LOW CARBON LIVING CRC

Mainstreaming Net Zero Energy Housing

Cost Analysis Report

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Executive Summary

The Cooperative Research Centre for Low Carbon Living (CRCLCL) research project *Mainstreaming Net Zero Energy Housing* aims to improve industry understanding of Net Zero Energy Homes (NZEH) while addressing cost and consumer interest barriers. The project also provides a unique opportunity to increase collaboration between industry players such as land developers and volume builders. This report is the second of a series of three by the authors, following on from the *NZEH Design Review Report* and explores the costing and financial payback of the NZEH upgrades for each of the four case study designs.

Based on energy modelling conducted in the design review process and retail costings provided by the builders, initial installation costs and annual savings were calculated. The costing analysis was then conducted across a 25-year lifespan, aligning with previous research on high performance buildings, as well as placing the analysis over a similar time period to a standard mortgage. The analysis used energy prices for each of the four case study locations and accounted for maintenance and replacement costs of appliances. Analysis was conducted across five different electricity market scenarios including increased electricity prices, continuation of feed-in tariffs, and elmination of feed-in tariffs.

The key findings are:

- Solar PV and Heat Pump or Evacuated Tube hot water systems are the two most cost effective upgrades across all case studies. Both of these upgrades show payback within 10 years at current energy prices.
- Thermal shell upgrades provide effective and meaningful cost reductions, however increased installation costs compared to the standard house design pushes payback beyond 10 years. In most cases, given the extended lifespan of the thermal shell, these savings outweigh the costs over the 25 year analysis period.
- NPV of NZEH upgrades is positive under energy price increase scenarios.

Introduction

In 2016, Australia ratified the Paris Climate Agreement, committing to reach net zero emissions by 2050 alongside other developed countries ('United Nations Treaty Collection', 2015). While Australia is reported to being on target to meet the interim targets for 2020 and 2030 (Department of Environment and Energy, 2018), this includes 'carryover' from overachieving against earlier targets, meaning a true net zero target still requires significant effort to achieve. Approximately 50% of electricity consumption is from buildings (Vivid Economics, 2013), both commercial and residential, resulting in nearly 25% of Australia's carbon emissions being directly attributed to buildings, including emissions from direct combustion (Department of Environment and Energy, 2018). Buildings must therefore be a crucial part of the overall strategic carbon reduction plan.

The residential building minimum energy efficiency performance standards have remained unchanged since 2012. The NatHERS pathway, part of the 'Deemed to Satisfy' provisions within the National Construction Code (NCC) mandates a 6-star for new dwellings (Australian Building Codes Board, 2016). It is important to remember that states and territories may adapt or alter sections of the NCC, and so this standard may not necessarily represent a truly nation-wide minimum. NatHERS also only evaluates heating and cooling loads per square metre for a dwelling (40% of total loads), and does not include other major sources of energy use such as water heating (21%), fixed appliances and cooking (33% for combined appliances and cooking loads) (McGee, 2013). Increases in the number of appliances per household and reductions in numbers of occupants per dwelling indicates that overall consumption in the residential sector may rise (Moore, Clune and Morrissey, 2013). Ignoring these components when targeting reductions in energy use is likely to restrict the effectiveness of the strategy for reducing overall carbon emissions.

Net Zero Terminology

Many terms are used within the literature when discussing high-performance dwellings. These include, but are not limited to, 'zero energy', 'low energy', 'nearly zero energy', and 'net zero energy' homes. Broadly speaking, these terms have been used interchangeably to mean buildings that are highly efficient in their use of energy, not just with regards to heating and cooling loads, but the overall energy consumption of the home. An important point however is that a 'zero energy home' does not literally mean a home which uses no energy. For this study, the more understandable term 'net zero energy' home is used.

A 'net zero energy' building uses the concept of an annual energy balance, consuming less energy than it generates on-site (Marszal *et al.*, 2011; Sartori, Napolitano and Voss, 2012), regardless of the time-of-demand supply. This implies that the dwelling may be connected to the grid, and can at times import electricity, but the net effect of the import-export results in more energy being exported than imported on an annual basis.

There are potentially numerous ways in which to define the energy balance of a net zero energy building, for example weighting energy use based on peak demand periods. For this study, the simpler approach of balancing annually aggregated energy consumption and generation is used.

Achieving 'Net Zero Energy' Homes

Achieving net zero energy homes comes down to improving the efficiency of energy use as much as reasonably possible, and then offsetting the remaining energy demand by using an on-site generation system (Berry, Whaley, Saman, *et al.*, 2014) - typically solar PV arrays, increasingly including battery systems for on-site storage. Reducing energy demand comes in the form of designing a high-performance thermal shell, and utilising high-efficiency appliances for air conditioning, water heating, as well as other fixed appliances and white goods (Berry, Whaley, Saman, *et al.*, 2014). This results in minimising the required size of the on-site generation and storage system, which has traditionally been the single largest expense. As technology has improved, it has become easier to reduce the demand caused by a single appliance as well as increase the on-site generation capacity.

Benefits of Net Zero Energy Homes

The benefits of Net Zero Energy homes are numerous. The two most obvious benefits are of course reductions in running costs of the dwelling (Berry and Davidson, 2016), as less energy is imported and revenue is gained from energy exported, and the reduction in carbon emissions as the on-site generation is typically a renewable source (Sartori, Napolitano and Voss, 2012). The reduction in carbon emissions is highly important as this links the development of more net zero energy buildings with Australia's international commitments.

In addition to these 'direct' benefits, there are indirect or flow-on benefits relating to health and wellbeing, both for the occupants of the net zero energy home and the wider community. Energy efficient homes (including NZEH) generally show better health of the occupants (Berry and Davidson, 2015; COAG Energy Council, 2018). This is both related to physical health, demonstrated by fewer visits to hospital or doctors, and to mental health as a result of reduced bill stress. Homes are also considered to be more comfortable than 'inefficient' homes, also resulting in perceived increases in happiness among occupants (Moore *et al.*, 2019).

Since the net zero energy building has a reduced demand and (generally) a high thermal performance, the strain on the energy grid during peak events is also reduced. Peak events in Australia typically occur on days of excessive heat, where electricity demand spikes due to increased use of air conditioning (ClimateWorks, 2018). These 'peak events' have previously caused localised blackouts in areas where the grid has failed, leading to a number of cases of heat related health issues, particularly in the elderly.

Challenges for Net Zero Energy Buildings

There are obvious technical challenges to be solved when creating high performance housing, particularly as the design requirements shift with location and climate. Australia, in particular, has a wide range of very different climatic conditions, ranging from Cool Temperate in Hobart to 'High Humidity summer, warm winter' in Darwin and other far north regions (Australian Building Codes Board, 2015).

It has already been shown that the technical challenges of designing low energy homes in a range of Australian climates can be overcome based on a range of design guidelines. Coupling a high-performance thermal shell and widely available efficient appliances with on site generation is an approach already proven. The technical challenge of creating a home that generates more energy than it consumes can be considered to be solved. However, within the overall building stock these homes are few and far between.

The major challenges faced when developing zero energy buildings come with the human interactions with the projects; both in perceived value to the individual and the behaviour of the final occupants.

Split incentives

Complex interactions between building stakeholders result in complications around the value of energy efficient features in buildings (Zeng *et al.*, 2018). There is limited incentive, for example, for a landlord to improve the efficiency of a rental dwelling if they are not able to recoup the investment from the renter. Upgrading features of a multi-dwelling apartment may also have difficulty when coordinating the entire owners' group. Balancing the benefits across the building is also difficult as different occupants may benefit more due to different use patterns, number of occupants, size of dwelling and so on.

Occupant engagement

High performance homes frequently have large amounts of high-tech appliances to assist in reducing the energy load. Occupant engagement with the home, in understanding how the various appliances works and then actually using them, represents an area traditionally lost in the building hand over (Willand, Ridley and Pears, 2016). Effective use of the building can drastically impact whether the home performs at the net-zero level. Poor usability and lack of education have been identified as barriers for effective use of technology in energy efficient homes (Zeng *et al.*, 2018).

Misconceptions About Delivering High Performance Homes

Increasing the saturation of zero energy homes in the market place requires addressing misconceptions of zero energy homes. The oft-cited issue is that energy efficient homes cost more to build, but do not attract a sales premium to cover this increase (Moore and Morrissey, 2010; Ambrose *et al.*, 2013; Wells, Rismanchi and Aye, 2018). While it is true that higher quality materials, such as higher levels of insulation or high-performance glazing, will cost more than the standard alternative (Moore and Morrissey, 2010; Zeng *et al.*, 2018), this is not the only way to create a high performance home. Many passive design principles, such as optimising the orientation of the building or locating the living areas to take best advantage of solar gains, cost little or nothing to implement in terms of construction costs (Sustainability House, 2012; Ambrose *et al.*, 2013; ClimateWorks, 2018). It must be recognised that there are likely restrictions due to site constraints, but these can often be worked around with intelligent design choices.

There is also the notion that energy efficient features are not valued or understood by consumers. Evidence from energy efficiency certification schemes in Australia and overseas however show that buildings advertised as being energy efficient draw both sales and rental premiums (Brounen and Kok, 2011; Kahn and Kok, 2014; Chegut, Eichholtz and Holtermans, 2016; Walls *et al.*, 2017). The value of this premium varies from between 2% to 10%, with higher ranking certificates drawing higher premiums (Brounen and Kok, 2011; Chegut, Eichholtz and Holtermans, 2016) Increasingly consumers are more aware of the benefits of low energy housing. Studies of Florida's Energy Star scheme did find that over time the Energy Star certified homes drew a lower premium, but this is partly attributed to increased stringency of the local building code over time, and lack of ability for individuals to market features on resale (Bruegge, Carrión-Flores and Pope, 2016).

Locally, it has been shown that established houses with sustainability features sell for 10% more, and sell faster than their standard counterparts (PRD and Queensland University of Technology, 2018).

Evidence of Affordable NZEH Buildings

Despite the misconceptions and apparent lack of zero energy homes in the Australian housing stock, affordable examples of these buildings exist.

Arguably the highest profile of the true NZEHs in Australia is 'Josh's House', a long term living laboratory project. Located in Hilton, Fremantle, 'Josh's House' is a standard 200 m^2, 3-bedroom family home which uniquely combines a 10-star NatHERS design with materials and techniques typically used for a 6-star design, delivered in a similar timeframe and for a similar per-square-metre cost (Byrne, 2014). The long term monitoring of the home is undertaken as part of the of the Low Carbon Living CRC. When originally built, the home did not have a battery system, meaning that on average just under half of the 11.15kWh of electricity used per day was being imported from the grid. However, the orientation of the building maximised the potential of the 3kW solar PV system, resulting in an average of 15.4kWh of electricity generated each day, a net benefit of 4.25kWh (Byrne, 2014). Low energy consumption has not come at the cost of lower comfort levels either. During the first monitoring period, the internal temperature only exceeded 28^0C on 5 occasions across the summer and dropped below 18^0C on 15 occasions during winter – and this was predominantly during the early hours of the morning while the occupants were asleep. In addition to the energy savings, the grey water recovery system installed reduced water consumption by 92% compared to the local average, a crucial part of a holistically sustainable development in the Perth area.

