COAG Energy Council

Report for Achieving Low Energy Homes

December 2018

A collaborative project of the Commonwealth, State and Territory Governments

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Executive Summary

Energy efficiency in residential buildings plays an important role in lowering energy bills for households, ensuring energy security and affordability, and addressing climate change. It also improves the comfort and health of occupants, saves energy and reduces wastage for the wider economy, and reduces the risk of blackouts by reducing peak demand.

Most buildings in Australia are only built to the minimum energy efficiency requirements in the National Construction Code (NCC). This misses cost effective opportunities to lower energy bills for households, as new energy efficient technology costs have been falling considerably in recent years, while energy prices have been rising. These requirements have also not been updated since 2010.

As part of the National Energy Productivity Plan (NEPP), the Council of Australian Governments' (COAG) Energy Council (the Council) agreed to consider changes to the NCC to achieve better energy efficiency outcomes for Australia's buildings. Energy efficiency requirements in the NCC are a key mechanism for delivering the NCC's 'Sustainability' goal, while also supporting its 'Health' and 'Amenity' goals.

The Trajectory for Low Energy Homes project considered opportunities for the NCC in the context of a broader trajectory for the residential building sector. This Report brings together the findings from this project, which was developed cooperatively between Commonwealth, State and Territory Governments, and identified cost effective opportunities for energy efficiency improvements throughout the building system, from thermal performance to appliance energy usage and renewables.

This Report acknowledges the strong calls from energy consumer groups and many in the building and building products sectors to improve the affordability of operating new and existing homes. Extensive stakeholder consultation was conducted over a one year period with over 220 stakeholders engaged through this process, consisting of representatives from a range of sectors including: building and property, appliance and technology, energy supply and distribution, household energy consumer advocacy groups, academia and different levels of government. A summary of comments received from stakeholders is included at the end of this Report.

Also considered for this Report was the Australian Sustainable Built Environment Council (ASBEC) and ClimateWorks *Built to Perform* report, which was released in July 2018 and supported by the 27 industry members of ASBEC. It produced similar findings to what is in this Report, but also identified additional cost effective opportunities, such as improving building sealing and lighting energy efficiency. It is recommended these opportunities be considered for inclusion in the NCC along with those identified in this Report.

A cost benefit analysis of different scenarios and energy modelling for different climate zones was conducted as part of the Trajectory for Low Energy Homes project, using a relatively conservative methodology. Cost effective opportunities for energy efficiency were identified throughout the building system, from thermal performance to appliance energy usage and renewables, and this has formed the basis of the recommendations in this Report.

The Council will consider in late 2018 the recommendations in this Report, along with other relevant information, and establish its forward policy for energy efficiency in residential buildings, noting the analysis of costs and benefits used to inform this Report is not a Regulatory Impact Statement (RIS) and a comprehensive RIS process will need to be conducted prior to any changes to the NCC.

Based on the extensive consultation and modelling that has been conducted, this Report recommends that:

A trajectory towards 'zero energy (and carbon) ready homes' should be set to provide direction and greater industry certainty. Zero energy (and carbon) ready homes have an energy efficient thermal shell and appliances, have sufficiently low energy use and have the relevant set-up so they are 'ready' to achieve net zero energy (and carbon) usage annually if they are combined with renewable or decarbonised energy systems either on-site or off-site. Setting this policy direction for the sector would deliver considerable energy savings for households and enable industry to plan, innovate and invest with greater confidence.

The energy efficiency objective in the NCC should reflect the broader policy objectives of energy efficiency, beyond just reducing greenhouse gas emissions. The policy intent is to improve energy efficiency and reduce energy use, which has benefits of lower energy bills for households, improved comfort and health for occupants, saved energy and reduced wastage for the wider economy, improved resilience of buildings to extreme weather and blackouts (peak demand), and reduced carbon emissions. A narrow climate policy objective can especially disadvantage health and resilience benefits of improved thermal performance.

A climate-specific energy usage budget should be quantified as a performance requirement in NCC 2022, which increases the thermal and appliance efficiency of new homes. An annual energy usage budget should be quantified using a delivered energy and carbon metric, and deliver an overall Benefit Cost Ratio greater than 1:1. The starting point for developing this budget should be thermal energy efficiency being increased up to 6.5 stars *equivalent* (based on 2018 accredited NatHERS software) in tropical and temperate climates, such as Sydney, Perth and Darwin, and up to 7 stars *equivalent* in colder climates such as Melbourne, Canberra and Hobart, with a focus on well orientated and sized windows.

The thermal performance requirements should also consider having a single level (i.e. 7 stars) set across a jurisdiction to support compliance and then be paired with a flexible overall energy requirement *equivalent* to the sum of (while allowing trade-off between) a new space conditioning appliance performance with *equivalent* COP to 5 star gas heating or 4 star electric space conditioning; hot water performance *equivalent* to 5 star gas instant or a climate appropriate heat pump hot water system; and existing performance levels for lighting and pool pumps.

