Increasing the Affordability and Performance of New Homes in the ACT

National Construction Code Whole of Home and Thermal Shell Modelling

Prepared for:	**Environment, Planning and Sustainable Development Directorate, ACT Government**
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Table of Contents

Index of Figures

Index of Tables

Summary for policymakers

Higher energy performance standards in the ACT would deliver economic, environmental and cost of living net benefits worth $380.1m.[1]

In addition to lifetime financial savings to householders of $472.2m, increased standards would avoid 66.1kt CO2-e cumulatively, worth $14.9m (avoided social cost of carbon), and lead to a reduction in peak electrical demand of 7.3MW, worth $156.7m (avoided infrastructure costs). Incremental construction costs would be $263.7m. **In all, benefits outweigh additional costs by a factor of 2.4:1.**

Our analysis shows that almost all households will be cashflow positive from day one, because energy cost savings will outweigh increased borrowing costs. These savings are even greater if upgrades are financed using "green" loans.

Higher energy performance standards represent a sound investment proposition for households and for society. The Internal Rate of Return (IRR) for households would be 8.9%, which is at least double typical bank deposit rates, while the societal IRR is higher at 12.3%, due to the additional value of avoided greenhouse gas emissions and electricity network infrastructure costs.

Delivering these outcomes requires different upgrade strategies across the Territory's new residential buildings:

- For houses and townhouses, improving the efficiency of appliances and increasing solar PV uptake is more cost effective than current minimum requirements.
- For apartments, increasing thermal efficiency is cost effective and will contribute to reducing grid investment and addressing social inequalities.

This report also examines a range of future opportunities to further improve the ACT's residential energy efficiency standards, including through information provision, increasing battery adoption, and supporting solar uptake in apartments.

[1] Financial values are all present values in FY2025 dollars with a real discount rate of 5%, assuming a 10 year policy duration.

Key findings

1) Based on our analysis of the most cost-effective solutions, the optimal minimum NatHERS requirements for new dwellings in the ACT are:
   a. 100 WOH points for Class 1 dwellings, while maintaining the current 7 star thermal shell requirement.
   b. A 7.5 star average, and 6.5 star minimum, thermal shell requirement in Class 2 dwellings, while maintaining the current 50 WOH requirement.
2) There is a case for encouraging uptake of dwelling-appropriate least-cost efficiency strategies by developing supporting materials for home builders and buyers based on the findings of this report.
3) Future improvements to residential energy efficiency standards should be informed by:
   a. Monitoring uptake of solar PV in the apartment sector with an eye to future increases to Class 2 WOH stringencies.
   b. Developing a more comprehensive understanding of the private and social costs of household battery uptake to inform future improvements to the NatHERS model.

Key economic indicators	**Value**
Additional capital investment from homeowners	$263.7m
Lifetime operational savings from reduced energy use	$472.2m
Value of avoided carbon emissions	$14.9m
Avoided energy network investment	$156.7m
Net Present Value of recommended energy performance improvements	$380.1m
Societal Benefit Cost Ratio	2.4
Internal Rate of Return	8.9%
Social Internal Rate of Return	12.3%

Executive Summary

This report explores the feasibility of enhancing the minimum energy performance standards for new residential dwellings in the Australian Capital Territory (ACT), focusing on Class 1 buildings (houses and townhouses) and Class 2 buildings (apartments). The primary objective of this work is to identify cost-effective strategies to minimise lifetime costs for homeowners, while also minimising social costs associated with greenhouse gas emissions and energy distribution infrastructure. Additional analysis on the impact of lighter roof colours and future climate change on energy consumption and costs has also been conducted.

Currently, the ACT has adopted the NCC 2022 energy performance requirements, which mandate a minimum thermal performance rating of 7-stars under the Nationwide House Energy Rating Scheme (NatHERS) for Class 1 dwellings and an average 7-star rating with a minimum of 6 stars for individual units in Class 2 dwellings.[2] Additionally, Whole-of-Home (WOH) performance requirements - which are based on the energy efficiency of fixed appliances, space conditioning systems, hot water systems, onsite renewable energy and/or batteries - are set at a minimum of 60 points for Class 1 dwellings and 50 points for Class 2 dwellings. Despite these recent increases in performance requirements, **our analysis has found there is potential to further enhance energy performance standards to achieve greater economic and environmental benefits, including reductions in the cost of living.**

Methodology

The methodology employed in this study combines dwelling-level thermal and energy modelling and financial analysis to assess the marginal impact of increasing energy performance standards by comparing a base case scenario with various potential scenarios. The base case represents current compliance with NCC 2022 standards, while the comparator cases incorporate the potential enhancements in energy performance requirements. Representative dwelling types, or archetypes, were selected to reflect common ACT housing designs, including standalone houses, townhouses, and apartments. The thermal performance of these archetypes was assessed using NatHERS modelling with HERO software, focusing on achieving various star ratings and evaluating the impact of different thermal shell improvements. WOH performance was analysed (also using HERO) by testing different energy efficiency measures for appliances, lighting, and the integration of solar photovoltaic (PV) systems. A sensitivity analysis examining the financial implications of incorporating batteries into a 100 WOH point dwelling was also undertaken. By contrasting the base case with the enhanced scenarios, the study determined the marginal costs and benefits of the proposed changes. A cost-benefit analysis was conducted to determine the net present value (NPV) of various energy efficiency upgrades, considering both capital investment and lifetime energy and

[2] Star ratings apply to the 'thermal shell' of a dwelling – a phrase that refers to its basic structure including its overall design and size, the construction materials used, insulation levels and air tightness.

carbon savings. A stock model projected new dwelling completions to estimate the overall impact of the proposed standards in the ACT, assuming the proposed stringencies apply from 2026 to 2035.

Findings

For Class 1 dwellings (houses and townhouses), achieving net-zero energy cost, or 100 WOH points, is more cost effective than meeting current minimum requirements, generating significant lifetime financial savings for residents, as well as immediate reductions in the cost of living.[3] This result is primarily achieved through the integration of solar PV systems, which significantly offset the need for more expensive thermal shell improvements and high-efficiency appliances. The average size of PV systems required to achieve 100 WOH points in Class 1 dwellings, 7.7kW, is considerably smaller than the average size of PV systems currently being installed in the ACT, which has exceeded 10kW in recent years. Due to the cost effectiveness of solar PV, increasing WOH scores in isolation was generally found to produce greater private and social benefits than improving WOH scores combined with thermal shell stringency, as shown in Figure 1.[4] We therefore recommend the ACT considers lifting the WOH performance requirement for Class 1 dwellings to 100 points.

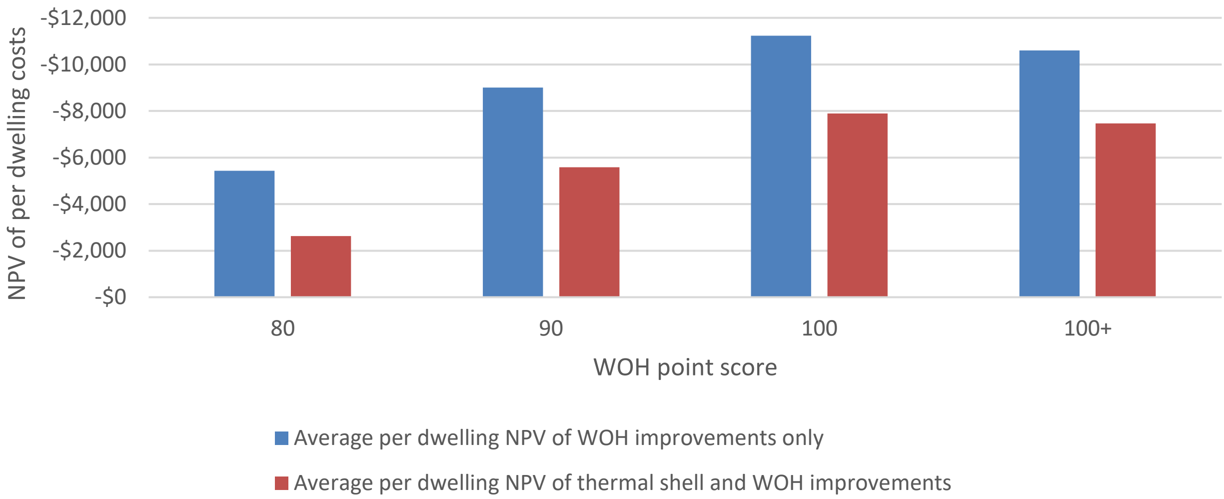

Figure 1: Weighted average Class 1 NPV of private costs by WOH point score by strategy

[3] A WOH score of 100 points implies a household is receiving as much value from feed-in tariffs over the course of a year as it is expending on the purchase of grid supply.

[4] In this Figure, and throughout the report, a key indicator of cost-effectiveness presented is the net present value (NPV) of costs, both private and social. Improving energy performance often requires a capital cost to be incurred, with that investment leading to a reduction in energy costs (and other benefits). Where the present value of the energy cost savings exceeds the present value of the extra investment costs, the NPV of costs will be negative. In this context, a negative NPV can be interpreted as 'the more negative the better'. In Figure 1, for example, the 100-WOH point blue bar has the highest negative cost, meaning that this option has the highest net benefit. A range of alternative metrics and KPIs is presented in Section 4.4.

For Class 2 dwellings, the study found that significant improvements in WOH scores were not possible without the use of solar PV. Technical and governance challenges in installing solar PV on apartment buildings limit the feasibility of relying on energy generated on site to meet higher regulatory performance standards. Initial results suggested upgrades to the apartment thermal shell alone were likely to be cost effective, though the sums involved were small.

To test our initial findings, we conducted additional detailed analysis of thermal shell upgrades on a wider range of apartment types. The results of this analysis confirmed that upgrading thermal shell requirements to a 7.5 star average, and 6.5 star minimum, would be cost effective over the life of the dwelling, particularly for the worst performing apartments. This finding is supported by the fact that the average NatHERS star rating of apartments issued certificates in 2024 was 7.3 stars.[5] There are also significant uncosted benefits of higher thermal shell ratings, such as improved comfort and climate resilience. Given these findings, and the importance of ensuring apartment dwellers are not left behind as the residential sector transitions to an increasingly low energy and cost future, we recommend adopting this higher thermal shell requirement for Class 2 dwellings.

Although we do not recommend increasing WOH stringencies for Class 2 dwellings at present, we do recommend the ACT Government monitor the uptake of solar PV in the apartment sector in coming years to inform future potential improvements.

Cost benefit analysis

The whole-of-policy cost-benefit analysis reveals substantial net benefits associated with the proposed enhancements to Class 1 WOH and Class 2 thermal shell stringencies. **Implementing the recommended stringencies could result in a net present value (NPV) of approximately -$380.1 million** (representing a negative cost, or benefit), including both private and societal benefits. Homeowners are expected to incur additional capital costs of **$263.7 million**, though these capital investments are outweighed by lifetime operational savings of **$472.2 million**, stemming from reduced energy consumption. Social benefits include avoided carbon emissions of **$14.9 million** and avoided network investments amounting to **$156.7 million**. The balance of cost savings, $380.1 million, is shown in the final bar of Figure 2. Together, the recommended changes would generate a societal Benefit/Cost Ratio (BCR) of greater than 2.4, indicating they would generate 2.4 times more benefit than cost in present value terms.

[5] https://ahd.csiro.au/dashboards/energy-rating/lga/

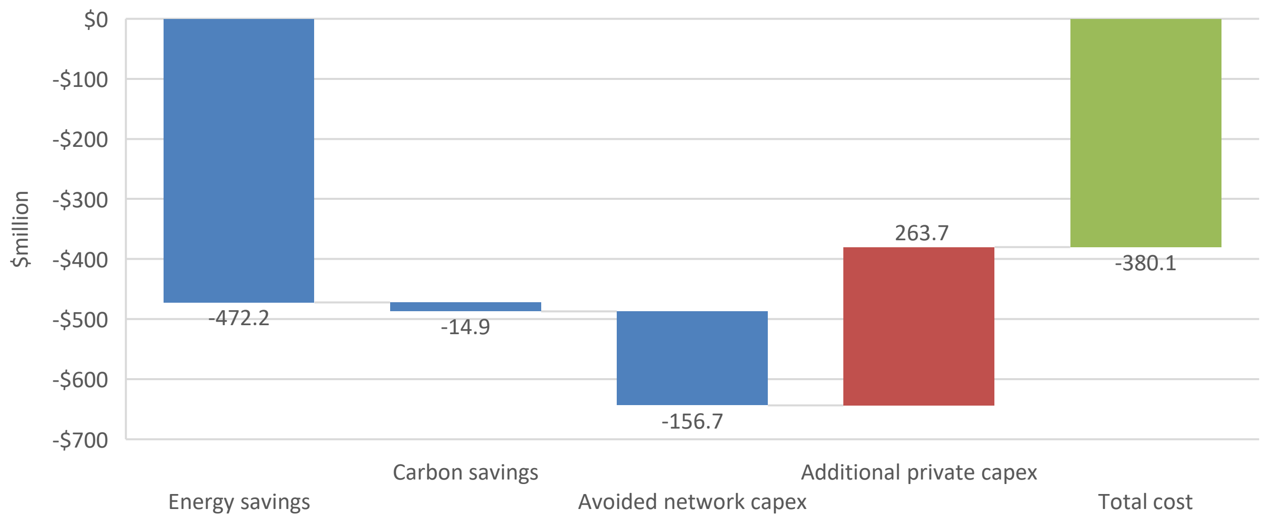

Figure 2: Present Value of Total Costs, Recommended Stringencies, by Component

We also interrogated the results using a range of different financial metrics in addition to NPV and BCR. For example, the householder's payback period for the private costs of the upgrades ranges between 12 and 16 years depending on the dwelling type. While this may seem like a long time, the payback period metric masks the fact that these upgrades would leave households better off financially from Day 1, and every day thereafter. This is because the reduction in energy costs more than offsets the extra mortgage costs - even with current (early 2025) above-average interest rates - with this benefit accruing as soon as the dwelling is occupied. The financial attractiveness of adopting the recommended stringencies is greater still if the dwelling is funded using lower interest rate "green" loans, which can provide a lower interest rate on the entire mortgage for a period of time, as shown in Table 1. A key result of this analysis is that the higher energy performance standards would *reduce* the cost of living in the ACT, at least for occupants of new homes.

Table 1: Monthly cashflow impact of adopting recommended stringency with green mortgage[6]

	New dwelling price (,000)	Base case mortgage (20% dep) (,000)	Rec stringency mortgage	Base case payments @ 6.15%	Rec stringency payments @ 5.57%	Mortgage savings	Energy savings	Total savings
SBH01	$1,100	$880	$892,602	$5,751	$5,519	-$232	-$136	-$368
SBH04	$950	$760	$769,093	$4,967	$4,755	-$212	-$104	-$316
SBH015	$800	$640	$648,138	$4,182	$4,007	-$175	-$89	-$264

[6] Note: Apartments have been excluded from this analysis as it is unlikely an upgrade to 7.5 stars would qualify for a "green" mortgage. The sums involved are also small.

In addition to finding that net-zero energy Class 1 buildings generated significant private and societal cost savings, the study also highlights the variability in potential cost outcomes for builders and homeowners in meeting increased energy efficiency standards. **To maximise benefits and ensure stakeholders can realise cost-effective compliance strategies, the ACT Government should develop materials that communicate these strategies effectively.** By providing guidance on least-cost approaches, the ACT Government can facilitate the adoption of higher energy performance standards quickly and efficiently. For example, it would not be widely understood that many of the almost 13,000 dwellings that installed PV systems in the ACT over 2023 and 2024 – when installations averaged 10kW per system – will be operating at or beyond net zero energy, equivalent to 100 WOH or more.[7]

Additional analysis

Sensitivity analysis using CSIRO RCP8.5 2050 climate projections indicated a net reduction in energy costs due to decreased heating requirements, despite a slight increase in summer cooling needs.[8] These findings are consistent with the ACT's heating-dominated climate, as future warming will reduce heating demand to a greater extent than it will increase cooling needs, leading to net energy savings. That said, CSIRO future climate files may under-estimate the impact of extreme heat days and of heatwaves, while the increased electrical loads in summer may require additional infrastructure investment.

Sensitivity analysis on roof colour revealed that mandating lighter roof colours results in small increases in lifetime energy costs. This is because the ACT is, and is predicted to remain, a heating-dominated climate, and lighter-coloured roofs increase heating needs in the cooler months, which are not fully offset by reduced cooling demand in summer. The financial impact of such a policy would be minimal and may be offset by uncosted factors such as reductions in the urban heat island effect or by reduced health impacts during extreme heat events.

Finally, we conducted a secondary analysis of the impact of batteries on the NPV of a least-cost, 100 WOH point dwelling (which does not include batteries). This analysis shows that incorporating batteries in a 100 WOH point Class 1 dwelling does not improve the cost-effectiveness of the overall strategy. The initial capital cost and replacement requirements of batteries over time outweigh the benefits from increased behind the meter consumption of low-cost electricity from PV systems.

Importantly, this assessment only considers private costs using the NatHERS model, which treats batteries as simple storage tanks, and does not capture broader market, climate, or social cost/benefit factors. Given the evolving role of batteries in a future decarbonised grid—where factors such as coordinated operation, grid support services, and evolving time-of-use tariff

[7] Note: The use of gas appliances makes reaching 100 WOH points difficult, even with large PV installations.
[8] For more information on the CSIRO RCP8.5 climate files used in this analysis, see: https://ahd.csiro.au/other-data/predictive-weather-files-for-building-energy-modelling/

structures could improve their attractiveness—further research is required to develop a more holistic financial and emissions model that captures these dynamic factors.

Key findings

1) Based on our analysis of the most cost-effective solutions, the optimal minimum NatHERS requirements for new dwellings in the ACT are:
    a. 100 WOH points for Class 1 dwellings, while maintaining the current 7 star thermal shell requirement.
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1. Introduction

1.1 Purpose

This project investigates the case for the ACT to increase current minimum energy performance requirements for Class 1 (houses and townhouses) and Class 2 (apartment) dwellings.

This report considers this case separately for Class 1 and 2 'archetypes', or representative designs, and it also separately considers thermal shell or 'envelope' (star rating) requirements and whole-of-home (WOH) requirements.

In addition, we undertake sensitivity analyses to test the impact of:

- cool or light-coloured roofs (SA<0.4) roofs when compared medium (SA 0-4-0.6) or dark roofs (SA >0.6)
- historical vs future average climate assumptions.

This work leads to provides optimal stringency levels for the ACT. Our overall approach to this task is summarised in Section 0, with the methodology detailed in Chapter 2.

The wider objectives of this work include exploring least-cost and/or cost-effective opportunities to:

- minimise lifetime energy costs for home-owners and occupants in the ACT,
- reduce greenhouse gas emissions attributable to the ACT,
- minimise related societal costs, such as the cost of providing energy infrastructure, and;
- better understand the climate resilience of ACT housing, taking into account expected future climate change.

In addition to the current project, the ACT Government has committed to several measures to improve the energy efficiency of buildings in the ACT. These include:

- a Sustainable Buildings Pathway plan to encourage better choices in building, operating, and renovating to ensure all buildings cope with the effects of climate change now and in the future,
- mandating the disclosure of the Energy Efficiency Rating (EER) at point of sale/lease for homes,
- encouraging consumers to uptake energy efficient appliances in existing homes through ACT Government's Climate Choices Sustainable Household Scheme,
- introducing minimum insulation requirements for all rental properties by 30 November 2026,

- conducting investigations on cool and light-coloured roofs to reduce the urban heat island effect, and;
- decarbonising the ACT's built environment through electrification via the Integrated Energy Plan and through the implementation of no new gas connection regulation.

1.2 Context

The ACT adopted current (NCC 2022) energy performance requirements for residential dwellings from 15 January 2024. This included:

- minimum thermal shell requirement of:
  - 7 star under NatHERS (or equivalent)[9] for Class 1 dwellings, and;
  - 7 star average and 6 star minimum (or equivalent) for Class 2 dwellings.
- minimum WOH performance requirements of:
  - 60 points for Class 1 dwellings, and;
  - 50 points for Class 2 dwellings.

NCC 2022 emerged from a protracted consideration of options for new residential energy performance requirements, over at least 5 years, with key contributions including:

- a RIS methodology report by Houston Kemp, *Residential Buildings Regulatory Impact Statement Methodology*, April 2017.
- technical reports by AECOM (*Technical Annexes 1 – 4*) covering thermal shell and WOH analysis for Class 1 and Class 2 dwellings.
- a 'Trajectory' or policy pathway report released by Energy Ministers, *Trajectory for Low Energy Buildings Report,* 2019.
- further technical analyses supporting the Australian Building Codes Board code development work:
  - Tony Isaacs Consulting, *Cost and Benefits of upgrading building fabric from 6 to 7 stars*, June 2021
  - Energy Efficient Strategies, NCC 2022 Update – Whole of Home Component, August 2021
- a consultation RIS, ACIL Allen*, NCC 2022 Consultation Regulation Impact Statement,* September 2021.

[9] Noting that the NCC offers numerous compliance verification pathways, of which NatHERS is only one – albeit that the vast majority of new homes in Australia use this pathway, depending on the state/territory, see: https://ahd.csiro.au/other-data/certificates-vs-building-approvals/

- a final Decision RIS in August 2022.

NCC 2022 was formally adopted by Buildings Ministers in August 2022, with the intention of coming into effect by 1 May 2023, or optionally from October 2023. However, Tasmania and the Northern Territory have indicated they will not adopt these measures; some states adopted them (or similar) between October 2023 and October 2024; South Australia recently announced regional variations with the state; and Western Australia will apply them from May 2025.

These changes were the first made to residential efficiency standards in Australia since the 2010 version of the Code (BCA 2010), albeit that that version was also generally delayed until May 2012, now more than 12 years ago.

It is clear the history of residential standards development in Australia has been difficult, contested, and opposed by some influential elements within the building industry.

Importantly, however, over this same period there have been significant technical developments that enable homes to achieve much higher – including 'net zero' or 'carbon positive'[10] – performance, primarily through cost and performance break-throughs in photovoltaic (PV) panels, and later by the growing availability and reducing costs of home storage batteries. Heat pump and solar hot water technologies, and heat pump space conditioning systems also experienced major performance improvements and cost reductions over this period. Finally, this period also saw dramatic rises in the cost of grid-supplied energy – including in the cost of providing electricity network capacity to homes – which enhanced the cost effectiveness of higher energy performance in dwellings. There have also been growing community concerns about anthropogenic climate change, greenhouse gas emissions, and the climate resilience of homes.

Reflecting these factors, the technical work undertaken by Energy Efficiency Strategies for NCC 2022 originally included a 100 WOH point option (net zero energy cost), and our estimation is that this would have been found to have been the most cost-effective option, at least for Class 1 dwellings, had it been subjected to impact analysis. Unfortunately, a 100 WOH point option was removed before this hypothesis was tested. In effect, the current study completes this analysis, at least for the ACT.

The technical developments noted above supported achieving much higher energy (and emissions) performance in new homes by widening the focus from the thermal shell or envelope (which was the primary but not exclusive focus of BCA 2010) to the WOH perspective that was agreed for NCC 2022. We summarise the key differences between these elements below.

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[10] 'Net zero' in this context generally refers to the US Department of Energy definition, which is where onsite renewable energy generation over a typical year equals expected energy consumption; while 'carbon positive' occurs when onsite renewable energy generation is expected to exceed consumption in a typical year.

1.2.1 Thermal Shell Performance

The thermal shell or envelope refers primarily to the 'external facing' elements of a home: the slab or floor components, walls, roofing, glazing, external shading devices/roof overhang, orientation on the block, and air leakage or uncontrolled infiltration. In addition, the thermal properties of the building materials, and their locations within the design, influence the performance of the thermal shell. This includes the 'thermal mass' of materials, and their propensity to store (or lose) heat or 'coolth' over different timeframes.

The performance of the thermal shell is a key determinant of how comfortable the dwelling is. Dwellings with poor thermal performance experience significant swings in internal temperature throughout the daily and seasonal climate cycles. Even when mechanical heating and cooling is added to try and offset these effects, heat or cold still radiates into the dwelling through its thermal shell, which we experience as discomfort. High-performing thermal shells (and solar passive designs) can enable internal surfaces and materials (with thermal mass) to radiate heat in winter and coolth in summer, and these effects, in addition to temperature stability and an absence of drafts, are associated with a subjective perception of thermal comfort. High performance thermal shells also diminish external noise, which may be particularly valuable near noisy roads.

A dwelling's thermal shell elements – along with the design and size of the dwelling – contribute to its star rating under NatHERS. The star rating is a scale from 0 to 10 stars, with 10 stars (approximately) equal to zero heating/cooling loads. Key indicators of thermal performance include the heating and cooling 'loads' experienced by the dwelling. These loads indicate how susceptible the dwelling is to changes in *internal* temperatures as a result of changes in *external* temperatures and other climate conditions. This, in turn, affects how much heating or cooling energy will need to be expended to maintain a comfortable temperature inside the dwelling. The lower the heating and/or cooling loads, the higher the star rating, and also the less energy that is required for (mechanical) heating or cooling of the home.

Of course, the local climate is an important factor in the thermal performance of a given design. Canberra has a climate that is heating-dominated – due to its inland position and significant elevation above sea-level – but where there are also hot summers, and so cooling loads also matter. Similarly, climate change is expected to impact on the thermal performance of dwellings in the ACT, and this is discussed in Section 2.2.3.

An important factor to note with respect to star ratings and thermal performance is that NatHERS star bands are not linear. Rather, as the star rating increases, the degree of reduction in thermal loads becomes smaller and smaller – see Figure 3. This implies that the *additional* or *incremental* savings in heating and cooling energy (associated with the thermal shell) become smaller at higher star ratings. Also, as a rule of thumb – but not necessarily the case, as explored in this report – the costs associated with achieving higher and higher star ratings (lower thermal loads) tend to increase. This means that eventually we are likely to encounter 'diminishing returns' when seeking to achieve higher and higher star ratings. At the same time, this risk has to be weighed against the increasing risks associated with climate change – such as the risk of more frequent and severe 'heat storms', for example – where a higher performing thermal shell can maintain safe internal temperatures for longer, even in conditions such as power outages (which also tend to increase in extreme temperature conditions).

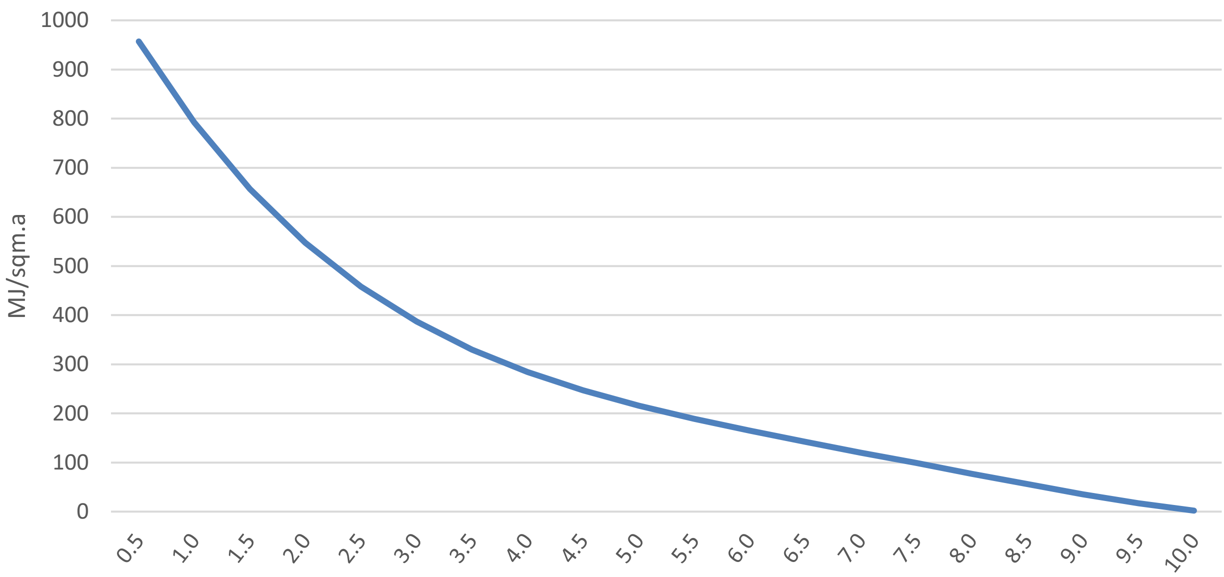

Figure 3: ACT Total Thermal Loads by Star Rating

1.2.2 Whole of Home (WOH) Performance

As the name indicates, the WOH performance aims to encompass all of the home's energy consumption, including space conditioning (heating and cooling), domestic hot water, wired-in cooking devices, lighting, any pool or spa pumps, and whitegoods or other 'plug loads' (anything that can be plugged in and which is not permanently wired in). NatHERS does not model plug loads in any detail and, for NCC compliance purposes, a non-variable allowance is made for this load. In addition, any PV systems or batteries connected to the dwelling will influence its WOH performance.

WOH performance is, since NCC 2022, calculated using a point scale from 0 – 150. 100 on this scale is equivalent to net zero energy cost, as defined above, while scores above 100 are energy cost negative, meaning the value of net annual exports of renewable energy from the dwelling exceeds the cost of residual grid supply to the dwelling. As noted above, under NCC 2022 new houses and townhouse must achieve at least 60 points, and new apartments 50 points.

Compliance with the NCC WOH requirements can be demonstrated either using the NatHERS WOH performance score, or by using the ABCB's simplified excel calculator. In both cases the WOH points system is complex and non-transparent. The NatHERS WOH points are stated to be proportional to a measure of the 'social cost of energy' and take into account varying (societal) energy costs depending upon the time of use of energy. This explains why batteries feature in the WOH calculation – even though they are net consumers of energy – as they can effectively change the time of use of energy within the home, by storing surplus PV energy during the day and using this energy to reduce the need to import from the grid during peak demand periods.

Given the lack of transparency, the 'dividend' or yield of points that can be derived from particular features in the home must be established experimentally – as we do in this project – by testing a wide range of potential solutions.

The WOH points system is separate from the thermal shell star rating requirement, as described in the previous section, but not independent of it. For example, if a home achieves greater than the minimum star rating requirement, then this will translate into extra WOH points, compared to a home that only just meets the minimum star rating requirement (or equivalent). This home could then meet its 60 points WOH requirement with lower-specification equipment, or with less PV installed. However, the inverse does not apply. That is, it is not possible to trade-off above-minimum requirements for WOH points against below-minimum thermal shell star rating requirements. As noted in the previous section, this reflects the critical value of thermal shell performance for thermal comfort and for climate resilience, which are separate from and additional to its effects on energy costs.

1.3 Approach

The previous section highlights that there are many different elements that contribute to overall residential energy performance. Many of these elements have benefits, or savings effects, that are dependent on how and where these elements are used, and in combination with what other elements. As an example, insulating between internal walls, where both rooms are space conditioned, may save little if any energy. However, that same insulation placed inside an external wall would save a great deal of energy over the whole life on the dwelling. Similarly, installing a PV system facing south may cost the same as one facing north, but the benefits associated with the south-facing installation will be very low. This 'contingent' nature of elemental savings explain why NatHERS rating tools require the assessor to input many details of the home's design, specifications, materials, orientation and other features, so that its overall energy performance can be calculated accurately.

In this project, we use NatHERS tools to assess a range of common or typical dwelling designs ('archetypes') specified to achieve a range of both thermal shell and WOH performance targets, ranging from current minimum requirements in NCC 2022, to star ratings above 7 star, and WOH points ratings from current minimum requirements to well over 100 points. In each simulation, we calculate the combination of all the possible elements that could achieve the targeted performance scores and selected the combination that is 'least cost'.

'Least cost' combines two key elements.

The first is the up-front or capital cost of each element, which is measured relative to the (unavoidable) cost of just meeting the current minimum requirement. For example, if the minimum-required specification under NCC 2022 is modelled to require R4 insulation in the ceiling, and an above-minimum specification requires R5 insulation, then the incremental or additional capital cost of the higher specification is just difference in the cost of R5 vs R4 insulation. The cost associated with the R4 will have to be incurred anyway. If there were additional labour or other additional costs associated with the R5 insulation, then these would be counted as well.

The second element of 'least cost' takes into account the value of savings that a higher-specification would have over the life of the home, or over the life of the element concerned, where that is shorter. In the insulation example above, the R5 specification may cost more upfront, but it will also generate a stream of energy savings over the 40- or 50-year life of the home. The 'present value' of these savings (explained in Chapter 2) effectively offsets the incremental or additional capital costs of the R5 insulation.

2. Methodology

NatHERS modelling with HERO (v4.1) energy rating software was used to model the thermal performance (star rating) as well as the WOH energy loads (WOH score) for a range of dwelling archetypes.

A bespoke Excel calculator was developed to allow costing of energy efficiency parameters used to adjust the thermal and WOH modelling, record energy loads and calculate costings compared to a minimum compliance base case. Importantly, these costings are based on figures derived from the HERO software used, and the assumptions, inputs and NatHERS/Chenath model underlying it.

