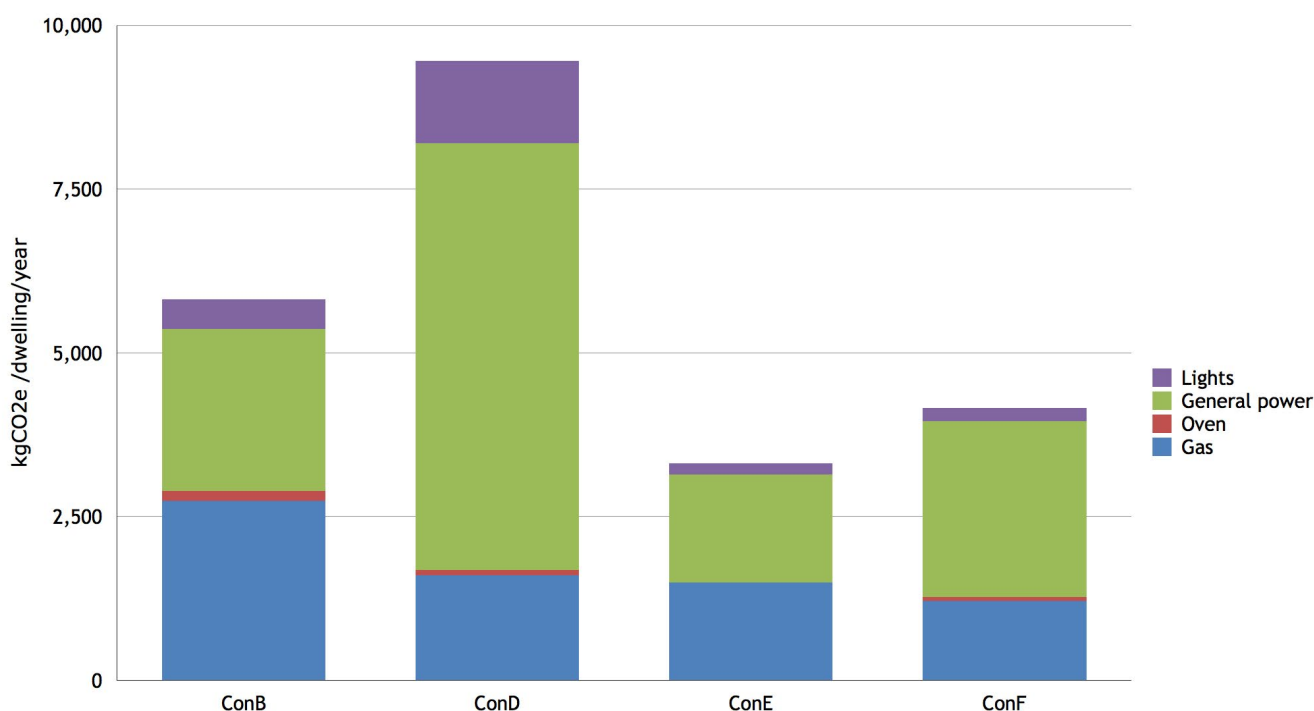
**Figure 31: Organica Engineering's initial environmental performance predictions of Catalyst house performance (across all four) compared with actual performance (source: Ian Adams – Organica Engineering).**

Looking at the Control houses in more detail, Figure 32 presents the contribution of each house for gas and electricity to annual CO<sub>2</sub>e, with Figure 33 breaking this down further to the various electrical elements

monitored. There is significant difference (285 per cent) between the lowest (ConE) and the highest (ConD) Control houses, which is driven by a large difference in general power environmental impact.