As Josh's House is a Living Laboratory project, when new technology becomes available the systems in the home are upgraded. A battery was added to the house in 2015, and then 2018 saw a major upgrade to the system, with a 6.4kW PV array installed with a 10kWh battery. The initial battery installation reduced grid reliance to 19% (Byrne, Taylor and Green, 2017), and the subsequent upgrade has reduced this to nearly 10% (Josh Byrne and Associates, 2018). This is despite also making the home all-electric, and adding an electric vehicle.

While not strictly a net-zero project overall, the Lochiel Park project is a high-performance 'niche green' development in South Australia (Blaess *et al.*, 2006; Berry, Davidson and Saman, 2013). Within the development, there are 23 dwellings designated as either social housing or for sale to low-income households (Goodchild *et al.*, 2019). It has been estimated that the final 7.5 NatHERS star rated designs, high performance appliances and solar PV increased total construction costs by $11,000 compared to a standard 6-star design. While not all homes perform at a zero-energy standard, some homes do achive this high performance standard (Saman, 2013; Berry, Whaley, Davidson, *et al.*, 2014a), though perhaps not as many as would have been desired.

Whilst Lochiel Park has been used as a location for workshops for various building industry professionals, it has been noted that the vast majority of the industry has not been part of this learning process, and widespread changes to building practices have not occurred as a result of the niche development (Berry, Davidson and Saman, 2013).

Approaching the Financial Hurdles

Demonstrating financial feasibility for net zero energy construction removes the bottom-line argument as an obstacle for constructing these types of buildings, making it a more attractive proposition for stakeholders. This can be seen as a win-win outcome: not only does a zero energy home address carbon emission targets, it does so without compromising the financial bottom line. This also provides a sound marketing opportunity without the risk of 'greenwashing'. Economic feasibility has previously been demonstrated, using Lochiel Park as a case study (Berry and Davidson, 2015) as well as modelling studies incorporating other zero-energy developments across Australia (Moore, 2014; Moore and Morrissey, 2014).

Cost-benefit analysis (CBA) or lifecycle costing (LCC) are frequently used to evaluate and compare financial value of projects and scenarios in both Australian and international contexts (Moore and Morrissey, 2010, 2014). The literature shows that this is not only limited to showcasing the effectiveness of low-energy and NZEH projects, but also as part of the Regulatory Impact Statements for changes to the National Construction Code (Moore, 2014). Typically, studies use a 'Present value' approach in order to provide context and compare the long-term costs and benefits of the project. This is particularly important for NZEH projects, as the benefit is typically in reduced running costs and revenue from energy exports over time, rather than savings on initial construction compared to 'business as usual (BAU).

While the Net Present Value (NPV) equation is commonly used, there is some disagreement regarding best practice in applying detail. The standard government practice is to apply a discount rate of 7% (Office of Best Practice Regulation, 2016), however it may be argued that this ignores the additional long term benefits of energy efficient housing that arise from reduced stress on the electricity network and improved health and wellbeing of occupants (Simpson and Walker, 1987; Stern, 2006; Morrissey *et al.*, 2013).

While it has been determined that lower discount rates will favour projects with higher upfront costs and long term benefits (Morrissey *et al.*, 2013), most studies reviewed have utilised a real discount rate of

7%, in line with the Australian Government's Office of Best Practice regulation (Office of Best Practice Regulation, 2016). Ultimately this is applied within a nominal discount rate nearer to 10%, accounting for inflation of 3.3%. Even with these higher rates being applied, the consistent message across the literature is that high performance homes (i.e performance well above minimum regulatory standards) are more cost effective across the lifespan of the building than their standard or BAU counterparts.

Additional Benefits

Beyond the direct financial benefits to occupants in the form of reduced bills, high performance homes have been shown to have a wide range of benefits, economic and non-economic, to the occupants and the community.

These include the obvious benefit of reduced carbon production and reduced peak loads on the electricity network (Langham *et al.*, 2010), as well as improvements in health and wellbeing (Leech, Raizenne and Gusdorf, 2004; Hansen *et al.*, 2008; Berry, Whaley, Davidson, *et al.*, 2014b). Occupants have also reported being happier and less stress, likely related to the reduced bills and lack of bill-stress associated with living in an efficient home (Moore *et al.*, 2017).

The non-energy benefits of efficient homes has been estimated as being between 43% and 250% of the direct energy benefit (Chapman *et al.*, 2009; Berry, Whaley, Davidson, *et al.*, 2014b).

Purpose of *Mainstreaming Zero Energy Homes* Project

Much of the research demonstrating the effectiveness of Zero Energy Homes in Australia utilises either niche case studies or computer modelling to demonstrate performance and lifetime cost-benefits. Despite the evidence showing that the associated costs are outweighed by the benefits in the longer term, and that there is consumer appetite for high-performance homes evidenced by energy label premiums identified in other markets, the vast majority of homes constructed are designed simply to meet minimum standards (CSIRO, 2019). High efficiency homes in general remain a niche construction, largely due to lack of knowledge among large-scale builders regarding delivery of these types of homes within established supply chains and standard house designs.

The *Mainstreaming Zero Energy Homes* project seeks to overcome these issues, working with volume builders to gain a step-change in whole of house performance of standard home designs in the most cost effective fashion. The project showcases how minor changes in the thermal shell coupled with high efficiency appliances and on-site generation from solar-PV can drastically improve the overall energy use of a new home. Furthermore, the project is showcasing how these improved designs can be effectively marketed to consumers, allowing the builder to tap in to the 'green' premium to recoup the additional construction costs.

Further information regarding the *Mainstreaming Zero Energy Homes* project can be found in the *Design Review Report*.

This Report

This report is the second of three reports for the Cooperative Research Centre for Low (CRC LCL) Carbon Living project 'Mainstreaming Net Zero Energy Homes', which inlcude:

1. NZEH Design Review Report
2. NZEH Cost Analysis Report
3. NZEH Consumer Interest Report

Using information gathered from the volume builders during a series of workshops, the additional costs of upgrading features has been gathered, allowing the research team to evaluate the overall costs of lifting a standard home design to the NZEH performance level. These costs are provided by the builders, so are reflective of their particular supply chain and any markups they apply as standard. They may not be reflective of the best value options available in the market.

Utilising the information in the literature, this report demonstrates the value of the NZEH design with respect to the standard design with respect to NPV from the long-term cost-benefit analysis and simple payback period. The report includes sensitivity analysis based on alternative energy-pricing futures.

Case Studies

This section describes the inclusions and modifications made to the baseline design of the four case study homes in Melbourne, Townsville, Canberra and Perth as well as the resulting effects in annual energy use.

The decision making criteria for the selection of design modifications was primarily energy efficiency; but consideration was also given to cost effectiveness, aesthetics, occupant comfort, space usability and consumer preferrences. The builders' experiences guided the conversation.

Melbourne - Z-Range Home

The 'Z-Range' display home was built by SJD Homes in the Timbertop development by Parklea in the suburb of Officer, in South-East Melbourne. The house is 258 m^2 and includes four bedrooms, two bathrooms, a lounge, an open plan kitchen/living/dining area and a garage in addition to an outdoor living space.

Given Melbourne's mild temperate climate (characterised by mild dry summers and cool humid winters), emphasis was put on design aspects that favoured heat gain in winter. Table 1 shows the alterations to the baseline design that were agreed to by the builder and land developer following consultation with researchers and energy modelling. These changes enabled the house to achieve a rating of 7.6 Stars, which was an improvement of 1.1 Stars compared to the baseline. The inclusion of energy efficient appliances contributed further to reduce annual energy by nearly 60%, resulting in a total annual energy consumption of 5,409 kWh considering that the house is fully occupied daily by a family of four.

A PV system of 5kW was chosen by the builder to cover these needs and make the house not only net zero-energy, but net energy positive over the course of each year.

Table 1 Design modifications in the Z-Range home compared to the baseline design.

GLAZING	BASELINE	Z-RANGE
Double glazing	Double glazing to all windows	Addition of double glazing to all sliding doors

INSULATION	BASELINE	Z-RANGE
Roof/ceiling	R2.5 batts to ceiling	R4 roof batts to ceiling cavity R2 Anticon

BUILDING ENVELOPE	BASELINE	Z-RANGE
Modifying window apertures		Remove entry corner window (East) and reduce size of two front windows Front door - switch from glass to a solid door Southern elevation (laundry) - solid door instead of glass sliding door + small window Northern windows – reduce height Master bedroom - remove window and keep sliding door
Walling types	No internal doors	Internal sliding doors for controlled openings - lounge, passage and meals to rear passage

BUILDING ENVELOPE	BASELINE	Z-RANGE
Floor cover	85mm slab coverage over waffle pods for slab Floating timber (family, meals and kitchen)	100mm slab coverage over waffle pods for slab Tiles (family, meals and kitchen)

APPLIANCES	BASELINE	Z-RANGE
Fans	None	Ceiling fans in the bedrooms and living areas
HVAC	Gas central heating Split system in lounge, family and bedrooms	Split system in lounge and family area
HWS	Gas storage	Heat pump
Stove/Oven	Gas stove and oven	Induction stove and electric oven Saving from no gas connection

Townsville - Innovation House 2.0

The 'Innovation House 2.0' display home by Innovation House was built in Townsville at the North Shore display village by Stockland. The house is 239 m^2 and has three bedrooms, two bathrooms, a home theatre, an open plan kitchen/living/dining area and a garage in addition to an alfresco.

The tropical climate in Townsville, characterised by humid summers and warm winters, meant that the house was designed to minimize heat gain year-round and maximize cross-ventilation. Table 2 shows the alterations to the baseline design that were agreed to by the builder and land developer following consultation with researchers and energy modelling. These design modifications enabled the house to achieve a rating of 6.3 Stars, which was an improvement of 1.9 Stars compared to the baseline. The inclusion of energy efficient appliances contributed to reduce annual energy by a further 20%, resulting in a total annual energy consumption of 4,114 kWh considering that the house is fully occupied daily by a family of four.

A PV system of 5 kW was chosen by the builder to cover these needs and make the house not only net zero-energy, but net energy positive over the course of each year.

Table 2 Design modifications in Innovation House 2.0 compared to the baseline design.

GLAZING	BASELINE	INNOVATION HOUSE 2.0
Low E	Standard single glazing	Low-e to all windows
Louvres	None	Timber or glass louvres on selected windows
INSULATION	**BASELINE**	**INNOVATION HOUSE 2.0**
Roof/ceiling	R2.5 batts to ceiling	R4 roof batts to ceiling cavity Anticon
Walls	Foil	R2.5 batts
BUILDING ENVELOPE	**BASELINE**	**INNOVATION HOUSE 2.0**
Colours	Medium colours	Light coloured walls
APPLIANCES	**BASELINE**	**INNOVATION HOUSE 2.0**
Fans	1200mm (diameter	1400mm (diameter)
HVAC	Split system COP 2.8 Split system in lounge, family and bedrooms	Thermosphere
HWS	Standard heat pump	Evacuated tube
Stove/Oven	Standard electric cooktop	Induction cooktop and electric oven

Canberra - Grace 25

The 'Grace 25' display house will be built by Rawson Homes in Canberra, at the Ginninderry display village. The house is 239 m^2 and has four bedrooms, two bathrooms, a lounge, an open plan kitchen/living/dining area and a garage in addition to an outdoor living space.