2.1 Data collation

2.1.1 Representative dwelling types

Six example dwellings representing three dwelling typologies (2 x standalone houses; 1 x townhouse and 1 x Class 2 apartment building made up of three apartment designs) were selected from the CSIRO NatHERS 'Standard Benchmark Houses' (SBH) to provide a range of dwelling types to test the financial impact of increasing stringency of thermal fabric and WOH energy efficiency measures. These dwellings were selected as being representative of the ACT housing stock. They are designs that have been utilised previously for testing of regulatory impacts for energy efficiency measures, therefore providing consistency and comparability against other similar studies in other jurisdictions. The archetypes selected are set out in Table 2.[11]

Table 2: Summary of Modelled Archetypes

NatHERS Standard Benchmark House ID	Description	NatHERS Floor Area (m^2)	Conditioned Floor Area (m^2)	Unconditioned Floor Area (m^2)	Garage Floor Area (m^2)
Detached Dwellings					
SBH01	Detached 2 Storey, 4 Bedroom	309.6	261.2	14.8	33.6
SBH04	Detached, 1 Storey, 4 Bedroom	165.8	125.6	7.7	32.5
SBH15	Attached Townhouse, 2 Storey, 2 Bedroom	88.4	84.5	4.0	n/a
SBH20-27 Apartment Building					

[11] Note: In light of our initial findings for the modelled apartment building, we conducted detailed secondary analysis on a second, larger apartment building archetype. The thermal modelling approach used in this secondary analysis is set out in 6.1.5, with results presented in Section 3.3.2.

Design 610	Apartment, 1 Storey, 2 Bedroom	89.4	85.7	3.8	n/a
Design 620	Apartment, 1 Storey, 1 Bedroom	59.3	54.1	5.2	n/a
Design 630	Apartment, 1 Storey, 2 Bedroom	96.5	92.6	3.9	n/a

Refer Appendix 6.1 for floor plans, elevations and detailed modelling inputs for each of the dwelling types.

2.1.2 Establishing base cases

For the purposes of the Benefit Cost Analysis, there is the need to establish base cases against which to compare the effects of increased compliance stringency. Initially we established two baseline constructs – one reflecting minimum compliance with NCC 2022, and a second based on current ACT construction practices.

Current Practice

Even though NCC 2022 only took effect in the ACT from 1 January 2024 data from the CSIRO Australian Housing Data (AHD) portal – filtered for approvals after 1 January 2024 – shows there is already over-compliance with NCC 2022 minimum requirements, as set out in Table 3 below. This data source is invaluable in several respects, including that it provides detailed insights into the construction practices and building materials choices that are made in specific regions, including the ACT. Data from this source (covering 2016 – 2024) was therefore used to inform NatHERS modelling of the archetypes, to ensure alignment with ACT construction practices. A summary of this data is provided in Appendix 0.

Then, data from designs completed only after 1 January 2024 (roughly the commencement date for NCC 2022 in the ACT) was examined to determine both the performance outcomes, and construction features, of the NCC 2022 cohort – which totalled some 727 dwellings. The average results for each class were used to model current practice, as summarised in per Table 3 below.

Table 3: Current Practice Benchmarks and Sample Sizes, Since 1 January 2024

Parameter	Class 1	Class 2
Approvals to date – No.	596	131
NatHERS star rating – average	7.1	7.3

The CSIRO data indicates the most common construction practices for external walls, floors and ceiling/roofs, and these were extracted from the building approval data to inform construction assemblies for the archetypes – see Table 4. In some cases, the specifications from the NatHERS standard (SBH) design documentation were overruled by the most common construction practices in the ACT, so that current practices were better reflected in the assessment. The main exception was the SBH20-27 apartment building retaining the lightweight cladding, as per the design documentation, as all types of light weight cladding combined accounted for more buildings than the most common concrete panel construction.

Table 4: Revealed Typical Building Element Choices, ACT

	Apartments		**Houses**		**Townhouses**	
	Most common	**%**	**Most common**	**%**	**Most common**	**%**
External wall	concrete panel	18%	brick veneer	57%	brick veneer	39%
External floor	concrete slab	24%	waffle pod	47%	concrete slabs	38%
Roof construction	Concrete	22%	metal	76%	metal	68%

NCC 2022 Minimum Compliance

From a regulatory perspective, the current NCC 2022 requirements provide the most important base case, as these are the standing legal requirements for new dwellings in the ACT. The over-compliance with these standards demonstrated above reflects home-owner-led, voluntary decisions. Therefore, any costs associated with over-compliance are not attributable to NCC 2022. However, they are important in illustrating market preferences, consumer willingness to pay, and above-minimum practices that are demonstrably feasible.

The NCC 2022 minimum compliance base case is therefore a 'counterfactual' that reflects de-specified versions of the current practices revealed in the CSIRO data. These are described below.

2.1.3 Base Case – NCC minimum compliance

The following are the maximum energy load requirements, defining the base cases of the various archetypes:

- Class 1 – SBH01, SBH04, SBH15 – all with concrete slab to ground on lower level, where applicable
  - 7 stars – 122MJ/m^2/yr
  - Heating load limit – 129MJ/m^2/yr

- Cooling load limit – 34MJ/m²/yr

- Class 2 – SBH20-27 (Design 610, 620 and 630)
    - Minimum star rating 6 stars – 161MJ/m^2/yr
    - Heating load limit – 145MJ/m^2/yr
    - Cooling load limit – 33MJ/m^2/yr
    - Average star rating 7 stars – 122MJ/m^2/yr
    - Average heating load limit 130MJ/m^2/yr
    - Average cooling limit – 28MJ/m^2/yr

2.2 NatHERS modelling

NatHERS modelling with HERO (v4.1) energy rating software was used to model the thermal performance (star rating) as well as the WOH energy loads (WOH score) for the range of dwelling archetypes.

The apartment building, SBH20-27 was considered on the basis of the whole building since the NCC 2022 energy efficiency requirement is for Class 2 buildings to achieve an average 7-star rating across all units , and the poorest performing unit to have a minimum star rating of 6 stars.

2.2.1 Thermal fabric modelling

The modelling inputs for each base case, current practice and recommended stringency are summarised in Appendix 6.1.

To calculate the financial cost of any given thermal modelling strategy, a range of modelling inputs were preselected and costed, based on the appropriate unit of measurement. As the thermal model was adjusted, the appropriate parameter and the associated quantitative metric were used to calculate the cost of the improvement.

The main modelling inputs that were used as variables to adjust the thermal performance star rating were as follows:

- Roof colour:
    - Dark roof – NCC minimum compliance roof was selected as dark, as this has the best performance in ACT NatHERS climate zone 24.
    - Medium roof – representing the current practice roof colour.
    - Light colour roof – to test the financial impact of "cool roofs".
- Insulation:

- External and internal walls – bulk insulation; R0 – R4.0.
- Sub or intermediate floor – bulk insulation; R0 – R4.0.
- Ceiling – bulk insulation R0 - R8.
- Waffle pod floor – 175mm, 225mm, 300mm and 375mm with 85mm concrete slab fixed.
- Roof blanket – 60 or 100mm.

- Windows – A range of WERSLink default windows were selected to cover the following window options:
    - Window types – fixed, sliding windows, sliding doors, awning and hinged doors.
    - Frame types - aluminium, thermally broken aluminium and PVC.
    - Glazing type – single glazed clear, tinted and low-E; double glazed clear, tinted and low-E.
- Ceiling fans – 900mm, 1200mm, 1500mm and 1800mm ceiling fans could be used in the modelling. Ceiling fans were only applied in a few situations. (Note: The improvement in thermal performance was minimal with the addition of fans, as generally the cooling loads were much lower than the heating load.)
- Window shading – an option for installing shading over windows was costed as an energy efficiency option. However, this was not employed as a cost effective option in the archetypes tested.

NatHERS modelling parameters that were not varied as part of the testing:

- Wall colours – wall colour was set at medium throughout. Wall colour was not used as a variable for adjusting the thermal modelling.
- External wall frame structure –. Steel frame was used on the SBH20-27 apartment building. Timber framing was used for the Class 1 dwellings archetypes.
- Thermal Breaks – R0.2 applied to steel frames in SBH20-27.
- Floor coverings – Floor coverings were not used to adjust thermal modelling as the variable cost of each type of floor covering (carpet, vinyl and timber) does not align with modelling outcomes, which are highly variable depending on building geometry, window selection, size and orientation, building construction and zoning of room outcome. Furthermore, the choice of floor coverings is usually selected based on personal choice of floor covering selection resulted. Given these factors, NatHERS default floor coverings were applied and set to all modelling:

- Carpet to living areas and bedrooms.
- Ceramic tiles – bathrooms, ensuites, kitchens, laundries.
- Exposed concrete – garages.

- Downlights – all downlights are assumed to be sealed LED, IC4 rated, having no effect on the modelling.
- Exhausts – all exhausts were assumed to be sealed, as per NCC Deemed to Satisfy requirements for Building Sealing.

Current practice applications:

- Insulated roof blankets – Though not specified in the NatHERS standard designs, under-roof blanket insulation was determined as being a very common strategy in the ACT. Hence roof blankets were introduced into the dwelling architypes

Approach to determining least cost thermal fabric

Ultimately, the most cost-effective improvements, required to achieve the targeted star ratings focused on the following strategy:

1. Allow for ceiling, wall and floor insulation, aligned with the NCC2022 deemed to satisfy provisions,
2. Selection of the lowest cost window strategy,
3. Readjust insulation levels to achieve the desired star rating,
4. Add internal wall insulation incrementally to internal garage walls, if present, then internal walls to unconditioned zones, and;
5. Add ceiling fan for fine-tuning, if there is overheating.

2.2.2 Orientation

Since volume builders have floor plans that can be built in multiple layouts, each floor plan was modelled in a second orientation. Refer Appendix 6.1 for floor plans of dwelling archetypes.

Table 5: Archetype orientations modelled

Archetype	Primary orientation	Second orientation
SBH01	North to the top of the design documentation	Horizontal mirror image
SBH04	North to the top of the design documentation	Horizontal mirror image

SBH15	North to the top of the design documentation	Front entrance oriented to 270 degrees
SBH20-27	North to the top of the design documentation	Front entrance oriented to 90 degrees

2.2.3 Testing 2050 RCP8.5 climate file

The base case model of each dwelling archetype was run a second time using CSIRO future climate data for NatHERS modelling. The Representative Concentration Pathway (RCP) 8.5 selected reflects a future with little curbing of GHG emissions. While this might be thought of as a 'worst case' for climate action, the future climate files used still represent 'expected averages', with limited representation of extreme events such as protracted heatwaves. This is consistent with the future climate files selected by the ABCB to examine the impact analysis of energy efficiency improvements for commercial buildings in Volume 1 of the NCC ahead of an anticipated change in 2025. In these senses, RCP 8.5 is considered an appropriate choice to test the sensitivity of this study's results to expected climate change. Section 3.2.2 discusses the outcomes of this modelling.

2.2.4 Roof colour sensitivity testing

Modelling of each archetype to quantify the effect of roof colour on the net present value of private costs was undertaken to provide insight to broader discussions of policy around roof colour. Section 3.2 discusses the outcomes of this modelling.

2.3 Whole-of-home energy modelling

Similar to the method used for testing for the least cost thermal shell outcomes, a predetermined range of proposed appliance types and efficiencies were costed. Appliance types available in NatHERS for heating and hot water were curtailed due to ACT policies:

1) No new natural gas fittings allowed
    a. No gas heating appliances allowed
    b. No gas hot water allowed
    c. No gas cooking appliances
2) No woodheaters allowed.

Base case WOH energy use

The following pie-charts indicate the end-uses of energy, and the extent of PV generation, modelled for the NCC 2022 minimum compliance base case.

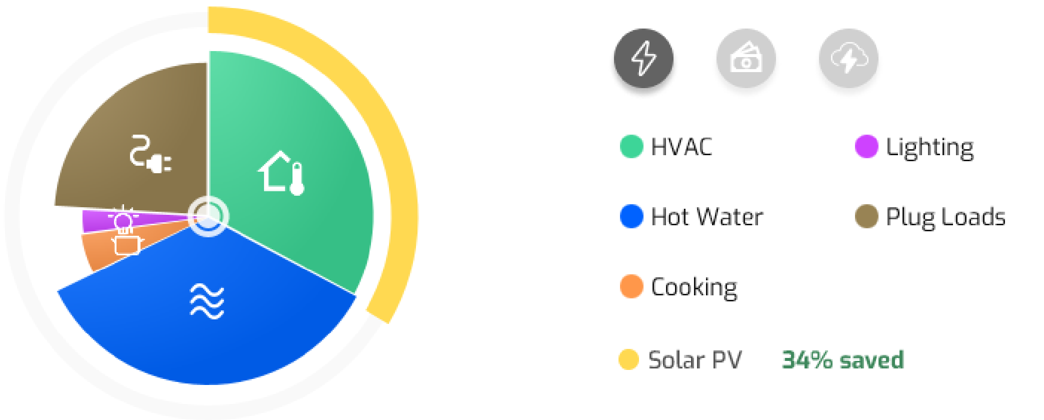

Figure 4: SBH01 – WOH 60 – Energy Consumption and PV Shares

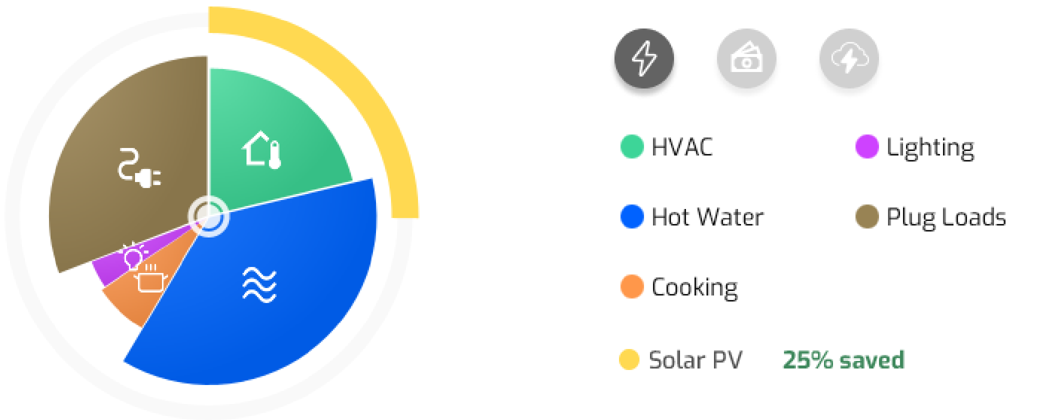

Figure 5: SBH04 – WOH 60 – Energy Consumption and PV Shares

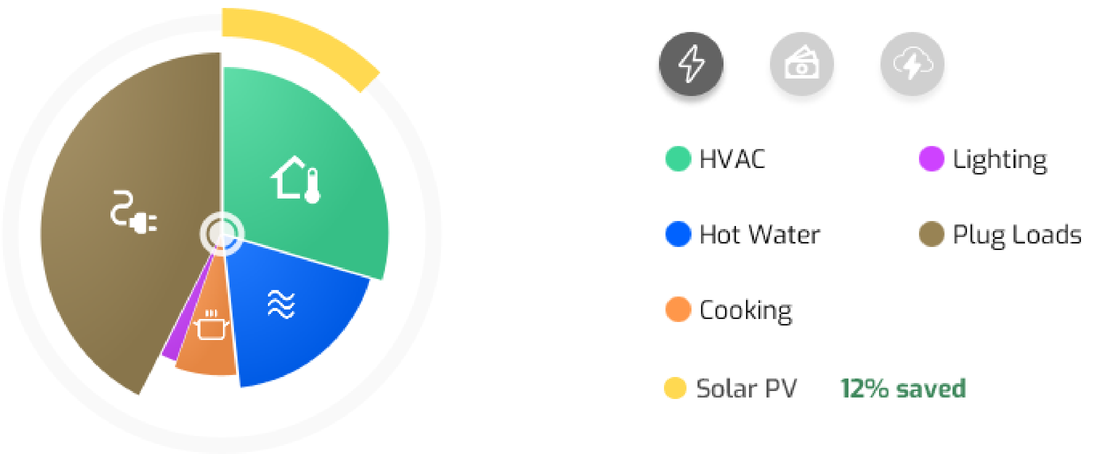

Figure 6: SBH15 – WOH 60 – Energy Consumption and PV Shares

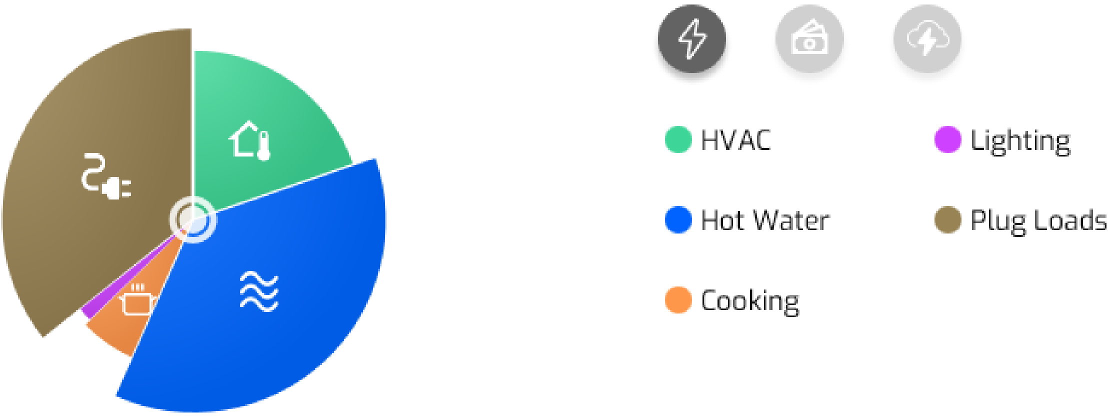

Figure 7: SBH20-27 – WOH 50 – Energy Consumption and PV Shares

2.3.1 HVAC and air-conditioning strategy

In the ACT, space heating in new dwellings can only be provided by electrical appliances, with room reverse cycle and ducted heat pumps being costed and available for modelling.

HVAC appliances were selected based on their efficiency. The ACT falls in the cool climate ZERL star rating zone. Appliance efficiencies selected for testing the financial cost benefit are as follows, for both stand-alone reverse cycle heat pumps and ducted systems. Note that the NatHERS modelling assigns additional efficiency factors as appropriate (e.g. ducted systems entail additional air and heat loss in ducting).

- 1 star heating; 2.5 star cooling
- 2 star heating; 3.5 star cooling
- 3 star heating; 4.5 star cooling
- 4 star heating; 5.5 star cooling

For the purpose of costing HVAC appliances, heat pumps were assigned one of the following sizes based on the predicted required demand for the individual zone :

- <3kW
- 3-6kW
- 6-10kW
- 10-20kW
- 20kW+

HVAC sizing was assigned based on the peak heating and cooling load generated by the thermal fabric modelling. Associated zones were combined and the largest value for either heating or cooling load decided the heater size range.

In the interests of assigning realistic costs, closely associated zones were combined and appliances sized to deliver the heating or cooling load for the combined zones.

A standardised heating strategy was taken for rooms with low peak heating and cooling loads of less than 1kW. As it is unlikely these rooms would have standalone heat pumps, they were modelled with electric resistant heaters, and cooling was assigned the NatHERS default cooling appliance (minimum energy performance, MEPS, reverse-cycle heat pump i.e. ZERL for cool climate heating 1 star; cooling 2 stars).

Standalone reverse cycle heat pumps were applied to the base case, as these are significantly more cost effective than providing the same air conditioning outcome with a ducted system. However, we note that ducted heat pumps are common practice in the ACT, even if they are not least cost.

In summary, each archetype's space conditioning solutions in the base case are set out below.

Table 6: Summary of heating appliances by archetype

Archetype	Room reverse cycle heat pumps	Ducted reverse cycle heat pump
SBH01	3 x 3-6kW 2 x <3kW	10-20kW
SBH04	1 x 3-6kW 2 x <3kW	6-10kW
SBH15	2 x <3kW	<3kW
SBH20-27[12]	24 x 3-6kW 48 x<3kW	18 x 3-6kW 6 x <3kW

Note that as thermal fabric efficiency increases with higher star ratings, the peak heating and cooling loads diminish. However, HVAC sizing was maintained across all star bands, as the size of the reduced heating or cooling load was generally not enough to justify reducing HVAC sizing. This reduced the complexity of tracking additional variation in an already very complex system. However, we note that there would be a small additional cost saving to be made in the higher thermal shell scenarios from this source.

[12] Note: Apartment figures relate to the whole modelled building, which contains 24 apartments.

2.3.2 Hot water heating strategy

Again, hot water heating appliances were limited to those utilising electricity. The types costed for the purpose of testing appliance efficiency were:

- Electric resistant hot water
- Reverse cycle hot water
- Electric boosted solar hot water

Electric resistant hot water was generally used in the archetype base cases, except where meeting minimum WOH requirements necessitated heat pump hot water, as in some of the modelled apartments.

For each type of electric hot water system, peak or off-peak electricity supply can be opted for. For consistency, off-peak models were chosen for all variations. This reduced the complexity of results, but it should be noted the impact of electricity supply tariffs does impact the WOH score significantly.

Hot water system sizing

Sizing of hot water systems was based on a nominal number of likely occupants for each archetype and floor plan. The table below summarises the volume of HWS for each floor plan. Note that the smallest heat pump hot water systems available is 160L and was necessarily applied to each of the SBH20-27 apartment types, despite being oversized for the hot water demands.

Table 7: Hot water system size by technology and archetype

	SBH01	SBH04	SBH15	SBH20-27		
				Design 610	Design 620	Design 630
NatHERS calculated number of occupants	4.0	2.9	2.4	2.2 (average)		
Occupants - number allowed for	5	4	3	2	1	3
Electric storage HWS vol (L)	400	315	250	125	80	160
Heat pump HWS vol (L)	400	315	250	160	160	160
Electric boosted solar hot water vol (L)	400	315	250	n/a	n/a	n/a

Hot water system efficiency

Heat pump hot water systems were tested at four different efficiencies, as per the 10-year STCs applied to each type. The ACT falls in Zone 5 for heat pump hot water systems. The following efficiencies were tested:

- 28 STCs
- 30 STCs
- 32 STCs
- 34 STCS.

Electric-boosted solar hot water was tested on the house archetypes but was not considered a likely scenario for SBH20-27 apartment building. The ACT falls in Zone 4 for solar hot water heater models. For SBH04, the efficiency of the electric-boosted solar hot water, when tested, was nominally 24 STCs, based on a 22 tube, 315L Apricus evacuated tube hot water system. For the larger SBH01, the efficiency of the electric-boosted solar hot water, when tested, was nominally 34 STCs, based on a 30 tube, 400L Apricus evacuated tube hot water system.

2.3.3 Lighting strategy

For each archetype, including each of the three floor plans in the SBH20-27 apartment building (Design 610, 620 and 630), three lighting scenarios were specified to result in the following lighting densities:

- 5W/m2
- 3.5W/m2
- 2W/m2

Each lighting density scenario was costed based on contemporary fittings.

Changing lighting density had such minimal impact on the WOH score, that after the first example, we settled on fixing the lighting intensity at 2W/m2 for all remaining testing.

2.3.4 Cooking appliances

Due to the restriction on gas connection, cooking appliances were modelled as all electric.

Cooktops could be selected as electric resistance or induction. Initially the choice of cooktop was used as an option to fine tune the WOH score, but again, the impact on the score was so minimal that after the first example, cooking appliances were all set as induction cooktops and electric oven.

2.3.5 Plug load

Plug loads (electrical loads associated with all plugged in devices) are fixed in NatHERS, based on floor area and number of occupants, which means there is no opportunity to test the impact of improving efficiency in this area. The fixed nature of the archetype plug load had a significant impact on the viability of WOH improvements in Class 2 dwellings, as heating and hot water make up a relatively small portion of total electricity use, rendering efficiency improvements financially marginal. The impacts of this effect are discussed further in Section 0.

Table 8: Plug load assumptions by archetype

Plug load	SBH01	SBH04	SBH15	SBH20-27
Energy kWh/yr	2446	2310	2233	2223
Cost $/yr	$586	$554	$535	$533
GHG emissions (t/CO2-e)	0.43	0.4	0.39	0.39

2.3.6 Pools and spas

No pools or spas were modelled or taken into consideration. If a pool or spa were to be present, it will become more onerous to achieve the target WOH score, as total energy consumption will be higher.

2.3.7 PV solar generation

PV solar generation is key to achieving higher WOH scores in NatHERS, allowing net zero cost and higher outcomes. PV modelling for each archetype reflected realistic scenarios, which are discussed below. The overarching limitation for the ACT is that there is a 5kW/phase limitation on solar export for Class 1 dwellings. Therefore, for the houses and townhouse, the maximum installation was 15kW. Also, Class 2 buildings can be constrained in the availability of suitable roof area for PV, particularly when that area needs to be divided by the number of apartments in the building. This specific constraint is also discussed further below.

For the purpose of the modelling, inverters were sized as per the PV installation size. Where there were multiple aspects (PV orientations), all strings were routed through a single inverter, sized equivalent to the total rated PV.

All calculations have assumed a 440Watt rated panel size.

SBH01 PV considerations

SBH01 has a multifaceted hip roof. Of the total 250m2 of roof area, only ~99m2 was reasonable for PV. PV installation was assumed to be limited to the upper roof areas, as shown in Table 9.

Table 9: SBH01 PV capacity limit

SBH01 - Pitch 23˚

	Area m2	Max rated PV kW	Max generation kWh/yr
Optimal roof area - north	56	9	
East facing roof area - west	31	5	17,097
West facing roof area - east	12	2	
South facing roof area or sub optimal	151	-	-

While the available area allowed for a total rated capacity of 16kW, slightly exceeding the 15kW limit above, the sub optimal installation will ensure the 5kW/phase is never exceeded.

SBH04 PV considerations

While the design documentation for SBH04 has a hipped roof, for the purpose of modelling and PV installation the design was assumed to have a flat skillion roof 236m^2 which easily accommodates up to the maximum 15kW of PV, as shown in Table 10. This kind of modest design adaptation is considered likely, as homeowners increasingly appreciate the value of rooftop PV systems.

Table 10: SBH04 PV capacity limit

SBH04 - Pitch 30˚

	Area m2	Max rated PV kW	Max generation kWh/yr
Optimal roof area - north	236	15	16,481

SBH15 PV considerations

The actual roof structure of SBH15 is complex. For the purpose of this investigation, the roof was assumed to have 25m2 north facing and 25m2 south facing roof, both pitched at 23 degrees.

The limited roof space restricted the PV installation to 4 kW on the north facing roof and 4 kW on the south facing roof, as shown in Table 11.

Table 11: SBH15 PV capacity limit

SBH15 - Pitch 23˚

	Area m2	Max rated PV kW	Max generation kWh/yr
Optimal roof area - north	25	4	10,918
South facing roof area or sub optimal	25	4	

SBH20-27 PV considerations

NCC 2022 Vol2 1 Part J1P4 requires that a Class 2 building must at least have features that facilitate the future installation of on-site renewable energy generation and storage and electric vehicle charging equipment.

Part J5D5(2) allows for provisions of solar photovoltaics to at least 20% of the roof area. This was used to calculate a roof area for PV installation.

The total roof area is 1,065m2, 20% of the roof area equates to ~207m2. For the purpose of modelling PV this area would allow 36kW to be installed on the roof top, as shown in Table 12. If the PV generation was distributed equally between all 24 apartments, that is equivalent to 1.5kW rated PV for each apartment.

Table 12: SBH20-27 PV capacity limit

SBH20-27 - Pitch 30˚

	Area m2	Max rated PV kW	Max generation kWh/yr
Roof area - north	213	36	39,554

SPR determined, in conjunction with ACT Government representatives, to examine the apartment building without solar, on the grounds that not all new apartments will be able to access solar, and therefore this element should not be relied upon to determine minimum performance requirements. We note that, from a longer-term perspective, it would not be ideal to forego or discourage, the use of PV on apartment buildings, as a lack of access to solar energy will have significant cost consequences for apartment dwellers. We expect that, over time, innovative solutions are likely to become available to assist with this dilemma.

2.4 Whole-of-home score targeting strategies

WOH modelling was undertaken with the aim of targeting a range of specific WOH scores, adopting a range of design strategies and equipment specifications, in order to determine the strategy resulting in the best Net Present Value (equivalent to least cost or greatest net benefit).

The process was to apply three different scenarios of HVAC appliance efficiency and hot water appliances, then adjust the size of the PV installed to achieve the target score.

For the Class 1 SBH01, SBH04 and SBH15 the range of WOH scores to be achieved were:

- WoH score 60 (NCC 2022 minimum compliance base case)
- WoH score 80
- WoH score 90
- WoH score 100 – net zero energy cost
- WoH score 115 – net negative energy cost

The three strategies applied, which tested a range of efficiencies of key appliances, were:

Strategy 1:

- HVAC – standalone heat pump: ZERL 1 star heating, ZERL 2.5 star cooling, sized appropriate to the dwelling
- Hot water – Heat pump hot water STCs 30
- Lighting density – 2 W/m^2
- Cooking appliances – electric oven, induction cooktop

Strategy 2:

- HVAC – standalone heat pump: ZERL 3 star heating, ZERL 4.5 star cooling, sized appropriate to the dwelling
- Hot water – Heat pump hot water STCs 34
- Lighting density – 2 W/m^2
- Cooking appliances – electric oven, induction cooktop

Strategy 3:

- HVAC – standalone heat pump: ZERL 1 star heating, ZERL 2.5 star cooling, sized appropriate to the dwelling
- Hot water – Electric boosted solar hot water STC 24
- Lighting density – 2 W/m^2
- Cooking appliances – electric oven, induction cooktop.

Lighting density was fixed at $2W/m^2$. Depending on the archetype, the 3.5 and 5 W/m^2 strategies affected the WoH score between 2 and 7 points. For simplicity it was decided to fix the lighting density at $2W/m^2$ because with the uptake of LED lighting, this is readily achievable.

Cooking appliances were also fixed at the most efficient option of electric oven and induction cooktop. Changing between induction cooktop and ceramic did not usually change the WoH score at all.

2.5 Financial modelling

The core of our financial model is built on a cost-calculator, which quantifies the costs associated with changes in the thermal fabric and WOH components of the archetypes, when compared with a costed base case. Where appropriate the cost calculator also accounts for the replacement cost of thermal or WOH components, adjusted for future expected price change. The calculator includes pricing for the following thermal shell components:

- Windows (by glazing, frame and operation)
- Insulation (by application and R value)
- Thermal bridging
- Waffle-pods
- Ceiling fans
- Awnings/window coverings
- Roof blankets

The calculator also includes pricing for the following WOH components:

- Solar PV
- Batteries
- Lighting density
- Cooktop

- Heating (by type, size and efficiency)
- Hot water (by type, size and efficiency)

Costs were drawn from a variety of sources, including prior work SPR has delivered for industry bodies, online searches, and Cordells Housing Cost Guide. To the greatest extent possible our costings represent the lowest cost available option that met the performance requirements, in line with NCC RIS practice.[13]

In addition to quantifying the incremental purchase costs of a given change to the base-case dwelling, our model uses annual energy, cost and emission saving data generated by HERO to quantify lifetime cost changes for both the homeowners and for society. This calculation accounts for expected changes in electricity prices, grid intensity and the social cost of carbon. These calculations are based on a 5% discount rate to align with draft NCC 2025 input assumptions, a 10-year policy period, and a 40-year dwelling life.[14] The outputs of this process are quantified as a Net Present Value (NPV) of the modelled individual dwelling changes. NPV account for all expected costs (positive and negative) incurred over the period considered, adjusted for when in the period they occur, to give the present value of this stream of costs and benefits over time.

The multiple modelling runs for each archetype, accounting for changes to WOH scores and thermal efficiencies using different strategies to deliver the desired stringency, were then sorted by cost effectiveness to determine the least-marginal cost approach to achieving the desired stringency.[15] A wide range of costs outcomes were discovered while delivering this analysis, as shown in Figure 8, though our efficiency identifying cost effective approaches improved as the project developed. The term “cost” is used throughout this analysis, though in many cases the modelled figures are negative costs. These negative costs can also be read as “benefits”.

[13] This means that the cheapest fit-for-purpose solution is selected, even if some householders may in reality prefer more recognised brands with higher prices. Such preferences can lead to households willingly paying higher costs than are absolutely necessary to achieve a given performance outcome, but these higher costs should not be attributed to a regulatory requirement, since they are optional and discretionary.

[14] We note that NPV results can be sensitive to the real discount rate but, as a rule, are quite insensitive to either the assumed lifetime of the policy or the assumed economic life of a dwelling.

[15] This is equivalent to the greatest possible net benefit, where the present value of the benefits exceeds the present value of costs; and to the smallest possible net cost, where the present value of costs exceed the present value of benefits.

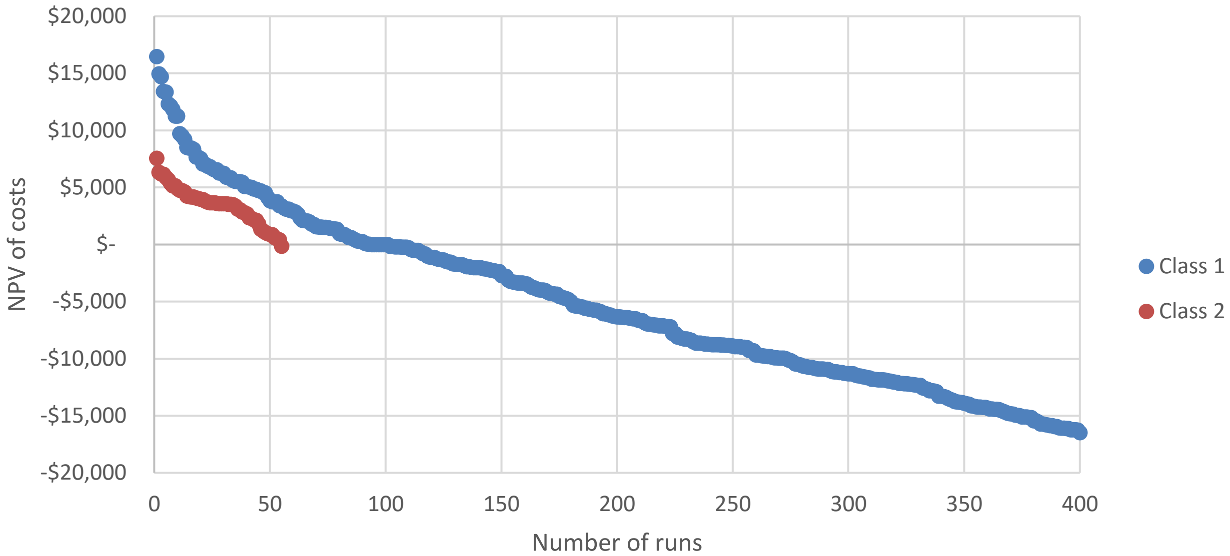

Figure 8: Indicative distribution of NPV outcomes of modelling runs

Finally, our model applies identified least cost per dwelling cost calculations to a whole-of-ACT dwelling stock model, described below, which accounts for the quantity and distribution by archetype of new dwelling construction across the policy period, to produce a whole-of-policy NPV that represents the expected all-in cost of opting for a given stringency.