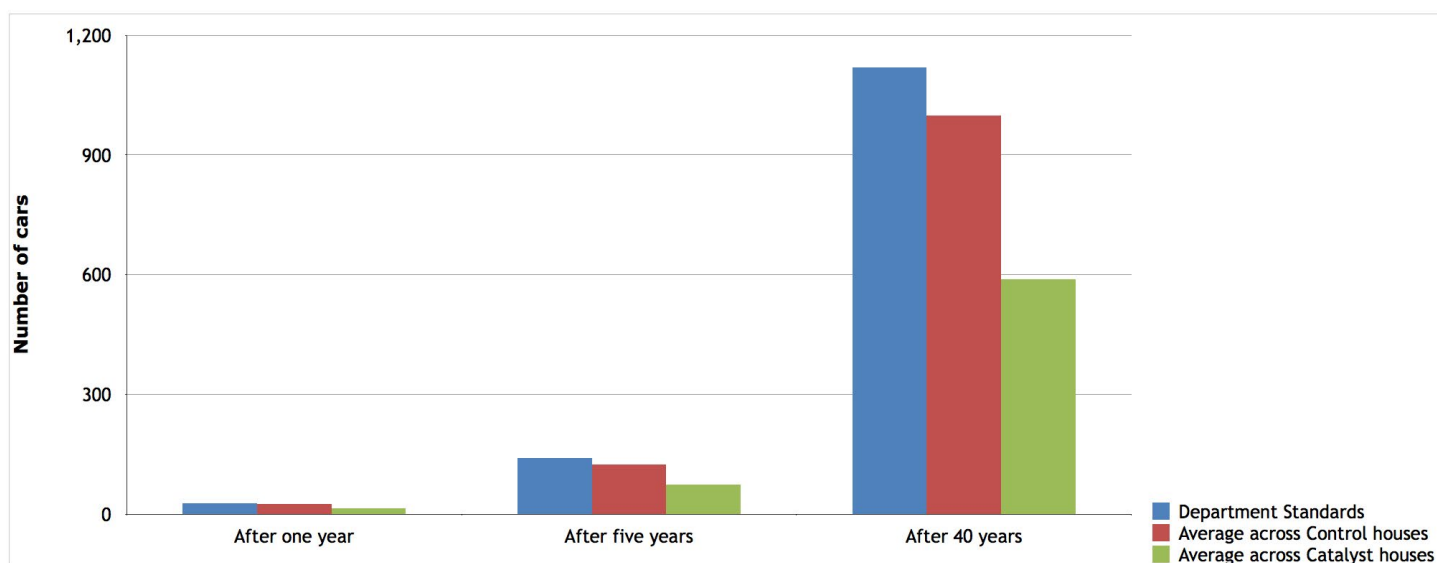
**Figure 32: Contribution of gas and electricity to annual CO<sub>2</sub>e from Control houses (source: Ian Adams – Organica Engineering and RMIT University).**



**Figure 33: Contribution of gas and individual elements of electricity to annual CO<sub>2</sub>e from Catalyst houses (source: Ian Adams – Organica Engineering and RMIT University).**

Figure 34 presents the above environmental impact data in terms of equivalent number of cars across different timeframes. Across an assumed 40-year lifespan of a Catalyst dwelling, it saves an average

of 551 cars worth of greenhouse gas emissions compared to a department Standards house, and 387 cars worth of greenhouse gas emissions compared to the average across the Control houses.



**Figure 34: Car equivalent of environmental performance.**





UNIT 1

# 7. Summary of research findings

This section presents a summary of the research analysis from Sections 3 to 6 and draws implications for the department, tenants and the wider stakeholders involved in the project.

## 7.1. Household interviews

Overall, Catalyst households reported or were observed:

- expressing satisfaction with their dwellings and taking pride in the appearance of their dwelling (except with some issues with one of the households)
- having lower utility consumption
- having significantly lower utility costs due to the sustainability features (for example, water tank plumbed into house and solar panels)
- being able to pay their utility bills more easily with reduced stress
- having additional money available for discretionary items and experiences such as going on a holiday or buying clothes
- demonstrating an improvement to their thermal comfort and health during extreme weather events compared to their previous dwelling, translating to fewer trips to the doctor or hospital
- being able to adequately adapt during extreme heat without the use of an air conditioner (although one household had an air conditioner installed for health reasons) and staying at home during such events
- demonstrating an overall improvement in life circumstances, life satisfaction and wellbeing, including one household removing themselves from all CentreLink payments
- having improved neighbourhood satisfaction,

perception of neighbourhood safety and relationships with the department regional office.

However, there were some indicators that had not changed in comparison to their previous dwelling, including:

- engagement with environmental sustainability as households already believed they were low consumers of utilities
- engagement in gardening and composting activities.

Control households reported limited and less consistent improvements across the above evaluation indicators compared to their previous dwellings.

In comparison to Catalyst households, Control households were found to:

- have more issues paying their utility bills on time (including two who had been put on prepayment plans)
- report lower satisfaction with thermal comfort and demonstrate an over-reliance on mechanical cooling to stay cool in summer (which in turn impacted on electricity usage and costs), including one household who had to vacate their house during prolonged periods of heat
- have significant neighbourhood issues and safety concerns in one cluster of three households living on the same street
- experience ad hoc changes to improved life circumstances unrelated to their dwelling (but related to the provision of secure tenure)
- experience lower satisfaction with their relationship with the department regional office.