The baseline house design was modified to suit the Canberra cool temperate climate, characterized by cool winters and dry warm summers. Table 3 shows the alterations to the baseline design that were agreed to by the builder and land developer following consultation with researchers and energy modelling. These design modifications enabled the house to achieve a rating of 7 Stars, which was an improvement of 0.8 Stars compared to the baseline. The inclusion of energy efficient appliances contributed to reduce annual energy by a further 34%, resulting in a total annual energy consumption of 5,945 kWh considering that the house is fully occupied daily by a family of four.

A PV system of 4 kW was chosen by the builder to cover these needs and make the house not only net zero-energy, but net energy positive over the course of each year.

Table 3 Design modifications in Grace 25 compared to the baseline design.

GLAZING	BASELINE	GRACE 25
Double glazing	Standard single glazing	Double glazing for all windows and sliding doors
Thermally broken windows	None	Thermally broken windows in the living area and lounge

INSULATION	BASELINE	GRACE 25
Ceiling	R3.5 batts to ceiling	R5 batts to ceiling
Walls	R2 batts	R2.5 batts

BUILDING ENVELOPE	BASELINE	GRACE 25
Modifying window apertures		Increased glazing apertures in living area - northern windows

APPLIANCES	BASELINE	GRACE 25
HVAC	Ducted split system (3 COP)	Ducted split system (3.5 COP)
HWS	Gas instantaneous	Electric heat pump
Stove/Oven	Gas cooktop	Induction cooktop and electric oven

Perth - Windsor

The 'Windsor' will be built by Terrace in the Iluma Private Estate, in the suburb of Bennett Springs, Perth. The building is a terraced two-storey 175 m^2 house and has three bedrooms, two bathrooms, a lounge, an open plan kitchen/living/dining area and a garage in addition to an outdoor living space and a balcony.

The house design takes advantage of the winter sun, while ensuring heat protection in summer and maximizing summer breezes, characteristic of the Perth climate. Table 4 shows the alterations to the baseline design that were agreed to by the builder and land developer following consultation with researchers and energy modelling. These design modifications enabled the house to achieve a rating of 8.4 Stars, which was an improvement of 0.5 Stars compared to the baseline. The inclusion of energy efficient appliances contributed to reduce annual energy by a further 45%, resulting in a total annual energy consumption of 5,215 kWh considering that the house is fully occupied daily by a family of four.

A PV system of 5 kW was chosen by the builder to cover these needs and make the house not only net zero-energy, but net energy positive over the course of each year.

Table 4 Design modifications in Windsor compared to the baseline design.

GLAZING	BASELINE	WINDSOR
Low E	Standard single glazing	Low E in the balcony sliding door

INSULATION	BASELINE	WINDSOR
Roof	-	Anticon R1.5
Walls	Permicav on bottom floor only	Permicav on all external walls on both floors

BUILDING ENVELOPE	BASELINE	WINDSOR
Ventilation		Sliding windows throughout with security screens on ground level and on balcony sliding door to enable them to stay open for cross-ventilation

APPLIANCES	BASELINE	WINDSOR
Fans	No fans	Ceiling fans in 3 bedrooms
HVAC	Ducted system	Split system in the living area/dining room
HWS	Gas instantaneous	Electric heat pump
Stove/Oven	Gas cooktop	Induction cooktop and electric oven Saving from no gas connection

Methodology

Cost and savings estimation

After the design review workshops, each builder reported the increased building cost due to the individual NZEH additions noted in the previous section. This cost breakdown is listed for each building in the relevant analysis below.

These estimations represent the additional investment required on top of the BAU house design, not the total cost of instalation. Analysis is limited to the direct financial benefit arising from changes to the thermal shell and aplpiances. Wider cost savings, to the electricity network for example, and savings for improved health and productivity are not included in this analysis.

Savings estimates are based on energy reductions modelled using AusZEH and applying the tariffs specifically for each location.

Energy modelling

The software AusZEH Design Tool (AusZEH) was used to model the scenarios. This software combines a thermal energy simulation model; a projection of energy used for lighting, water heating and major household appliances; and house occupancy profiles(Ren, Chen and Wang, 2011; Ren, Z., Foliente, G., Chan, W., Chen, D., & Syme, 2011) . The simulation of the building thermal energy is carried out by the software AccuRate, which is typically employed for NatHERS energy star-rating. This model takes into consideration information about local climate, building orientation, construction materials and conditioned area to determine the required energy for heating and cooling over a one-year period. The simulation of the building thermal energy demand is combined in AusZEH with further predictions of energy used for lighting, water heating and to run high-energy appliances such as fridges, dishwashers and TVs. The model for total annual energy consumption in the home is further refined according to the house occupancy pattern, which can be specified by the modeller. For the purpose of the simulations carried out in this project it was assumed that a family of four occupy the house.

While AusZEH is comprehensive and currently considered a leading practice residential energy modelling tool in Australia, some of the appliance/fittings specifications embedded in the software are out-of-date; for example, indicating higher Wattages compared to more recent appliances. In order to overcome this limitation, the builders were asked to provide the specification of appliances being installed as part of the building construction package (e.g. air conditioners, heaters, hot water system). These were inserted manually into the software for a more accurate estimation of annual energy consumption. An updated version of AusZEH is currently being considered by CSIRO, however, it was not yet available for use in this project.

AusZEH does not directly account for renewable energy systems such as solar photovoltaic (PV) panels. The software SAM (System Advisor Model), developed by the U.S. National Renewable Energy Laboratory (NREL), was employed to determine net demands of the building on the grid. This software predicts hour-by-hour PV electricity production based on variables such as house location and orientation, associated solar radiation, weather, roof tilt, the size of the PV system and inverter (Blair *et al.*, 2018).

While the total savings are based on the entire NZEH scenario as a package, sensitivity analysis was also conducted on each element to determine the savings attributed to each item. Care should be taken when viewing these individual breakdowns, particularly in relation to thermal shell upgrades. The influence of individual elements in the thermal shell can have complex outcomes on the overall performance, and weakening the thermal shell in one area may reduce the effectiveness of the other thermal shell upgrades.

Cost-benefit analysis

The cost-benefit analysis is conducted based on the additional costs and additional savings of the NZEH upgrades compared to BAU. The analysis presents the value of the NZEH upgrades, not the value of the building as a whole.

Five future scenarios are included as part of a sentivity analysis. This accounts for changes in energy pricing and feed-in tarifs over the next 10 years. These scenarios are displayed in Table 5.

Table 5 Energy price scenarios

SCENARIO	ELECTRICITY PRICE	FEED-IN TARIFF
Base	Current electricity price remains constant	Current feed-in tariff remains constant
1	Electricity price increases 2.5% each year	Current feed-in tariff remains constant
2	Electicity price increases 5% each year	Current feed-in tariff remains constant

SCENARIO	ELECTRICITY PRICE	FEED-IN TARIFF
3	Current electricity price remains constant	Feed-in tarif remains constant for 5 years, then eliminated
4	Electicity price increases 5% each year	Feed-in tarif remains constant for 5 years, then eliminated

Net Present Value
Net present value is used as the cost-benefit calculation method, in line with previous studies. As well as calculating the value of the NZEH upgrages, it is also used as the basis for Return on Investment calculations. The NPV calculation is defined by Equation 1, where t = time in years and i is the chosen discount rate value .

Equation 1 Net Present Value

$$NPV\ (i) = \sum_{t=0}^{N} \frac{(benefits - costs)t}{(1+i)^t}$$

For the purposes of this study, 'benefits' and 'costs' relate only to the upgraded features; how much they cost to install and maintain, and how much money is saved due to the reduction in energy use. The time period used is 25 years. This period aligns with the shorter time periods utilised in the literature, and represents the value across a 25-year mortgage. This also aligns with the assumed lifespan of the solar PV system.

In line with the Office of Best Practice regulations, a 'real' discount rate of 7% will be used, with additional sensitivity analysis conducted used 3% and 10%. While other research has utilised a 'nominal' discount rate and increased the discount rate in line with inflation (which would result in a nominal rate of approximately 10% with sensitivity anlaysis as 6% and 13%), it is recommended by the OBPR that the 'real' value is used. The two NPV methods, 'real' and 'nominal', will achieve consistent results if inflation rates and discount rates are consistent.

As noted in the literature review, the lower discount rate of 3% may be more applicable for environmentally beneficial projects where part of the economic benefit is societal and indirect. This study is examining the benefit of the project for an individual, so it is more appropriate to use the OBPR recommended 7% rate rather than the 3% value, as the individual does not necessarily gain the benefit gleaned by society at large.

Return on Investment
Return on investment is defined by Equation 2.

Equation 2 Return on Investment

$$ROI = \frac{Net\ profit}{Investment} * 100\%$$

Return on investment does not utilise the discounted value of future savings.

Payback Period
The payback period calculated for this report can be termed 'simple payback'. Payback period in years is defined by Equation 3

Equation 3 Payback Period

$$Payback\ Period = \frac{Initial\ Investment}{Annual\ savings}$$

The payback period does not utilise the discounted value of future savings. As payback periods are less reliable over long periods, paybacks will only be evaluated if under 10 years.

Assumptions
A number of assumptions are made for calculating the running costs of each scenario.

Electricity Rates

All electricity tariffs are assumed to be flat rate tarifs, rather than peak/offpeak structured tariffs.

Electricity unit prices and export tariffs are displayed in Table 6.

Table 6 Electricity pricing

LOCATION	ELECTRICITY IMPORT COST (c/kWh)	FEED-IN TARIFF (c/kWh)
Melbourne	28.25	9.9
Townsville	27.83	9.4
Canberra	23.64	11.0
Perth	28.33	7.1

(Australian Energy Regulator, 2016; Canstar, 2018a)

Gas Savings

Where a gas appliance has been replaced by a high-efficiency electric appliance, annual savings have been calculated by comparing the cost of running the original gas appliance, including supply charge, against the running cost of the high efficiency electric appliance. Supply charge has been weighted relative to the volume of gas used by that appliance. As electricity will be connected to the home regardless of upgrading the gas appliances, supply charge is not included in the running costs of the electric appliance.

The supply charges used are based on actual energy plans available for the relevant design location. Lower supply charges have been used as a conservative measure in the analysis. Gas supply charges and unit costs are displayed in Table 7.

Table 7 Gas Supply Charge Estimates

LOCATION	DAILY GAS SUPPLY CHARGE ($A)	GAS UNIT COST (c/MJ)
Melbourne	0.70	2.5
Townsville	N/A	N/A
Canberra	0.75	3.1
Perth	0.21	3.9

(Department of Treasury, 2018; Energy Watch, 2019)

Note that since no gas appliances were included in the Base 'Innovation House 2.0' design, there is no saving due to gas calculated for the Townsville location.

Where applicable, Gas savings have been calculated as an initial upfront saving for the builder for not having to install a gas connection during construction. This estimate has been provided by the builder where possible.

Maintenance Costs

As most upgrades are replacements for similar appliances and features, the maintenance costs are considered to be the same between the BAU home and the NZEH design, and therefore are not included in the calculations.

However, the lifespan of individual appliances is shorter than the 25 year analysis period, and therefore cost of replacement is included for air conditioning, hot water, solar PV and cooktop upgrades. The lifespan of these appliances is assumed to be the same for the NZEH and BAU designs, and the cost of replacement accounted for is the increased cost over the cost of the standard unit. This is assumed to be the same as the initial installation cost in all cases, except solar PV systems as the panels and the inverter have different lifespans.