2.6 Stock modelling

Our stock model uses the ABS' long-run housing activity and population data, as well as their medium-scenario population projections, to forecast total new dwelling completions over the policy period. Figure 9 shows new dwelling completions peaking at 3,899 in 2027 before falling to 3,442 in 2035. Our projections suggest 36,417 new dwellings will be delivered over this period.

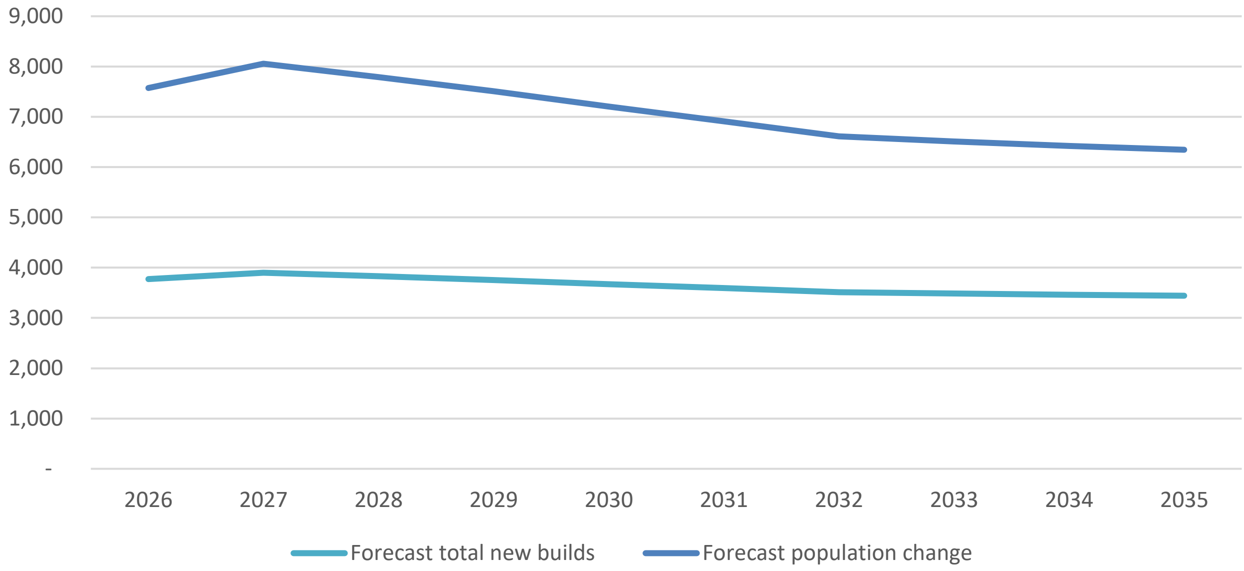

Figure 9: Forecast annual new dwelling completions 2026-2035

The stock model then uses the ABS' housing activity data to separate detached (standalone houses) and attached (townhouses and apartments) dwelling types, with the projected split between these broad categories forecast using a best fit trend. Figure 10 shows the detached share of new dwellings falling from 36% to 33% over the policy period, while the attached share of new dwellings increases from 64% to 67%.

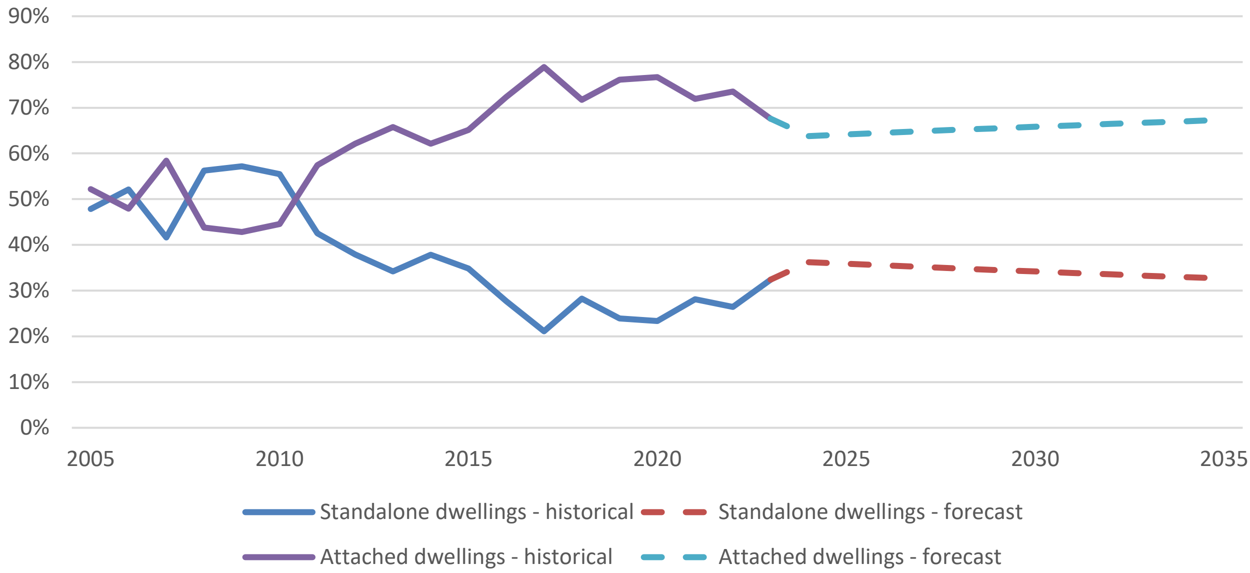

Figure 10: Composition of new builds over time - historical and forecast

Finally, the stock model uses Census data, average new-build floor area data and detailed demographic projections to separate these two high-level categories into the specific archetypes used in this study. Figure 11 shows the forecast composition of new dwellings over the policy period, with apartments making up 40.2% of completions, townhouses 25.7%, smaller houses 19.0% and larger houses 15.1%.

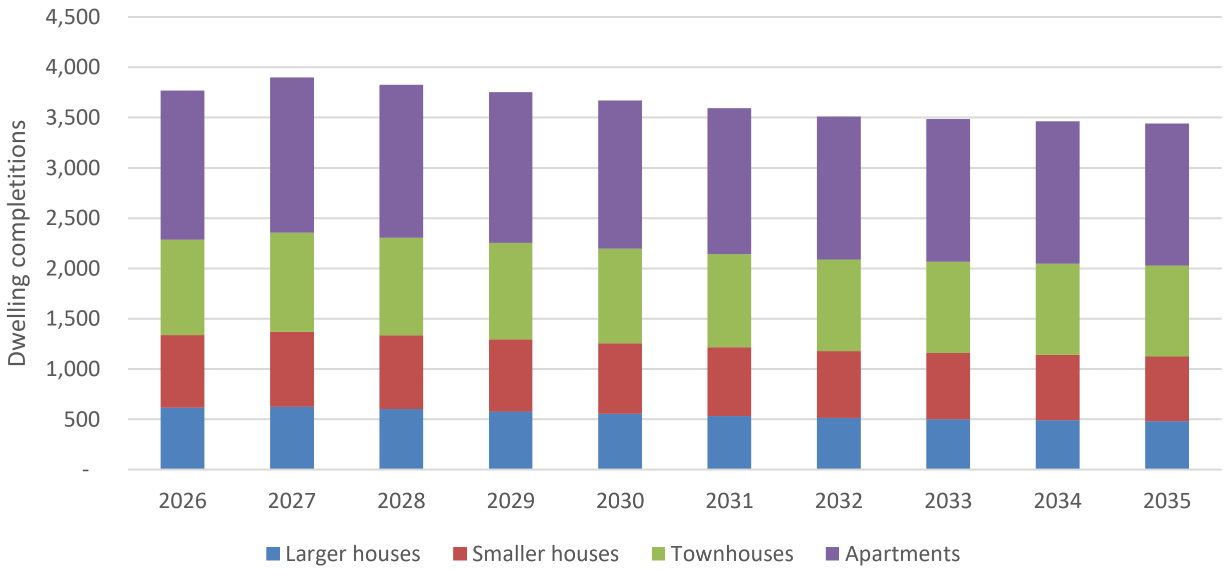

Figure 11: Forecast dwelling completions by archetype over policy period

3. Financial and thermal modelling results

3.1 Archetype results

The results below are broken into two categories, 1) WOH improvements only, and 2) Thermal shell and WOH improvements together. The data in the tables is broken up into several cost categories:

- **Private additional costs** – The cost to the builder/home-buyer of making the proposed changes, above and beyond costs associated with NCC 2022 minimum compliance, broken into initial capital costs and the replacement costs of WOH components (adjusted for price change over time)
- **Private ongoing cost** – The lifetime operational cost of the dwelling experienced by the home-owner (or renter) as a result of the modelled changes above and beyond the costs they would have experienced were the dwelling built to NCC minimum compliance.
- **Social ongoing cost** – The lifetime carbon cost of the dwelling experienced by society as a result of the modelled changes above and beyond the costs society would have experienced were the dwelling built to NCC minimum compliance. [16]
- **Total lifetime cost** – The balance of initial and ongoing costs.

The results tables also include information on the collection of WOH options identified as lowest cost, when compared to the lowest costs NCC minimum compliance. All results are calculated using 2025 inputs and values, and are presented in 2025 dollars. The cost/benefit analysis in Section 4 covers the period 2026-2035, with values adjusted accordingly.

Carbon emissions from electricity use in the ACT

The ACT has been powered by 100% renewable electricity since 2020, with the ACT Government signing Power Purchase Agreements (PPAs) with projects that produce sufficient Large Generation Certificates (LGCs) to fully offset the Territory's consumption. This arrangement means that the ACT's electricity supply is zero carbon for emission accounting purposes. For network planning and system administration purposes, the Australian Energy Market Operator (AEMO) groups the ACT in with the NSW region of the National Electricity Market (NEM), which still produces significant, though falling, per unit emissions. Given this arrangement, every kWh of avoided consumption in the ACT directly offsets a kWh consumed in NSW, and therefore avoids emissions. Because of this fact, we have opted to retain emission savings in our calculations, and have applied NSW region emission intensities to avoided electricity consumption. This is the same approach the Australian Building Codes Board took for the cost benefit analysis of NCC 2025.

[16] Note: Social cost in this per-archetype analysis only relates to costs associated with CO_2 emissions. Avoided peak demand, and associated costs, are quantified for the recommended stringencies in Section 4.2.2. Avoided network costs are also incorporated into the secondary metric analysis in Section 4.4.

3.1.1 Class 2 WOH improvements

Though the initial project brief requested analysis on WOH scores of up to 90 for apartment buildings, subsequent analysis identified that this stringency cannot currently be achieved without the use of solar PV. Unlike the Class 1 archetypes, which were all modelled with solar PV, the decision was made not to model PV for Class 2 buildings, as noted earlier. Although a small number of apartment buildings have installed solar PV across the ACT, widespread adoption of the technology still faces significant technical and governance challenges. In the context of investigating cost-effective increases to minimum standards, SPR does not believe it is realistic to assume solar PV will be a viable technology to meet these requirements in all, or even most, instances. In addition to the challenges installing solar on Class 2 buildings, the nature of the installation (common area supply, central installation with sharing, direct connection, or a combination of these options) affects whether it can be counted towards an apartment WOH score.

As a result of the decision to exclude solar PV from our analysis, the Class 2 modelling was limited by the WOH scores achievable using only changes to fixed appliances. As a result, the maximum apartment WOH score modelled was 60 points.

3.1.2 Whole of Home improvements only

SBH01 (Class 1 detached dwelling)

Base case	Scenario	Results
NCC2022 Minimal Compliance Base Case (dark roof for Class 1s)	7 star, 60pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, 2kW solar, room heating (x5 low efficiency), electric resistance hot water
NCC2022 Thermal Shell Requirements, higher WOH #1	7 star, 80pts	Private additional costs = $9,716 ($6,394 initial and $3,321 replacement) Private ongoing cost = -$16,950 Social ongoing cost = -$1,381 Total lifetime (40yr) cost = -$8,616 2W/m2 lighting, Induction cooktop, 4.9kW solar, room heating (x5 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #2	7 star, 90pts	Private additional costs = $13,639 ($8,881 initial and $4,758 replacement) Private ongoing cost = -$25,576 Social ongoing cost = -$2,231 Total lifetime (40yr) cost = -$14,168 2W/m2 lighting, Induction cooktop, 7.5kW solar, room heating (x5 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #3	7 star, 100pts	Private additional costs = $20,445 ($12,602 initial and $7,843 replacement) Private ongoing cost = -$34,046 Social ongoing cost = -$2,643 Total lifetime (40yr) cost = -$16,244 2W/m2 lighting, Induction cooktop, 7.3kW solar, room heating (x5 high efficiency), solar hot water
NCC2022 Thermal Shell Requirements, higher WOH #4	7 star, 100+pts	Private additional costs = $33,573 ($20,926 initial and $12,647 replacement) Private ongoing cost = -$46,123 Social ongoing cost = -$3,833 Total lifetime (40yr) cost = -$16,384 2W/m2 lighting, Induction cooktop, 16kW solar, room heating (x5 high efficiency), solar hot water WOH points = 115

SBH04 (Class 1 detached dwelling)

Base case	Scenario	Results
NCC2022 Minimal Compliance Base Case (dark roof for Class 1s)	7 star, 60pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, 1.15kW solar, room heating (x3 low efficiency), electric resistance hot water
NCC2022 Thermal Shell Requirements, higher WOH #1	7 star, 80pts	Private additional costs = $8,367 ($5,263 initial and $3,104 replacement) Private ongoing cost = -$13,384 Social ongoing cost = -$1,148 Total lifetime (40yr) cost = -$6,165 2W/m2 lighting, Induction cooktop, 3.75kW solar, room heating (x3 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #2	7 star, 90pts	Private additional costs = $11,301 ($7,109 initial and $4,192 replacement) Private ongoing cost = -$19,951 Social ongoing cost = -$1,794 Total lifetime (40yr) cost = -$10,444 2W/m2 lighting, Induction cooktop, 5.75kW solar, room heating (x3 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #3	7 star, 100pts	Private additional costs = $14,454 ($9,093 initial and $5,362 replacement) Private ongoing cost = -$25,995 Social ongoing cost = -$2,416 Total lifetime (40yr) cost = -$13,956 2W/m2 lighting, Induction cooktop, 7.9kW solar, split system room heating (x3 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #4	7 star, 100+pts	Private additional costs = $23,223 ($14,608 initial and $8,614 replacement) Private ongoing cost = -$35,531 Social ongoing cost = -$3,122 Total lifetime (40yr) cost = -$15,430 2W/m2 lighting, Induction cooktop, 9.75kW solar, room heating (x3 high efficiency), solar hot water WOH points = 115

SBH15 (Class 1 semi-detached dwelling/townhouse)

Scenario	SBH15	Results
NCC2022 Minimal Compliance Base Case (dark roof for Class 1s)	7 star, 60pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, 1kW solar, room heating (x2 low efficiency, electric resistance hot water
NCC2022 Thermal Shell Requirements, higher WOH #1	7 star, 80pts	Private additional costs = $6,520 ($4,237 initial and $2,284 replacement) Private ongoing cost = -$11,209 Social ongoing cost = -$944 Total lifetime (40yr) cost = -$5,633 2W/m2 lighting, Induction cooktop, 3.1kW solar, room heating (x2 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #2	7 star, 90pts	Private additional costs = $9,307 ($6,001 initial and $3,307 replacement) Private ongoing cost = -$16,845 Social ongoing cost = -$1,501 Total lifetime (40yr) cost = -$9,038 2W/m2 lighting, Induction cooktop, 5kW solar, room heating (x2 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #3	7 star, 100pts	Private additional costs = $12,681 ($8,138 initial and $4,543 replacement) Private ongoing cost = -$22,304 Social ongoing cost = -$2,057 Total lifetime (40yr) cost = -$11,679 2W/m2 lighting, Induction cooktop, 8kW solar, room heating (x2 low efficiency), heat pump hot water (low efficiency)
NCC2022 Thermal Shell Requirements, higher WOH #4	7 star, 100+pts	Private additional costs = $20,031 ($12,267 initial and $7,764 replacement) Private ongoing cost = -$28,222 Social ongoing cost = -$2,476 Total lifetime (40yr) cost = -$10,667 2W/m2 lighting, Induction cooktop, 8kW solar, room heating (x2 high efficiency), solar hot water WOH points = 110

Apartments

Scenario	Apartments	Results
NCC2022 Minimal Compliance Base Case (dark roof for Class 1s)	7 star, 50pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, room heating (x2 mid efficiency), heat pump hot water (low efficiency).
NCC2022 Thermal Shell Requirements, higher WOH #1	7 star, 60pts	Private additional costs = $5,339 ($3,366 initial and $1,973 replacement) Private ongoing cost = -$1,673 Social ongoing cost = -$96 Total lifetime (40yr) cost = -$3,570 2W/m2 lighting, Induction cooktop, room heating (x2 high efficiency), heat pump hot water (high efficiency)

3.1.3 Thermal shell and Whole of Home improvements

SBH01 (Class 1 detached dwelling)

Base case	Scenario	Results
NCC2022 Minimal Compliance Base Case (dark roof for Class 1s)	7 star, 60pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, 2kW solar, room heating (x5 low efficiency), electric resistance hot water
Improved Thermal Shell Requirements, higher WOH #1	7.5 star, 80pts	Private additional costs = $19,776 ($16,493 initial and $3,283 replacement) Private ongoing cost = -$16,804 Social ongoing cost = -$1,358 Total lifetime (40yr) cost = $1,615 2W/m2 lighting, Induction cooktop, 4.4kW solar, room heating (x5 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #2	7.5 star, 90pts	Private additional costs = $23,589 ($18,911 initial and $4,679 replacement) Private ongoing cost = -$25,514 Social ongoing cost = -$1,891 Total lifetime (40yr) cost = -$3,815 2W/m2 lighting, Induction cooktop, 7kW solar, room heating (x5 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #3	7.5 star, 100pts	Private additional costs = $30,373 ($23,212 initial and $7,161 replacement) Private ongoing cost = -$33,942 Social ongoing cost = -$3,038 Total lifetime (40yr) cost = -$6,606 2W/m2 lighting, Induction cooktop, 11.75kW solar, room heating (x5 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #4	7.5 star, 100 + pts	Private additional costs = $44,425 ($31,527 initial and $12,897 replacement) Private ongoing cost = -$46,709 Social ongoing cost = -$3,911 Total lifetime (40yr) cost = -$6,196 2W/m2 lighting, Induction cooktop, 16kW solar, room heating (x5 high efficiency), solar hot water WOH points = 115

SBH04 (Class 1 detached dwelling)

Base case	Scenario	Results
NCC2022 Minimal Compliance Base Case (dark roof for Class 1s)	7 star, 60pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, 1.15kW solar, room heating (x3 low efficiency), electric resistance hot water
Improved Thermal Shell Requirements, higher WOH #1	7.5 star, 80pts	Private additional costs = $11,751 ($9,451 initial and $2,300 replacement) Private ongoing cost = -$13,322 Social ongoing cost = -$1,041 Total lifetime (40yr) cost = -$2,611 2W/m2 lighting, Induction cooktop, 3.2kW solar, room heating (x3 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #2	7.5 star, 90pts	Private additional costs = $14,685 ($11,249 initial and $3,435 replacement) Private ongoing cost = -$19,909 Social ongoing cost = -$1,686 Total lifetime (40yr) cost = -$6,911 2W/m2 lighting, Induction cooktop, 5.2kW solar, room heating (x3 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #3	7.5 star, 100pts	Private additional costs = $17,692 ($12,949 initial and $4,742 replacement) Private ongoing cost = -$26,016 Social ongoing cost = -$2,057 Total lifetime (40yr) cost = -$10,381 2W/m2 lighting, Induction cooktop, 7.25kW solar, room heating (x3 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #4	7.5 star, 100 + pts	Private additional costs = $26,701 ($18,508 initial and $8,192 replacement) Private ongoing cost = -$35,719 Social ongoing cost = -$3,158 Total lifetime (40yr) cost = -$12,176 2W/m2 lighting, Induction cooktop, 10.75kW solar, room heating (x3 high efficiency), heat pump hot water (high efficiency) WOH points = 115

SBH15 (Class 1 semi-detached dwelling/townhouse)

Base case	Scenario	Results
NCC2022 Minimal Compliance Base Case (dark roof for Class 1s)	7 star, 60pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, 1kW solar, room heating (x2 low efficiency, electric resistance hot water
Improved Thermal Shell Requirements, higher WOH #1	7.5 star, 80pts	Private additional costs = $6,125 ($4,745 initial and $1,381 replacement) Private ongoing cost = -$10,917 Social ongoing cost = -$885 Total lifetime (40yr) cost = -$5,676 2W/m2 lighting, Induction cooktop, 2.6kW solar, room heating (x2 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #2	7.5 star, 90pts	Private additional costs = $8,509 ($6,215 initial and $2,294 replacement) Private ongoing cost = -$16,490 Social ongoing cost = -$1,435 Total lifetime (40yr) cost = -$9,416 2W/m2 lighting, Induction cooktop, 4.25kW solar, room heating (x2 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #3	7.5 star, 100pts	Private additional costs = $12,066 ($8,442 initial and $3,624 replacement) Private ongoing cost = -$22,178 Social ongoing cost = -$2,009 Total lifetime (40yr) cost = -$12,122 2W/m2 lighting, Induction cooktop, 6.7kW solar, room heating (x2 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #4	7.5 star, 100 + pts	Private additional costs = $17,774 ($12,027 initial and $5,747 replacement) Private ongoing cost = -$27,134 Social ongoing cost = -$2,422 Total lifetime (40yr) cost = -$11,783 2W/m2 lighting, Induction cooktop, 8kW solar, room heating (x2 high efficiency), heat pump hot water (high efficiency) WOH points = 109

Apartments

Scenario	Apartments	Results
NCC2022 Minimal Compliance Base Case	7 star, 50pts	No costs associated with minimum compliance 2W/m2 lighting, Induction cooktop, room heating (x2 mid efficiency), heat pump hot water (low efficiency).
Improved Thermal Shell Requirements, higher WOH #1	7.5 star, 50pts	Private additional costs = $1,595 ($1,005 initial and $589 replacement) Private ongoing cost = -$648 Social ongoing cost = -$24 Total lifetime (40yr) cost = $922 2W/m2 lighting, induction cooktop, room heating (x2 mid efficiency), heat pump hot water (low efficiency) OR electric resistance hot water (depending on location of apartment)
Improved Thermal Shell Requirements, higher WOH #2	7.5 star, 60pts	Private additional costs = $7,455 ($4,746 initial and $2,709 replacement) Private ongoing cost = -$2,698 Social ongoing cost = -$132 Total lifetime (40yr) cost = $4,625 2W/m2 lighting, induction cooktop, room heating (x2 high efficiency), heat pump hot water (high efficiency)
Improved Thermal Shell Requirements, higher WOH #1	8 star, 50pts	Private additional costs = $2,057 ($1,310 initial and $748 replacement) Private ongoing cost = -$837 Social ongoing cost = -$36 Total lifetime (40yr) cost = $1,185 2W/m2 lighting, induction cooktop, room heating (x2 low efficiency), heat pump hot water (low efficiency)
Improved Thermal Shell Requirements, higher WOH #2	8 star, 60pts	Private additional costs = $7,669 ($4,882 initial and $2,787 replacement) Private ongoing cost = -$3,346 Social ongoing cost = -$155 Total lifetime (40yr) cost = $4,168 2W/m2 lighting, induction cooktop, room heating (x2 high efficiency), heat pump hot water (high efficiency)

3.2 Additional sensitivity analysis

3.2.1 Light roof sensitivity

Adjusting the modelled archetypes for a range of roof colours led to small increases in lifetime costs where lighter colour roofs were selected. These increased costs are a result of increased heating load, which was not offset by a small decrease in cooling load associated with lighter roof colours. Internal dwelling temperatures are not overly sensitive to roof colour, due to the large amounts of roof and ceiling insulation already required by the NCC. Changing the colour of the roof on apartment buildings only makes a small difference to those apartments on the top storey of the building. Hence the effect on the apartment building as a whole is minimal.

SBH01 (Class 1 detached dwelling)

Run	Rating	Heating (MJ/m^2yr)	Cooling (MJ/m^2yr)	Total (MJ/m^2yr)	WoH score	Energy (kWh/yr)	Lifetime cost per dwelling
Base Case - Dark roof	7	102.6	17.6	120.3	60	6735	$0
Base case - med roof	7	104.1	16.9	121	60	6769	$167
Base case - light roof	7	105.1	16.3	121.4	60	6788	$284

SBH04 (Class 1 detached dwelling)

Run	Rating	Heating (MJ/m^2yr)	Cooling (MJ/m^2yr)	Total (MJ/m^2yr)	WoH score	Energy (kWh/yr)	Lifetime cost per dwelling
Base Case - Dark roof	7	103.9	16.6	120.5	60	5639	$0
Base case - med roof	7	108.3	13.2	121.5	60	5684	$272
Base case - light roof	7	109.3	11.5	120.8	60	5765	$423

SBH15 (Class 1 semi-detached dwelling/townhouse)

SBH015	Rating	Heating (MJ/m²yr)	Cooling (MJ/m²yr)	Total (MJ/m²yr)	WoH score	Energy (kWh/yr)	Lifetime cost per dwelling
Base Case - dark roof	7	118.5	1.7	120.2	60	4521	$0
Base case - med roof	7	119.5	1.5	121	60	4808	$332
Base case - light roof	7	120	1.4	121.4	60	4815	$373

SBH20-27 (Class 2 apartments)

SBH015	Rating	Heating (MJ/m²yr)	Cooling (MJ/m²yr)	Total (MJ/m²yr)	WoH score	Energy (kWh/yr)	Lifetime cost per dwelling
Base Case - dark roof	7.2	99.5	13.1	112.5	50	4739	$0
Base case - med roof	7.2	102.6	11.7	114.3	50	4767	$152
Base case - light roof	7.2	104.5	11.1	115.6	49	4786	$263

3.2.2 2050 climate file sensitivity

Applying the CSIRO's 2050 climate files (RCP 8.5) to our modelled archetypes led to meaningful negative costs (that is, benefits) associated with reduced heating load. Despite increased cooling load associated with higher temperatures, reduced heating needs more than outweighed these additional costs. Under the current NatHERS star bands, this would lead to an increase in star ratings of 0.5 to 1 star for the base Class 1 designs, as total energy consumption per m2 would fall. This finding is consistent with the ACT being a heating-dominated climate zone.

Importantly, there would be significant costs to both homeowners and society associated with the RCP8.5 emissions pathway which are not accounted for in our calculations, including increased natural disaster risks and increased extreme heat risk.

SBH01 (Class 1 detached dwelling)

SBH01	Rating	Heating (MJ/m^2yr)	Cooling (MJ/m^2yr)	Total (MJ/m^2yr)	WoH score	Energy (kWh/yr)	Lifetime cost per dwelling
Base case - dark roof - 2050 RCP8.5	7.5	66.2	35.5	101.8	65	5914	-$4,320.16
Base case - med roof - 2050 RCP8.5	7.5	67.4	34.6	102.1	65	5933	-$4,224.55
Base case - light roof - 2050 RCP8.5	7.5	68.1	33.9	102	65	5942	-$4,182.72

SBH04 (Class 1 detached dwelling)

Run	Rating	Heating (MJ/m^2yr)	Cooling (MJ/m^2yr)	Total (MJ/m^2yr)	WoH score	Energy (kWh/yr)	Lifetime cost per dwelling
Base case - dark roof - 2050 RCP8.5	7.5	68	33.9	101.8	63	5218	-$2,292
Base case - med roof - 2050 RCP8.5	7.6	71	28.4	99.4	63	5228	-$2,208
Base case - light roof - 2050 RCP8.5	7.6	71.8	26	97.8	63	5303	-$2,099

SBH15 (Class 1 semi-detached dwelling/townhouse)

Run	Rating	Heating (MJ/m^2yr)	Cooling (MJ/m^2yr)	Total (MJ/m^2yr)	WoH score	WoH (kWh/yr)	Lifetime cost per dwelling
Base case - dark roof - 2050 RCP8.5	8	75.1	7.6	82.7	64	4341	-$2,190

Base case - med roof - 2050 RCP8.5	8	75.9	7.3	83.2	64	4349	-$2,148
Base case - light roof - 2050 RCP8.5	8	75.6	7	83.3	64	4354	-$2,127

SBH20-27 (Class 2 Apartment Building)

Run	Rating	Heating (MJ/m²yr)	Cooling (MJ/m²yr)	Total (MJ/m²yr)	WoH score	WoH (kWh/yr)	Lifetime cost per dwelling
Base case - dark roof - 2050 RCP8.5	7.7	64	30.2	94.2	59	4487	- $1,365
Base case - med roof - 2050 RCP8.5	7.7	66.4	28.1	94.5	59	4506	-$ 1,261
Base case - light roof - 2050 RCP8.5	7.7	68	27	95	59	4518	-$ 1,198

3.3 Recommended stringencies

The recommended stringencies below are based on our analysis of individual archetypes, adjusted where appropriate for each dwelling type's contribution to total new builds over the forecast period. Although our broader results, set out in Section 4, incorporate social costs in the form of avoided carbon emission and network development, our recommended stringencies are based on the private costs home builders/owners face in both marginal upgrade cost and ongoing energy savings.

3.3.1 Class 1 buildings – SBH01, SBH04 & SBH15

Figure 12 shows the spread of modelled results for private costs only in the Class 1 archetypes studied. Despite thermal shell improvements in conjunction with WOH improvements being the most cost-effective net zero energy cost strategy in the townhouse-style SBH15, WOH improvements in isolation were the most cost-effective approach in the standalone SBH04 and SBH01. The distribution of cost effectiveness of WOH improvements and WOH improvements in tandem with thermal shell upgrades can be seen in Figure 12. Note that all these results show negative net costs in present value terms, meaning that each one delivers a net financial benefit.

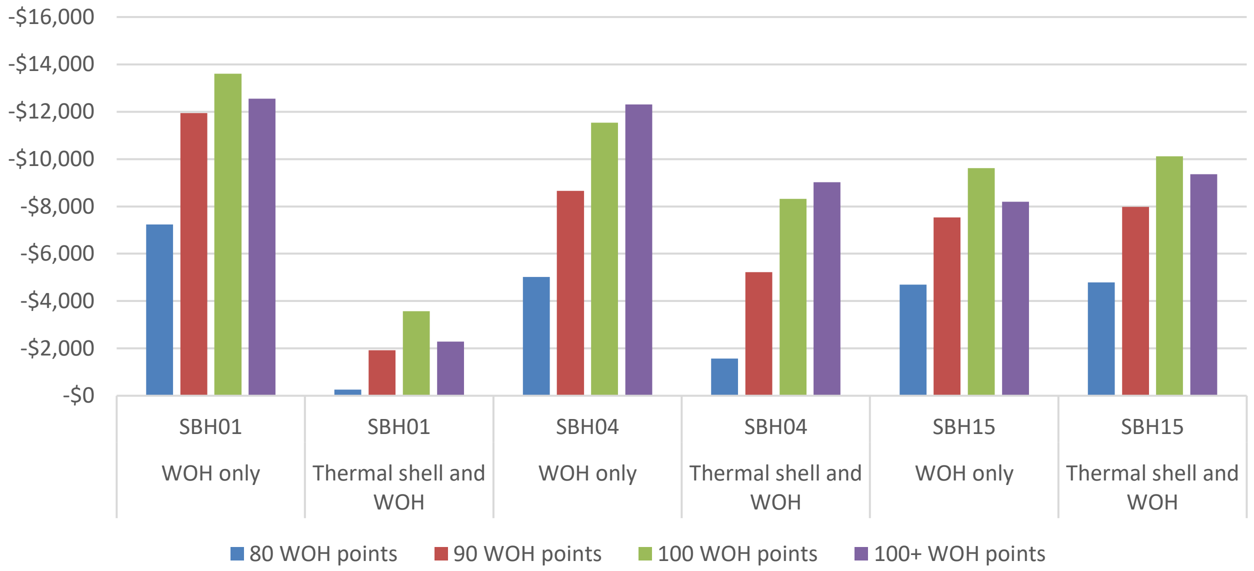

Figure 12: NPV of private costs by archetype by strategy

Figure 13 shows the average NPV of costs associated with increased WOH points in isolation and increased WOH points in addition to a 0.5 star thermal shell improvement. Adjusting the raw averages for SBH15 making up the greater share of projected new builds than the detached archetypes gives an average gap of -$3,176 across the range of WOH point scores.