## 7.2. Stakeholder interviews

The tradespeople who were interviewed were happy to have been involved in the project and believed the project worked well overall. However, they also reported no increase of ESD work because of their involvement in the project. There were three key reasons raised as to why this was the case: 1) there was no location promotion of the project; 2) changes to Federal and State Government policies, rebates and feed-in tariffs meant that the incentive for sustainability technologies (specially solar) were reduced; and 3) they needed to build a portfolio of sustainability work before additional work would be forthcoming. The tradespeople did acknowledge, however, significant benefits for the department and tenants as a result of the project.

While all stakeholders were satisfied with the project overall, there were some key lessons with regards to design, material and technology choices that could improve future developments. Significant delays at the start of the project between design and construction caused issues in terms of efficiency of work and resulted in some outdated material and technology choices being made in this rapidly changing area. There was also a high number of variances made to the design and construction after the contract had been signed, which added time and costs to the project.

Despite working on a market-leading innovative sustainability development, only one of the tradespeople interviewed had used this experience to make changes to their own practices.

## 7.3. Housing performance and cost-benefit analysis

Overall the Catalyst houses performed significantly better than the Control houses and the department

Standards for utility consumption, environmental performance and thermal comfort. However, financial payback through a traditional CBA was problematic within 40 years. Specifically:

- On a per dwelling basis, the Catalyst households purchased 73 per cent less electricity compared to the SIP household, 62 per cent less electricity compared to the department Standards, and 45 per cent less electricity compared to the Control households.
- On a per dwelling basis, the Catalyst households consumed 239 per cent more gas compared to the SIP household, three per cent less gas compared to the department Standards, and 15 per cent less gas compared to the Control households.
- Overall the Catalyst houses used five per cent more energy than the SIP household, 12 per cent less energy than the department Standards, and seven per cent less energy than the Control households.
- On a per dwelling basis, the Catalyst households purchased 30 per cent less mains water compared to the SIP house, 28 per cent less mains water compared to the department Standards, and 22 per cent less mains water compared to the Control households.
- On a per household basis, the Catalyst houses had 63 per cent less environmental impact from their energy operation compared to the SIP house, 50 per cent less impact compared to the department Standards, and 40 per cent less impact compared to the Control houses.
- When looking at the adaptive thermal comfort criteria, the Catalyst houses were comfortable 10 per cent more of the time in the living areas and comfortable seven per cent more of the time in the bedrooms compared to the Control houses.
- The difference is more pronounced during

extreme weather events. For example, on the second consecutive day of temperatures above 41oC, the difference between the hottest Control house (which had air conditioning) and the coolest Catalyst house was 16.6oC (without air conditioning).

- In terms of the blower door test, the Catalyst houses performed better than the Control houses, indicating quality design and construction.
- The additional capital cost for the improved sustainability elements was about twice that found in recent Australian and international research.
- Only two of the Catalyst households will achieve a payback within 40 years at a high energy price future (and none at a low energy price future) using the traditional CBA approach.
- This outcome improves if elements such as improved tenant health and wellbeing and improved resale value are included.
- When analysing the individual sustainability elements, the most cost-effective option was the inclusion of solar panels, followed by the rainwater tank plumbed into the house. The building envelope improvement was the least cost-effective element.

## 7.4. Home advisory tours

Home advisory tours were conducted with a sustainability expert, who was also a member of the research team, to inform them about ways to further reduce the households' utility bills and environmental impact (see Section 3). These tours were well received by the households that participated. However, there was a limited number of suggestions that could be made due to a range of challenges, including financial and health considerations, and because most households were already frugal in their use of utilities. The third round of interviews found that only two households had made a significant change to the way

they did things in their dwelling as a direct result of the home advisory tour. These changes were reported as switching from washing clothes in warm water to cold water in one house, and turning the heater off properly when not home in another. Many of the households indicated that they did not think the savings were worth the effort or did not want to change what they had always done (for example, leaving the computer on all the time).