Inverters for solar PV systems are assumed to have a lifespan of 10 years, and are therefore assumed to be replaced at the beginning of the 11th and 21st years. This cost is discounted for the NPV calculation in line with other cash flows. Inverters have been costed at between $1,000 for 'budget' models and $2,000 for 'premium' models (SolarQuotes, 2019). For this study a value of $1,500 is used to represent a good mid-tier model.

Table 8 Typical lifespan of appliances

APPLIANCE	ASSUMED LIFESPAN (Years)
Air Conditioner	9
Hot Water System	10
Cooktop and Oven	9
Solar PV Inverter	10

(SolarQuotes, 2012; Shapiro and Puttagunta, 2016; Canstar, 2018b)

Construction Costs

All efforts have been made to ensure construction costs have been estimated by the builder. Where this has not been possible an estimate has been made by the research team. These estimates have been noted in the relevant section.

Costs were requested as retail costs, including margin as determined by the builder. This is to represent the final cost of owning and then operating the building for the occupant, not simply the increased cost of construction to the builder.

Results

Melbourne - Z-Range Home

Table 9 Z-Range Home Costings.

	INITIAL ADDITIONAL COST	ANNUAL OPERATIONAL SAVINGS	ANNUAL REVENUE	OBSERVATION
TOTAL COSTS/SAVINGS/REVENUES	A$19,750	A$1,311	A$469	
Glazing	A$1,500	A$70		
Double glazing to sliding door	A$1,500			
Insulation	A$4,000	A$211		
Additional roof insulation	A$2,000			
Anticon	A$2,000			
Building envelope	A$1,700	A$ 102		
Modified window apertures	A$0			Cost neutral
Sliding doors for internal zoning	A$700			
100mm slab coverage for additional thermal mass	A$1,000			
Appliances	A$6,550	A$328		
Fans in bedrooms and living areas	A$1,250			
Split systems	A$4,000	A$206		Additional cost required
Heat pump	A$0	A$104		Cost neutral. Annual saving includes gas supply charge
Induction stove and electric oven	A$1,300	A$18		Annual saving includes gas supply charge
Gas supply	-A$500			Savings from gas installation.
Solar system	A$,000	A$600	A$469	
5kW PV	A$6,000	A$600	A$469	

The additional cost of A$19,750 represents an 8% increase in the house price, originally set at A$247,900.

Payback

Figure 1 Z-Range full package cashflow and payback sensitivity.

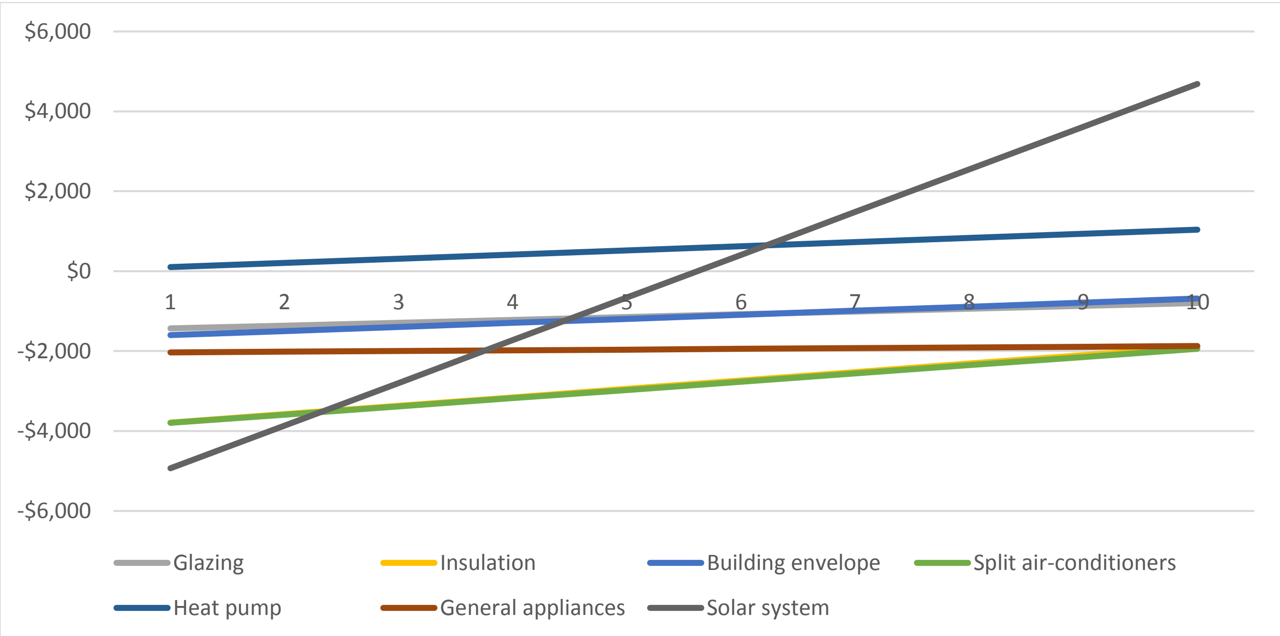


Figure 2 Z-Range individual upgrade paybacks, Base Scenario.

Return on Investment

Table 10 Z-Range full upgrade ROI

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Net profit (A$)	-1,456	121	1,923	-4,268	-889
Investment (A$)	19,250	19,250	19,250	19,250	19,250
ROI	-8%	1%	10%	-22%	-5%

Net Present Value

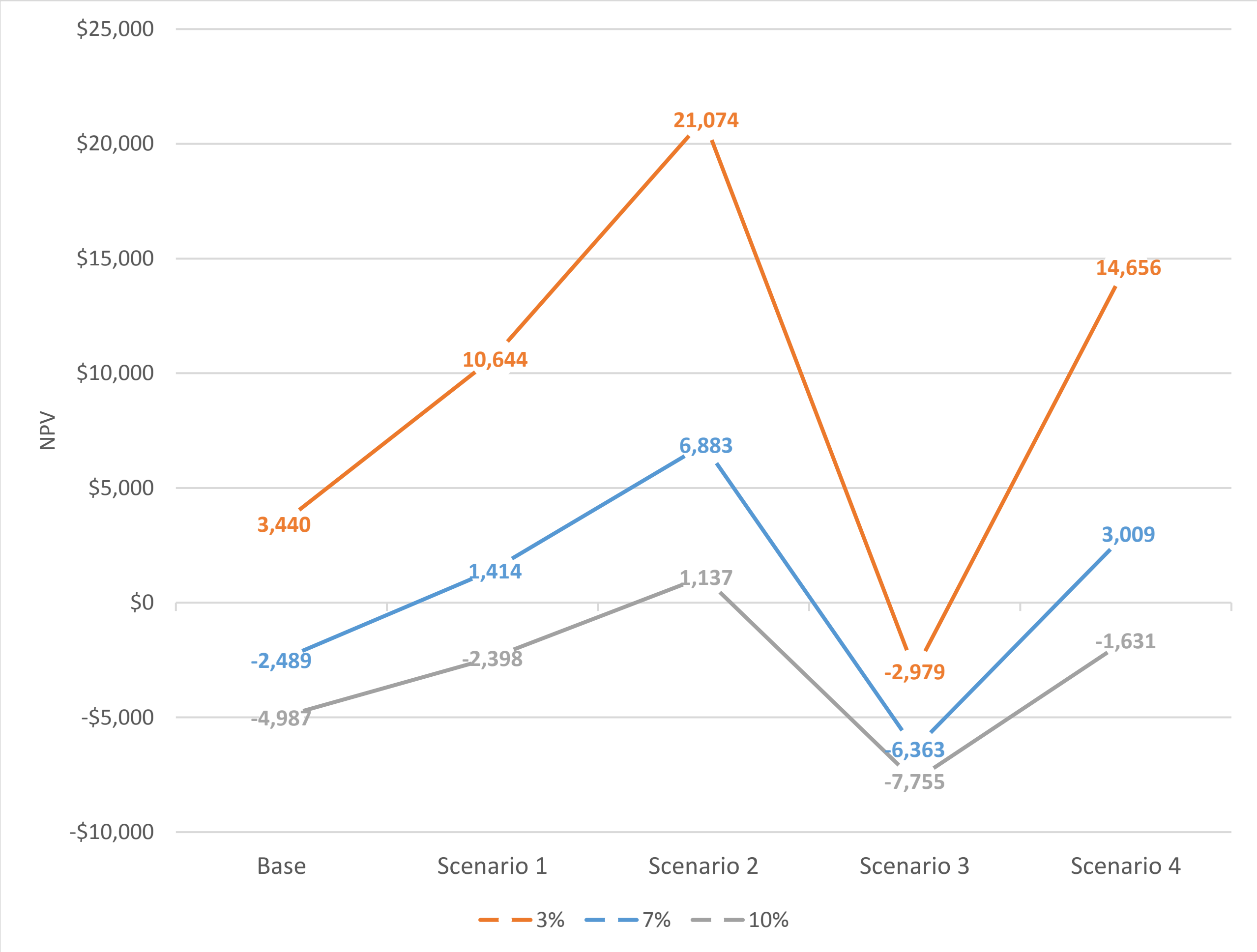


Figure 3 Z-Range full upgrade NPV with sensitivity analysis.

Table 11 Z-Range NPV at 7% discount rate.

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Benefit (A$)	17,836	21,739	27,208	13,962	23,334
Cost (A$)*	-20,325	-20,325	-20,325	-20,325	-20,325
NPV (A$)	-2,489	1,414	6,883	-6,363	3,009

*Cost figure includes inverter replacement discounted at 7%.

Discussion

The Z-Range upgrade package pays back inside 10 years for scenarios where electricity prices increase and the feed in tariff is not eliminated (Figure 1). Under the base scenario, the most effective upgrades are the Solar PV system and Heat Pump hot water system (Figure 2). The insulation and building envelope upgrades are financially the least effective, and do not pay back within a 10 year period, but will do so across a 25-year mortgage.

The upgrade of gas to induction cooktop is also not financially effective, but is required to gain the savings related to gas supply.

The Z-range NZEH upgrades have a positive net-present value at the 7% discount rate across all scenarios where electricity prices rise.

Townsville - Innovation House 2.0

Table 12 Innovation House 2.0 Costings.

	INITIAL ADDITIONAL COST	ANNUAL OPERATIONAL SAVINGS	ANNUAL REVENUES	OBSERVATION
TOTAL COSTS/SAVINGS/REVENUES	**A$21,030**	**A$1,432**	**A$444**	
Glazing	A$4,300	A$146		
Low-e glazing to all windows	A$1,500			
Timber louvres for shading	A$2,800			
Insulation	A$3,500	A$218		
Ceiling insulation	A$400			
Wall insulation	A$1,500			
Anticon	A$1,600			
Appliances	A$8,280	A$836		
Fans in bedrooms and living areas	A$280			
High efficiency reverse cycle AC - split systems	A$3,600	A$235		Additional cost required
Evacuated tube hot water	A$2,900	A$585		
Induction stove and electric oven	A$1,500	A$16		
Solar system	A$4,950	A$231	A$444	
5kW PV	A$4,950	A$231	A$444	

The additional cost of A$21,030 represents a 6% increase in the house price, originally set at A$335,000.