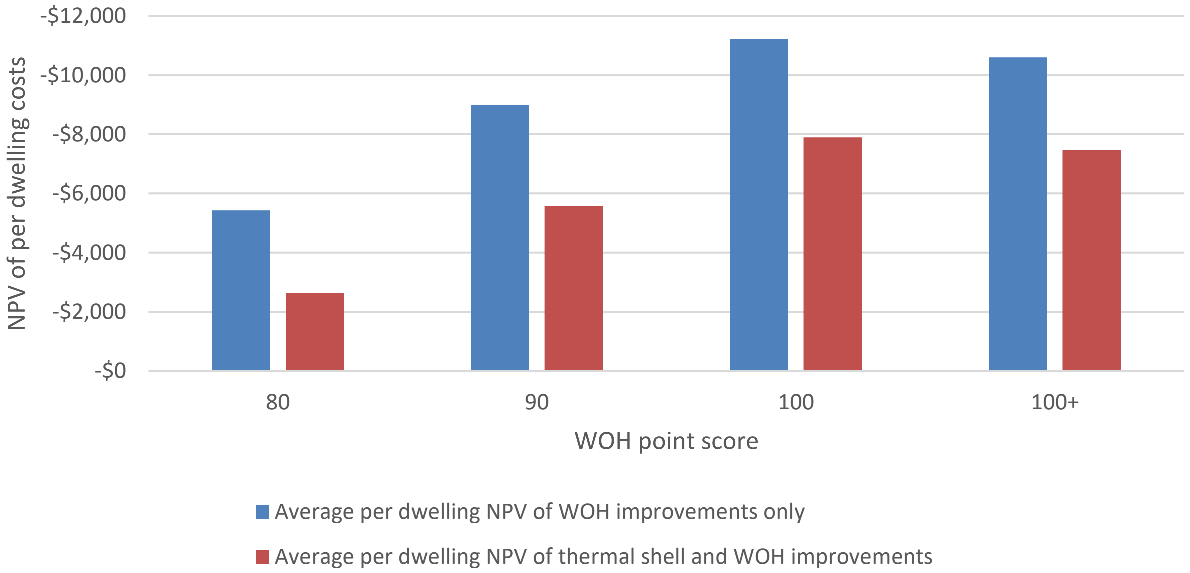

Figure 13: NPV of private costs by WOH point score by strategy (adjusted for forecast archetype contribution to total Class 1 new builds)

We recall that the essential purpose of this report is to identify cost-effective strategies to improve the energy efficiency of new buildings above NCC2022 minimum compliance. Our analysis shows the optimum minimum stringency for new dwellings in the ACT is a 100-point WOH score requirement for Class 1 buildings without changes to the current NCC 7 star thermal shell. Adopting a lower 90-point WOH score would reduce the benefits to residents, while a 100+ score would increase capital costs while providing limited additional lifetime benefits.

Though meeting this requirement will require the installation of solar PV, an average of 7.7kW across the three Class 1 archetypes, the average new solar installation in the ACT has been above this size since 2019.[17]

Importantly, our work found that improvements to the thermal shell (beyond 7 star), in conjunction with a higher WOH score are still cost-negative. There are significant lifetime benefits associated with this strategy, and there may be reasons, such as thermal comfort and climate resilience, that cause home builders to pursue continued improvements in the thermal performance of new builds. These aspects are not quantified in this study. We also note that for some dwellings, such as the townhouse style SBH15, the lower surface area to volume ratio increases the cost effectiveness of thermal shell upgrades, as shown in Figure 12, by reducing upfront capital costs (i.e. less roof, wall and window area means lower insulation and glazing costs).

[17] https://www.energycouncil.com.au/media/fn4kkd2q/australian-energy-council-solar-report-q22024.pdf

3.3.2 Class 2 buildings

Due to the challenges associated with installing solar on many apartment buildings, our research found improving WOH scores in isolation was not a cost-effective approach in Class 2 buildings/dwellings. The limited range of available improvements, and the small share of total energy consumption associated with heating and hot water in the modelled apartments, meant the additional capital cost of high-efficiency appliances outweighed the resulting energy savings.

Similarly, our initial modelling did not find a strong case for improvements to the apartment thermal shell in isolation. The figures involved – $946 over 40 years for 7.5 stars and $1,221 for 8 stars – suggests these improved thermal stringencies are likely to be broadly cost neutral. Supporting this view is analysis of NatHERS data on apartment approvals under NCC2022, which suggests the average new-build apartment is already meeting a 7.3 star thermal shell rating.[18] It is unlikely this outcome would occur were the additional costs involved in achieving this stringency prohibitive to builders or buyers.

To test this view, we conducted detailed thermal and financial modelling of a second more complex, apartment building made up of a wider range of apartment types to broaden the coverage of ACT apartment types and better reflect real world conditions. Additional detail on this secondary analysis can be found at Appendix 6.1.5. The results of this secondary analysis, shown in Table 13, found a lifetime cost of -$160 at 7.5 stars and $879 at 8 stars.

Table 13: Results of secondary analysis of thermal shell improvements to Class 2 dwellings

Scenario	Apartments	Results
NCC2022 Minimal Compliance Base Case	7 star, 50pts	No costs associated with minimum compliance
Improved Thermal Shell Requirements	7.5 star, 50pts	Private additional costs = $249 Private ongoing cost = -$397 Social ongoing cost = -$12 Total lifetime (40yr) cost = -$160
Improved Thermal Shell Requirements	8 star, 50pts	Private additional costs = $1,981 Private ongoing cost = -$1067 Social ongoing cost = -$36 Total lifetime (40yr) cost = $879

In addition to the direct financial impact of thermal shell improvements, there are also significant private uncosted benefits associated with improved thermal efficiency not considered in our

18 https://ahd.csiro.au/dashboards/energy-rating/lga/

analysis, such as improved thermal comfort, reduced noise pollution, and increased safety for vulnerable populations during extreme weather events. Though not captured in our analysis, these benefits are potentially significant, and are likely to become more important as the climate continues to warm.

Equity is also a relevant concern in considering the case for improved apartment efficiency standards, as many of the WOH improvements available to residents of Class 1 dwellings are not available to residents of Class 2 dwellings. Thermal shell improvements are therefore the only tool available to ensure those living in apartments are not left behind as Class 1 dwellings become increasingly efficient and low-cost to operate. There are also equity issues within apartment buildings to be considered, as there can be a wide range of star ratings within a single block. Generally, north facing apartments benefiting from passive solar heating easily exceed average requirements, while south facing apartments struggle to meet minimums. Increasing minimum efficiency requirements has an outsized positive financial impact on these worst performing apartments, as shown in Figure 14.

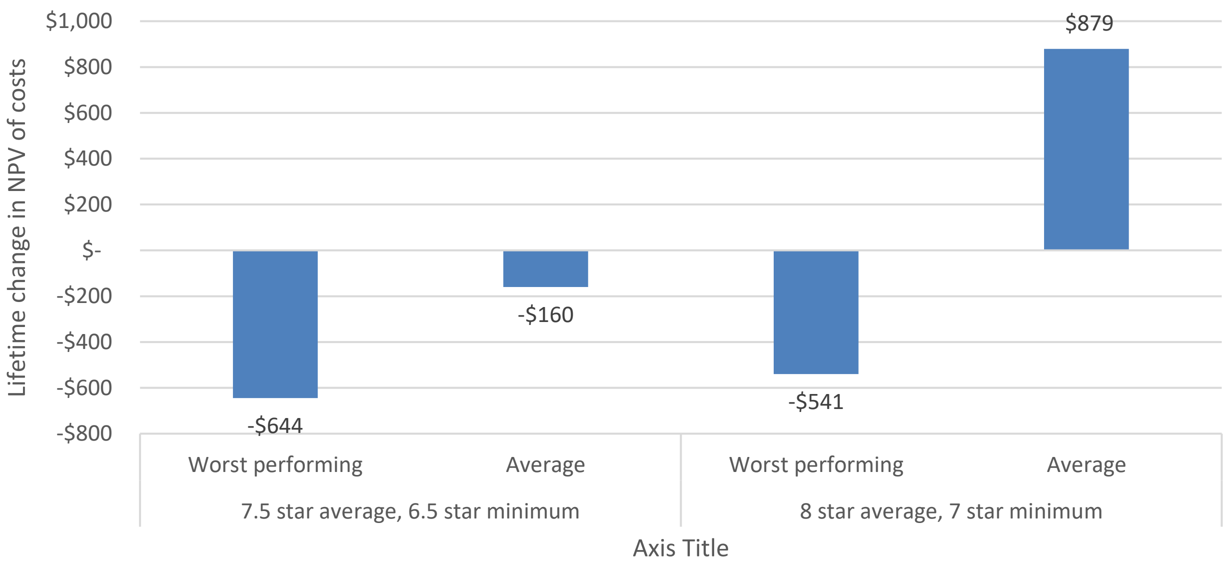

Figure 14: Comparison of worst performing apartment and average of building, by stringency

This additional analysis, coupled with the significant uncosted benefits associated with improved thermal performance, suggests an optimum minimum stringency of 7.5 star average thermal shell requirement, and a 6.5 star minimum for Class 2 dwellings. To ensure apartment dwellers continue to reap the benefits of improved energy performance, the ACT Government should monitor the success of its Solar for Apartments program, and solar uptake in the apartment stock more broadly, and consider future increases in WOH stringency in light of results.

3.4 Batteries

Scope of additional analysis

The inclusion of batteries was not identified as a part of the most cost-effective strategy to reducing net energy use at any of the WOH stringencies examined. Based on our initial analysis using the methodology set out in Section 2.2, the initial capital cost, and need for frequent replacements, outweighs the benefits generated from reduced household solar exports and grid consumption.

Despite these initial results, given significant interest in the role household batteries will play in a future decarbonised grid, we conducted a secondary analysis to isolate the direct change in lifetime costs resulting from including batteries. This analysis focused on the inclusion of batteries in a 100 WOH point Class 1 dwelling, with Class 2 dwellings excluded due to limitations on the installation of solar PV, as described in Section 3.1.1.

Methodology

To allow ease of comparison, the only adjustment made to accommodate batteries in a 100 WOH point dwelling was a corresponding reduction in solar PV. Though this approach may seem counterintuitive, given the relationship between excess solar PV generation and battery utility, all archetypes modelled at 100 WOH points included significant export of excess solar generation. Additionally, given the unique heating and hot water needs of each archetype, modifying wider WOH settings would not allow for an equivalent comparison. The reduction in solar PV required to maintain 100 WOH points is shown in Figure 15. The greatest reduction in solar PV is associated with the installation of a small 3kWh battery, with larger batteries requiring smaller reductions in capacity. This result is a function of the net-zero energy requirement for a 100 WOH score, which implies a minimum required amount of generation to meet the energy demand of the dwelling.

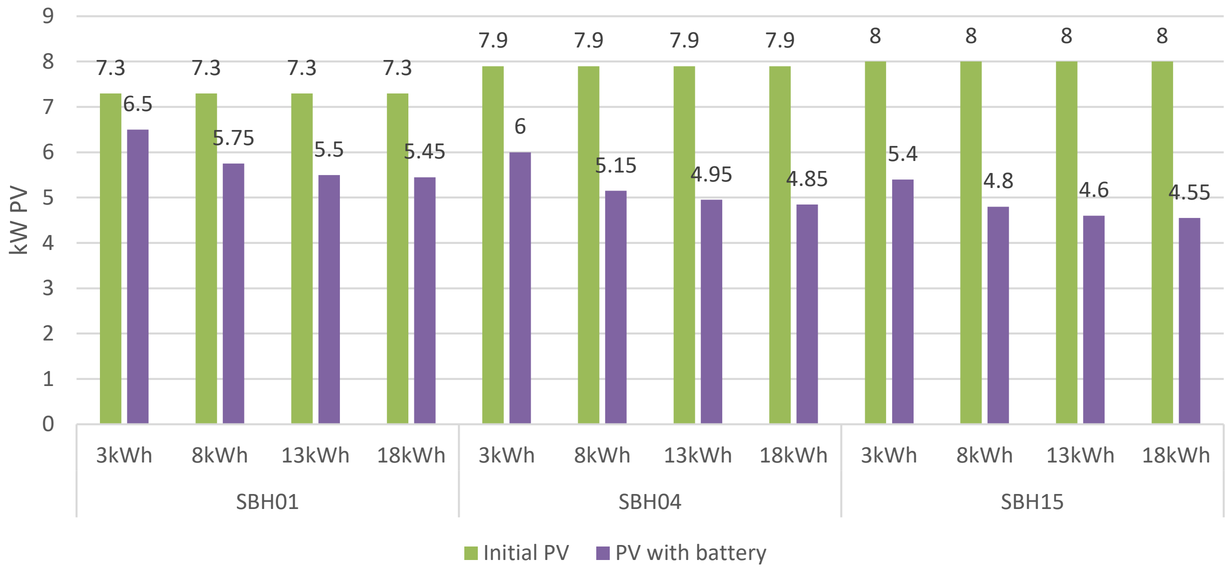

Figure 15: Change in solar PV capacity to meet 100 WOH points with addition of batteries

Importantly, this secondary analysis examines only the private costs of battery installation, as determined by the NatHERS model and HERO software. The NatHERS WOH model treats batteries as a "simple energy storage tank" in which excess on-site solar generation is stored for later use.[19] The methodology does not account for broader climate, network and market factors, such as time-of-use tariffs, that may influence optimum charging/discharging cycles, nor does it account for a range of broader social costs/benefits. Important possible cost/benefits not factored into our analysis include (but may not be limited to):

- **Private costs associated with optimised battery operation:** The private cost calculations used in our analysis rely on the operational assumptions and cost calculations built into the models and systems used for our analysis. Understandably, given limited adoption of Virtual Power Plants (VPPs) or coordinated optimisation software/tools, these calculations do not consider the additional private benefits (negative costs) participation in these systems may generate.[20] These include the opportunity for households to shift consumption to periods when the opportunity cost of the output of their PV systems is low (or even zero, where exports are curtailed). The extent to which such opportunities arise is contingent upon many factors and therefore hard to predict. Yet at the same time, the advent of simple phone apps to control PV systems, EV charging, hot water systems and stationary batteries, means

[19] See Section 3.8 of the NatHERS Whole of Home Calculations Method: https://www.nathers.gov.au/sites/default/files/2025-01/NatHERS%20Whole%20of%20Home%20Calculations%20Method%2020250123.pdf

[20] A VPP is an aggregated network of distributed energy resources—such as rooftop solar panels, batteries, and demand response assets—that is centrally managed to function like a single, large-scale power plant.

that even complex optimised control strategies can be readily achieved. As a result, centrally coordinated household batteries dynamically participating in wholesale or ancillary services markets may generate significant private benefits which the results below do not capture.

- **Costs of carbon:** In the modelled scenario, the addition of batteries to meet a 100 WOH point target reduces total solar PV generation, which in turn increases the total societal consumption of carbon-intensive grid electricity, leading indirectly to increased total emissions. Though the impact of this change can be quantified, the rapid decarbonisation of the NEM and slow rollout of batteries to date make it difficult to accurately determine what timing and intensity assumptions should be used in this analysis. It also becomes important to understand when in the day this additional consumption is occurring, as emissions resulting from higher daytime consumption, when per-kWh grid emissions are lower, may be offset by reduced evening consumption, when per-kWh emissions are higher. Given these constraints, we opted to exclude this consideration entirely (noting effects were likely to be marginal).
- **Reduced grid investment:** Batteries reduce peak demand by storing excess PV generation, or by time-shifting grid consumption. Quantifying the reduced costs associated with this functionality would require significant additional work, with results likely to vary widely depending on assumptions made about battery operation, including the level of central control exercised over charging/discharging cycles, the nature of tariffs and private incentives offered, and behavioural responses to these incentives.

Given these constraints, the following results should be understood as a limited, and incomplete, examination of the financial implications of household battery installation. We propose an additional body of work to overcome these limitations below.

Results

As implied in our initial analysis, no modelled battery size generated negative changes in NPV (i.e. increased benefits) when compared with the least-cost 100 WOH point strategies described in Section 3.1. Figure 16 shows that the change in per-dwelling NPV associated with battery installation is largely uniform across archetypes. This result is primarily a function of the uniform battery capital and replacement cost assumptions across archetypes, the shared 100 WOH point target, and similar increases in lifetime costs associated with reduced solar PV installation.

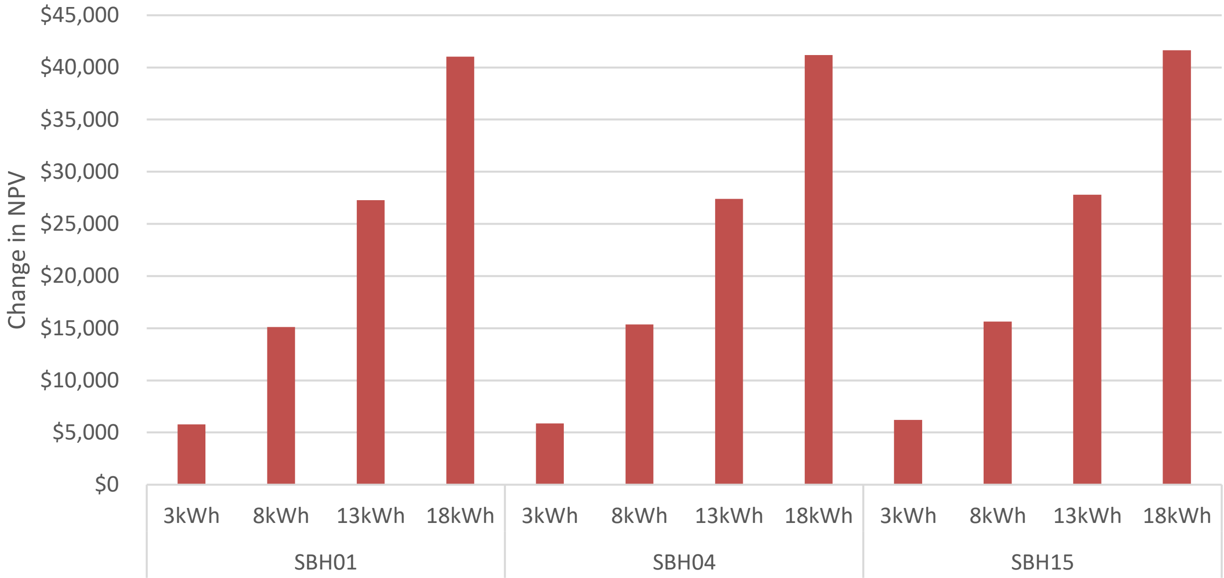

Figure 16: Change in NPV resulting from battery installation compared to least cost 100 WOH point strategy

It was also not clear in our analysis that the installation of a battery generates significant private benefits when traded off against greater installed solar PV capacity. Although less solar PV is being exported to the grid at low prices as a result of battery installation, the total volume of solar being produced is also significantly lower, meaning more periods when grid supply is supplementing on-site generation and lower feed-in revenue. Figure 17 shows the change in lifetime operating costs resulting from installing a range of battery sizes, when compared with the identified least-cost scenario. The sums involved, ranging from -$104 to $230 are small when considering the analysis incorporates 40 years of cashflows, and are significantly outweighed by the substantial additional capital cost discussed above.

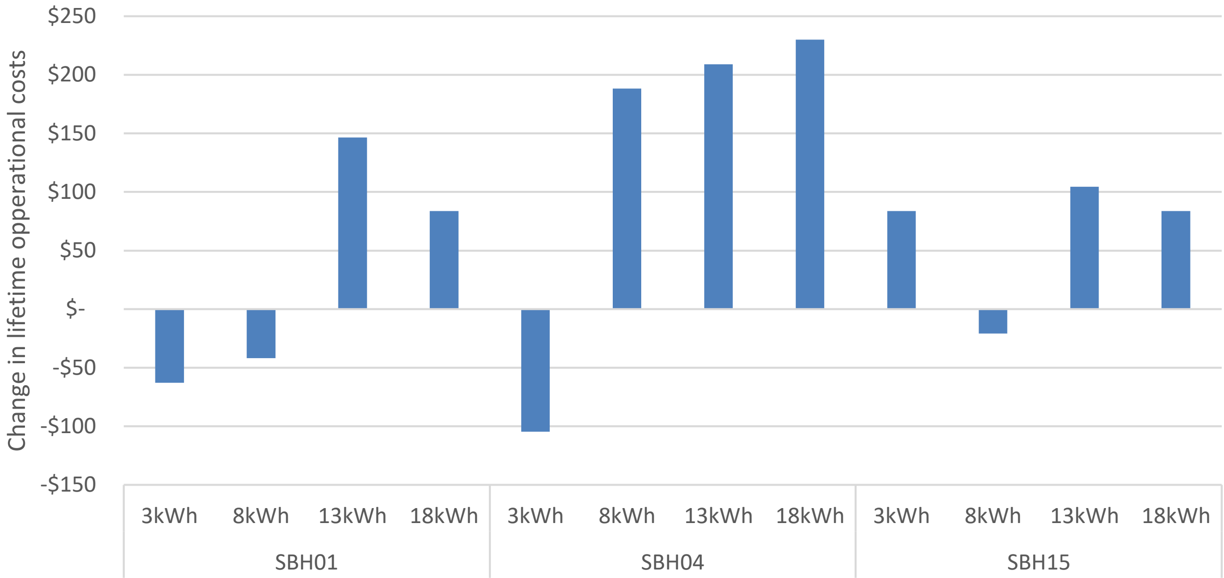

Figure 17: Change in lifetime operating costs resulting from battery installation compared to least cost 100 WOH point strategy

3.4.1 Future research

Significant uncertainty remains among policy makers, households and market participants on the future role household batteries will play in Australia's electricity system. Central to this uncertainty is a lack of clear understanding of the underlying economics of their adoption, particularly when compared to alternative storage options such as grid-scale batteries, pumped hydro, or integrated vehicle-to-grid storage.

Developing an accurate understanding of the relative costs and benefits of household batteries will become increasingly important as electricity market participants and regulators move to limit the uncontrolled expansion of on-site solar PV. Several retailers have already flagged the possibility of introducing negative day-time feed in tariffs, while network companies and market operators are looking to exert centralised control over solar PV systems during periods of peak unscheduled generation. As a result of these trends, the financial benefits householders with solar PV have enjoyed in recent years are likely to decline. This shift may in turn improve the relative attractiveness of storage and higher efficiency appliances, altering the least-cost combination of WOH elements from those identified in Section 3.1.2.

Where household batteries sit in the "pecking order" of available storage solutions will largely be determined by their relative cost in relation to these other options, though consumer preference for energy independence and low-carbon living will play a role at the margins. Household batteries are expensive per kWh when compared with EV batteries, for example. One recent analysis suggests household batteries in Australia are 6 times (600%) more expensive than EV batteries, while grid-scale batteries are understood to be considerably cheaper than EV batteries.[21] The long-awaited adoption of coordinated vehicle-to-grid technology will pose a particular challenge to fixed household batteries, given broader moves to decarbonise the vehicle fleet and the significant size of EV batteries (50-100kWh vs <20kWh for almost all household models). The impact of vehicle batteries on the shape and scale of total available storage will be shaped by the cost-competitiveness of bi-directional chargers[22] and the extent to which market incentives will encourage EV owners to make their vehicle batteries available for grid support. The economies of scale offered by neighbourhood and community batteries, such as those funded through the Commonwealth Government's Community Batteries for Household Solar program, may also pose a challenge to the viability of widespread household battery uptake.

The limited analysis above demonstrates that understanding relative attractiveness of household battery installation requires factoring in a range of both private and social costs not currently captured in the NatHERS model.

Developing a holistic understanding of the private and social costs of household battery installation would require:

- A financial model that incorporates:
    - A range of possible operating models, including "storage tank", intra-day arbitrage, and coordinated wholesale and ancillary market participation.
    - A wider range of current and future tariffs than those currently incorporated into the HERO software to generate costings, including zero or negative feed-in tariffs.
    - A range of capital cost futures to reflect uncertainty over the pace of declines.
    - A range of battery efficiencies, reflecting both improvements in technology and changed performance as a result of alternative operating models. The current NatHERS WOH methodology includes set values for battery round-trip efficiency and charge depth – additional research would be required to determine if these fixed rates held across the operating modes analysed.
- An emissions model that accounts for changes in grid intensity and electricity use across the day for different operating modes to accurately assess the impact of household battery adoption on total emissions.
- A Conservation Load Factor (CLF) model capable of generating dynamic avoided grid investment results based on operating modes and assumptions.

[21] See https://reneweconomy.com.au/the-role-of-distributed-energy-can-it-be-a-marriage-of-equals/, viewed online 18 February 2025.
[22] At the time of writing, there was one such charger on the market, for over $11,000 – see https://thedriven.io/2025/02/13/some-v2g-drivers-saving-heaps-but-big-changes-needed-to-make-it-work-for-all/, viewed online 18 February 2025.

4. Policy cost benefit analysis

Considering all private costs, social carbon costs, and avoided network costs, our analysis suggests a lifetime cost of enacting the optimal Class 1 and 2 stringencies set out above of -$380.1m. Additional capital expenditure incurred over the policy period, borne by households, totals $263.7m. Total lifetime costs incurred total -$643.8m, made up of -$472.2m private benefits associated with reduced energy consumption, -$14.9m social cost associated with avoided carbon emissions, and -$156.7m associated with avoided peak demand – see Figure 18. These figures give a cost benefit ratio of 2.44.

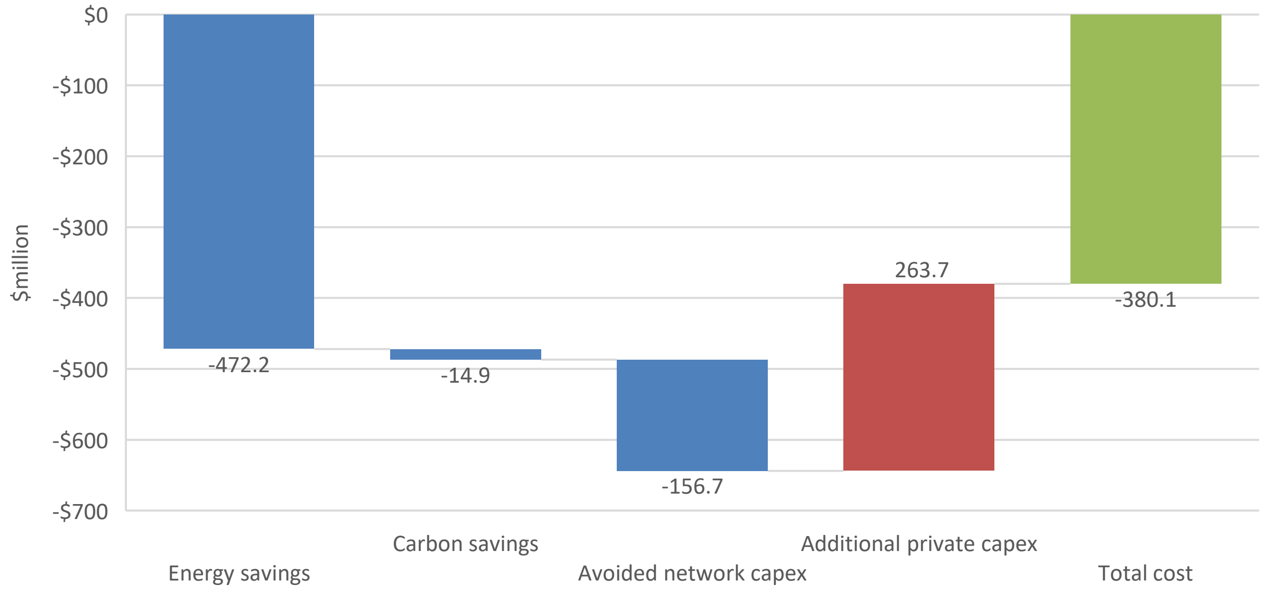

Figure 18: Present Value of Total Costs, Recommended Stringencies, by Component

4.1 Private costs

4.1.1 Private capital costs

Private capital costs over the policy period total $263.7m. Figure 19 shows the contribution each archetype makes to the total private capital expenditure over the policy period, with SBH01 making up 34.6%, SBH04 28.0%, and SBH15 36.3% and apartments 1.1%.

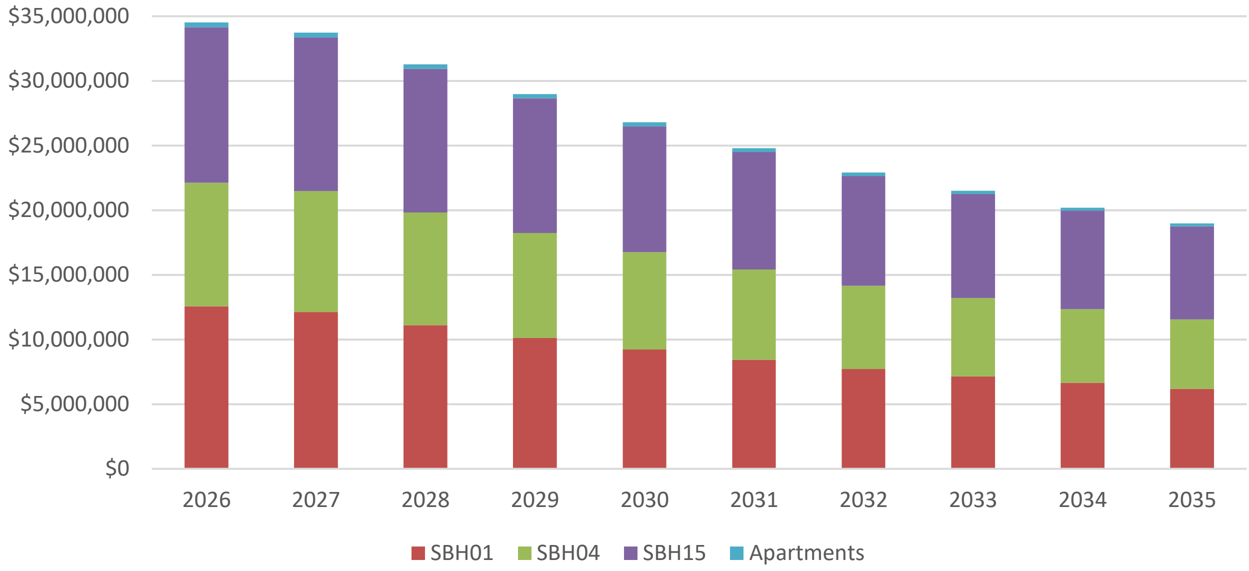

Figure 19: Annual contribution to private capital costs by archetype[23]

4.1.2 Private operational costs

Private operational costs make up the majority, 73.3%, of lifetime costs in our analysis, and total -$ 472.2m over the policy period. Figure 20 shows the contribution each archetype makes to the total private NPV over the policy period, with SBH01 making up 32.2%, SBH04 31.0%, and SBH15 35.7% and apartments 1.0%.

[23] Note: The present value of costs and benefits decline over time for the same reason – the time value of money. A discount rate quantifies this decline in the present value of future costs or benefits.

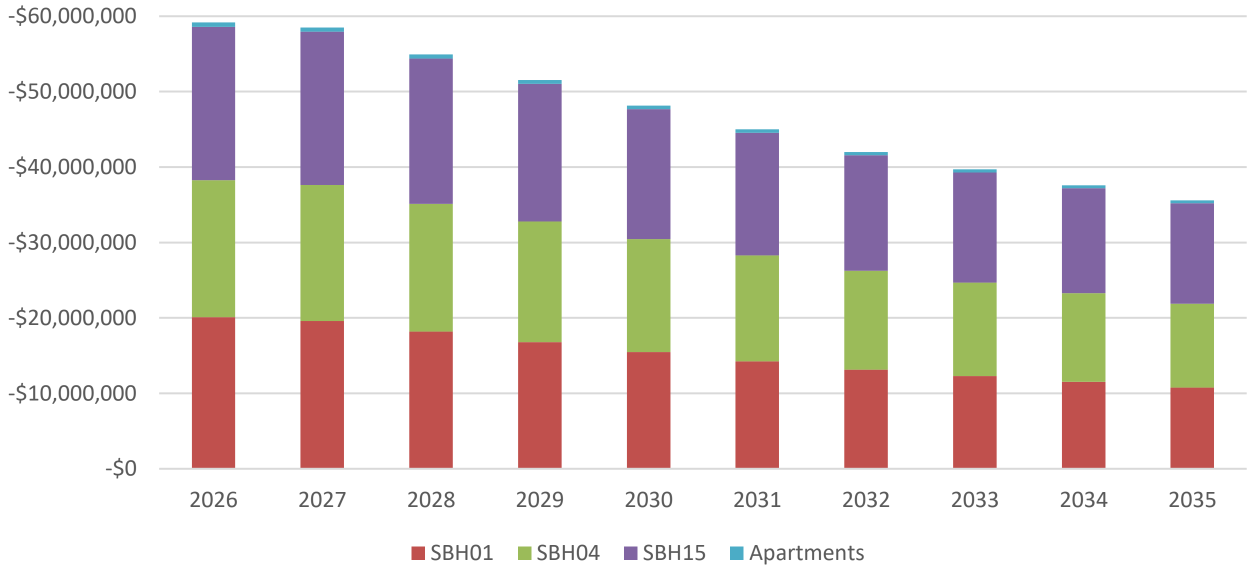

Figure 20: Annual contribution to private operational costs by archetype

4.2 Social costs

Avoided social costs (or social benefits) account for 26.7% of total lifetime costs, and are a combination of avoided carbon emissions, 8.7% of social costs, and avoided network expenditure, 91.3% of social costs.

4.2.1 Avoided emissions

Emission savings account for a relatively small share of total costs, 2.3%, primarily because the grid intensity of electricity is forecast to fall rapidly over the policy period, as shown in Figure 21.