## 7.5. Implications

Catalyst houses and households performed significantly better across a range of indicators and metrics compared to the Control houses and households and against the department Standards and SIP households. In this regard the Catalyst houses are both Australian and international leading examples of sustainable housing best practice, particularly at the time of their design when there were very few nine-star-plus housing examples in Australia. With a nine-star performance rating, the houses are comparable to the German Passive House standard, which is regarded as one of the most stringent sustainable housing standards in the world. Since construction, there have been some other nine- and now 10-star developments (for example, Josh Bryne's 10-star house in Western Australia), but these remain the exception in the building industry, with the majority of new construction being built in the six to seven-star range. Additionally, there are few other examples of such low carbon, energy and sustainable housing developed by housing agencies, either in Australia or internationally.

The Catalyst houses are performing well in terms of both overall utility consumption and utilities bought from the grid in comparison to the Control houses, the department Standards and SIP house. This has a number of implications if replicated more broadly across the department or general public housing

stock. Firstly, it reduces the requirement to use fossil fuel energy, which could negate the need for new generation plants to meet the demand of an increasing population, and secondly, it could help generate a business case to close down old fossil fuel energy plants that are no longer required to provide energy. Thirdly, the wider adoption of Catalyst housing could also reduce peak electricity demand on extreme heat days, which would assist in stabilising electricity pricing across the electricity network. In addition, a reduction in potable water use would help future-proof communities against predicted ongoing drought conditions.

The Catalyst households achieved a 50 per cent performance improvement of greenhouse gas (GHG) emissions compared to the department Standards dwelling. Such improvement has major implications if replicated across the department housing stock of 85,200 dwellings. While it is more difficult to improve the environmental performance of existing dwellings, the research provides evidence to support a new benchmark for new department housing, and provides a pathway for upgrades to existing housing stock. For example, the department could set a 25 per cent improvement in energy efficiency for existing dwellings. If this could be achieved, it would also have wider implications on the operational GHG emissions from the Victorian and Australian housing sector. Based upon Australian Bureau of Statistics data [105], department housing stock represents approximately 3.7 per cent of total housing in Victoria. A 25 per cent improvement to energy efficiency and GHG emissions across department housing stock could therefore have a small, but not insignificant improvement for the housing stock in Victoria of 0.9 per cent. The department therefore has the ability to shape wider housing developments in Victoria and Australia due to the department's unique ownership of a large number of dwellings.

Furthermore, there is a challenge regarding how much active engagement to reasonably expect from tenants in order to maximise ESD outcomes. For example, the inclusion of solar PV 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 Catalyst 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 ESD processes. This can impact on the overall benefits to the tenants, the department and the environment, and prompts the question about how much of the design should be passive and not rely on tenants to direct outcomes and performance. Importantly, there is no simple division between 'design' and 'behaviour' that can be drawn here. Tenants engaged with their dwellings in a range of ways (predictable and unpredictable) that both supported and undermined sustainability objectives.

Understanding how to keep the department tenants engaged with sustainability and making efficient use of their dwellings will help to maximise the benefits outlined above, for the department, tenants and broader society. It was clear from the interviews with the tenants of both Catalyst and Control households that providing them with written material in the form of a guidebook or similar is unlikely to be an effective option. Personalised home advisory tours with a sustainability expert were trialled as a way of improving the performance and use of each dwelling. A number of difficulties were also raised during this process, including how much change these households could realistically achieve. However, there was some evidence of households making small changes. Reminders or advice about how to use houses efficiently could be integrated into the inspections

conducted by housing agency staff.

However, the above benefits and outcomes are offset against the higher initial capital costs of the Catalyst houses. On a traditional CBA approach, the Catalyst houses do not achieve payback within a 40-year assumed lifespan. This does not factor in considerations of broader benefits such improved household health, especially during extreme weather events. This has led to a reduction in the number of trips to the doctor and hospital for tenants and, if replicated across the department housing stock, could have significant implications for health and healthcare costs.

In addition, the research found that the extra capital costs for the sustainability elements of the Catalyst houses could be significantly reduced if the development is repeated (about 50 per cent less) due to cost efficiencies in the design, materials and technologies. This would significantly address issues of payback periods and make the project a more financially viable option.

The research highlights the question of trade-offs and overall objectives. For example, if capital cost efficiency is important, a future development could be built to a slightly lower star rating (for example, eight star) but include more solar panels, thus reducing living costs for tenants even further. However, by reducing the thermal performance of the dwelling, this negates

some of the clear benefits for health and comfort both across the year and in extreme weather events. Further, an eight-star house would likely require some form of air conditioning, whereas the Catalyst houses demonstrated that at nine stars, air conditioning can be excluded. A key question is whether the objective is to reduce living costs of tenants as cost efficiently as possible or whether it is to improve the health and wellbeing (including financial wellbeing) of tenants.