Payback

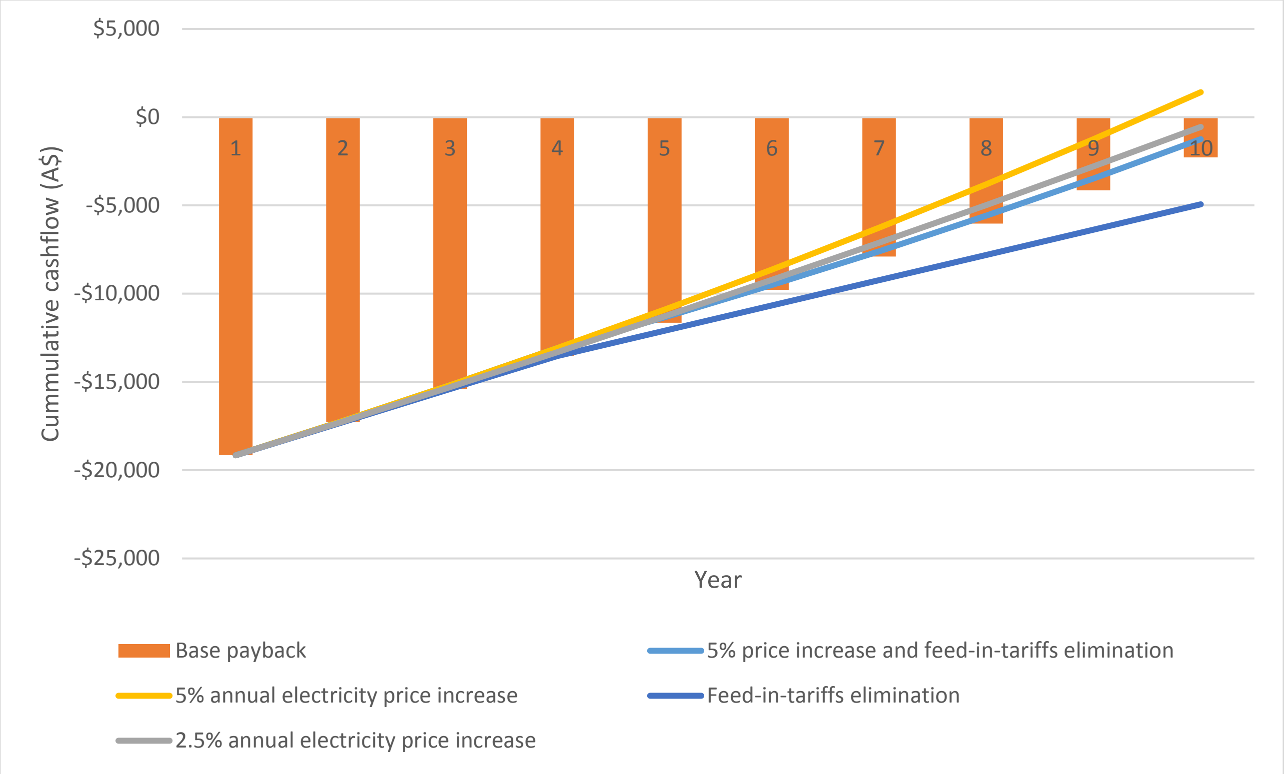


Figure 4 Innovation House 2.0 full package cashflow and payback sensitivity

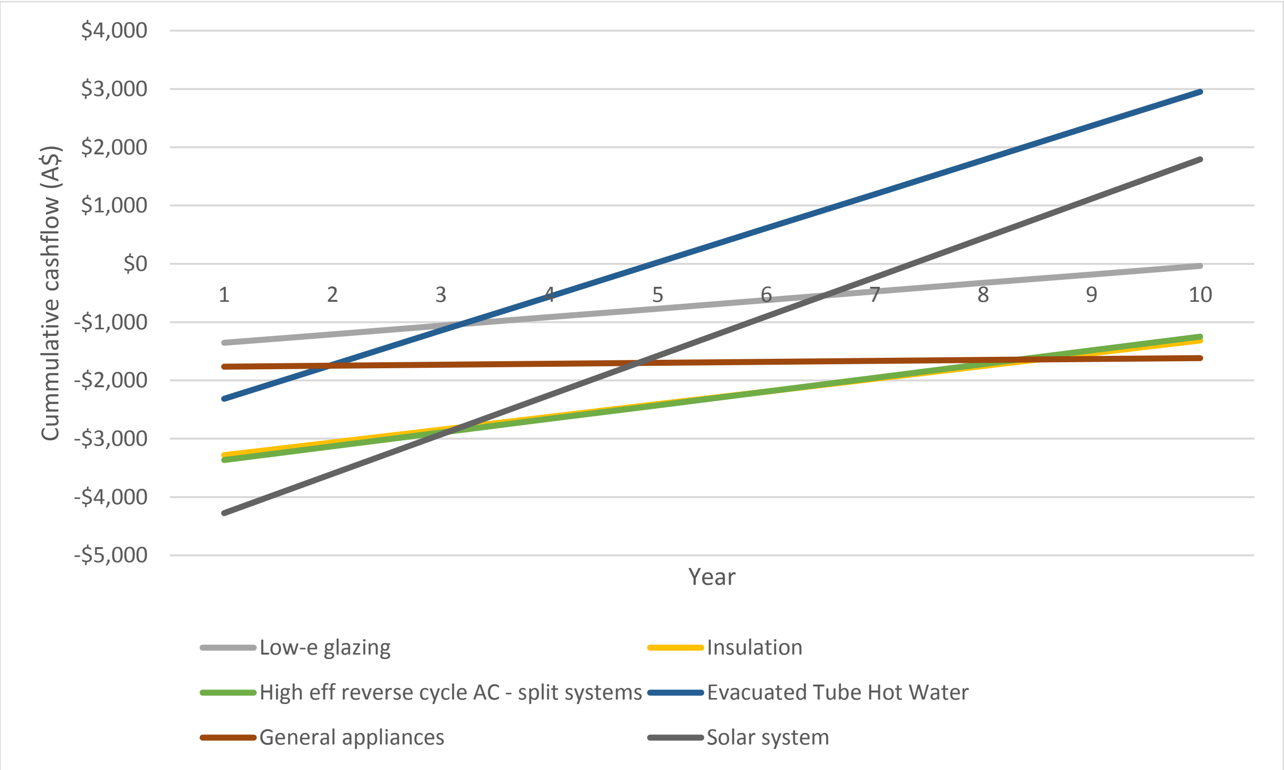


Figure 5 Innovation House 2.0 individual upgrade paybacks, Base Scenario.

Return on Investment

Table 13 Innovation House 2.0 full upgrade ROI.

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Net profit (A$)	-2,275	-551	1,417	-4,936	-1,244
Investment (A$)	21,030	21,030	21,030	21,030	21,030
ROI	-11%	-3%	7%	-23%	-6%

Net Present Value

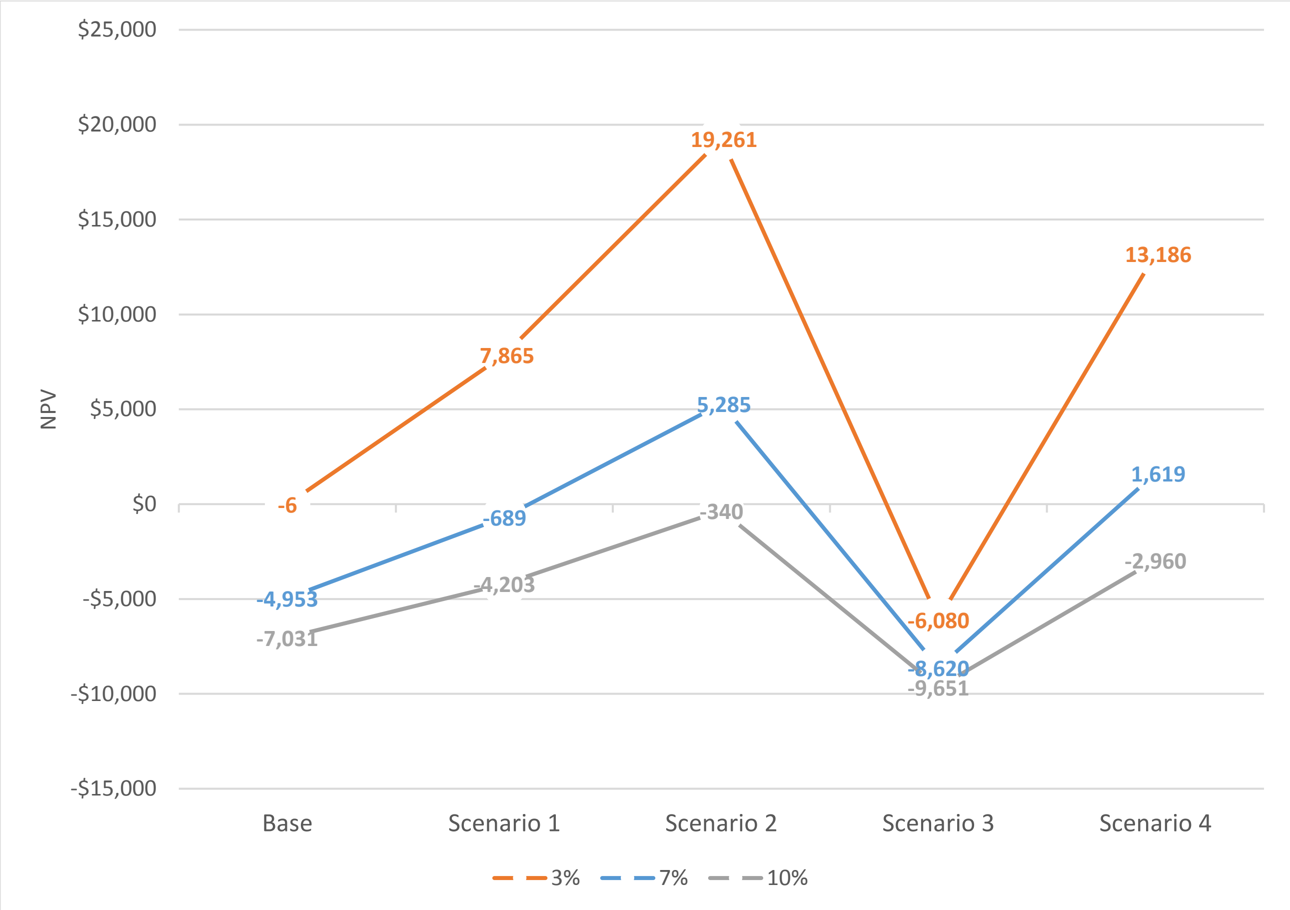


Figure 6 Innovation House 2.0 full upgrade NPV with sensitivity analysis.

Table 14 Innovation House 2.0 NPV at 7% discount rate.

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Benefit (A$)	19,230	23,494	29,468	15,563	25,802
Cost (A$)	-24,183	-24,183	-24,183	-24,183	-24,183
NPV (A$)	-4,953	-689	5,285	-8,620	1,619

Discussion

The Innovation House 2.0 does not have a payback inside 10 years under the Base scenario, but will do so with 5% electricity price increases.