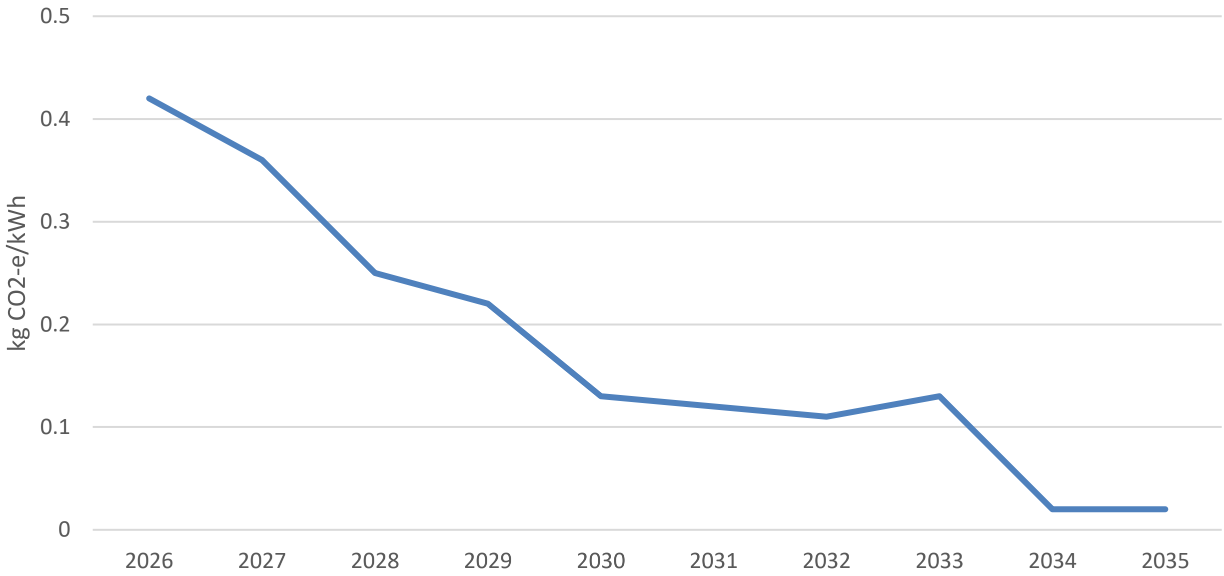

Figure 21: Australian Energy Market Operator forecast NSW region grid intensity

As shown in Figure 22, our modelling suggests the NPV of avoided carbon costs over the policy period is -$14.8m, with annual contributions falling from -$3.96m in 2026 to -$0.28m in 2035.

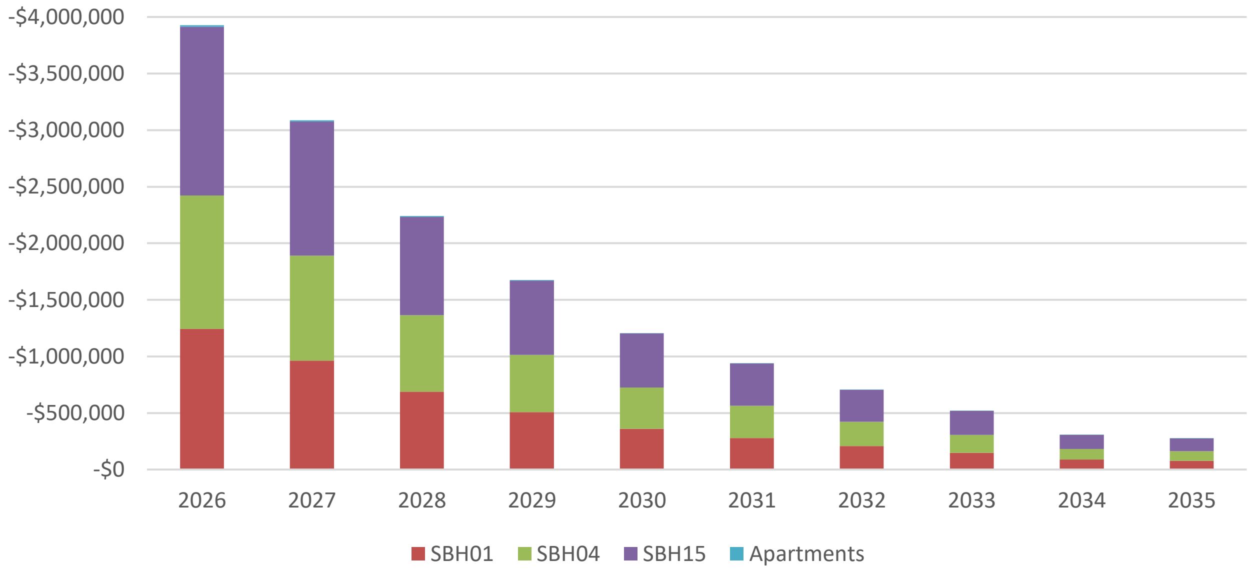

Figure 22: Annual contribution to total NPV of social costs

Emission savings as a result of adopting the recommended stringency total 66.1 kt/CO2-e, with savings largely plateauing towards the end of the policy period due to declining grid intensity, as can be seen in Figure 23.

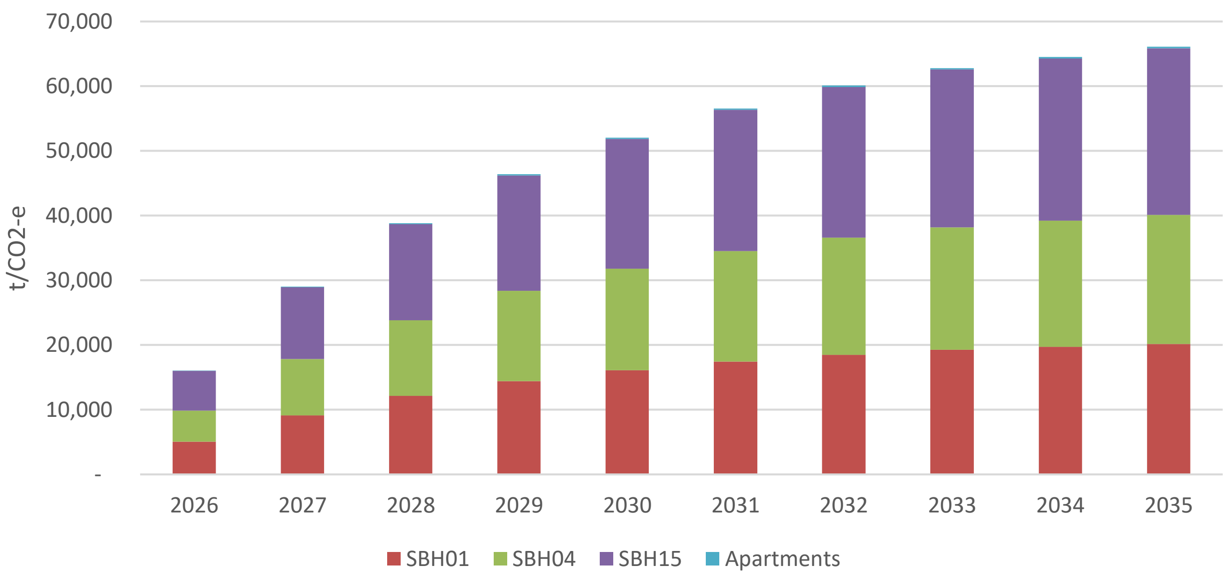

Figure 23: Cumulative emission savings by archetype (by dwellings built by year)

4.2.2 Avoided peak demand

Although not considered in the per-dwelling results in Section 3 above, there are significant benefits associated with reduced network expenditure as a result of avoided peak demand in more energy efficient dwellings. Using the Conservation Load Factor (CLF) approach to quantifying peak demand reductions, by 2035 the improved efficiency of the 2026-2035 dwelling cohort avoids 7.3MW of peak demand. Based on this figure, and transmission expenditure figures from EVO Energy's Regulatory Information Notice (RIN) reporting, the NPV of avoided network expenditure from 2026-2075 totals $156.7m, as shown in Figure 24. The average annual per-dwelling infrastructure savings resulting from adopting the recommended stringencies are set out in Table 14.

Table 14: Per-dwelling annual distribution infrastructure savings by archetype (2025 $)

Archetype	Annual saving
SBH01	-$830
SBH04	-$641
SBH15	-$148
Apartments	-$24

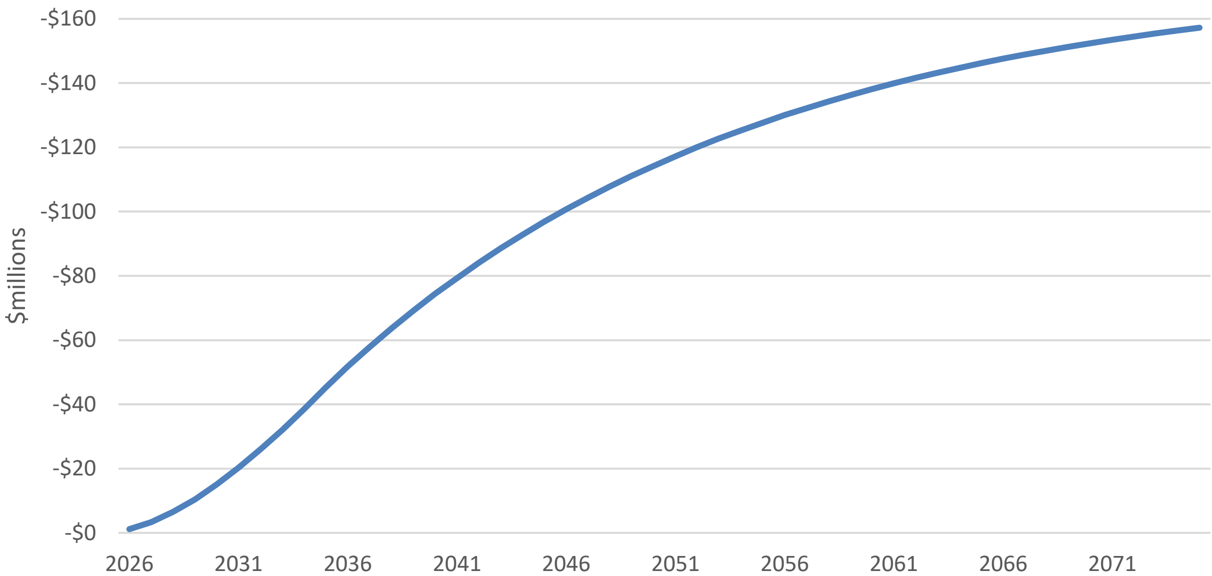

Figure 24: Cumulative value of avoided network costs (2025 $)

4.3 Sensitivity analysis

4.3.1 Discount rate

The results above have been calculated using a 5% discount rate to align with recommended economic parameters for use in analysis relating to NCC2025.[24] Though a 7% discount rate has been widely accepted as the norm in Australia for some time, which saw it used in analysis of NCC2022, recent commentary from economists and regulators suggests real discount rates are falling over

[24] The ABCB has released recommendations for economic parameters to be used in the development of analysis related to NCC2025, though at present only for commercial buildings. We believe the 5% figure adopted in this context represents current best practice for all building energy efficiency analysis, including residential. For more information see: https://www.abcb.gov.au/sites/default/files/resources/2024/ABCB-Commercial-EE-RIS-Econ-parameters.pdf

time, which has seen increased adoption of a 5% discount rate in policy analysis.[25] Many jurisdictions also apply a lower discount rate to energy efficiency and climate mitigation policies and interventions in recognition of the long-term value of avoided emissions and associated warming. As the analysis below demonstrates, the recommended stringencies set out in this report generate significant negative costs even at much higher discount rates than that used in our analysis.

Given the long timeframe over which the costs of this intervention are realised, the discount rate applied to future costs has a significant impact on the NPV of the intervention. Table 15 shows the NPV of costs applying a 2%, 5% and 7% discount rate, with costs almost 4 times lower at 2% than at 7%. This relationship is further illustrated in Figure 25, with a range of costs from $-1,142.6m at a 1% discount rate, to $-86.8m at 10%.

Table 15: NPV of costs by discount rate

Discount rate	Net Present Value of costs
2%	$ -870.2m
5%	$ -380.1m
7%	$ -219.5m

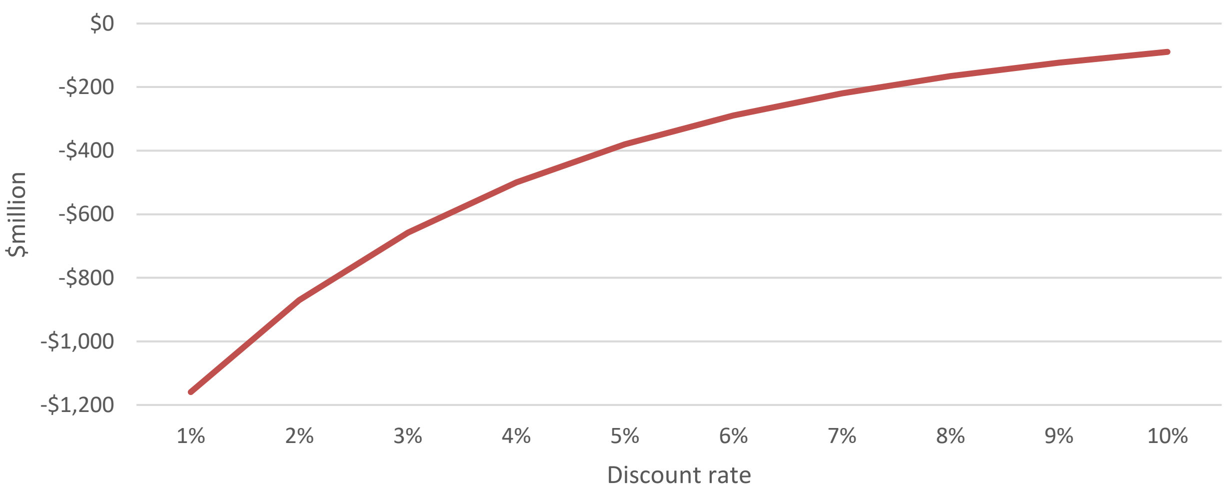

Figure 25: NPV of policy by discount rate

[25] See, for example: https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

4.3.2 Carbon costs

The cost of carbon used in this analysis aligns with that used in the 2025 National Construction Code, Consultation Regulation Impact Statement, which is in turn derived from the US Environmental Protection Agency's (EPA) 2022 *Report on the Social Cost of Greenhouse Gases*.[26][27] The EPA's carbon price is a "social cost of carbon", which represents the NPV of a range of long-run costs associated with emissions above and beyond the cost of simply offsetting emissions, including future economic, social and environmental costs. Variation in the price trajectories is a function of the discount rate applied to future costs, ranging from 1.5% in the high series, 2% in the medium series and 2.5% in the low series. The carbon costs derived from the EPA's work and adopted in this report are shown in Table 16. SPR's analysis uses the medium series price trajectory to calculate the value of emission savings as a result of increased NatHERS stringencies. Figure 26 shows the impact applying higher and lower social cost of carbon price trajectories has on the total value of avoided carbon, with the high trajectory giving a value 2.7 times that of the low trajectory.

Table 16: Social cost of carbon over time (constant 2025$)

	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
Low series	$175	$188	$208	$228	$248	$268	$288	$308	$328	$348	$362	$375
Med series	$282	$308	$335	$362	$389	$415	$442	$469	$489	$509	$529	$549
High series	$483	$509	$543	$576	$610	$643	$677	$710	$737	$764	$784	$804

[26]https://oia.pmc.gov.au/sites/default/files/posts/2024/05/Consultation%20Regulation%20Impact%20Statement.docx
[27] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf

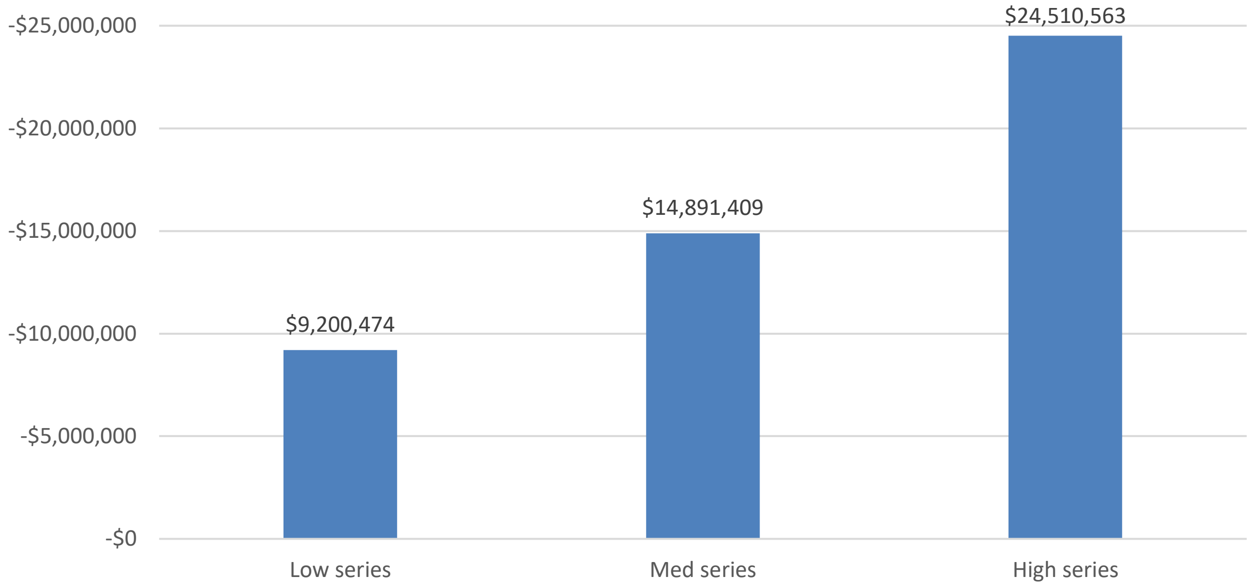

Figure 26: Impact of emission price trajectories on value of avoided carbon

In addition to the EPA's social cost of carbon figures, the ACT Government supplied SPR with an alternative set of carbon cost trajectories to apply to the recommended stringencies (show in Appendix 6.3.1). These alternative carbon costs led to higher total avoided carbon costs across the board, with the gap increasing from $1.1m in the low series, to $5.6m and $6.3m in the medium and high series respectively, as shown in Figure 27.

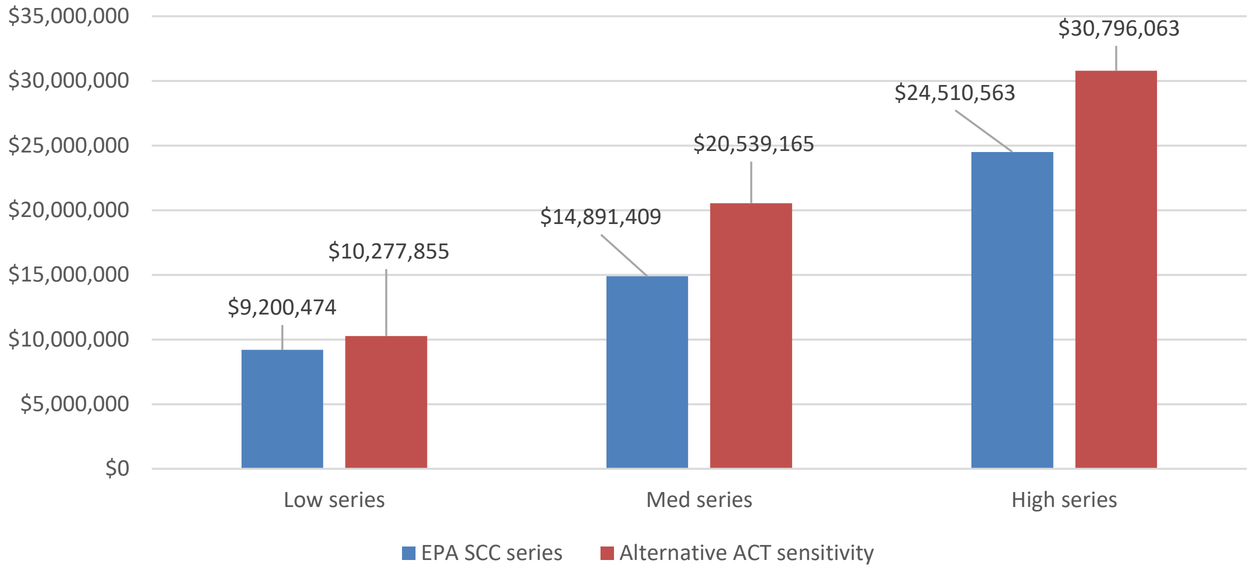

Figure 27: Comparison of impact of emission price trajectories on value of avoided carbon

4.3.3 Electricity prices

The financial model developed for this analysis uses HERO's cost calculations to quantify change in electricity costs, as this figure captures the nuances of when electricity is consumed, and when solar generation is either used behind the meter or exported. To adjust this point-in-time figure for expected future price change, SPR's analysis adopts an electricity price trajectory drawn from NCC 2022 inputs provided by the ACT Government. Changes in electricity costs are represented in our model as a percent of 2025 prices, as shown in Table 17. This price trajectory does not account for inflation, consistent with other cost inputs in the financial model. For the sake of our analysis feed-in tariffs are assumed to move in parallel with electricity prices.

Table 17: Electricity price over time (% of 2025)

	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075
Electricity price	100%	108%	117%	129%	125%	125%	125%	125%	125%	125%	125%

Given the role electricity prices play in determining the total cost of the proposed policy change, and uncertainty over future prices, it is useful to demonstrate the range of possible cost outcomes different electricity price trajectories will generate.

Figure 28 shows the distribution of private cost outcomes as a result of changes to expected electricity prices over the modelled period. As would be expected, as prices increase the financial benefits of improved energy efficiency increase, with 75% higher prices in 2075 resulting in an additional -$134.1m private cost from the baseline price trajectory. Conversely, falling electricity prices reduce the financial benefits of improved energy efficiency, with 75% lower prices in 2075 generating an equivalent $134.1m cost above the baseline trajectory. Although lower prices reduce private costs, even if electricity prices are 75% lower in 2075 than modelled, private operational costs less additional private capitals costs are still negative to the tune of -$74.4m.

Importantly, SPR's financial model does not account for the wider social, environmental or economic costs associated with higher or lower electricity prices, or the total cost to households of changing prices. The figures above pertain only to the change in costs households would face as a result of changing electricity prices were the proposed thermal shell and WOH stringencies adopted, when compared to the NCC2022 base case.

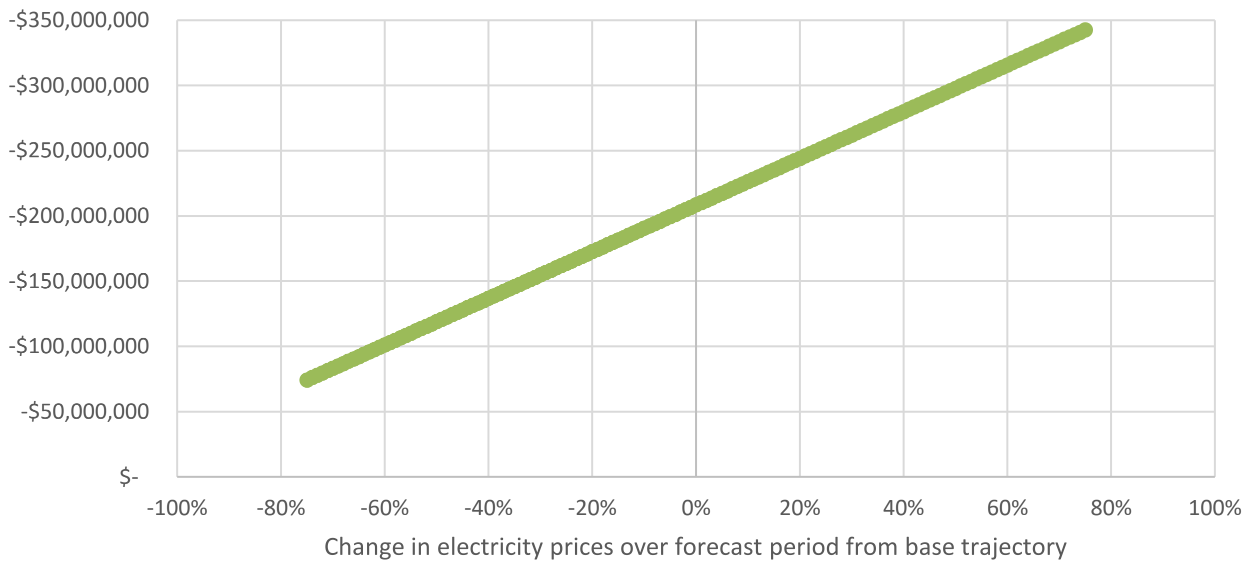

Figure 28: Impact of changes in electricity prices on private costs

4.4 Broader metrics for understanding results

The analysis in Chapter 4 relies on Net Present Value (NPV) and Benefit Cost Ratio (BCR) metrics to report on the results of our analysis. As described above, these terms mean:

- Net Present Value: Represents the difference between the present value of benefits and costs over time. NPV calculations consider the value of money over time (discount rate). An

NPV can reflect costs and benefits that accrue to private parties (private NPV), or, as in this analysis, can include societal costs and benefits (societal NPV).

- Benefit Cost Ratio: Represents the ratio of the present value of an investment or policy's total expected benefits to the present value of its total anticipated costs. BCR is generally shown as a single number, such as 2.44 in the case of this report, which means the policy change will generate $2.44 of benefits for every $1.00 of costs. Unlike NPV, BCR does not indicate the absolute size or value of net costs or benefits, but only the ratio of the two.

Though these are both useful and widely used metrics, NPV and BCR are not the only two ways we can understand complex financial results. These metrics tell us very little about the day-to-day financial impact of a policy on the people impacted. For example, a policy with a strong BCR result can incorporate a range of benefits not directly experienced by households, such as avoided carbon emissions, while changes with a positive private NPV may entail unaffordable up-front investments before anticipated benefits are realised. The following analysis uses a range of metrics, set out in Table 18, to provide additional context for how the proposed policy change, 100 point WOH requirement for Class 1 dwellings and 7.5 star thermal shell for Class 2 dwellings, will impact home builders and buyers.

Table 18: Summary of metrics

Metric	Strengths	Weaknesses
Net Present Value (NPV)	Provides a clear, absolute measure of a project's value, including all costs and benefits, in today's dollars. Are scalable, and can be interpreted as 'the larger the NPV the better'.	Accuracy depends on discount rate assumptions and the timing of forecast cash flows. Not intuitive to non-expert readers.
Benefit/Cost Ratio (BCR)	Offers a simple, quick comparative metric of benefits to costs.	Can oversimplify complex investments by ignoring the scale and timing of cash flows. Non-scalable, and a higher BCR is not necessarily better than a lower one (i.e. if the latter has a higher NPV than the former).

Simple Payback Period	Helps to understand how quickly an initial investment is recovered. Relatively easy to understand and compare across options.	Ignores cash flows after the payback period. May give the misleading impression that household cashflow is negative pre-payback period.
Cashflow analysis	Allows homeowners and policymakers to understand the effect of interventions on real cashflow, including in the short term. Accounts for cost of servicing increased capital expenditure.	The analysis as expressed below is a "Day 1" metric that does not consider the changing balance of costs and benefits over the life of the dwelling.
Internal Rate or Return/Social Internal Rate of Return (IRR/SIRR)	Intuitive expression of returns as an 'interest rate equivalent' percentage facilitates comparisons across projects, and with safe investments such as bank deposit or term deposit rates.	Can yield multiple or misleading results with non-standard cash flows and rates of reinvestment.

We stress that these metrics are not necessarily alternatives to each other, nor are any of them necessarily right or wrong, or better or worse. Each has particular strengths and weaknesses and can be used to validly highlight different aspects of the benefits and costs of a policy proposition.

4.4.1 Simple Payback Period

The payback period of an investment or policy is the length of time it takes for additional benefits arising from the decision to outweigh the additional associated costs. A payback period is generally expressed as a number of years and months. The payback periods for the private costs associated with adopting the recommended stringency in modelled archetypes are shown in Table 19.

Table 19: Private payback period by archetype (average of policy period)

Archetype	Years	Months
SBH01	15	3
SBH04	12	2
SBH15	14	1
Apartments	16	2

Though payback period can be a useful way of understanding the attractiveness of a choice, and can be particularly useful when comparing options, the metric fails to capture the effect of a given choice on cashflow/flow of benefits arising as a result, or cashflow beyond the payback period. A payback period can also, mistakenly, be interpreted as implying that participants, in this case householders, receive no benefit arising from an investment or policy until the payback period is reached. This is particularly relevant when considering policies such as energy efficiency in buildings, which reduce operational energy use and therefore costs over a significant time period.

4.4.2 Cashflow analysis

A cashflow analysis examines the change in monthly budgets associated with adopting an investment or policy choice. This is a particularly useful metric in the context of the proposal set out in this report, because almost all the costs incurred will be borne by households. It is therefore important to quantify the impact of the proposed stringencies on household cashflows.

A significant majority of properties in Australia are purchased with a mortgage, 71.5% in 2023. [28] This fact means the bulk of households would not "pay" any additional upfront cost to meet the recommended stringencies proposed in this report, but would instead pay the cost associated with borrowing the additional capital required. If the monthly savings associated with the upgrades are greater than the additional costs of the borrowing required, the upgrade is cashflow positive. Table 20 shows the cashflow impact of the recommended stringency on monthly household cashflow for each of the archetypes modelled.

[28] https://www.pexa.com.au/staticly-media/2024/03/PEXA-Cash-Purchases-Report-CY23_FINAL-sm-1710219788.pdf

Table 20: Monthly cashflow impact of adopting recommended stringencies, by archetype.

Archetype	Base case annual electricity costs	100 WOH point annual electricity costs	Monthly savings	Additional capital costs	Monthly repayments on additional capital @ 6.15%[29]	Cashflow impact
SBH01	$1,618	-$10	-$136	$12,602	$82	-$54
SBH04	$1,233	-$17	-$104	$9,093	$59	-$45
SBH015	$1,064	-$3	-$89	$8,138	$53	-$36
Apartments	$1,009	$990	$-2	$249	$2	$0

The savings above assume all the costs of upgrading are met by borrowing on top of the buyer's initial mortgage at the same rate as the dwelling. There are an increasing number of "green" loans and mortgages available, some developed independently by banks, others supported by funding mechanisms such as the CEFC.[30] These green loans offer below market interest rates on loans to fund energy efficiency or renewable generation upgrades. While some loans are designed to encourage homeowners to improve the efficiency of their existing dwelling, and cover only the capital expenditure required to make the upgrades, some green loan products offer a lower interest rate on an entire mortgage for a limited time period.[31] Table 21 shows the monthly cashflow impact of adopting the recommended stringency in conjunction with a green mortgage offering an initial 0.58% rate reduction.

[29] Assumes 25 year term.
[30] https://www.cefc.com.au/where-we-invest/special-investment-programs/household-energy-upgrades-fund/
[31] Such as those offered by Bank Australia (https://www.bankaust.com.au/banking/home-loans/clean-energy-home-loan), which provides a 0.58% rate reduction for the first five years of the mortgage.

Table 21: Monthly cashflow impact of adopting recommended stringency with green mortgage[32]

	New dwelling price (,000)	Base case mortgage (20% deposit) (,000)	Rec stringency mortgage principal	Base case payments @ 6.15% (p/m)	Rec stringency payments @ 5.57% (p/m)	Mortgage savings (p/m)	Energy savings (p/m)	Total savings (p/m)
SBH01	$1,100	$880	$892,602	$5,751	$5,519	-$232	-$136	-$368
SBH04	$950	$760	$769,093	$4,967	$4,755	-$212	-$104	-$316
SBH015	$800	$640	$648,138	$4,182	$4,007	-$175	-$89	-$264

This cashflow analysis uses as its base a current (early 2025) average owner-occupier, principal and interest mortgage rate of 6.15%.[33] The average owner-occupier, principal and interest mortgage rate since July 2019 (the earliest record in the RBA dataset) is 3.99%. Were average interest rates to trend toward this average over the policy period, the cashflow benefits associated with the 100 WOH least-cost strategy would increase. Similarly, were interest rates to trend higher over the policy period, benefits would be reduced.

A final caveat to this analysis is that it is a "Day 1" metric, that doesn't consider changes in electricity prices (forecast to rise in our model) or interest rates (as explained above) over time, or the need for reinvestment at various points over the life of the dwelling. This fact means the cashflow benefits of adopting the recommended stringencies set out in this report are likely to change over time. As a result, these figures should not be used in isolation from the other metrics presented in this report.

4.4.3 Internal Rate of Return

The Internal Rate of Return (IRR) is the discount rate that makes the NPV of investment or policy equal to zero, effectively representing the project's break-even cost of capital. If the cost of capital, for example a mortgage rate or bank lending rate, is lower than the IRR, the investment or policy can be expected to generate negative costs.

The Social Internal Rate of Return (SIRR) is the same as the IRR, but incorporates the value of social benefits into calculations; avoided emissions and grid investment in the case of the policy examined in this report. SIRR can also factor in costs of a policy choice, lowering the attractiveness of an investment or proposal that increased emissions or imposed health costs on the community, for example.

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[32] Note: Apartments have been excluded from this analysis as it is unlikely an upgrade to 7.5 stars would qualify for a "green" mortgage. The sums involved are also very small.
[33] https://www.rba.gov.au/statistics/interest-rates/

Table 22 shows the IRR and SIRR of adopting the recommended stringencies set out in Section 3.3. Because our analysis examines a policy period of ten years, the IRR/SIRR is not the same for every dwelling constructed over the period. Because dwellings constructed in 2026 accrue benefits during the period we value them the most (the present) the IRR of adopting the recommended stringencies is highest at the start of the policy period. Conversely, more of the benefits associated with adopting the recommended stringency for a dwelling built in 2035 will accrue in a period when we value them less (the future), leading to a lower IRR. The SIRR falls more steeply over 2026-35 than the IRR because alongside the effect above the value of avoided emissions is higher earlier in the policy period due to falling grid intensity. The change in IRR and SIRR over the policy period is shown in Figure 29 and Figure 30 respectively. The IRR and SIRR of the policy are well above current and historical bank lending rates, meaning these policy settings can be expected to produce net benefits.