The final point concerns the stakeholders and tradespeople involved with the project. It was an aim of the department to help facilitate innovation with the tradespeople involved, but in reality there has been little improvement in terms of practices or increased ESD work from being involved in the project. While some of this is due to changes to government policy around rebates, there was also a missed opportunity to more widely promote the project and those involved. As already stated, the department has the opportunity to be a leader and shape the future direction of the new and renovated building industry in Victoria and Australia for a transition to a sustainable housing future; not only from an environmental sustainability perspective, but also in terms of improved tenant outcomes (finance, health and wellbeing) and broader social and business benefits.



## 8. Recommendations

The Catalyst houses resulted in improved outcomes for the department, the tenants, society and the environment across a range of metrics. The following recommendations assume this set of the department objectives for new housing:

- improved tenant comfort
- minimised tenant vulnerability to energy and water costs (low operating costs)
- tenant safety in extreme weather
- durability and low maintenance of assets
- low construction costs.

With this in mind, the research team makes the following recommendations:

### **Design and construction**

1. The department Standards can be improved to benefit tenants and the environment using low-risk construction methods and technologies.
2. In the social housing context, best value for money is achieved with an eight-star building envelope (rather than nine stars) and reinvesting some of these capital cost savings into a larger solar panel system for each dwelling. This would reduce costs for the department while improving economic outcomes for tenants. An eight-star house would also reduce peak energy demand during hot spells compared to a standard dwelling.
3. The design of both new and retrofitted dwellings should consider providing smaller spaces for tenants to heat and cool during times of extreme weather so they don't have to heat and cool entire dwellings or large open spaces.
4. Ensure dwelling gardens contain climate-appropriate plants to encourage more tenants to

participate in gardening activities.

### **Maintenance**

5. Develop a clear schedule of works for sustainability building elements and technologies, including maintenance and cleaning requirements, to ensure these elements can operate with maximum efficiency.
6. Consider installing remote monitoring of sustainability technologies to promote early detection of faults and maintenance needs.

### **Tenant-department relationship**

7. Engage tenants in home sustainability strategies through strong relationships with regional contacts and tailored in-person advice, rather than through generic call centres or extensive written information (which is only likely to assist a limited number of literate and engaged tenants). Focus mainly on interested tenants.
8. Provide alternative cooling options to air conditioning for tenants during extreme heat events, such as low-cost retrofitting (for example, ceiling fans, secure screen windows and doors, external shading), provision of other accommodation, and cooled community facilities (for example, public libraries).
9. Use language for trial projects that is more engaging for tenants and media. For example, rather than 'Catalyst', name projects to reflect their comfort, health and liveability benefits.

### **Evaluation, process improvement and data management**

10. Repeat holistic evaluations of new and existing

housing developments so that a more detailed understanding of the costs and benefits, including observed and unmeasurable health and wellbeing benefits, are captured and fed into the departments whole-of-life financials and policy development.

11. Develop a larger new build trial based on this evaluation to explore ways to improve capital costs for such projects across a range of department dwelling types. This would also address the limitation of this study, which is the small sample size.
12. It is important that these evaluations are mixed methods, as this evaluation has demonstrated that relying on quantitative or qualitative data alone would not have captured the complete story of how the Catalyst houses were performing.

## 9. Appendix 1 – Semi-structured household interview questions (round 1)

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### Experience of last home

1. Where did you live before you moved here?
2. Could you tell me/us a little bit about your last home/apartment?
  - a. How happy with it were you?
3. What did you like most about your last home?
4. What did you dislike most about your last home?

### Experience of current house

5. Thinking about this current house, what do you remember about moving in?
6. Do you have a particular memory about moving in here that you would like to share?
7. Now that you have been in this house for a year or so, how do you feel about living here/how have you settled in?
8. What do you like most about it?
9. What do you dislike most about it?
10. How do you find living here compared to your last home?
11. How/why do you think your quality of life has changed since living in this house?

### Thermal comfort

12. Do you find this home comfortable in winter?
  - a. Why? What makes it comfortable/uncomfortable?
  - b. How does keeping warm in winter in this home compare to your last house?
13. What do you do to keep yourself warm in your home during winter?
  - a. Do you do anything different to stay warm on really cold days?