The most effective individual upgrades are the Evacuated Tube hot water and the Solar PV systems. Across the 10 year ROI assessment period, none of the other upgrages pay for themselves, however the air conditioning and insulation will pay back within the span of a 25-year mortgage.

At the 7% discount rate, the project has a negative NPV only if prices do not increase or the feed-in tariff is eliminated. All other scenarios show a positive NPV across the 25-year period.

Canberra - Grace 25

Table 15 Grace 25 Costings.

	INITIAL ADDITIONAL COST	ANNUAL OPERATIONAL SAVINGS	ANNUAL REVENUES	OBSERVATION
TOTAL COSTS/SAVINGS/REVENUES	**A$42,430**	**A$1,439**	**A$401**	
Glazing	A$27,435	A$106		
Thermally broken to Lounge and living, all else double glazed	A$27,435			
Insulation	A$2,430	A$180		
Roof insulation	A$1,500			
Ceiling insulation	A$930			
Building envelope	A$0	A$5		
Increased glazing aperture for ventilation	A$0			Cost Neutral
Appliances	A$4,375	A$501		
Efficient ducted split systems	A$660	A$0		Additional cost
Heat pump	A$3,735	A$482		Additional cost required
Induction stove and electric oven	A$910	A$29		
Gas supply	-A$930			Savings from gas installation
Solar system	A$8,190	A$637	A$401	
4kW PV	A$8,190	A$637	A$401	

The additional cost of A$42,430 represents an 11% increase in the house price, originally set at A$377,750.

Payback

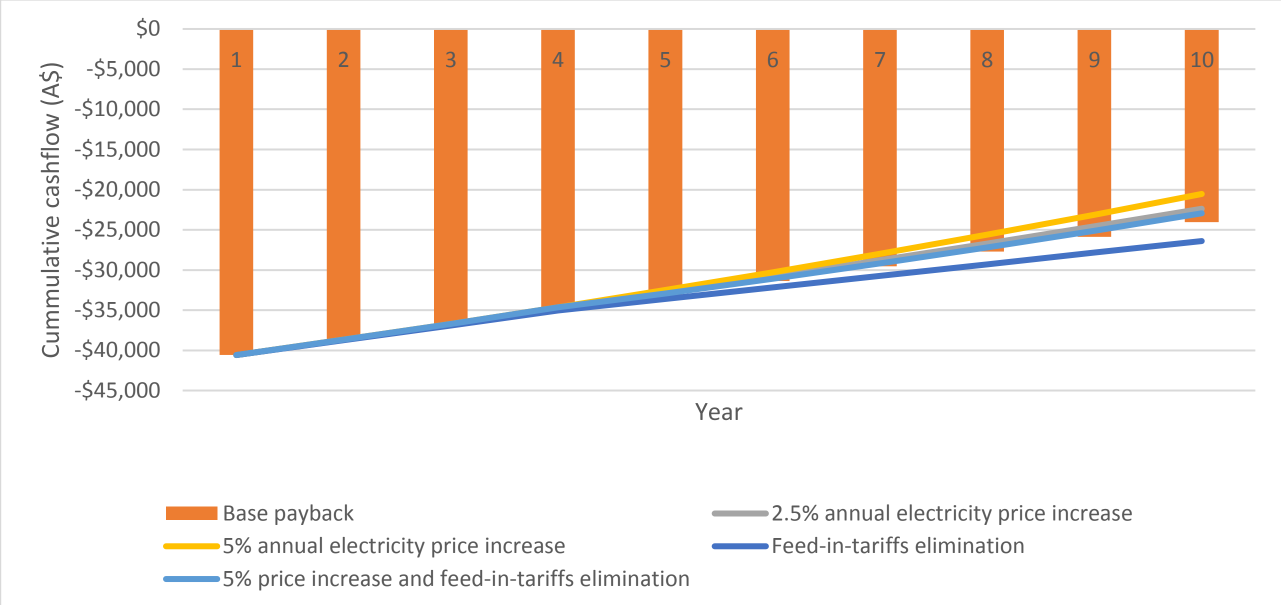
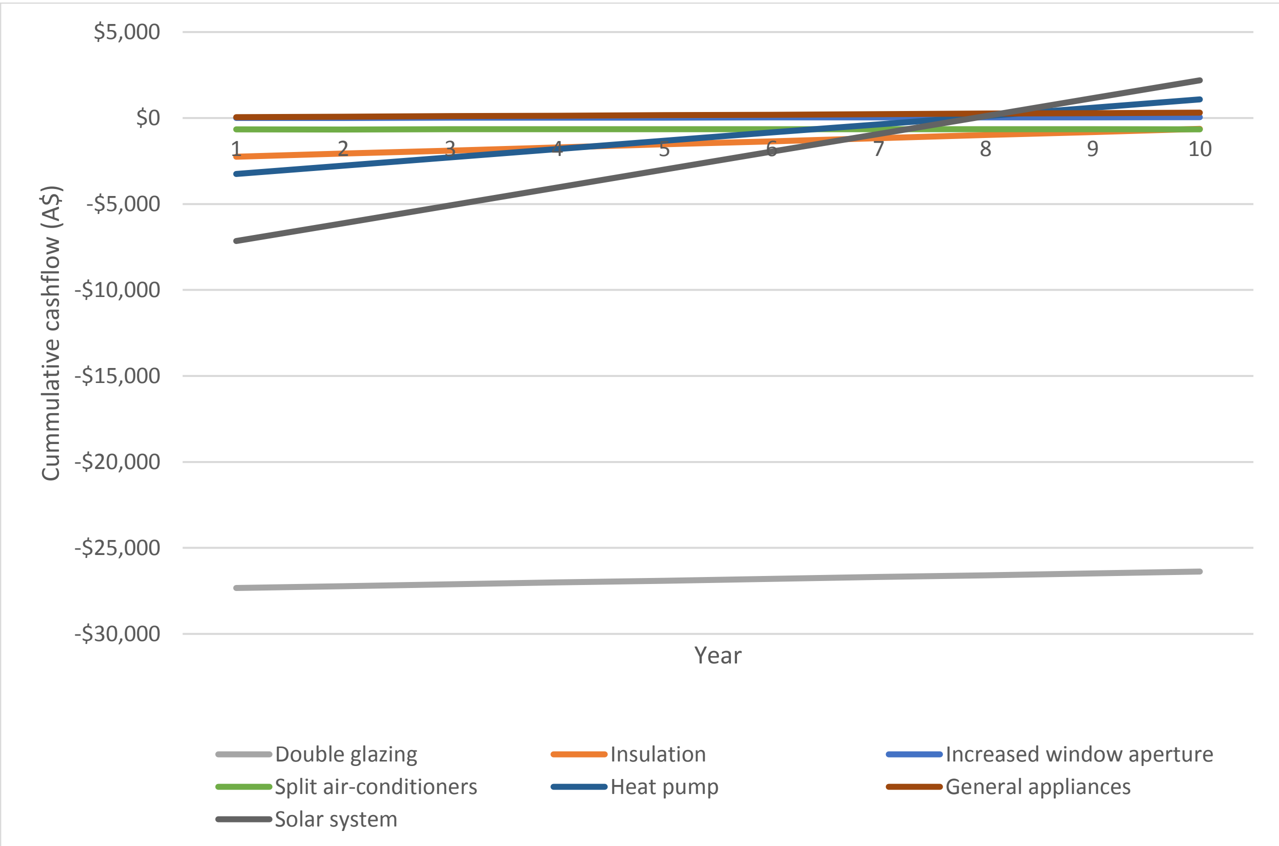


Figure 7 Grace 25 full package cashflow and payback sensitivity.

Figure 8 Grace 25 individual upgrade paybacks, Base Scenario.



Return on Invesment

Table 16 Grace 25 full upgrade ROI.

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Net profit (A$)	-24,024	-22,378	-20,536	-26,398	-22,944
Investment (A$)	42,430	42,430	42,430	42,430	42,430
ROI	-57%	-53%	-48%	-62%	-54%

Net Present Value

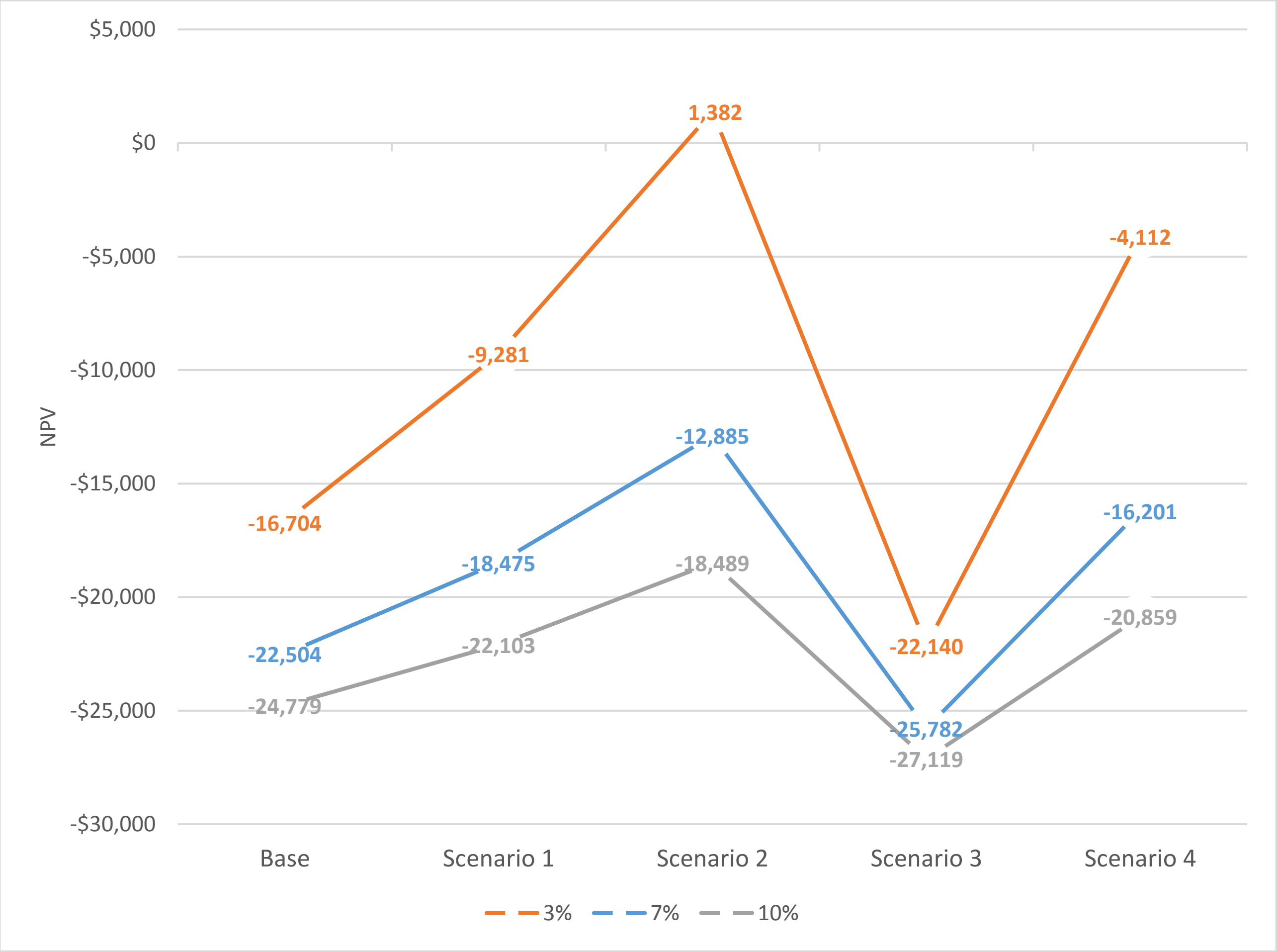


Figure 9 Grace 25 full upgrade NPV with sensitivity analysis

Table 17 Grace 25 NPV at 7% discount rate

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Benefit (A$)	24,225	28,254	33,844	20,948	30,528
Cost (A$)	-46,730	-46,730	-46,730	-46,730	-46,730
NPV (A$)	**-22,504**	**-18,475**	**-12,885**	**-25,782**	**-16,201**

Discussion

The Grace 25 NZEH package does not pay back inside 10 years. This is mostly due to the cost of the windows upgrade.