Table 22: IRR and SIRR of adopting recommended stringencies, by archetype

Archetype	Year one IRR	Year ten IRR	Policy period average IRR	Year one SIRR	Year ten SIRR	Policy period average SIRR
SBH01	9.7%	7.7%	8.5%	15.1%	9.6%	11.5%
SBH04	11.6%	8.6%	9.8%	18.2%	10.6%	13.2%
SBH15	10.2%	8.0%	8.9%	12.9%	8.6%	10.1%
Apartments	9.2%	7.5%	8.2%	19.6%	11.4%	14.3%

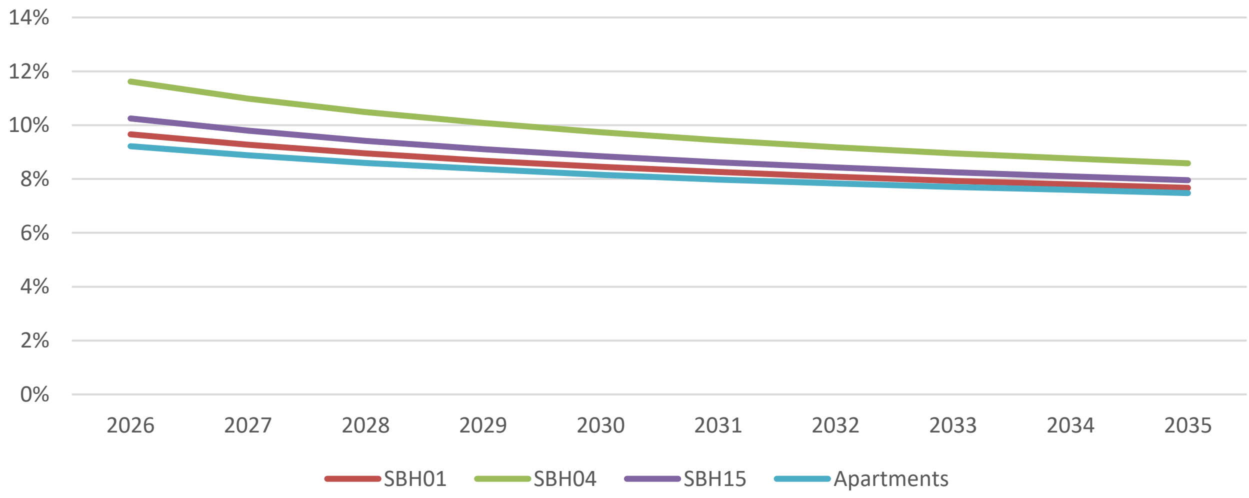


Figure 29: IRR of adopting recommended stringencies by year of construction

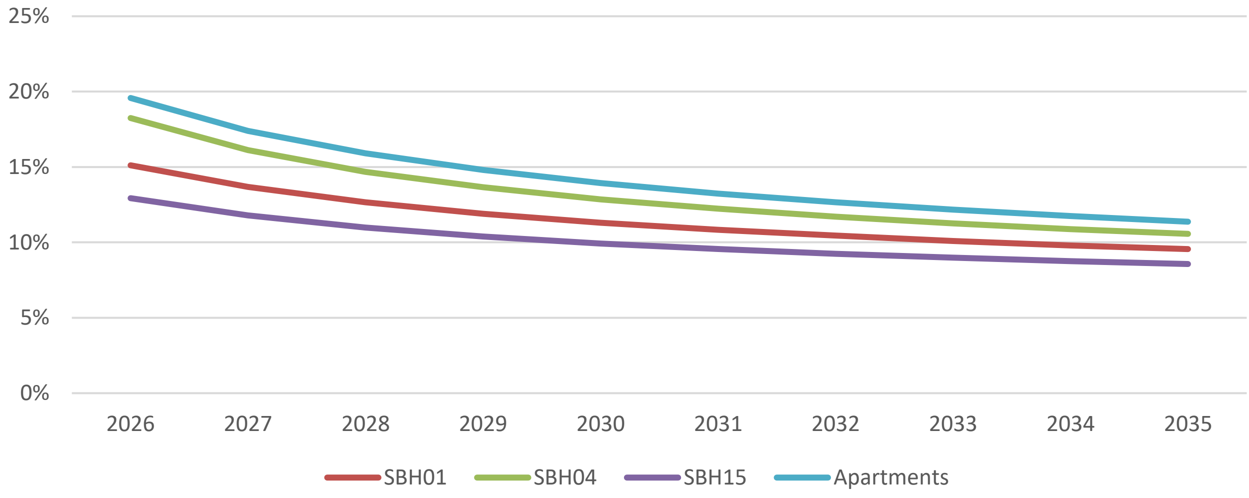


Figure 30: SIRR of adopting recommended stringencies by year of construction

One notable finding from an analysis of the IRR and SIRR results presented above is the significant jump in the rate of return on apartment efficiency improvements when social costs are considered. This result is a function of the greater share of total energy savings in apartments contributing to reduced distribution investment. Our model excludes avoided grid electricity consumption stemming from solar PV from our CLF calculations, meaning that for Class 1 dwellings only those distribution infrastructure savings attributable to improved appliance efficiency were quantified. Because all electricity savings resulting from increased thermal shell stringency in Class 2 dwellings factored into our CLF calculations, the contribution social costs make to this archetype's rate of return (SIRR) are correspondingly higher.

5. Conclusions

5.1 Key findings

5.1.1 The role of solar PV in increased WOH scores

Our results highlight the key role of solar PV in delivering net-zero energy homes and driving down costs for those able to access the technology. It is safe to say that the cost-negative results for Class 1 dwellings set out above would not be possible without access to low-cost solar PV.

In Class 1 dwellings with available roof space, solar PV generates significant private financial benefits for home builders/owners. In addition to generating direct energy cost savings, low-cost solar generation also offsets the need for both thermal shell improvements and higher efficiency appliances, significantly reducing capital costs. Class 2 dwellings, on the other hand, which were not able to access solar in our modelled results, could not offset these capital costs with low-cost onsite generation, making the financial case for upgrades to both the thermal shell and WOH score challenging.

This finding highlights again the importance of increasing access to and uptake of solar PV beyond those Class 1 buildings that have enjoyed its benefits to date. As discussed in Section 3.3.2, the ACT Government should monitor the success of the Solar for Apartments program, and solar uptake in the apartment stock more broadly, and consider future increases in WOH stringency in light of results. From a societal perspective, the choice to live in an apartment generally offers significant spillover benefits for the community, and ideally this choice would not come at the expense of these households being excluded from the financial and environmental benefits of access to PV.

Implied solar mandates

The recommended stringency for Class 1 dwellings set out in this report, 100 WOH points, could legitimately be understood to effectively mandate solar PV on new dwellings. There will be some who view this requirement as either an unreasonable impost on householders, or on the wider electricity system.

On the first of these concerns, our analysis has shown that solar PV uptake generates significant benefits for households from Day 1, which, of course, explains its ongoing widespread and large-scale uptake in the residential sector. Further, the PV capacity modelled in our least-cost scenario averages 7.7kW, which is well below the 10kW average rooftop installation seen in the ACT over 2023 and 2024.[34]

As for concerns an effective solar mandate would impose significant costs on the wider electricity system, this argument is based on an acceptance that households should forego benefiting from PV

[34] https://www.energycouncil.com.au/media/fn4kkd2q/australian-energy-council-solar-report-q22024.pdf

installation to delay the inevitable transition to a more flexible and consumer-centric grid. Given the significant benefits to individuals and society this transition would entail, we question the economic rationale for delaying its arrival.

Our analysis also shows that adopting a 100 WOH point requirement entails upgrades to fixed appliances in addition to installing solar PV. These appliance upgrades generate significant benefits to the electricity sector in the form of avoided peak demand and subsequent infrastructure upgrades.

5.1.2 Treatment of batteries in NatHERS model

As discussed in Section 3.4, our analysis shows that incorporating batteries in a 100 WOH point Class 1 dwelling does not improve the cost-effectiveness of the overall strategy. The initial capital cost and frequent replacement requirements of batteries outweigh the benefits from reduced solar PV exports and grid consumption. When batteries are added, the NatHERS model requires a corresponding reduction in installed solar PV to maintain the 100 WOH point target, resulting in a uniform increase in lifetime costs across all archetypes. In effect, no battery size modelled produced a negative change in NPV (i.e., increased benefits) compared with the least-cost 100 WOH point strategy, and any potential savings in operating costs were minimal relative to the significant additional capital expenditure.

This assessment only considers private costs using the NatHERS model, which treats batteries as simple storage tanks, and does not capture broader market, climate, or social cost/benefit factors. As such, the findings indicate that, under current assumptions, household batteries are not yet cost effective relative to additional solar PV capacity. However, given the evolving role of batteries in a future decarbonised grid—where factors such as coordinated operation, grid support services, and evolving tariff structures could improve their attractiveness—further research is required to develop a more holistic financial and emissions model that captures these dynamic factors.

5.1.3 Spread of results and implications

Our modelling identified a wide range of possible cost outcomes, particularly in the Class 1 archetypes, as shown in Figure 31. The implications of this finding are that home builders/owners may experience a wide range of cost outcomes in meeting any increases in NatHERS thermal shell or WOH stringencies. To ensure home builders/owners realise the full benefits described above, the ACT Government should consider developing materials to communicate least-cost approaches to meeting any increased stringency requirements.

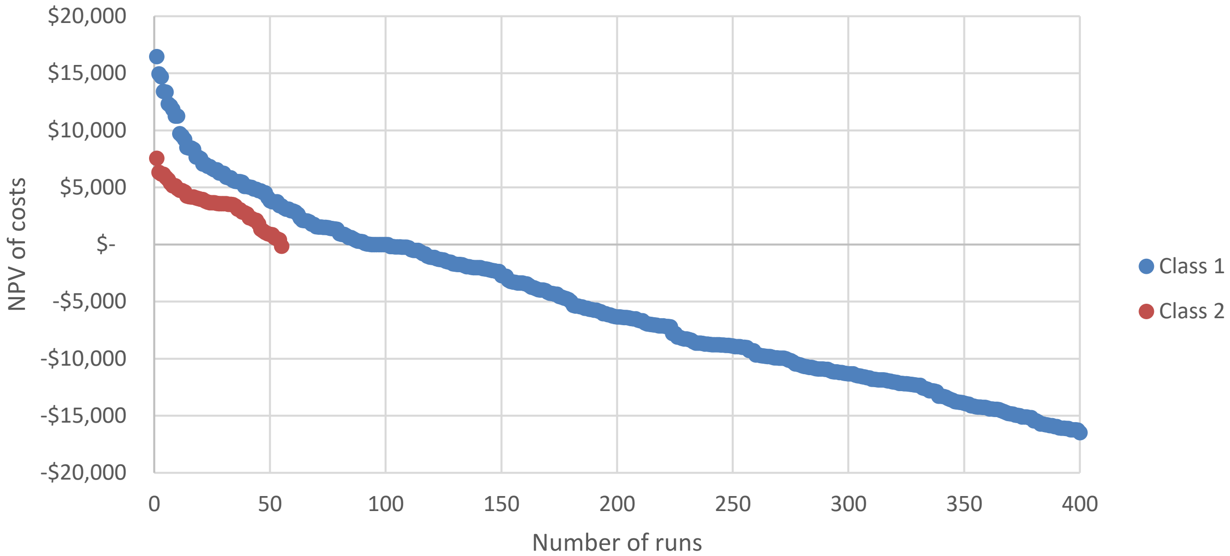


Figure 31: Indicative distribution of NPV outcomes of modelling runs

5.1.4 Sensitivity analyses

Light roof sensitivity

Modelled results for the change of roof colour suggest there are only marginal cost implications for moving from a dark to a light roof. These financial results do not appear to be significant enough to justify a change of regulation relating to roof colours in their own right. On the other hand, nor are these costs so significant that they will necessarily outweigh other costs not factored into our analysis, such as those associated with heat-island effects or extreme hot weather events, that light roofs may mitigate. Further analysis on the value of these potential costs would be required to determine the relative cost benefit of changes to regulations.

2050 climate file sensitivity

Applying a 2050 climate file reflecting an RCP8.5 emissions pathway to our NCC base cases demonstrated that the ACT's space conditioning needs would continue to be dominated by heating over the modelled period. All NCC base cases used in our analysis incurred meaningfully lower lifetime energy costs using the 2050 climate file due to a reduction in this heating load. This reduction was not offset by a slight increase in cooling needs over the same period.

Our analysis could not take into account the impact of extreme events falling outside the averages of the climate file. As a result, we were not able to consider the costs of natural disasters such as bushfires and extreme heat events on residents of modelled dwellings.

5.2 Summary of proposed policy solutions

1) Based on our analysis of the most cost-effective solutions, the optimal minimum NatHERS requirements for new dwellings in the ACT are:
    a. 100 WOH points for Class 1 dwellings, while maintaining the current 7 star thermal shell requirement.
    b. A 7.5 star average, and 6.5 star minimum, thermal shell requirement in Class 2 dwellings, while maintaining the current 50 WOH requirement.
2) There is a case for encouraging uptake of dwelling-appropriate least-cost efficiency strategies by developing supporting materials for home builders and buyers based on the findings of this report.
3) Future improvements to residential energy efficiency standards should be informed by:
    a. Monitoring uptake of solar PV in the apartment sector with an eye to future increases to Class 2 WOH stringencies.
    b. Developing a more comprehensive understanding of the private and social costs of household battery uptake to inform future improvements to the NatHERS model.

6. Appendices

6.1 NatHERS modelling considerations

- ACT postcodes: 2600 – 2617
- ABCB climate zone – CZ 7
- NatHERS climate zone: - CZ 24
- Solar hot water – Zone 3
- Air sourced heat pump hot water – Zone 5
- ZERL climate zone – cold
- Moderate cooling – suitable for evaporative coolers (NatHERS WoH)
- NatHERS 7 star annual energy load 122MJ/m2/yr (for Class 1 dwellings and the average of Class 2 dwellings in a building
- NatHERS 6 star annual energy load 161MJ/m2/yr (for individual Class 2 dwellings)
- Heating and Cooling load limits

  Class 1 CSOG
  - Heating load limit 129 MJ/m2/yr
  - Cooling load limit 34MJ/m2/yr

  Class 1 SF
  - Heating load limit 123 MJ/m2/yr
  - Cooling load limit 41MJ/m2/yr

  Class 2 (7 Star Average)
  - Heating load limit 130 MJ/m2/yr
  - Cooling load limit 28MJ/m2/yr

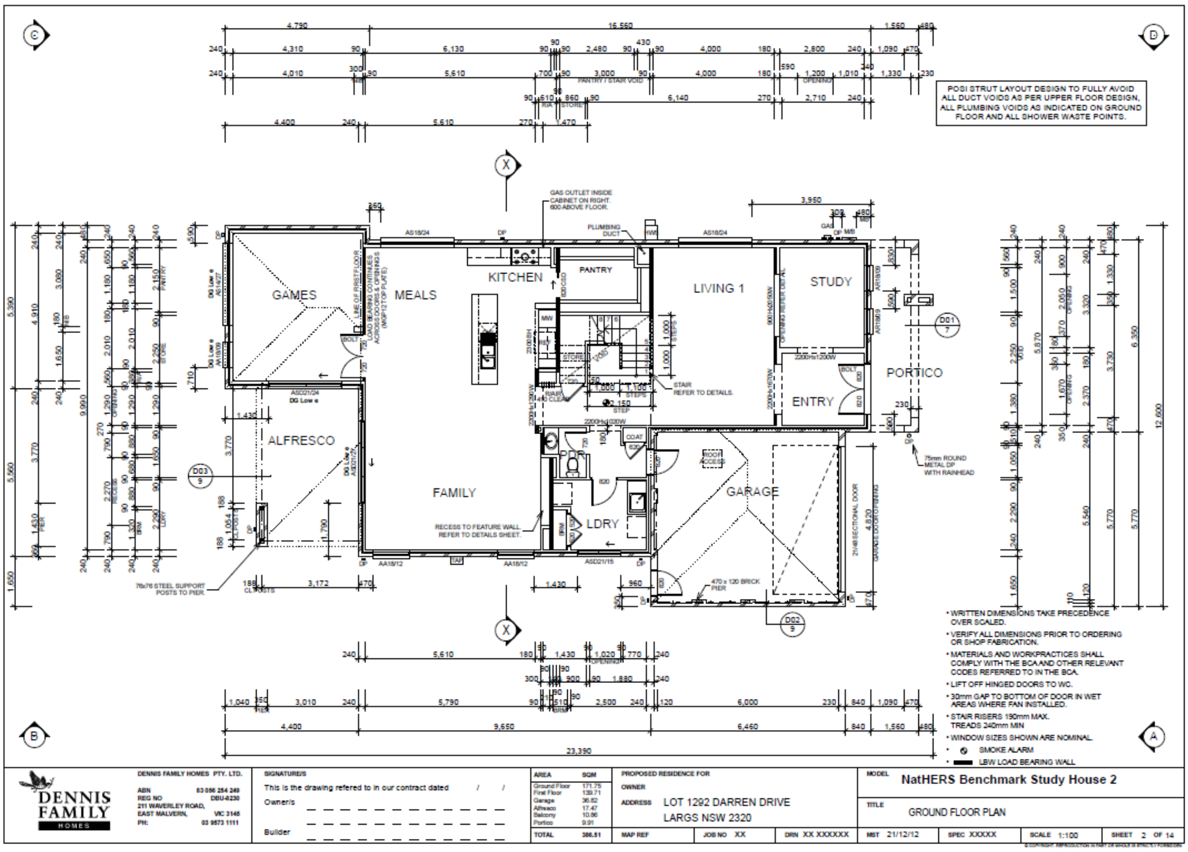
  Class 2 (6 star minimum)
  - Heating load limit 145 MJ/m2/yr
  - Cooling load limit 33MJ/m2/yr

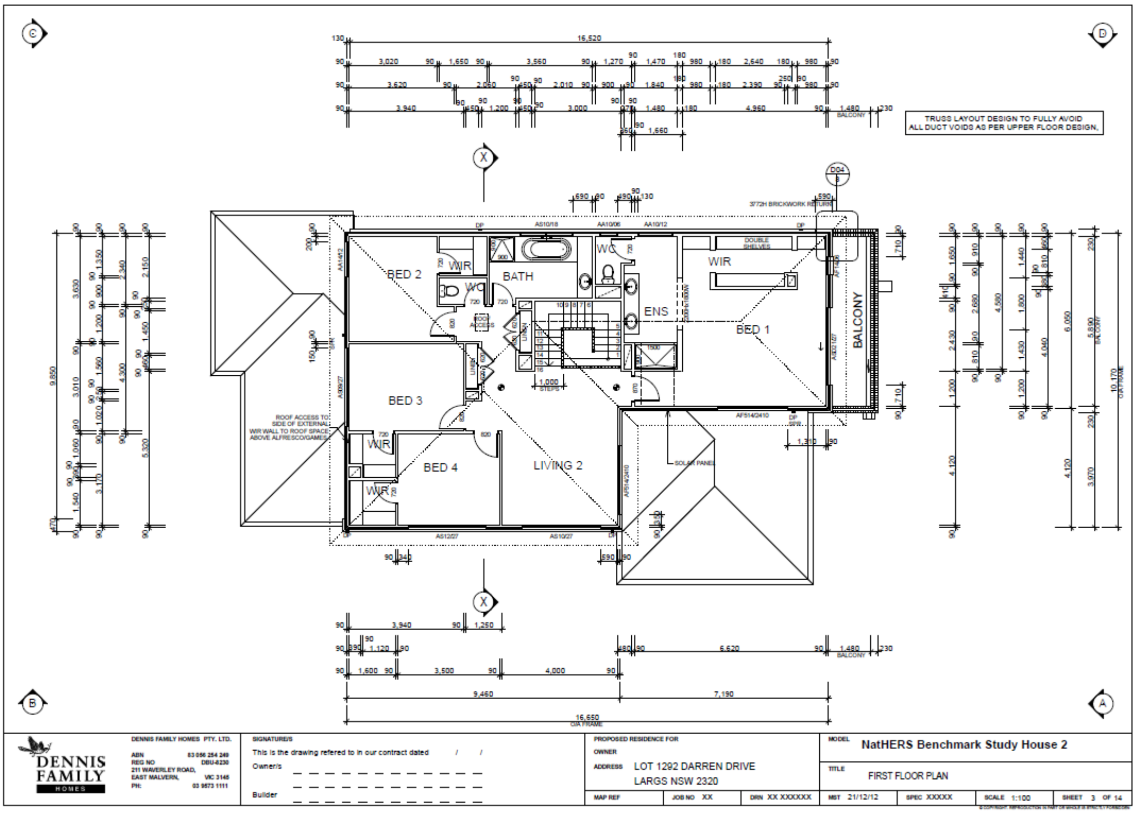
6.1.1 CSIRO ACT house data

		Apartments		Houses		Townhouses	
		Average	SD	Average	SD	Average	SD
All housing data (2016 to MONTH 2024)	Total approvals		3190		5178		9503
	Dwelling count/year average	354	233	575	200	495	310
	Star rating (average)	7.49	0.40	6.54	0.21	7.06	0.19
	Cooling (average) MJ/m2	13.52	4.37	19.84	1.65	18.01	1.75
	Heating (average) MJ/m2	85.74	14.71	121.16	8.17	100.36	7.11
	Conditioned floor area m2	82.80	10.78	174.78	9.27	93.56	7.22
	Unconditioned floor area m2 (average)	5.94	2.85	40.23	10.74	20.84	5.33
	Total floor area m2 (average)	88.81	10.86	227.11	11.87	117.11	12.04
	Window area m2 (average)	23.77	3.95	51.63	6.41	23.40	1.13
	Window to floor area %		27%		23%		20%
	Total		3190		5178		9503

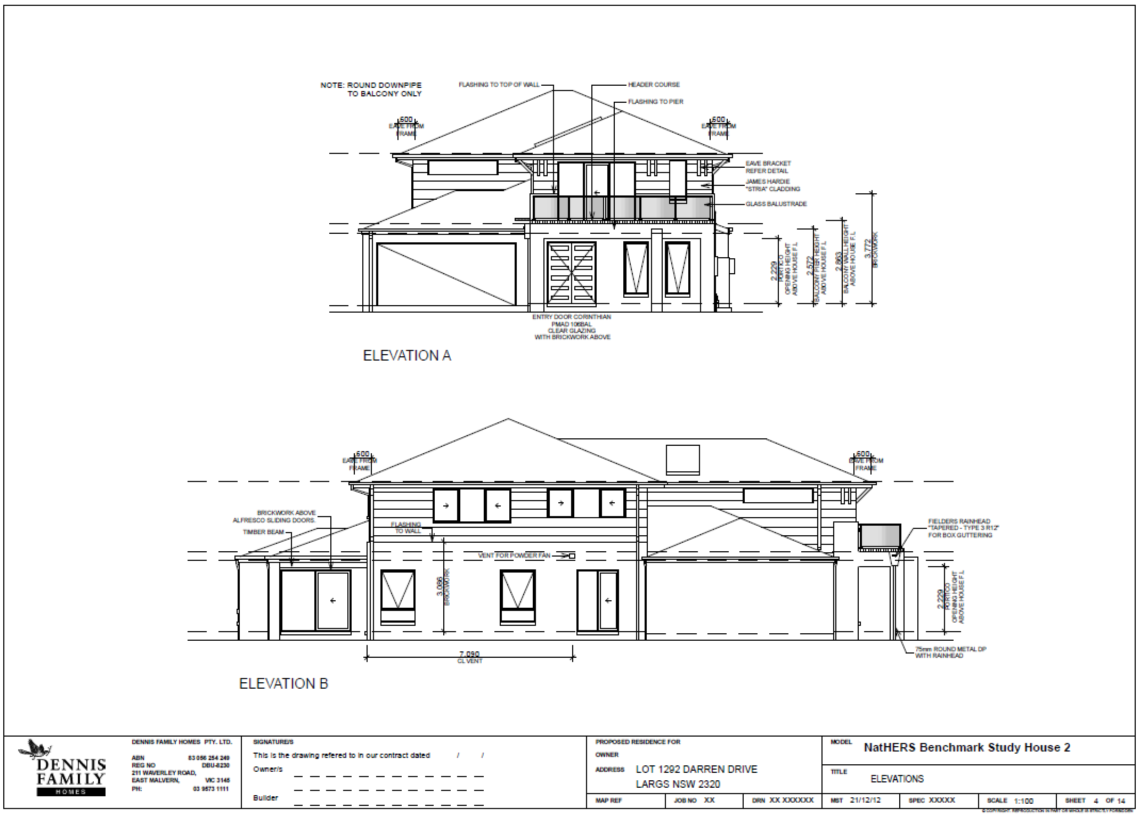
6.1.2 Dwelling Archetype - Architectural Drawings

SBH01

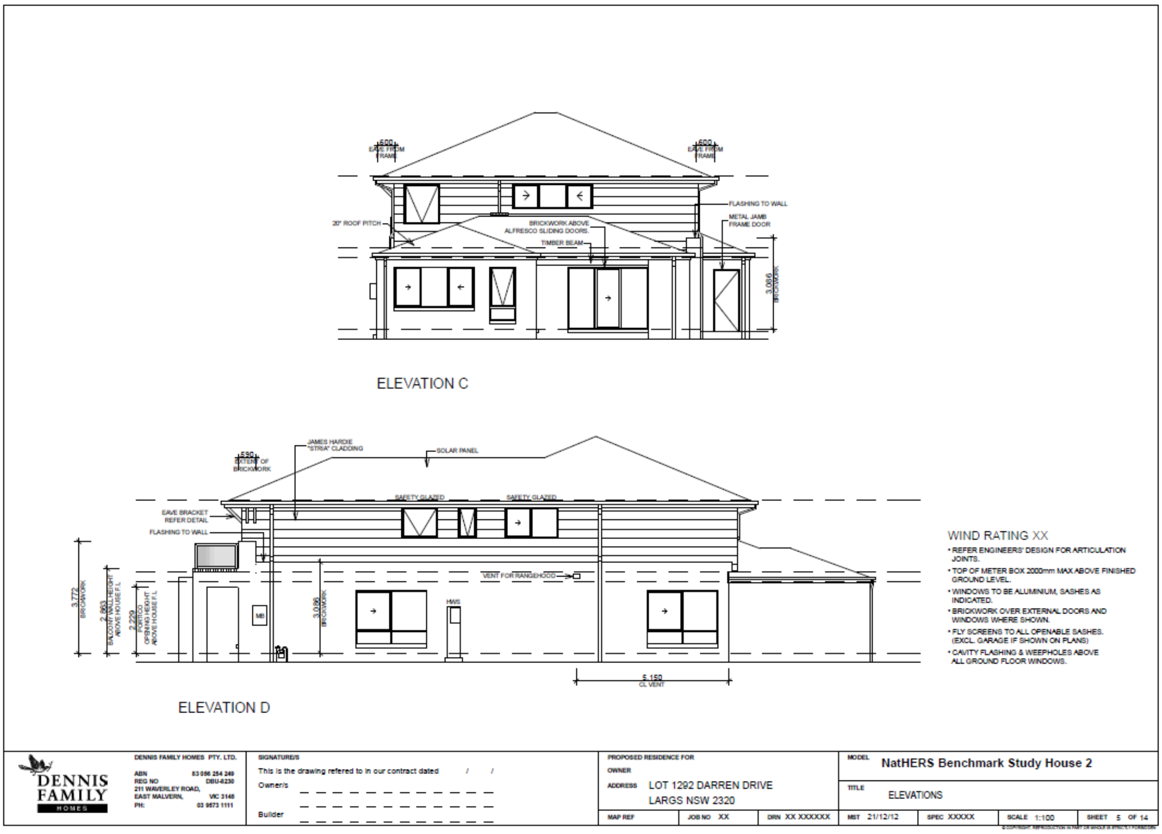




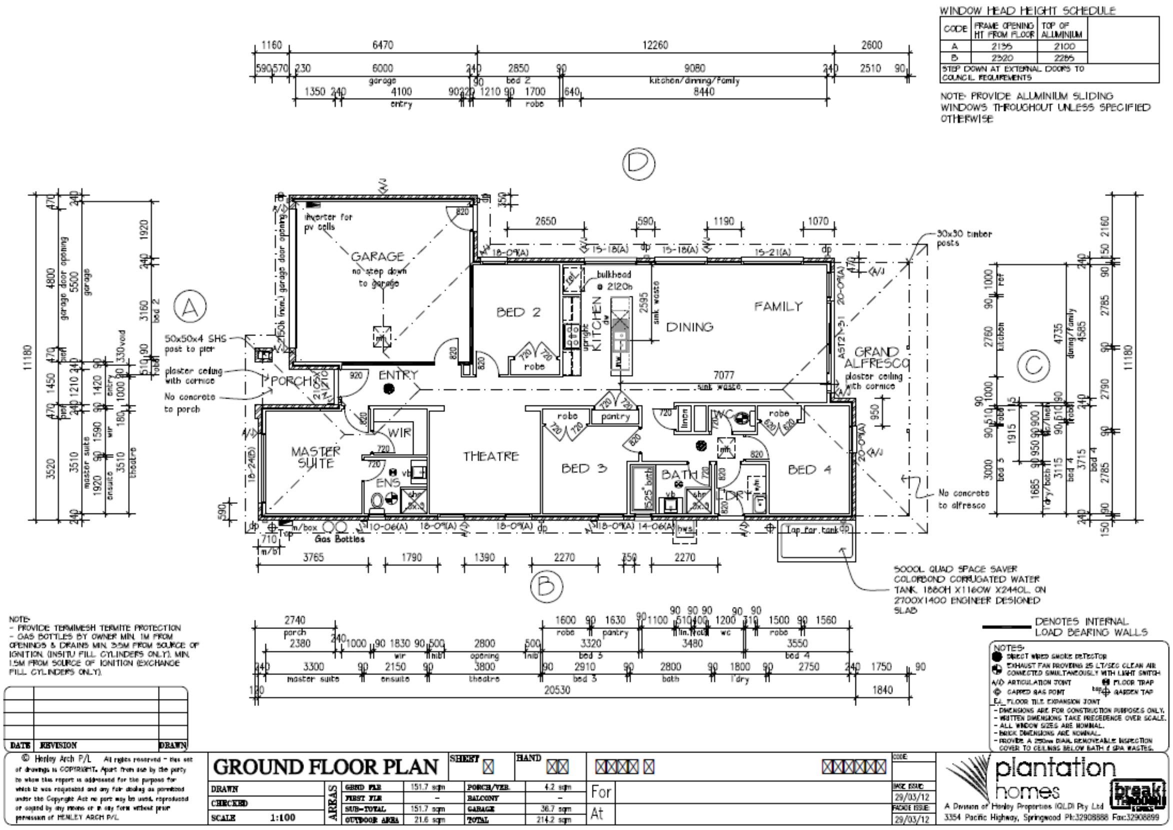
BED 2
WIR
BATH
WC
ENS
BED 1
BALCONY
BED 3
BED 4
LIVING 2
TRUSS LAYOUT DESIGN TO FULLY AVOID ALL DUCT VOIDS AS PER UPPER FLOOR DESIGN.
DENNIS FAMILY HOMES
NatHERS Benchmark Study House 2
LOT 1292 DARREN DRIVE
LARGS NSW 2320
FIRST FLOOR PLAN



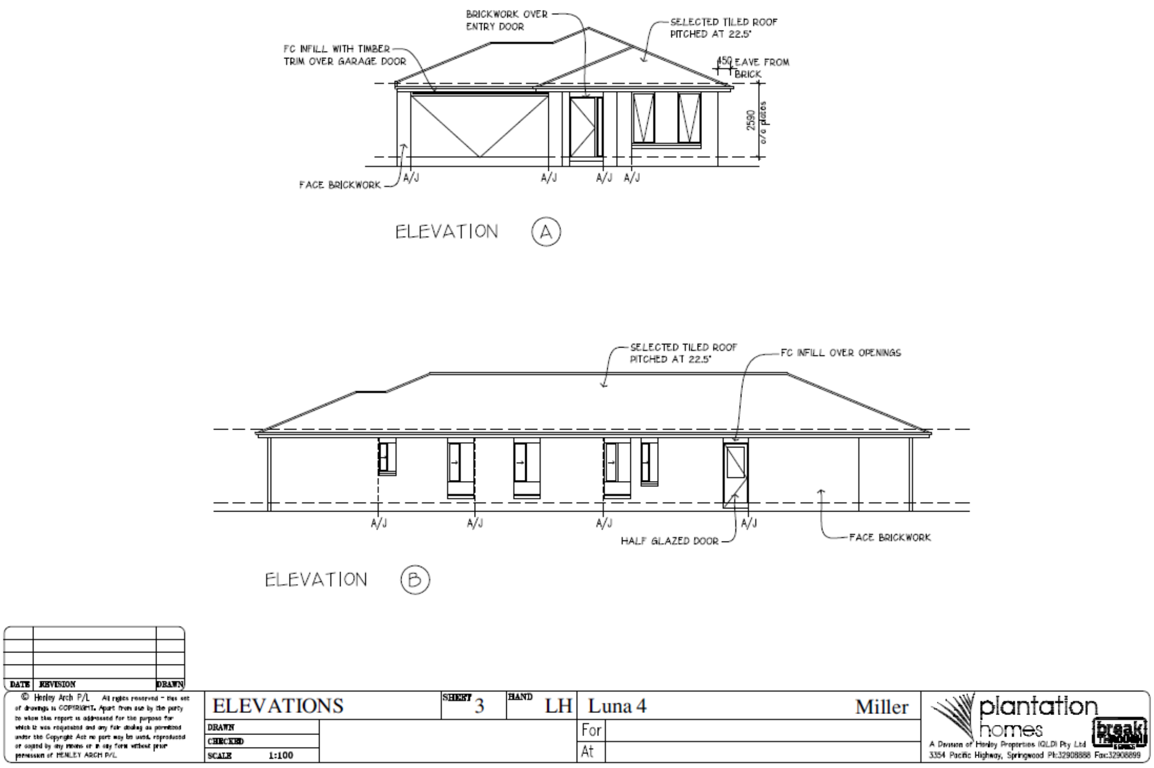
NOTE: ROUND DOWNPIPE TO BALCONY ONLY
ELEVATION A
ELEVATION B
DENNIS FAMILY HOMES
NatHERS Benchmark Study House 2
LOT 1292 DARREN DRIVE
LARGS NSW 2320
ELEVATIONS