14. Do you find this home comfortable in summer?
  - a. Why? What makes it comfortable/uncomfortable?
  - b. How does this compare to your last house?
15. What do you do to keep yourself cool in your home during summer?
  - s. Do you do anything different to stay cool on really hot days?
  - b. (If they have air conditioning or mention they use air conditioning) What temperature do you like to set your air conditioner to?
  - c. Does this change on a really hot or cold day?
16. Can you remember a day when the house has been really uncomfortable (too cold or too hot) over the past year?
  - a. If yes, what did you do on that day?
  - b. Are there any areas of the house that are particularly hot or cold?
17. Do you or other households have any health concerns that are affected by the heat or cold?
18. Have there been any changes to your health over the past year?
  - a. If yes, do you think any of these health concerns are linked to your current house?
19. Do you feel like there's enough ventilation/air flow in your house?
  - a. Do you do anything to increase/reduce the air flow?
20. (If needed – some may be solo households) Do some households feel the heat or cold more than others?
  - a. If yes, what sorts of things do you do to manage this?
21. If you have pets, do you ever heat or cool the house for them? If so, how?
22. Is there anything in your home that needs to be

kept at a certain temperature?

23. Have you experienced any electricity blackouts since moving into this house?
- If yes, have these blackouts ever occurred on really hot or cold days?
  - If yes, how did you stay cool/warm during these times? What sorts of things did you do?

## Utility consumption

24. Do you keep an eye on your energy and water consumption?
- Did you do this in your last house?
25. Have you noticed any changes to your energy or water consumption since moving into this house?
- If yes, how has it changed? Why do you think this has happened?
26. Have you noticed any changes in your energy/water/gas bills compared to your last house?
- Do you feel you can control your energy/water/gas costs?
  - Why/why not?
  - Have you had difficulty paying your energy/water/gas bills while living in this house?
  - Did you ever have difficulty paying your energy/water/gas bills while living in your last house?
27. Do you find you have additional money left over after paying your energy/water/gas bills compared to your last house?
- If yes, what do you do with this additional money?
28. Have you had any changes to concessions you may receive for energy/water/gas costs?
- If yes, how?
  - What do you think about this?
29. Have you purchased or acquired any new appliances since you moved into this house?
- If yes, which ones?
30. Can you tell me about how you use your television and computer in this house?
- Has this changed compared to your last house?

b. If so, how has this changed? Why?

31. Can you tell me how you use the lighting in your house?
- Has this changed compared to the last house?
  - If so, how has this changed? Why?
  - What is it like during the day with the lights off? Do you have enough light to do the things you want to do?
32. Can you tell me how you do your laundry in this house?
- Has this changed compared to the last house?
  - If so, how has this changed? Why?
33. Have you changed anything about how you bathe or shower since moving to this house?

## Sustainability features

34. Do you do anything/any other things around the home to try and help the environment?
- If no, why not?
  - If yes, what sort of things do you do?
  - If yes, have you always done these things or did you start them when you moved into this house?
35. Are you interested in gardening?
- If no, why not?
  - If yes, why?
  - Has this changed since you moved into this house?
  - If interested in gardening, do you grow any of your own food or compost food waste?
  - Have you noticed a reduction in waste going to landfill?
36. Were you provided with information on how to use the sustainability technologies/house when you moved in?
- If yes, who provided this information to you?
  - How and when was this information provided?
  - Did you learn anything from this information?
  - Is there anything you are still unsure about?
37. Have you had any issues/difficulties with any of these sustainability features/the house that we haven't already discussed?

- a. If yes, have you tried to contact anyone about this issue?

## Conclusion

- 38. If these houses were to be built again, what would you recommend to change, if anything?
- 39. What would you keep the same?
- 40. Do you have anything else you'd like to share about your home, the sustainability features or the way in which you use it?
- 41. Do you have any other questions for us?

## House tour

- 42. Would you mind taking me/us on a short tour of your house to point out some of the sustainability features/energy and water appliances/technologies and how you use them?

# 10. Appendix 2 – Semi-structured stakeholder interview questions (round 1)

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## Interview questions for the department staff

### House tour

- 1. Could you start by telling me a little bit about your professional role?
  - a. What do you do?
  - b. How long have you done this for?
- 2. What is the nature of your involvement in the Horsham Catalyst project?
  - a. How did you become involved in the project?
  - b. What was/is your specific role within the project?
  - c. Can you tell me an unexpected outcome or story to have come from the project?
  - d. What do you think has worked about the project?
  - e. What do you think has not worked about the project?