The most effective individual upgrades are the installation of the solar PV system and the Heat Pump hot water system. The induction cooktop and increased window aperture are cost netural (including the saving for removal of gas supply to offset the installation of the induction cooktop) and provide a small economic benefit immediately. Insulation upgrade provides a meaningful saving each year, though does not payback inside 10 years under the base scenario.

At the 7% discount rate, the project does not have a positive NPV across any scenarios.

Perth - Windsor

Table 18 Windsor Costings

	INITIAL ADDITIONAL COST	ANNUAL OPERATIONAL SAVINGS	ANNUAL REVENUES	OBSERVATION
TOTAL COSTS/SAVINGS/REVENUES	**A$19,618**	**A$1,161**	**A$338**	
Glazing	A$1,732	A$124		
Low-e glazing to balcony sliding doorsliding doors	A$1,732			
Insulation	A$2,280	A$9		
Wall insulation	A$895			
Anticon	A$1,385			
Appliances	A$8,426	A$520		
Fans in bedrooms	A$1,185			
Split systems	A$4,945	A$102		
Heat pump	A$2,050	A$368		
Induction stove and electric oven	A$1,646	A$8		
Gas supply	-A$1,400			Savings from gas installation
Lighting	A$1,180	A$3		
LED	A$1,180	A$3		
Solar system	A$6,000	A$547	A$338	
5kW PV	A$6,000	A$547	A$ 338	

The additional cost of A$19,618 represents an 9% increase in the house price, originally set at A$228,520.

Payback

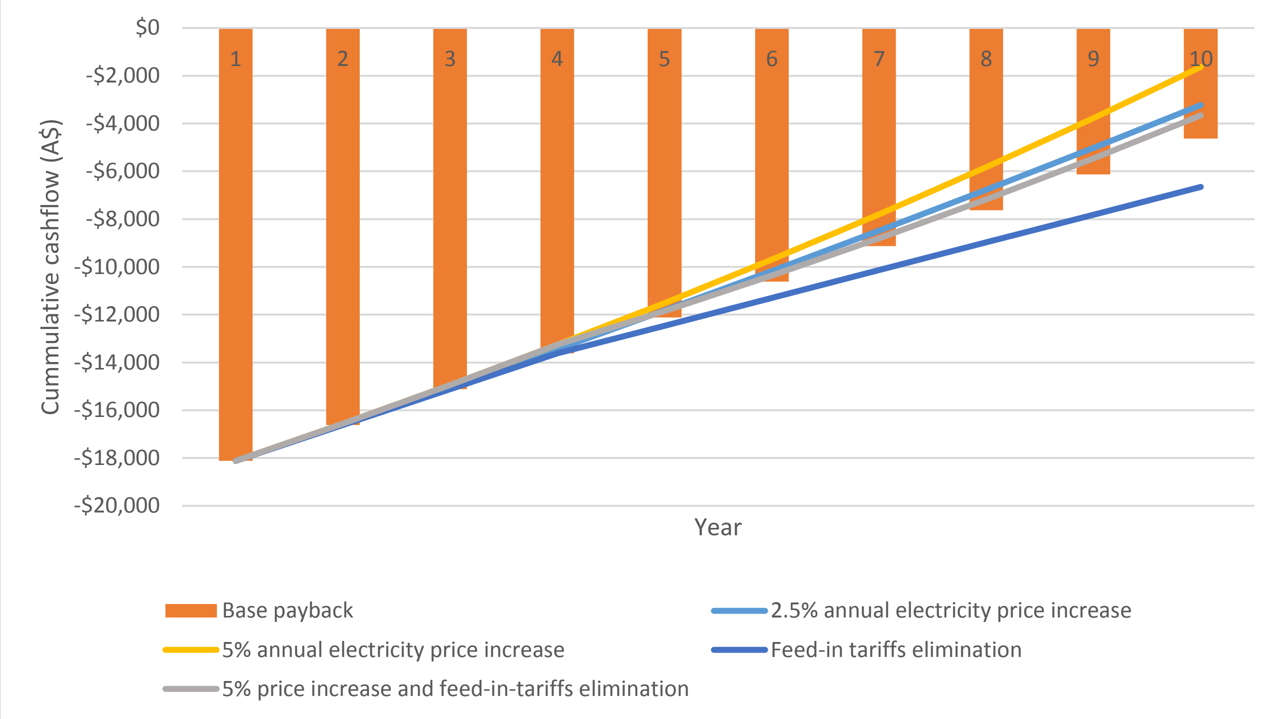


Figure 10 Windsor full package cashflow and payback sensitivity.

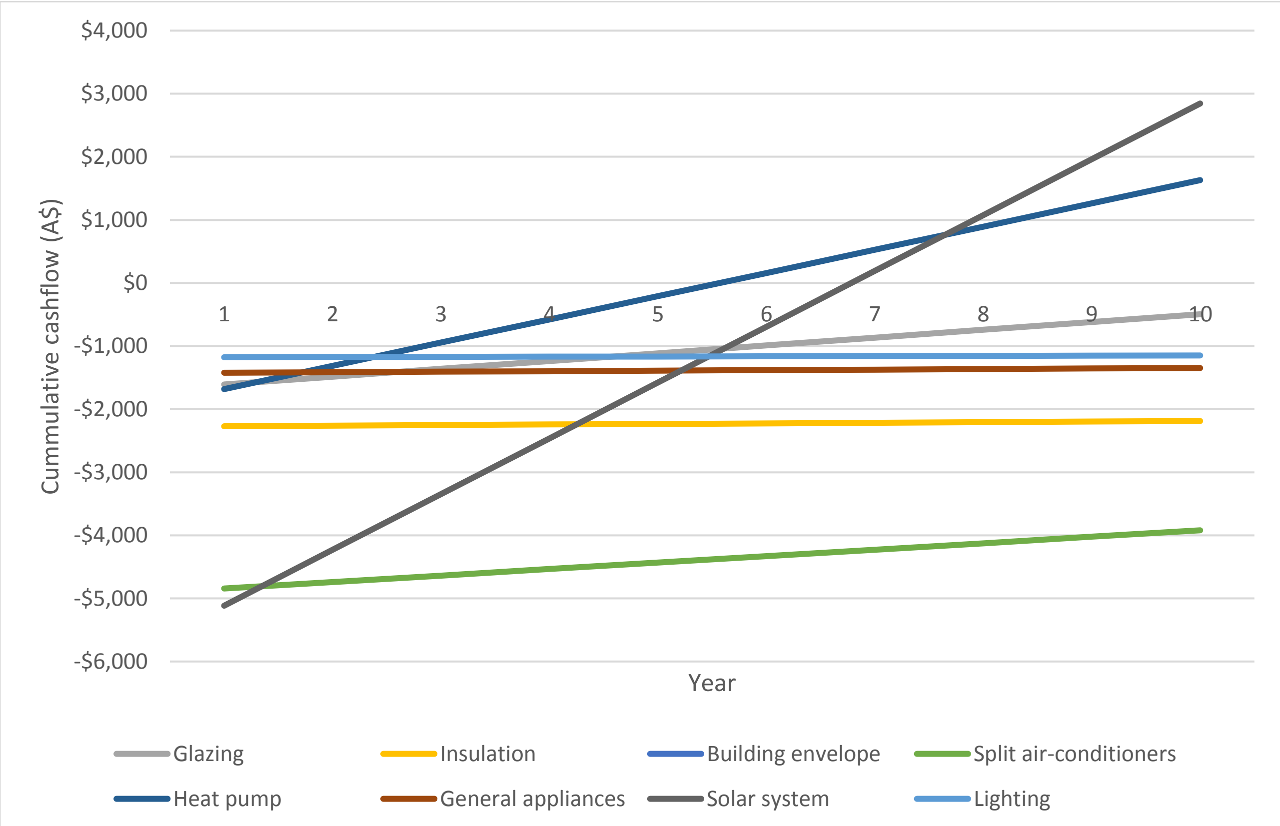


Figure 11 Windsor individual upgrade paybacks, Base Scenario

Return on Invesment

Table 19 Windsor full upgrade ROI (without security screens)

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Net profit (A$)	-4,626	-3,228	-1,632	-6,653	-3,659
Investment (A$)	19,618	19,618	19,618	19,618	19,618
ROI	-24%	-16%	-8%	-34%	-19%