ELEVATION C
ELEVATION D
EAVE FROM FRAME
FLASHING TO WALL
METAL JAMB FRAME DOOR
20° ROOF PITCH
BRICKWORK ABOVE ALFRESCO SLIDING DOORS.
TIMBER BEAM
JAMES HARDIE "STRIA" CLADDING
SOLAR PANEL
SAFETY GLAZED
EAVE BRACKET REFER DETAIL
FLASHING TO WALL
VENT FOR RANGEHOOD
HWS
MB
WIND RATING XX
• REFER ENGINEERS' DESIGN FOR ARTICULATION JOINTS.
• TOP OF METER BOX 2000mm MAX ABOVE FINISHED GROUND LEVEL.
• WINDOWS TO BE ALUMINIUM, SASHES AS INDICATED.
• BRICKWORK OVER EXTERNAL DOORS AND WINDOWS WHERE SHOWN.
• FLY SCREENS TO ALL OPENABLE SASHES. (EXCL. GARAGE IF SHOWN ON PLANS)
• CAVITY FLASHING & WEEPHOLES ABOVE ALL GROUND FLOOR WINDOWS.
DENNIS FAMILY HOMES
DENNIS FAMILY HOMES PTY. LTD.
211 WAVERLEY ROAD, EAST MALVERN, VIC 3145
SIGNATURE/S
This is the drawing refered to in our contract dated / /
Owner/s
Builder
PROPOSED RESIDENCE FOR
OWNER
ADDRESS LOT 1292 DARREN DRIVE LARGS NSW 2320
MODEL NatHERS Benchmark Study House 2
TITLE ELEVATIONS
MAP REF
JOB NO XX
DRN XX XXXXXX
MST 21/12/12
SPEC XXXXX
SCALE 1:100
SHEET 5 OF 14

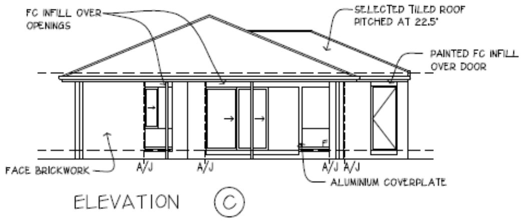
SBH04

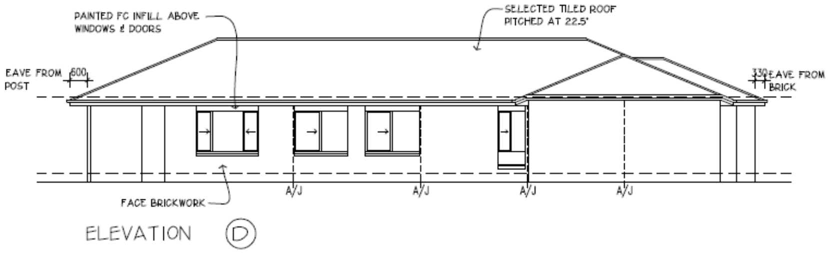


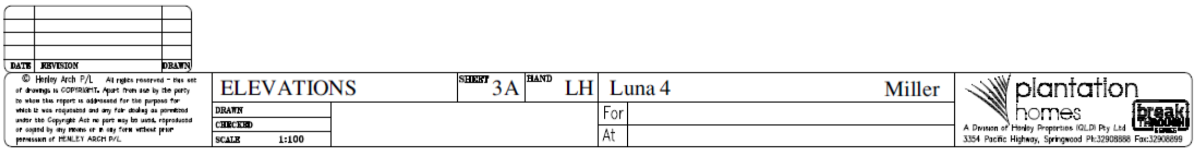
WINDOW HEAD HEIGHT SCHEDULE
NOTE: PROVIDE ALUMINIUM SLIDING WINDOWS THROUGHOUT UNLESS SPECIFIED OTHERWISE
GARAGE
BED 2
KITCHEN
DINING
FAMILY
GRAND ALFRESCO
PORCH
ENTRY
MASTER SUITE
WIR
ENS
THEATRE
BED 3
BATH
BED 4
5000L QUAD SPACE SAVER COLORBOND CORRUGATED WATER TANK. 1880H X1160W X2440L. ON 2700X1400 ENGINEER DESIGNED SLAB
DENOTES INTERNAL LOAD BEARING WALLS
GROUND FLOOR PLAN
SCALE 1:100
plantation homes
3354 Pacific Highway, Springwood



BRICKWORK OVER ENTRY DOOR
SELECTED TILED ROOF PITCHED AT 22.5°
FC INFILL WITH TIMBER TRIM OVER GARAGE DOOR
450 EAVE FROM BRICK
FACE BRICKWORK
ELEVATION A
SELECTED TILED ROOF PITCHED AT 22.5°
FC INFILL OVER OPENINGS
HALF GLAZED DOOR
FACE BRICKWORK
ELEVATION B
ELEVATIONS
SHEET 3
HAND LH
Luna 4
Miller
SCALE 1:100
plantation homes
3354 Pacific Highway, Springwood

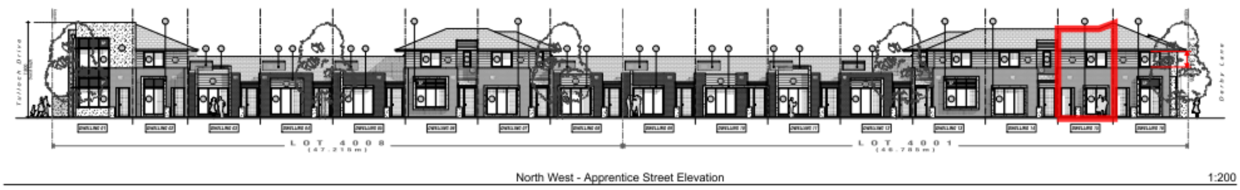

FC INFILL OVER OPENINGS
SELECTED TILED ROOF PITCHED AT 22.5°
PAINTED FC INFILL OVER DOOR
FACE BRICKWORK
A/J
ALUMINIUM COVERPLATE
ELEVATION C


PAINTED FC INFILL ABOVE WINDOWS & DOORS
SELECTED TILED ROOF PITCHED AT 22.5°
EAVE FROM POST
600
330
EAVE FROM BRICK
FACE BRICKWORK
A/J
ELEVATION D

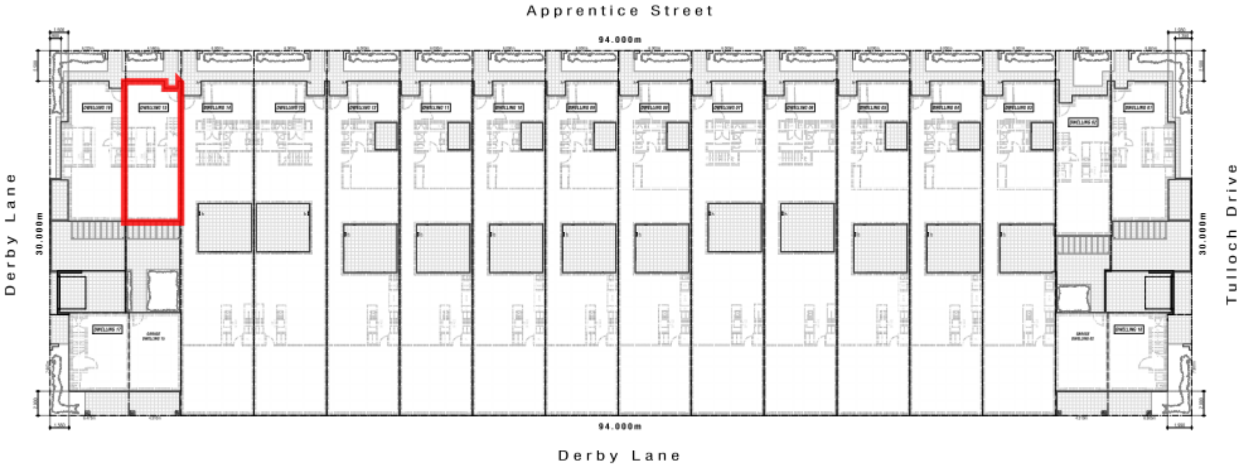

DATE
REVISION
DRAWN
© Henley Arch P/L
ELEVATIONS
SHEET 3A
HAND LH
Luna 4
Miller
DRAWN
CHECKED
SCALE 1:100
For
At
plantation homes
A Division of Henley Properties (QLD) Pty Ltd
3354 Pacific Highway, Springwood

SBH15

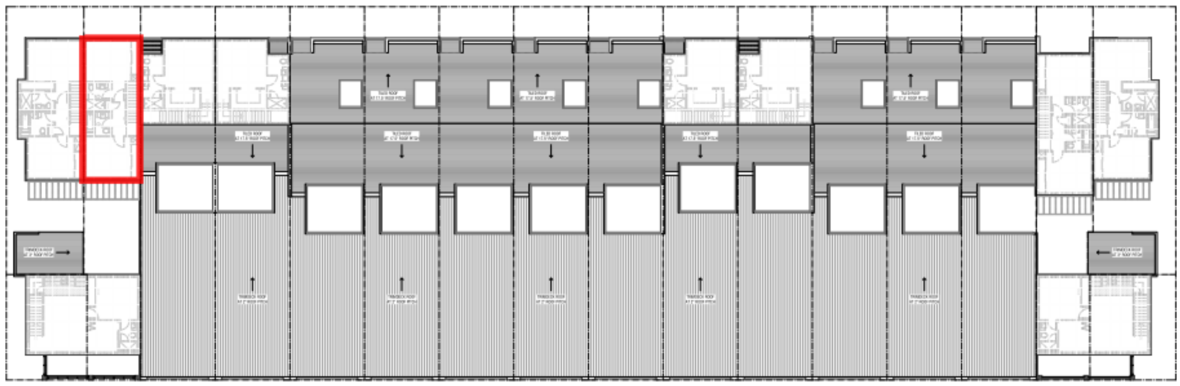

DINING
2820x3580
ENTRY
UP
KITCHEN
Ptry
WM
LIVING
4240x4150
PERGOLA
(Ground Floor)
BED 1
3590x3220
ROBE
ENS.
Linen
BATH
B
BED 2
3590x3250
ROBE
1500
SILL
(First Floor)


North West - Apprentice Street Elevation
1:200


South East - Courtyards Elevation
1:200



Site Layout - Ground Floor 1:200



Site Layout - First Floor 1:200

SBH20-27

CONTENT:
DESIGN 600
UNIT BLOCK
01 - COVER
02 - ELEVATIONS AND SECTIONS 1:200
03 - BASEMENT FLOOR PLAN 1:200

DESIGN 610
GROUND FLOOR, MIDDLE UNIT #4
01 - FLOOR PLAN
02 - ELEVATIONS AND SECTIONS
03 - CONSTRUCTION DETAILS
04 - WINDOW SCHEDULE
05 - FLOOR FINISHES
06 - ELECTRICAL PLAN
07 - ZONING PLAN

DESIGN 620
INTERMEDIATE LEVEL, MIDDLE 1 BEDROOM UNIT
WITH CORRIDOR UNIT #10
01 - FLOOR PLAN
02 - ELEVATIONS AND SECTIONS
03 - CONSTRUCTION DETAILS
04 - WINDOW SCHEDULE
05 - FLOOR FINISHES
06 - ELECTRICAL PLAN
07 - ZONING PLAN

DESIGN 630
TOP FLOOR, CORNER UNIT #19
01 - FLOOR PLAN
02 - ELEVATIONS AND SECTIONS
03 - CONSTRUCTION DETAILS
04 - WINDOW SCHEDULE
05 - FLOOR FINISHES
06 - ELECTRICAL PLAN
07 - ZONING PLAN

Australian Government

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Checked by	WF

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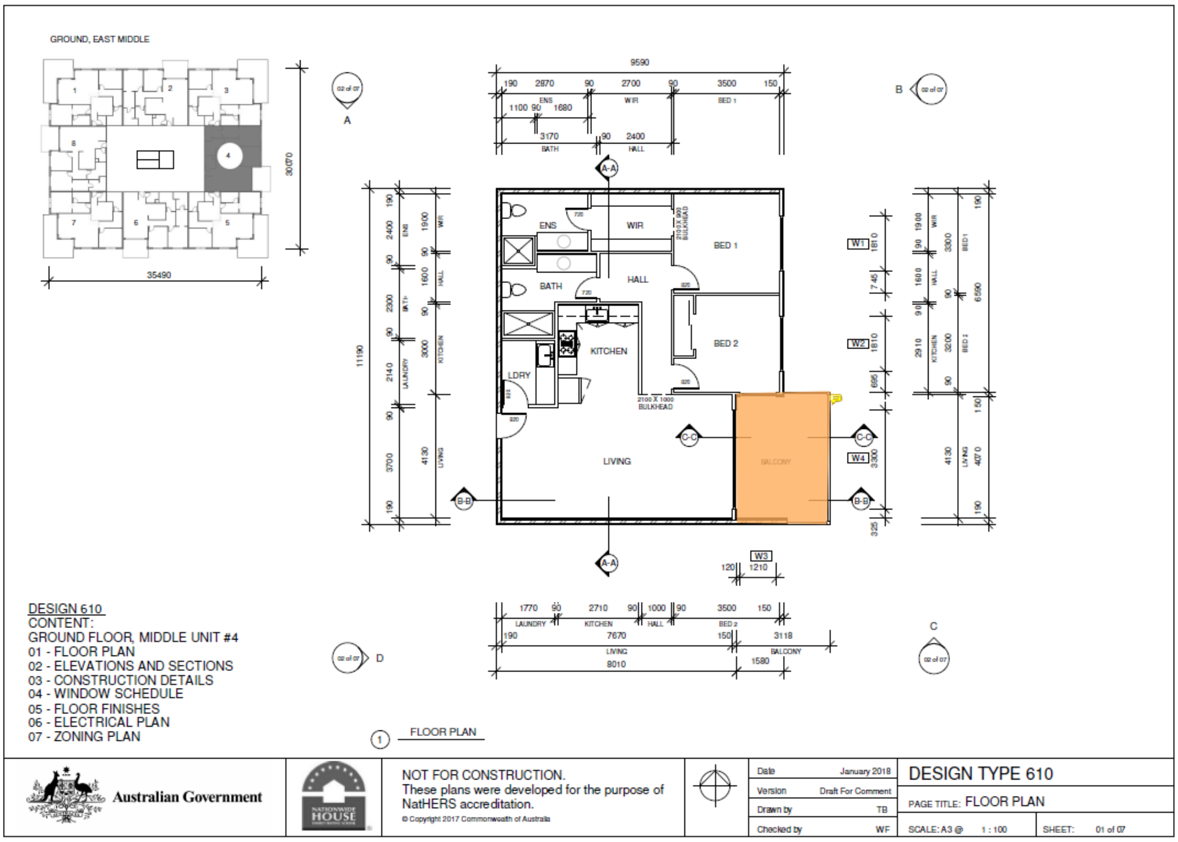
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30070
FLOOR PLAN
ENS
WIR
BED 1
HALL
BATH
KITCHEN
BED 2
LDRY
LIVING
BALCONY
DESIGN 610
CONTENT:
GROUND FLOOR, MIDDLE UNIT #4
01 - FLOOR PLAN
02 - ELEVATIONS AND SECTIONS
03 - CONSTRUCTION DETAILS
04 - WINDOW SCHEDULE
05 - FLOOR FINISHES
06 - ELECTRICAL PLAN
07 - ZONING PLAN
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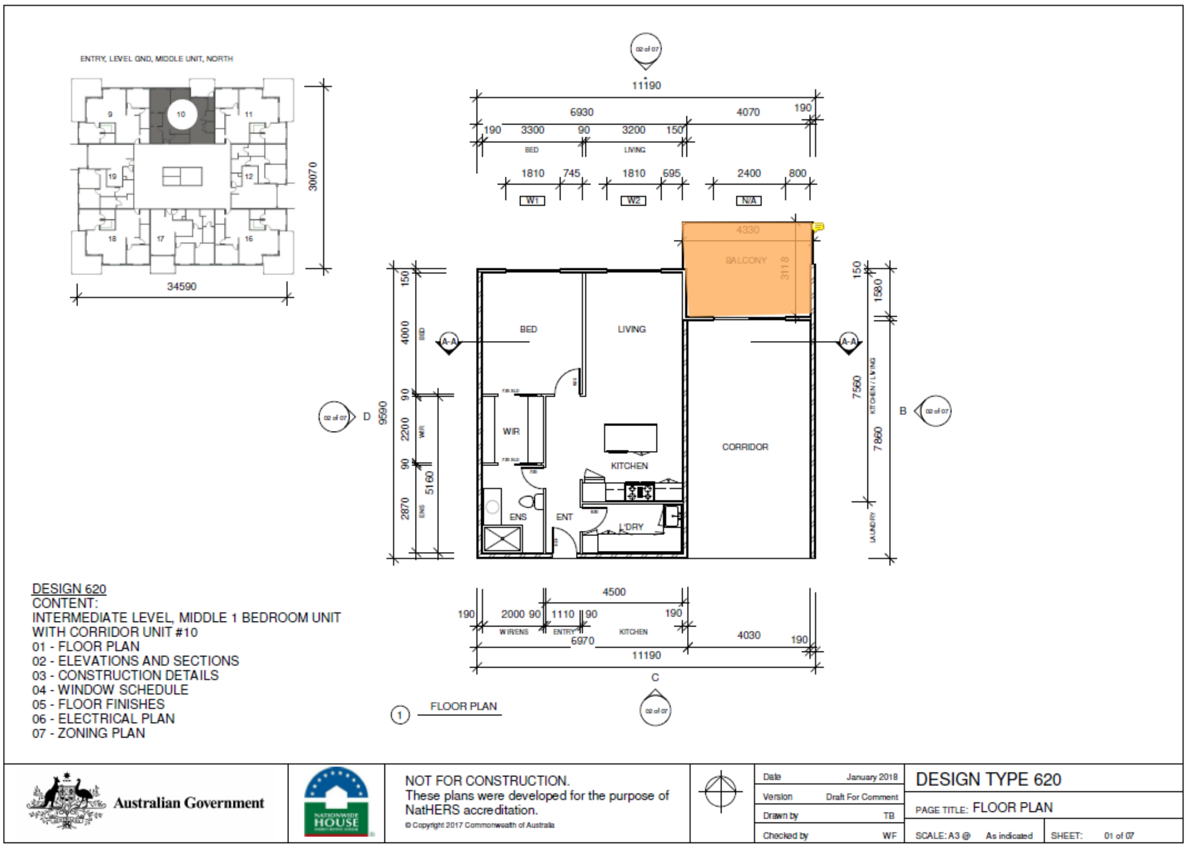
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34590
30070
FLOOR PLAN
BED
LIVING
BALCONY
WIR
KITCHEN
CORRIDOR
ENS
ENT
L'DRY
DESIGN 620
CONTENT:
INTERMEDIATE LEVEL, MIDDLE 1 BEDROOM UNIT
WITH CORRIDOR UNIT #10
01 - FLOOR PLAN
02 - ELEVATIONS AND SECTIONS
03 - CONSTRUCTION DETAILS
04 - WINDOW SCHEDULE
05 - FLOOR FINISHES
06 - ELECTRICAL PLAN
07 - ZONING PLAN
Australian Government
NOT FOR CONSTRUCTION.
These plans were developed for the purpose of NatHERS accreditation.
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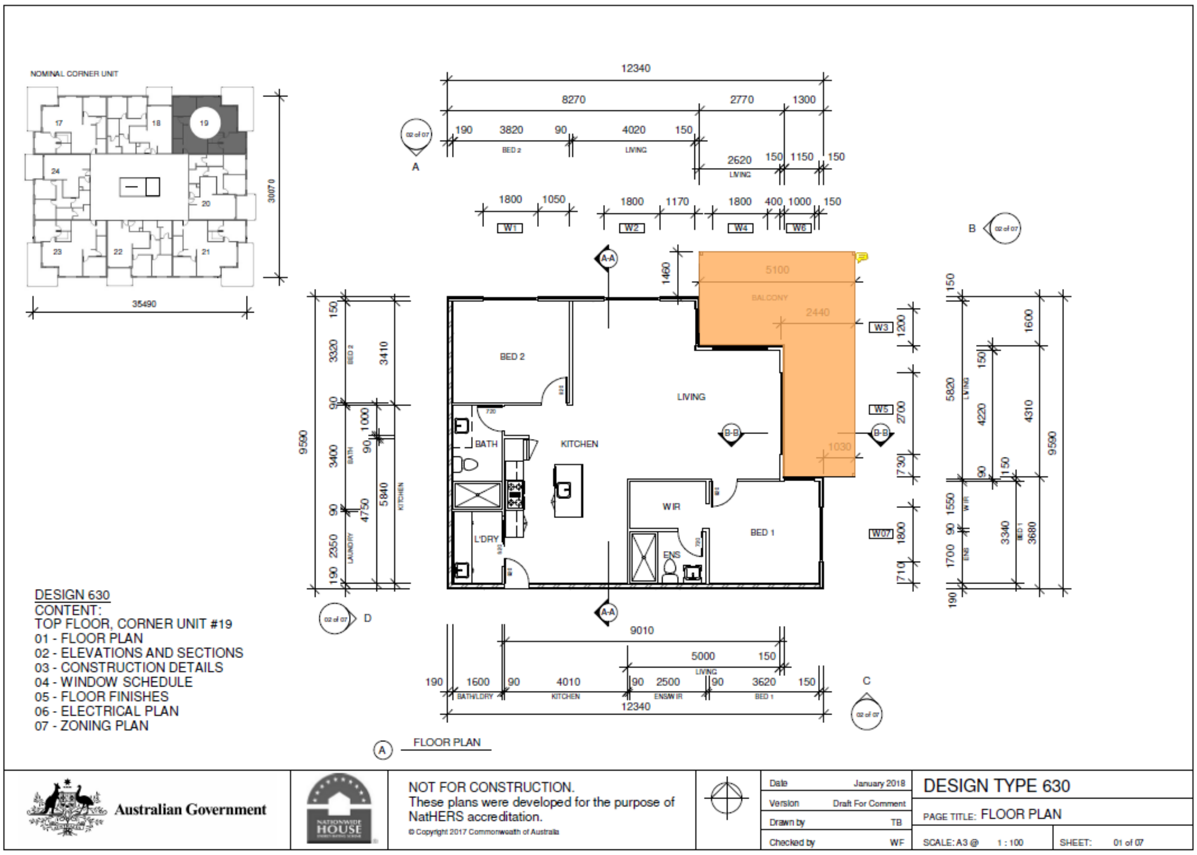
Date January 2018
Version Draft For Comment
Drawn by TB
Checked by WF
DESIGN TYPE 620
PAGE TITLE: FLOOR PLAN
SCALE: A3 @ As indicated
SHEET: 01 of 07



6.1.3 Archetype thermal modelling inputs

SBH01

House SBH01 – 2 storey **HERO: Total floor area = 309.6m2, Conditioned floor area = 261.2m2, Unconditioned floor area = 14.8m2, Garage = 33.6m2** **Area from floor plan (external wall areas) 174m2** **Ground floor =** 154m2 **Garage =** 34m2 **Total ground floor = 204.5m2** **Upper floor =** 134m2 **Total = 322m2** (Includes wall areas)			
Element	BASE CASE 7 stars; WOH 60	CURRENT PRACTICE 7.1 stars; WOH ??	OPTIMISED 7 stars; WoH 100
Construction	Lower level walls – brick veneer with timber studs Upper level walls – brick veneer and FC cladding Ground floor – waffle 175mm + 85mm concrete top; R0.56		

	Intermediate floor – timber Ceiling/roof – timber truss roof, with ceramic tiles		
Eaves	Where applicable 500 + gutter		
Insulation	Ceiling – Perimeter insulation R2.7; remainder R5 Roof – 60mm roof blanket R1.3 External walls – R2.5 Garage internal wall – R2.0 Internal wall – nil	Ceiling – Perimeter insulation R2.7; remainder R5 Roof – 60mm roof blanket R1.3 External walls – R2.5 Garage internal wall – R2.0 Internal wall – 2.0	Ceiling – Perimeter insulation R2.7; remainder R5 Roof – 60mm roof blanket R1.3 External walls – R2.5 Garage internal wall – R2.0 Internal wall – nil
Windows	Aluminium frame with clear double glaze + low-E: **Fixed**; HAFWD-030-050; U-value 2.96; SHGC 0.48; Area 8.1m2 **Sliding door**; HASDD-030-041; U-value 2.96; SHGC 0.40; Area 19.5m2 **Sliding window**; HASWD-030-045; U-value 2.98; SHGC 0.47; Area 20.3m2 **Awning**; HAAWD-030-050; U-value 2.99; SHGC 0.48; Area 114.3m2		
External colours	Walls – medium Roof - dark	Walls - Medium Roof - Medium	Walls – medium Roof - dark
Ceiling penetrations	Exhaust fans – sealed - kitchen rangehood, ensuite, bath. Fixed LED sealed IC-4 – 50. Fixed Unchanged		
Floor coverings	Carpet – Games, Living 1, Study, Bed 1, WIR, Living 2, Bed 4, Bed 4 WIR, Bed 3, Bed 3 WIR, Bed 2, Bed 2 WIR, Tiles – Kitchen (only),, pantry, laundry, Pdr, ensuite, ensuite WC, bath, WC Exposed - garage Unchanged		
Shading	Fence and neighbour as per plan. Unchanged		
Thermal Performance	Star: 7.0 Heating: 102.7 Cooling: 17.6 Total: 120.3	Star: 7.1 Heating: 99.7 Cooling: 18 Total: 117.7	Star: 7.0 Heating: 102.7 Cooling: 17.6 Total: 120.3

SBH01 was also modelled in a second orientation which was the horizontal mirror image of the first orientation. Minor changes were required to the modelling for the second orientation to achieve 7 stars for the NCC 2022 minimum compliance run.

SBH04

House SBH04 – 1 storey
HERO: Total floor area = 165.8m2, Conditioned floor area = 125.6m2, Unconditioned floor area = 7.7m2, Garage = 32.5m2

Area from floor plan (external wall areas) = 187 Roof area for PV = 207m2			
Element	BASE CASE 7 stars; WOH 60	CURRENT PRACTICE 7.1 stars; WOH 80	OPTIMISED 7 stars; WoH 100
Construction	External walls – brick veneer with timber studs Ground floor – waffle pod 175 + 85mm concrete topping Ceiling/roof – flat ceiling, roof pitched at 10degrees. Dark (SA 0.85).		
Eaves	550 mm where applicable		
Insulation	Ground floor – waffle pod 175mm R 0.56 External walls – R1.5 Internal walls • Garage walls – R1.5 • Utility walls (bath and laundry) – R1.5 • Others - nil Ceiling (excluding garage) – R4.0 + 60mm Roof blanket Ceiling garage – nil Roof – R4 on ceiling + 57mm roof blanket with reflective surface facing downwards (and default 40mm gap between ceiling insulation and roof blanket)	Ground floor – waffle pod 175mm R 0.56 External walls – R1.5 Internal walls • Garage walls – R2.0 • Utility walls (bath and laundry) – R2.0 • Others - nil Ceiling (excluding garage) – R4.0 + 60mm Roof blanket Ceiling garage – nil Roof – R4 on ceiling + 57mm roof blanket with reflective surface facing downwards (and default 40mm gap between ceiling insulation and roof blanket)	Ground floor – waffle pod 175mm R 0.56 External walls – R1.5 Internal walls • Garage walls – R2 • Utility walls (bath and laundry) – R2 • Others - nil Ceiling (excluding garage) – R4.0 + 60mm Roof blanket Ceiling garage – nil Roof – R4 on ceiling + 57mm roof blanket with reflective surface facing downwards (and default 40mm gap between ceiling insulation and roof blanket)
Windows	Aluminium frame with clear double glaze: **Fixed**; HAFWD-035-056; U-value 3.46; SHGC 0.578; Area 6.1m2 **Sliding door**; HASDD-035-045; U-value 3.45; SHGC 0.434; Area 6.5m2 **Sliding window**; HASWD-035-056; U-value 23.497; SHGC 0.544; Area 16.4m2 **Awning;** HAAWD-040-050; U-value 3.99; SHGC 0.518; Area 2.9m2 **Hinged door**; HAHDD-035-045; U-value 3.47; SHGC 0.441; Area 3.7m2		
External colours	Walls – medium Roof - dark (SA 0.8)	Walls - medium Roof - medium (SA0.50)	Walls – medium Roof - dark (SA 0.8)
Ceiling penetrations	Exhaust fans – sealed - kitchen rangehood, ensuite, bath. Fixed LED sealed IC-4 – 25. Non variable		
Floor coverings	Scenario 1: Living - carpet; Bed - carpet		
Shading	Not specified		
Thermal Performance	Star: 7.0 Heating: 108.3	Star: 7.1 Heating: 106.8	Star: 7.0 Heating: 103.9

	Cooling: 13.2 Total: 121.5	Cooling: 13.2 Total: 120.0	Cooling: 16.6 Total: 121.5

SBH04 was also modelled in a second orientation which was the horizontal mirror image of the first orientation. Minor changes were required to the modelling for the second orientation to achieve 7 stars for the NCC 2022 minimum compliance run.

SBH15

House SBH15 – 1 storey **HERO: Total floor area = 88.5m2, Conditioned floor area = 84.5m2, Unconditioned floor area = 4m2, Garage = 0m2** **Area from floor plan (external wall areas) =89.9m2**			
Element	BASE CASE 7 stars; WOH 60	CURRENT PRACTICE 7.1 stars; WOH 80	OPTIMISED 7 stars; WoH 100
Construction	External walls – brick veneer, or fibre cement on battens with non-reflective airgap, timber studs, timber studs, plasterboard Ground floor – concrete slab on ground 100mm Ceiling/roof – flat ceiling, roof pitched at 22 degrees.		
Eaves	850 mm where applicable		
Insulation	Slab on ground floor – nil External exposed floor – nil External walls – R1.5 Internal walls • Utility walls (bath and laundry) – nil • Others - nil Ceiling/roof– R2 on ceiling + 57mm roof blanket with reflective surface facing downwards (and default 40mm gap between ceiling insulation and roof blanket) Intermediate floor - nil Natural roof ventilation	Slab on ground floor – nil External exposed floor – nil External walls – R2 Internal walls • Utility walls (bath and laundry) – nil • Others - nil Ceiling/roof– R2 on ceiling + 57mm roof blanket with reflective surface facing downwards (and default 40mm gap between ceiling insulation and roof blanket) Intermediate floor - nil Natural roof ventilation	Slab on ground floor – nil External exposed floor – nil External walls – R1.5 Internal walls • Utility walls (bath and laundry) – nil • Others - nil Ceiling/roof– R2 on ceiling + 57mm roof blanket with reflective surface facing downwards (and default 40mm gap between ceiling insulation and roof blanket) Intermediate floor - nil Natural roof ventilation
Windows	Aluminium frame with tinted single glaze: **Sliding door**; HASDS-050-033; U-value 4.96; SHGC 0.33; Area 5.3m2 **Sliding window**; HASWS-050-037; U-value 5.0; SHGC 0.36; Area 7.7m2		

External colours	Walls – medium Roof - dark (SA 0.8)	Walls - medium Roof - medium (SA0.50)	Walls – medium Roof - dark (SA 0.8)
Ceiling penetrations	Exhaust fans – sealed - kitchen rangehood, ensuite, bath. Non variable LED sealed IC-4 – 25. Non variable		
Floor coverings	Scenario 1: Living - carpet; Bed – carpet Carpet area = 80.1m2 Tile area = 11.2m2		
Shading	Not specified – shading from SBH14 behind.		
Thermal Performance	Star: 7.0 Heating: 118.5MJ/m2/yr Cooling: 1.7 MJ/m2/yr Total: 120.2 MJ/m2/yr	Star: 7.2 Heating: 114.1MJ/m2/yr Cooling: 1.6MJ/m2/yr Total: 115.7MJ/m2/yr	Star: 7.0 Heating: 118.5MJ/m2/yr Cooling: 1.7 MJ/m2/yr Total: 120.2 MJ/m2/yr

SBH15 was also modelled in a second orientation which reoriented the North arrow to 270degrees, which was the worst performing orientation. Changed windows to untinted to establish NCC minimum compliance of 7 stars as follows.

Windows changed to aluminium frames with clear single glazing.