### Processes and governance

- 3. How are decisions currently made at the department regarding whether to include ESD features in new housing developments, and which

to include?

- 4. Who is responsible for sourcing and purchasing products?
- 5. What is the selection process for builders and trades to install and maintain ESD features?
- 6. Are builders and trades required to follow ESD guidelines regarding energy/water use and on-site waste?
- 7. If so, how are these guidelines communicated and who is responsible for checking compliance?
- 8. Who is responsible for communicating with builders/trades and monitoring their work?
- 9. Were there any issues with builders/trades?
  - a. If yes, what did you learn from these issues?
- 10. Who is responsible for monitoring and maintaining the houses, especially the ESD features?
  - a. Is this done on a regular basis?
- 11. Who do tenants contact if they have any questions about their houses in terms of ESD or other features?



12. What is the typical process for addressing these questions and resolving any issues that might arise?

## Stakeholder management

13. Were you or are you involved in managing any contractors for this project?
14. If yes, have you had any difficulties with this process?
- a. How did you deal with these difficulties?
  - b. What was the outcome of this process once the difficulty had been dealt with?
  - c. Do you have any recommendations on how this process could be improved for future projects?

## Engagement

15. In your role on the Horsham Catalyst project, do/ did you engage directly with the tenants of the Catalyst houses?
- a. If so, what is/was the purpose and nature of this engagement?
  - b. How did/do you engage with the households?
  - c. How often would you engage with them (indirectly and face to face)?
  - d. What resources/information did/do you provide to the households?
  - e. How was/is this received by the households?
  - f. In your opinion what engagement strategies worked best?
  - f. Which engagement strategies haven't worked so well?
  - g. How do you think tenant engagement activities could be improved?
16. What do you think it would be like to live in one of the Catalyst houses?
- a. Would you like to live in one?
  - b. Why/why not?
17. Have you spoken with the tenants of these houses informally?
- a. What sort of feedback have you received from the

tenants about the properties?

## Conclusion

18. What do you consider are the benefits of the Horsham Catalyst project?
- a. How would you improve similar projects in the future?
19. Is there anything else you'd like to add or any questions you have for us?

## Interview questions for building contractors and trades

## Introduction

1. Could you start by telling me a bit about your professional role?
- a. What do you do?
  - b. How long have you done this for?

## ESD, processes and governance

2. What is the nature of your/your company's involvement in the Horsham Catalyst project?
- a. What was your/your company's specific role within the project?
  - b. How did you/your company become involved in the project?
  - c. How many local (Horsham area) people were employed by your company to work on this project?
3. Was there a selection process you had to go through to get this work?
- a. What did this entail?
4. Did you have to meet any criteria or follow any guidelines from the department when undertaking work on the Catalyst houses?
- a. Can you describe these?
  - b. Did you require any specialist knowledge or skills to undertake work on the Catalyst houses, for example, in ESD features?
  - c. Where did you acquire this knowledge?

- d. Did the work require you to learn new ESD skills specifically for this job?
- 5. Prior to this work, did you or your company routinely follow any framework or guidelines for sustainable work practices, for example, energy and water use, waste etc.?  
a. If yes, how were/are these implemented and assessed?
- 6. Were you/your company involved in the decision-making process with the department for the selection and purchase of suitable ESD products for the houses?  
a. If so, what did this entail?
- 7. Are you/your company involved in the ongoing maintenance and repair of ESD and other features of the houses?  
a. If so, how is this coordinated?
- 8. Has your/your company's involvement in the Catalyst project changed the way you operate in any way, for example, promotion, training, skills, business practices?  
a. If so, please describe how?
- 9. Has there been any flow-on ESD work following your involvement with this project?
- 10. Were there any issues working with the department?  
a. Did you do anything to resolve these issues?  
b. If so, what did you do and what was the outcome?

## Work

- 11. Where did you source your materials from?  
a. Was there an increase of local materials?
- 12. Can you tell me if there was a reduction in construction waste from your work on this project?  
a. If so by how much (% wise)?  
b. Did you use local recycling facilities?
- 13. Can you tell me about any innovative building practices or materials used in this project?
- a. How did these turn out?
- b. Would you do anything differently if you had the chance?