Net Present Value

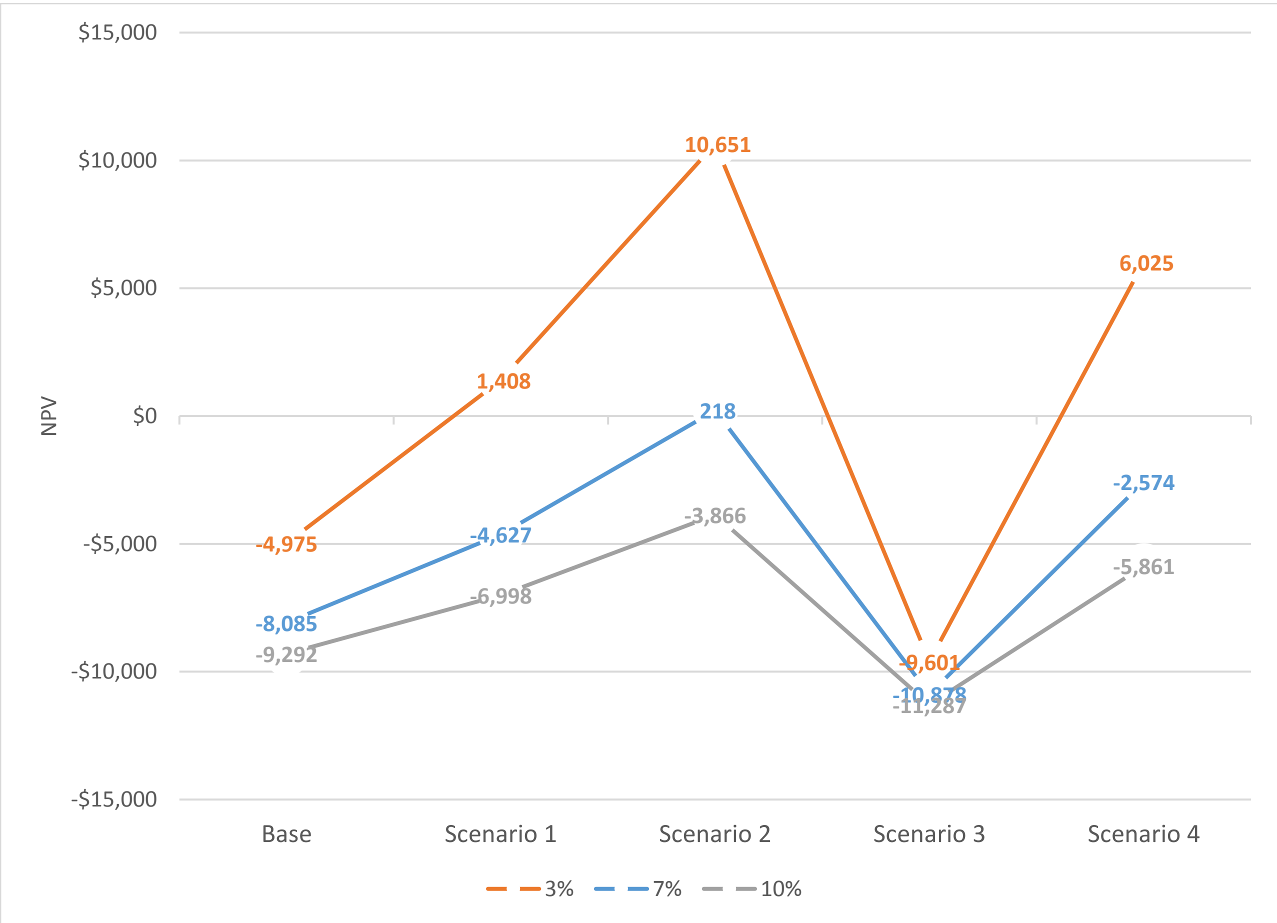


Figure 12 Windsor full upgrade NPV with sensitivity analysis (without security screens).

Table 20 Windsor NPV at 7% discount rate (without security screens).

	BASE SCENARIO	2.5% ANNUAL ELECTRICITY PRICE INCREASE	5% ANNUAL ELECTRICITY PRICE INCREASE	ELIMINATION OF FEED-IN-TARIFFS	5% ANNUAL ELECTRICITY PRICE INCREASE AND ELIMINATION OF FEED-IN-TARIFFS
Benefit (A$)	13,581	17,040	21,885	10,789	19,093
Cost (A$)	-21,667	-21,667	-21,667	-21,667	-21,667
NPV (A$)	**-8,085**	**-4,627**	**218**	**-10,878**	**-2,574**

Discussion
The Windsor NZEH package does not pay back within 10 years across any scenario.

The most effective individual upgrades are the Heat Pump hot water and Solar PV systems. Lighting, Insulation and Air Conditioner upgrades do not provide enough financial benetfit across either the lifespan of the upgrade/appliance or the 25-year mortgage period to offset the initial cost of installation.

At the 7% discount rate, the project has a positive NPV only when security screens are not included in the costing for Scenario 2.

Discussion and Conclusion

Construction Costs

The increased costs to lift the case study buildings from the base design to NZEH standard is between 6% (Innovation Home 2.0) and 11% (Windsor and Grace 25). This aligns with the sale premiums observed in the literature for top-level energy certificates. Cost summary is shown in Table 21.

Table 21 Summary of NZEH upgrade costs

DESIGN	INCREASED COST (A$)	% INCREASE
Z-Range	19,250	8
Innovation House 2.0	21,030	6
Grace 25	42,430	11
Windsor	19,618	9

The cost of both initial construction and NZEH upgrade packages is significantly higher for Grace 25 than the other three packages. The significant factor for the NZEH upgrade in Grace 25 is the window upgrade.

Individual Upgrades

Across all case studies, implementing a heat pump or evacutated tube hot water service and solar PV system provide strong financial incentives for installation, regardless of other upgrades. In terms of the solar PV system, this is because it reduces the overall house demand on the grid and generates revenue due to exports. The effectiveness of the solar PV system is diminished by the removal of the feed-in tariff as this removes the revenue stream, however the savings are still large enough to make the solar installation economically viable. The value of the solar system increases for scenarios where electricity prices rise.

Table 22 shows the savings and revenue generated by the solar PV system for each house.

Table 22 Summary of Solar PV costs, savings and revenue under Base scenario

DESIGN	SIZE	COST (A$)	ANNUAL SAVING (A$)	ANNUAL REVENUE (A$)
Z-Range	5 kW	6,000	600	412
Innovation House 2.0	5 kW	4,950	231	444
Grace 25	4 kW	8,190	637	401
Windsor	5 kW	6,000	547	338

Thermal shell upgrades provided a greater savings benefit than improved air conditioning, and whilst did not pay back inside 10 years, have a lifespan nearer to the whole-building lifetime without demanding additional maintenance costs when compared with the BAU designs. Improved insulation was found to be effective in all case studies except Perth. Low-e glazing was effective over 25 years in Perth and Townsville, while double glazing was only effective in Melbourne. It must be noted in these cases that the amount of improved glazed and cost of installation has a large impact on the cost effectiveness long term.

Table 23 Summary of Glazing Costs and Savings

DESIGN	DESCRIPTION	COST	ANNUAL SAVING
Z-Range	Double glazing to sliding door	$A 1,500	$A 70
Innovation House 2.0	Low-e Glazing to all windows*	$A 1,500	$A 146
Grace 25	Thermally broken to Lounge and Living, Double glazed all else	$A 27,435	$A 106
Windsor	Low-e Glazing to Balcony sliding door	$A 1,732	$A 124

*Innovation House 2.0 costing also included $2,800 for shading louvres.

Table 24 Summary of Insulation Costs and Savings

DESIGN	DESCRIPTION	COST	ANNUAL SAVING
Z-Range	Additional Roof + Anti-con	$A 4,000	$A 211

DESIGN	DESCRIPTION	COST	ANNUAL SAVING
Innovation House 2.0	Ceiling, Anti-con and Wall	$A 3,500	$A 218
Grace 25	Ceiling and Roof	$A 2,430	$A 180
Windsor	Wall and Anti-con	$A 2,280	$A 9

Based on the *Design Review Report*, expenditure on heating and cooling may be estimated at between 25%-35% of the overall electricity use for the Baseline designs, equating to $495-$693 based on the average household electricity bill. The total savings for the thermal shell upgrades (Glazing and Insulation, Table 23 and Table 24) therefore represent up to half of this cost, depending on region. This shows that the upgrade is effective in reducing running costs, especially across the lifetime of the building. For Grace 25 in particular, while the glazing upgrade shows similar savings to the other designs, it is the cost of the upgrade that makes the overall project unfeasible. If potential improvements in the supply chain and cost reductions for this upgrade can be identified, the effectiveness of the NZEH upgrade may be vastly improved.

Similar to Glazing, upgrading to an induction cooktop is wholly dependant on installation costs, as there is not a large enough saving when compared with the actual running costs of a gas stove.

Lighting upgrade was not found to be effective in the one case study it was present for (Windsor).

Gas to Electric

Creation of an all-electric home allows the entire energy demand, in theory, to be supplied or at least directly offset by a solar PV system. Despite the relatively low cost of gas compared to electricity, there are competitive savings to be found across the lifespan of the appliances when installing high-efficiency electric alternatives, even before applying additional savings due to solar.

The major influence for the Z-Range is the high cost of replacing the ducted gas system with reverse cycle. In the other two case studies where gas was part of the base design, the combination of heat pump hot water and induction cooktop paid back within the lifetime of the appliances. Once the cost of installing a gas connection and daily gas supply charges are accounted for as part of the all-electric upgrade, there is strong financial incentive to move to an all-electric home. This is also expected to improve the effectiveness of any future storage systems installed. Comparison of total all-electric conversion costs and annual savings is shown in Table 25.

Table 25 All-Electric upgrades

DESIGN	APPLIANCES	INCREASED COST ($A)	ANNUAL SAVING ($A)
Z-Range	Reverse cycle Air Conditioner, Heat pump hot water, Induction cooktop	4,800	412
Innovation House 2.0*	-	-	-
Grace 25	Heat pump hot water, Induction cooktop	4,375	511
Windsor	Heat pump hot water, Induction cooktop	2,296	376

*No gas connection for Innovation House 2.0 Base design.

Scenarios and NPV

The case studies show the NZEH upgrades to have positive NPVs for futures where electricity prices increase. The high cost of security screens for the Windsor design and Glazing for Grace 25 provide exceptions, where the upgrade performs best under a price increase scenario, but still has a negative NPV under the 7% discount rate. Due to the high importance of solar, the overall project is less effective when solar tariffs are removed.

NZEH upgrades therefore represent insurance against a future where electricity prices increase, even if the feed-in tariff is removed. The financial benefits to the homeowner are however reduced signifcantly if energy unit prices remain at current levels. There is some risk that the investment in NZEH does not provide good return if energy price remains static and supply charge increases.

It has been noted that there are some upgrades that are not cost effective. Based on the figures presented in the design report, removing these elements is not likely to remove the NZEH status of the home due to the size of the solar PV systems installed. However, removing thermal shell items is likely to have a flow on effect that may be larger than expected as it places increased pressure on the other thermal shell elements and the air conditioning system. The thermal shell projects are effective at providing cost savings, however relatively higher installation costs reduce the overall effectiveness. The largest improvement to overall feasibility of NZEH upgrades is likely to be found in reduction of construction costs for thermal shell rather than additional improvements in material performance.

Additionally, other studies evaluating long-term sustainability projects have utilised the lower discount rate for evaluating the NPV. Under the 3% discount rate, the NPV is only negative in Scenario 3, where electricity prices are kept constant and the feed-in tariff is eliminated. Note that the NPV of the Windsor design for the Base scenario is still negative under this scenario, but removing the lighting upgrade from the package ($1100 cost for a $3/year benefit) will address this. NPV at 3% may be considered more representative of a 'true' value of the NZEH upgrades considering the non-economic benefits noted in the literature. This has not been specifically analysed as part of this report however, and may be more applicable at the wider policy level than to the individual builder and homeowner who may not be the beneficiary of these additional impacts.

Conclusion

This report identifies the financial costs and benefits of upgrading four case study designs to a NZEH level. Further work, and monitoring of the response to these pilot homes may establish whehtherhow the increased construction costs compare to the potential increased sales premium for high performance, sustainable homes.

The most effective upgrade is installing solar PV followed by heat pump or evacuated tube hot water systems. Over the lifespan of the home, improved thermal shell is likely to provide good financial return, but returns on investment will not be seen for these items within 10 years. The major influence on the overall feasibility of thermal shell upgrades is cost of installation as in most cases the upgrade provided good savings to the household.

Installing electric appliances instead of gas is shown to be cost effective based on the running costs of the appliance, and will only improve the benefits of solar PV.

Upgrades to air conditioning units appears to be less effective than thermal shell improvement due to maintenance and replacement costs of the unit, but should be considered as part of an all-electric upgrade.

Applying the recommended 7% discount rate, only electricity price increase scenarios (1,2 and 4) provide economic incentives for embarking on the NZEH upgrade across the 25 year period. It may be argued that the 3% discount rate is more appropriate as it provides some accounting for non-economic benefits to the occupants. Using a 3% discount rate, the NPV of the Base scenario also provides economic incentives in three of four case studies.

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