HASWS-50-062 (U-value 4.96 SHGC 0.59)

HASDS-050-056 (U-value 4.96 SHGC 0.55)

SBH20-27

<table>
<tr><th colspan="3">Apartments: Design 610 #4 99m2; Design 620 #10 65m2; Design 630 #19 105m2</th><th></th></tr>
<tr><td>Element</td><td>BASE CASE 7 stars; WOH 50</td><td>CURRENT PRACTICE 7.1 stars; WOH 50</td><td>OPTIMISED – 8.1 Stars</td></tr>
<tr><td>Construction</td><td colspan="3">External walls – aluminium cladding on 30mm furring channel air gap fixed to 19mm plywood fixed to 90mm steel frame and 90mm plasterboard lining.
Walls to neighbours and corridors – concrete 110 lined both sides with 30mm furring channel air gap and PB.
Floor – 100mm suspended concrete
Ceilings – 100mm concrete with suspended ceiling
Roof – bituminous over concrete</td></tr>
<tr><td>Eaves</td><td colspan="2">Overhead decks above @2550mm height</td><td></td></tr>
<tr><td>Insulation</td><td>External walls
• Level 1 & 2 – R1.5
• Level 3 – R2
Walls to corridors
• Unit 6, 7, 15, 23 – R1.5 (Southwest corner units + southern unit on 1st floor)
Floor to basement carpark - suspended slab over basement carpark R1.8 50mm XPS
Roof – R5 on suspended ceiling, below concrete roof</td><td>External walls
• Level 1 & 2 – R1.5
• Level 3 – R2.5
Walls to corridors – R1.5
Floor to basement carpark - suspended slab over basement carpark R1.8 50mm XPS
Roof – R5 on suspended ceiling, below concrete roof</td><td>External walls
• Level 1 & 2 & 3– R2.5
Walls to corridors
• Level 3 only – R2.5
Internal walls to laundries – all levels – R2
Floor to basement carpark - suspended slab over basement carpark R1.8 50mm XPS
Roof – R5 on suspended ceiling, below concrete roof</td></tr>
<tr><td>Windows</td><td colspan="3">Level 1 – aluminium with clear double glaze
Fixed; HAFWD-035-056; U-value 3.46; SHGC 0.58; Area 71.3m2
Sliding door; HASDD-035-045; U-value 3.45; SHGC 0.43; Area 36.5m2
Awning; HAAWD-040-050; U-value 3.99; SHGC 0.52; Area 40.8m2

Level 2 & 3 – aluminium SG tinted
Fixed; HAFWS-045-041; U-value 4.5; SHGC 0.42; Area 143.2m2
Sliding door; HASDS-050-033; U-value 4.96; SHGC 0.33; Area 73.1m2
Awning; HAAWS-055-041; U-value 5.47; SHGC 0.41; Area 81.7m2</td></tr>
<tr><td>External colours</td><td>External walls – medium
Roof - dark</td><td>External walls – medium
Roof - med</td><td>External walls – medium
Roof - dark</td></tr>
<tr><td>Ceiling penetrations</td><td colspan="3">Exhausts – sealed 0.603m2 each
Design 610 – 4
Design 620 – 3
Design 630 – 4
Recessed downlights – 90mm sealed and insulated
Design 610 – 20</td></tr>
</table>

	Design 620 – 15 Design 630 – 20		
Floor coverings	Carpet – bedrooms and WIR, L/D and hall Tiles – bath, laundry, ensuite, kitchen Timber – K/L/D Class 2 common areas also carpeted Carpet area = 2035.3m2 Tiles area = 734m2		
Shading	As per decks. No neighbouring shading		
Thermal Performance	**Average** Star: 7.2 Heating: 99.5 MJ/m2/yr Cooling: 13.1 MJ/m2/yr Total: 112.5 MJ/m2/yr **Worst** Star: 6.1 Heating: 127.9 MJ/m2/yr Cooling: 28.7 MJ/m2/yr Total: 156.6MJ/m2/yr	**Average** Star: 7.6 Heating: 86.4 MJ/m2/yr Cooling: 12.6 MJ/m2/yr Total: 99.0 MJ/m2/yr **Worst** Star: 6.1 Heating: 133.4 MJ/m2/yr Cooling: 25 MJ/m2/yr Total: 157.9 MJ/m2/yr	**Average** Star: 8.1 Heating: 64.6 MJ/m2/yr Cooling: 14.6 MJ/m2/yr Total: 79.2 MJ/m2/yr **Worst** Star: 7.1 Heating: 108.7 MJ/m2/yr Cooling: 35.3 MJ/m2/yr Total: 118.1 MJ/m2/yr

SBH20-27 was also modelled in a second orientation which reoriented the North arrow to 270degrees. Minor changes were required to the modelling for the second orientation to achieve 7 stars for the NCC 2022 minimum compliance run.

6.1.4 Archetype WOH modelling inputs

SBH01

House SBH01 – 2 storey 354 m2

Roof area for PV = 207m2

WOH Deemed-to-satisfy allowance =

PV

Three strings for maximum PV of 16kW*:

Upper roof 1; azimuth 0˚; pitch 23˚; area 54/59m2; HERO PV rated size 9kW; HERO generation 13,407kWh/yr.

Upper roof 2; azimuth 270˚; pitch 23˚; area 31/33m2; HERO PV rated size 5kW; HERO generation 7,609kWh/yr.

Upper roof 3; azimuth 9˚; pitch 23˚; area 12/13m2m2; HERO PV rated size 2kW; HERO generation 2608kWh/yr.

Element	BASE CASE 7 stars; WOH 60	CURRENT PRACTICE 7.1 stars; WOH 80	OPTIMISED 7 stars; WoH 100

Air-conditioning	Room air-conditioner Heating; 1 star Cooling; 2.5 stars Kitchen/Meals/Family + Pantry = Heat pump 3 – 6kW Living 1 + Study + Entry + Hall small - lower + Pdr = Heat pump 3 – 6kW Games = Heat pump <3kW Living 2 + WC= Heat pump <3kW Bed 1 + Bed 1 Ens WC Bed 1 ensuite + Bed 1 WIR = Heat pump 3 – 6kW Bed 2 + Bed 2 WIR = resistance heater + default cooling Bed 3 + Bed 3 WIR = resistance heater + default cooling Bed 4 + Bed 4 WIR = resistance heater + default cooling	Ducted air-conditioner Heating; 1 star Cooling; 2.5 stars Sizing: 10-20kW Bed 2 + Bed 2 WIR = resistance heater + default cooling Bed 3 + Bed 3 WIR = resistance heater + default cooling Bed 4 + Bed 4 WIR = resistance heater + default cooling	Room air-conditioner Heating; 4 star Cooling; 5.5 stars Kitchen/Meals/Family + Pantry = Heat pump 3 – 6kW Living 1 + Study + Entry + Hall small - lower + Pdr = Heat pump 3 – 6kW Games = Heat pump <3kW Living 2 + WC= Heat pump <3kW Bed 1 + Bed 1 Ens WC Bed 1 ensuite + Bed 1 WIR = Heat pump 3 – 6kW Bed 2 + Bed 2 WIR = resistance heater + default cooling Bed 3 + Bed 3 WIR = resistance heater + default cooling Bed 4 + Bed 4 WIR = resistance heater + default cooling
Hot water	Electric storage (off-Peak) 400L		Electric boost solar HWS 400L 34 STCs
Lighting density	2 W/m2		
Cooking	Induction cooktop		
Plug load	2446 kWh/yr		
Roof potential for PV	2.1kW	7kW	7.3kW on north roof
WoH Results	Score: 60 Energy: 6758kWh/yr Cost: $1,612/yr GHG: 1.18T/yr	Score: 80 Energy: 977kWh/yr Cost: $800/yr GHG: - 0.17T/yr	Score: 100 Energy: -5884kWh/yr Cost: -$12/yr GHG: -1.03T/yr

SBH04

House SBH04 – 1 storey

Roof considered as a modern skillion roof @10-degree pitch to the north. Area = 207m2, which differs from the hip roof on design documentation.			
Element	BASE CASE 7 stars; WOH 60	CURRENT PRACTICE 7.1 stars; WOH 80	OPTIMISED 7 stars; WoH 100
Air-conditioning	Room air-conditioner Heating 2 star Cooling 3.5 stars K/L/D 1 x 3-6kW Theatre/entry 1 x <3kW Bed 1 + ensuite <3kW	Ducted air-conditioner Heating 1 stars Cooling 2.5 stars Size: 6 – 10kW	Room air-conditioner Heating 2 star Cooling 3.5 stars K/L/D 1 x 3-6kW Theatre/entry 1 x <3kW Bed 1 + ensuite <3kW
Hot water	Electric storage (off-Peak) 315L		Heat pump HWS (off-Peak) 315L 30 STCs
Lighting	3.5W/m2		
Cooking	Electric cooktop	Induction cooktop	Induction cooktop
Plug load	2310 kWh/yr		
PV	1.15	7kW	7.9kW
WoH Results	Score: 60 Energy: 5602kWh/yr Cost: $1236 GHG: 0.98T/yr	Score: 91 Energy: -3470kWh/yr Cost: $273 GHG: -0.61 T/yr	Score: 100 Energy: -5654kWh/yr Cost: -$27/yr GHG: -0.99T/yr

SBH15

House SBH15 – 2 storey **Roof area for PV = 25m2 facing north; 25m2 facing south – 22 degrees pitch** **PV limit – 4kW to north and 4 kW to south** DTS allowance = 2.5			
Element	BASE CASE 7 stars; WOH 60	CURRENT PRACTICE 7.1 stars; WOH 80	OPTIMISED 7 stars; WoH 100
Air-conditioning	Room air-conditioner Heating 2 star Cooling 3.5 stars K/L 1 x <3kW Living 1 x <3kW	Ducted air-conditioner Heating 1 stars Cooling 2.5 stars Size: <3kW	Room air-conditioner Heating 1 star Cooling 2.5 stars K/L 1 x <3kW Living 1 x <3kW
Hot water	Electric storage (off-Peak) 250L		Heat pump Off-Peak 250L 30 STCs
Lighting density	2W/m2		
Cooking	Induction cooktop		
Plug load	2233 kWh/yr		

PV	North 1.0 kW	4kW	4 kW on north roof 4kW on south roof
WoH Results	Score: 60 Energy: 4795kW/h/yr Cost: $1,063/yr GHG: 0.84T/yr	Score: 77 Energy: 203kW/h/yr Cost: $591/yr GHG: 0.04T/yr	Score: 102 Energy: -5745 kW/h/yr Cost: -$75/yr GHG: -1.0T/yr

SBH20-27

Apartments: Design 610 #4 99m2; Design 620 #10 65m2; Design 630 #19 105m2 PV not considered.			
Element	BASE CASE 7 stars; WOH 51 min	CURRENT PRACTICE 7.1 stars; WOH 51 min	OPTIMISED – WoH 55 min / 60 avg
Air-conditioning	Room air-conditioner Heating 2 star Cooling 3.5 stars 18 x 3-6kW units 48 x <3kW units	Ducted air-conditioner Heating 2 stars Cooling 3.5 stars 18 x 6-10 kW Design 610 and 630) 6 x 3-6kW (Design 620)	Room air-conditioner Heating 2 star Cooling 3.5 stars 18 x 3-6kW units 48 x <3kW units
Hot water	Heat pump 160L all apartments. 28 STCs	Heat pump 160L all apartments. 28 STCs (minimum WOH 50 could not be achieved with electric HWS).	Heat pump 160L all apartments. 28 STCs
Lighting density	2W/m2		
Cooking	Induction cooktop		
Plug load	2223.32 kWh/yr		
PV	Nil		
WoH Results	**Average** Score: 56 Energy: 4739kW/h/yr Cost: $1,086/yr GHG: 0.83T/yr **Worst** Score: 51 Energy: 5251kW/h/yr Cost: $1,207/yr GHG: 0.92T/yr	**Average** Score: 57 Energy: 4667kW/h/yr Cost: $1,066/yr GHG: 0.82T/yr **Worst** Score: 51 Energy: 5467kW/h/yr Cost: $1,262/yr GHG: 0.96T/yr	**Average** Score: 60 Energy: 4416kW/h/yr Cost: $1,002/yr GHG: 0.77T/yr **Worst** Score: 55 Energy: 4953kW/h/yr Cost: $1,134/yr GHG: 0.87T/yr

6.1.5 - Additional Complex Apartment Building Analysis

Introduction

As discussed above in Section3.3.2 additional analysis was conducted on a second, more complex apartment building. This analysis was added to the scope of the study after initial results were analysed from the NatHERS standard Apartment Building (SBH 20-27).

The results from the assessment of SBH 20-27 showed clearly that there was no room for increasing the stringency of the NatHERS WOH performance requirement. However, there was potential for an increase the thermal performance (NatHERS Star Rating) to be marginally cost-effective.

To further investigate the possibilities around increasing the thermal performance benchmark it was decided that further work focused on Class 2 Apartment buildings be undertaken.

The SBH20-27 building, though standard for NatHERS Certification purposes, was seen as not covering the full range of Apartment types that are being constructed in the ACT. The SBH20-27 apartments are all either 1 or 2 bedroom dwellings. They are all relatively small, and the overall building geometry is very simple.

It was considered beneficial to obtain another example apartment building that would broaden the representation of ACT apartments and may provide more insight into the possibilities around and increase to thermal shell performance.

A real-life apartment project that had recently been submitted for Building Approval in the ACT was selected for analysis. For privacy reasons, the identifying details of the project are not provided here. Rather a generic description of the building is provided as follows.

The project was submitted in 2023 but was completed under the then NCC 2019 requirements of 5 star minimum and 6 stars average thermal performance across all apartments.

The key characteristics leading to selection of this particular project were that it provided:

- A broader range of apartment types
- Larger apartment types
- A more complex overall building geometry
- A larger building overall
- Enough detail in the documentation available in order to realistically represent what was a real-life project.

Description of the building

The key overall characteristics of the building are:

- 9 storeys above ground + 3 carpark levels below ground

- 2 storey 'Town House' type apartments at the ground level, street front, each with their own separate entry
- Some commercial space on Ground floor and Level 1 – not included in the NatHERS assessment, but included in the NatHERS model as per NatHERS modelling requirements.
- Typical apartments in a mix of 2 and 3 bedroom apartments from levels 2 – 7
- 'Penthouse type apartments on Level 8 with access to roof top terraces above the top level apartments.
- The building modelled is one of two in the overall apartment complex. With the buildings shading each other to an extent.
- The geometry of the building is such that a wider range of more complex apartment plans were represented.

Methodology for the assessment

The methodology for assessment of the additional apartment building followed that of SBH20-27. To summarise:

- Establishing the NCC minimum compliance base case – NatHERS Assessments had been done on the apartments as part of the approvals process. These however were done to the 5 star minimum, 6 star average requirements. Hence the building was re-modelled in HERO V4.1 and the building elements were adjusted to improve the ratings to meet 2022 standards (min 6 stars, average 7 stars) and create the base case scenarios.
- Thermal Fabric Modelling – Variables to the thermal fabric tested were as per those described in section 0 above.
- Building Orientation – modelled as per the real-life conditions

Note that with the key focus of the testing on this additional apartment building being on thermal shell improvements, the following testing was not conducted on the additional apartment building:

- WOH variable testing
- sensitivity testing of roof colours
- sensitivity testing of 2050 climate files

Description of the results

Results from the analysis of the additional apartment building were presented above in Table 13.

Conclusions

Broadly the conclusion relating to the analysis of the additional apartment building are the same as for the SBH20-27 building. Costs were marginally beneficial over the lifetime, at the 7.5 stars performance level, but incurred an increased cost over the lifetime, at the 8.0 star performance level.

The results therefore added confidence to the 7.5 star stringency recommendation as stated in Section **Error! Reference source not found.**.

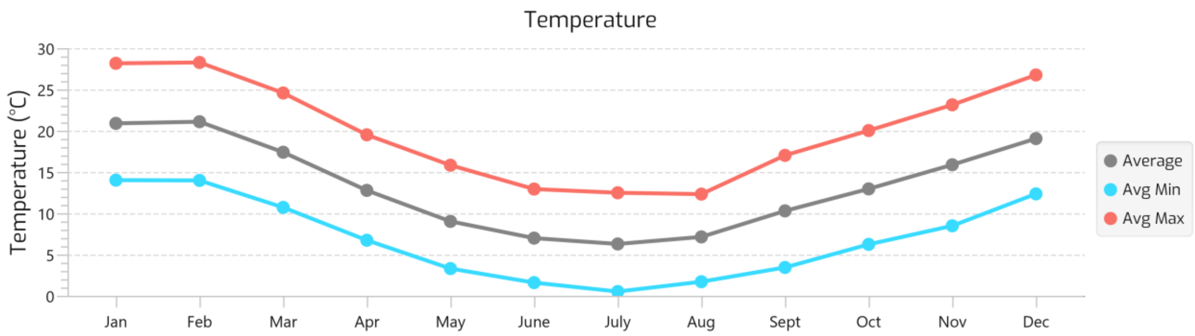
6.2 Climate file data summary

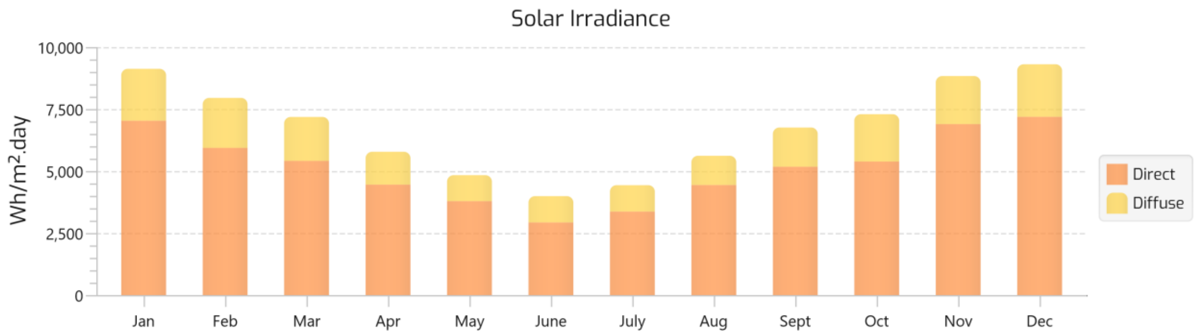
The figures below are the CSIRO NatHERS climate files for 2022 and 2050 (RCP8.5).

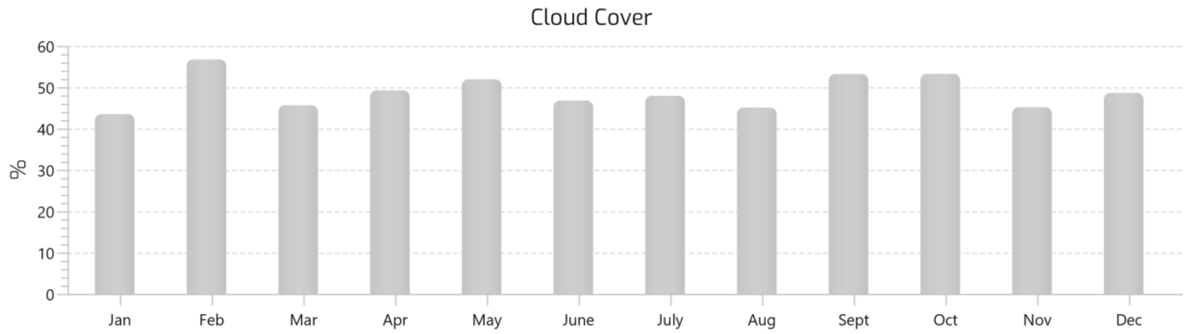
6.2.1 2022 climate files

ABCB Zone Index: 7 - Cool temperate | Longitude: 149.1 Latitude: -35.3

Annual Temperatures: Average: 13.3 Minimum -6.0 Maximum 38.4



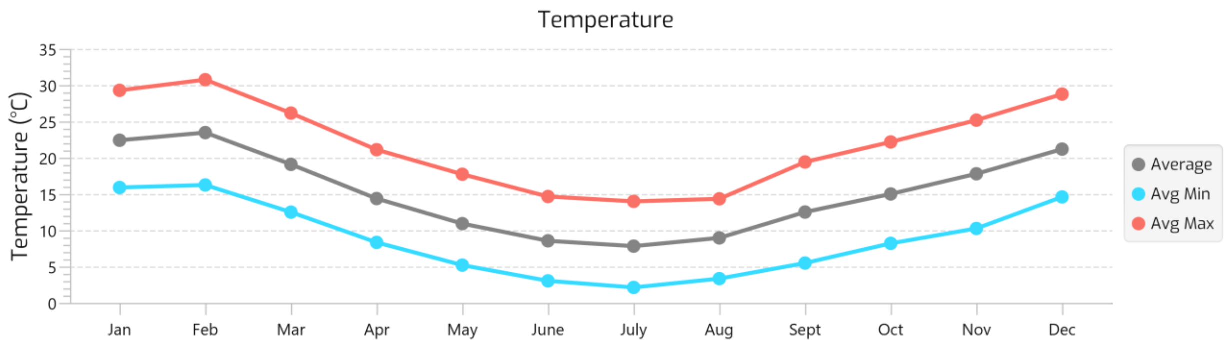


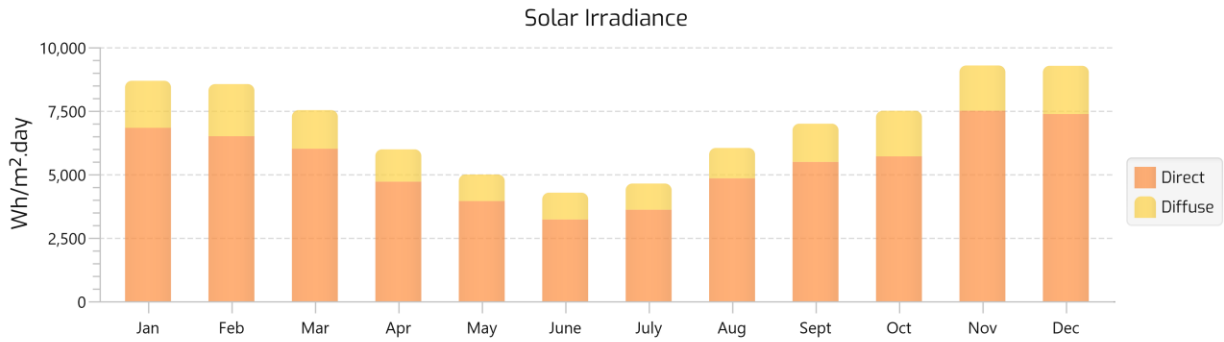


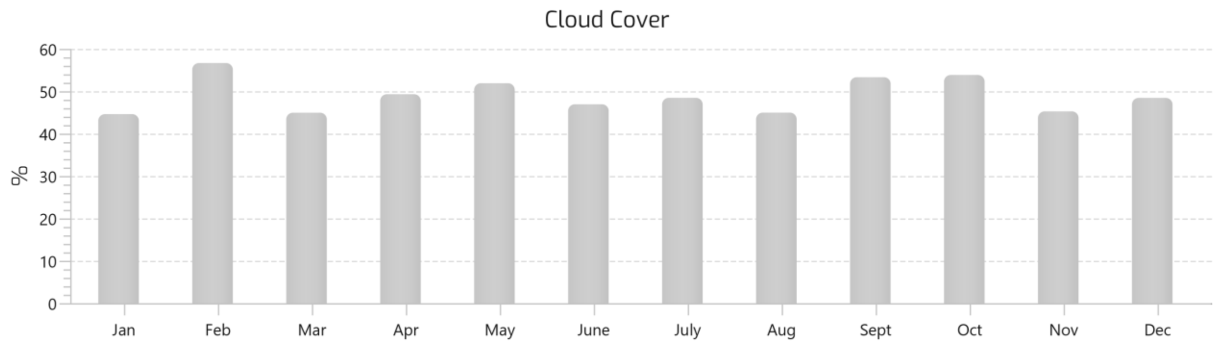
6.2.2 2050 climate files (RCP8.5)

ABCB Zone Index: 7 - Cool temperate | Longitude: 149.1 Latitude: -35.3

Annual Temperatures: Average: 15.1 Minimum -4.7 Maximum 39.0







6.3 Input assumptions

6.3.1 Social cost of carbon

Table 23: Social cost of carbon over time (constant 2025$)

	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
Low series	$175	$188	$208	$228	$248	$268	$288	$308	$328	$348	$362	$375
Med series	$282	$308	$335	$362	$389	$415	$442	$469	$489	$509	$529	$549
High series	$483	$509	$543	$576	$610	$643	$677	$710	$737	$764	$784	$804

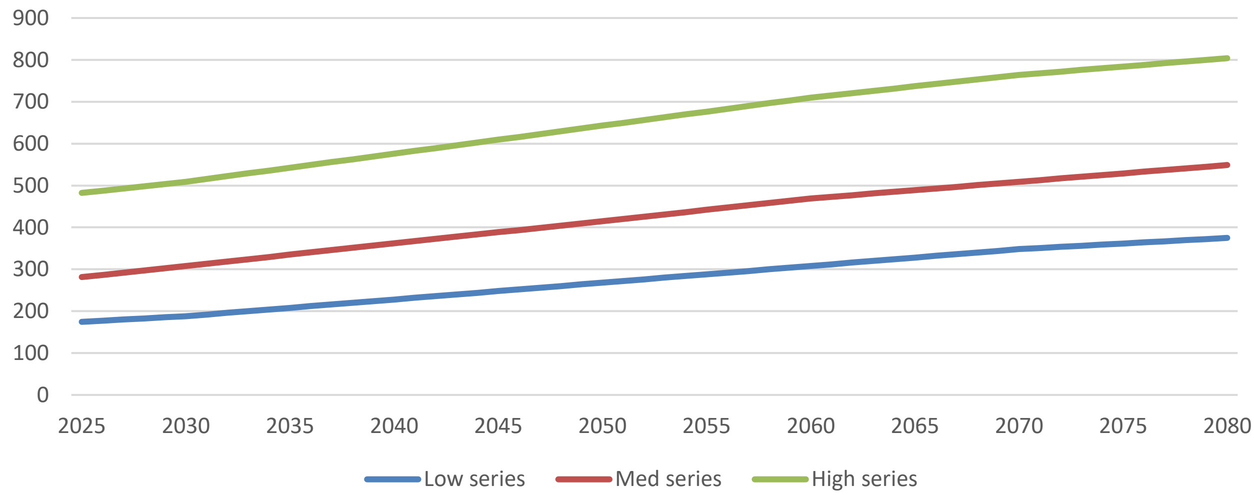


Figure 32: Social cost of carbon over time (constant 2025$)

Table 24: Alternative social cost of carbon over time (constant 2025$)

	2025	2030	2035	2040-2080
Low series	$125	$136	$357	$375
Med series	$250	$326	$714	$750
High series	$375	$489	$1,072	$1,125

6.3.2 Electricity prices

Table 25:Electricity price over time (% of 2025)

	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
Electricity price	100%	108%	117%	129%	125%	125%	125%	125%	125%	125%	125%	125%

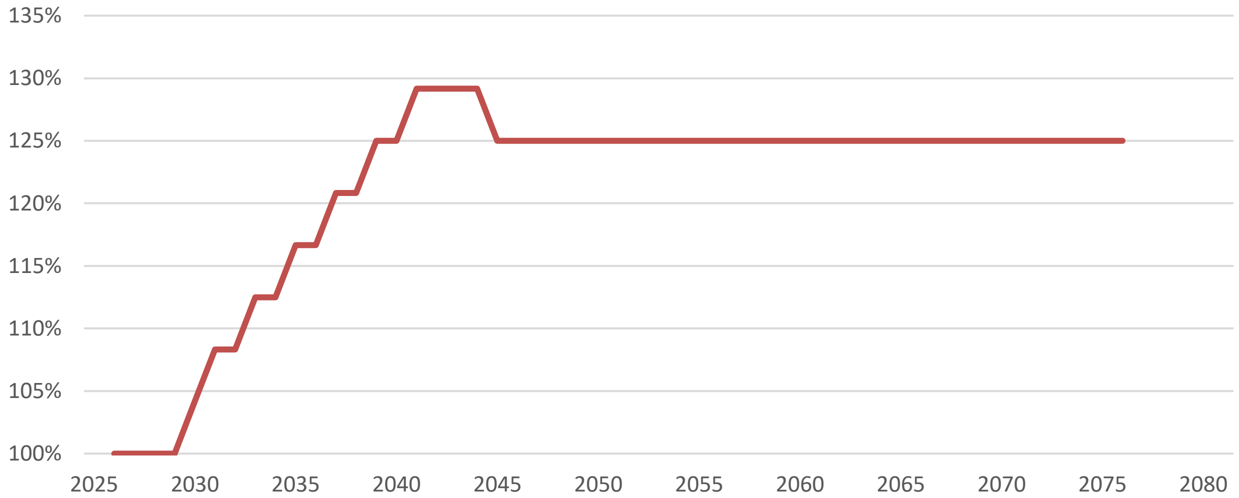


Figure 33: Electricity price over time (% of 2025)

6.3.3 Change in price of select WOH components

Table 26: WOH component price over time (% of 2025)

	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
Heat pumps	100%	91%	83%	79%	76%	76%	76%	76%	76%	76%	76%	76%
HP hot water	100%	91%	83%	79%	76%	76%	76%	76%	76%	76%	76%	76%
Solar PV	100%	91%	83%	79%	75%	74%	72%	72%	72%	72%	72%	72%
Battery	100%	82%	68%	59%	52%	48%	45%	45%	45%	45%	45%	45%

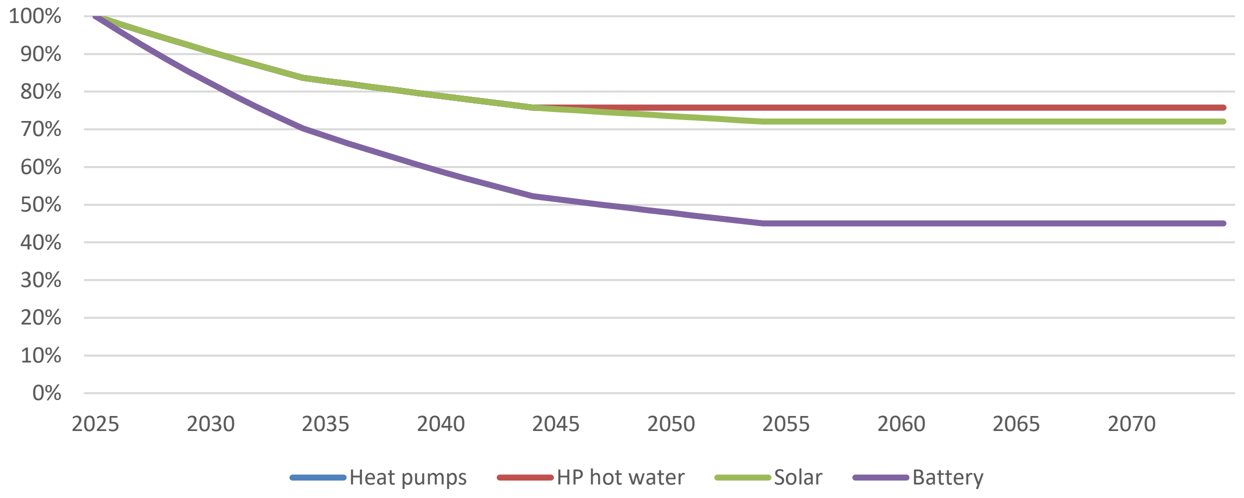


Figure 34: WOH component price over time (% of 2025)

6.3.4 NSW region grid intensity over time

Table 27: NSW region grid intensity over time (kg CO2-e/kWh)

	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
kg CO2-e/kWh	0.53	0.13	0.02	0.02	0.02	0	0	0	0	0	0	0

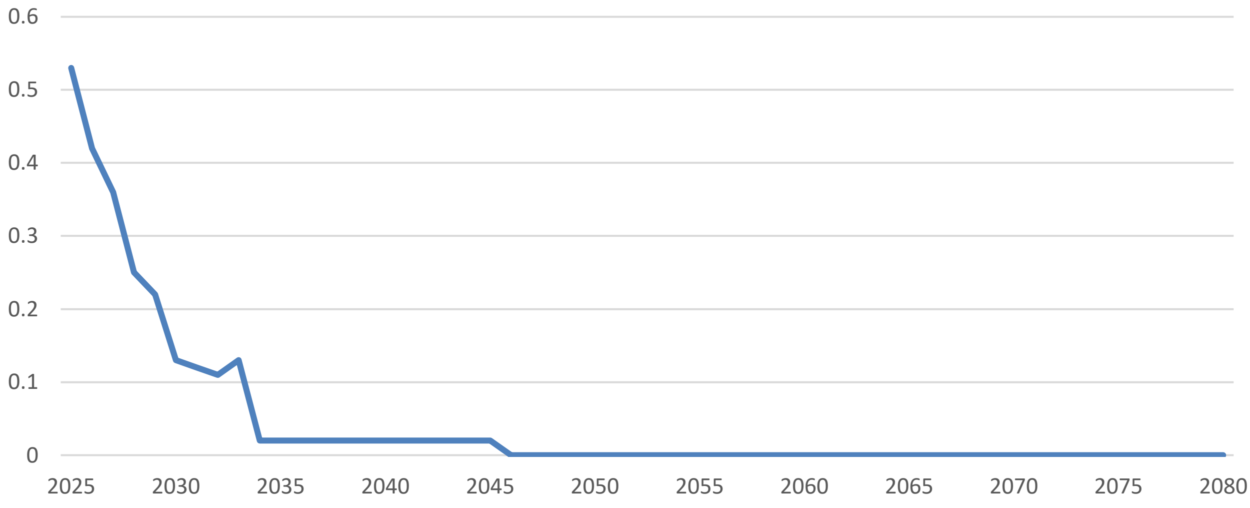


Figure 35: NSW region grid intensity over time (kg CO2-e/kWh)

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