## Engagement

- 14. Throughout your involvement with the department Catalyst development, did/do you/your company engage directly with the tenants of the Catalyst houses?  
a. If so, what is/was the purpose and nature of this engagement?  
b. How did/do you engage with the households?  
c. How often would you engage with them (indirectly and face to face)?  
d. What resources/information did/do you provide to the households?  
e. How was/is this received by the households?  
f. In your opinion what engagement strategies worked best?  
g. Which engagement strategies haven't worked so well?  
h. How do you think tenant engagement activities could be improved?

## Conclusion

- 15. Can you tell me a good news story or unexpected outcome to have come from the project?
- 16. What do you consider are the benefits of the Horsham Catalyst project?  
a. To the households?  
b. To the department?  
c. To companies like yourself?
- 17. Are there any things that you would have done differently?  
a. What are any key lessons you would give for similar projects in the future?
- 18. Is there anything else you'd like to add or any questions you have for us?

# 11. Appendix 3 – Advisor guide for home tour

Topic	Recommendation notes (assessor use)
Energy source(s):      Electricity only      Electricity & Gas Solar PV:                      Yes                      No Water tank:                  Yes                      No	
Electricity use Gas use Water use Concessions eligibility	
Kitchen <ul style="list-style-type: none"> <li>• Cooking</li> <li>• Washing up</li> <li>• Use/thermostat/type/maintenance of fridge(s) and freezer(s)</li> <li>• Other activities, for example, making coffee or hot drinks</li> <li>• Tap flow rates/drips*</li> </ul>	
Living room – staying cool and warm* <ul style="list-style-type: none"> <li>• Use of heaters</li> <li>• Use of fans (including reversibility) and/or cooling</li> <li>• Gaps/draughts including any chimneys</li> <li>• Use of windows and window coverings/shading</li> <li>• Use of doors (including for pets)</li> </ul> Catalyst: <ul style="list-style-type: none"> <li>• Use of celestial windows</li> <li>• Use of entry air lock</li> <li>• Check data logger</li> </ul>	
Living room – entertainment/study/work* <ul style="list-style-type: none"> <li>• TVs</li> <li>• ICTs</li> <li>• Standby power</li> </ul>	
Living room – lighting* <ul style="list-style-type: none"> <li>• Use</li> <li>• Type of globes</li> </ul>	

<p>Laundry</p> <ul style="list-style-type: none"> <li>• Washing clothes</li> <li>• Drying clothes</li> </ul> <p>Catalyst:</p> <ul style="list-style-type: none"> <li>• Use of laundry windows</li> <li>• Water tank gauge</li> </ul>	
<p>Bathroom</p> <ul style="list-style-type: none"> <li>• Toilet (flush volume and use)</li> <li>• Showering/bathing practices</li> <li>• Shower flow rate</li> <li>• Use of bathroom heating/heat lamps</li> <li>• Use of fan</li> </ul>	
<p>Bedrooms</p> <ul style="list-style-type: none"> <li>• As per above as relevant</li> </ul> <p>Catalyst only:</p> <ul style="list-style-type: none"> <li>• Bedroom 1: Check data logger</li> </ul>	
<p>Other activities using energy</p> <ul style="list-style-type: none"> <li>• For example, power tools</li> </ul>	
<p>Outdoors</p> <ul style="list-style-type: none"> <li>• Hot water system</li> <li>• Water/water tank</li> <li>• Garden</li> <li>• Compost</li> <li>• Recycling</li> </ul> <p>Catalyst only:</p> <ul style="list-style-type: none"> <li>• Maximising financial benefit from solar PV if on a feed-in tariff</li> </ul>	

\* Topics to be considered/discussed throughout walk-through as relevant to house features.

De-identified example of home tour recommendations sheet

Home Tour	
Name: <span style="background-color: black; color: black;">[REDACTED]</span>	
Address: <span style="background-color: black; color: black;">[REDACTED]</span>	
Going well	<p>External verandah blinds - very good for summer cooling.</p> <p>Little use of lighting or TV</p> <p>Drying clothes outside</p> <p>Washing in cold water</p> <p>Not using air conditioner (portable)</p>
Recommendations	<p>Lift verandah blinds for winter</p> <p>Switch off computer when not in use</p> <p>(summer) When very hot inside, try opening high windows for 10 minutes to let some heat out.</p> <p>Switch off heater when going out / to bed.</p>
Other notes	<p>Water tank is empty</p> <p>Fans are on summer setting.</p>

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