Other appliance and fuel options with *equivalent* performance should be allowed to meet the flexible energy usage budget, which should also be influenced by increases in thermal efficiency beyond minimum requirements, where they reduce space conditioning loads. Potential NCC 2022 improvements could deliver bill savings to new home buyers and their renters of over $650 each year in colder or tropical climates, such as Canberra, Townsville and Darwin, and around $170 each year in more temperate climates, such as Sydney, Melbourne and Adelaide. This could deliver a net financial benefit to households of over $1.7 billion up to 2050.

This requirement should cover Class 1 houses, Class 2 sole-occupancy units, Class 3 residential buildings, and Class 4 parts of buildings. Rules should also be developed to ensure there are no perverse outcomes as a result of the use of the energy (and carbon) budget (such as under sizing or post occupancy installation of applicable appliances) to ensure the appliances installed are fit for purpose.

The NCC should be fuel neutral. In meeting an overall energy usage budget (MJ/m^2) in the NCC, a delivered energy metric should be used with a conversion factor for different fuel types. This could be applied based on their relative carbon intensity, either nationally or at a jurisdictional level to reflect the considerable variation in carbon intensity of different fuels around Australia. A forecast national 2022 conversion factor was tested in this Report of: Electricity = 1, Gas/LPG = 0.239 and Wood/Biomass = 0.006. These factors should be updated with each NCC revision, given ongoing work by the gas and electricity sectors to reduce carbon intensity of fuel-types over time.

The NCC 2022 should include provisions that require buildings to be 'ready' to accommodate on-site renewable energy generation, storage and electric vehicles, and consider requiring a level of on-site renewable energy. New homes should have the capability to accommodate on-site renewable energy generation, storage and electric vehicle charging, by considering infrastructure (such as electrical conduit) and ensuring adequate roof space, pitch and orientation is available for future placement of infrastructure (such as photovoltaic panels).

Where practical and cost effective, opportunities should be considered for setting a tighter annual energy (and carbon) usage budget for Class 1 and Class 3 buildings, and Class 2 common areas, with flexibility to achieve the additional performance through on-site renewable energy generation (possibly with batteries) or increased thermal or appliance efficiency. For example, if the energy usage budget is set at 115MJ/m^2, it could be tightened to 100MJ/m^2 and the extra 15 MJ/m^2 achieved by increased thermal efficiency beyond the minimum thermal requirement, increased efficiency of appliances or through on-site renewable energy generation (note: this is an example and the final energy usage budget will be determined based on the outcomes of a RIS). Decarbonisation of the gas and LPG sectors could also assist in meeting a more stringent annual energy (and carbon) usage budget by reducing the gas conversion factors discussed in Recommendation 4. This should not allow any trading off against thermal or appliance efficiency requirements in Recommendation 3, to ensure that renewable energy is not a pathway to facilitate lower performing buildings.

Introducing renewable energy on this basis could offer a large increase in net present value for households of between $5.1 billion and $26.4 billion (up to 2050) and provide greater flexibility in cost effectively meeting the energy efficiency requirements. However, before introducing renewable energy options into the NCC, further analysis is needed on the impacts. This includes the ability of the renewable energy industry to meet a potentially rapid increase in demand for renewable installations, whether renewable energy requirements would drive a shift to full electrification and the potential grid impacts (both assisting with, and contributing to, peak demand), how to manage buildings with limited solar access or that have limited area to install renewable energy (i.e. limited roof area) and how the NCC can remain fuel neutral.

Energy efficiency provisions should be substantially updated in NCC 2022 and 2025, and then revert to triennial revisions that ensure provisions keep pace with changing technologies and changing energy prices to facilitate progress towards zero energy (and carbon) ready buildings. The NCC is an important and established mechanism to deliver improved energy efficiency of new homes for the benefit of households. Energy efficiency provisions should be substantially updated in NCC 2022, based on modelling for the Trajectory for Low Energy Homes project showing there are cost effective benefits not being realised, and the energy efficiency provisions for residential buildings having not been updated since 2010 despite improvements in technologies. While further national increases in thermal performance beyond NCC 2022 may or may not be cost effective in 2025, the move to climate-specific requirements is likely to see opportunities that offer a net benefit for some jurisdictions and climate zones into the future. Longer term, to accommodate improvements in appliance performance, changing technologies and ensure further energy savings for households, changes to energy efficiency provisions should be implemented in each triennial revision of the NCC. This would establish an expectation of regular adjustments to the annual energy usage budget, providing greater certainty to industry than the current ad hoc approach, and reduce the need for larger NCC changes in the future.

Whole-of-home tools and a simple elemental pathway should be included in the NCC to verify compliance. The NCC should be clear and simple to support compliance outcomes, while being flexible enough to allow the most cost-effective solution to be adopted. The NatHERS framework could be expanded to support whole-of-home tools, while the Deemed-to-Satisfy: Elemental provisions should be simplified and expanded to include space conditioning. This aims to offer a simple prescriptive approach and a flexible modelled approach. All verification methods should encourage improved orientation and sizing of windows along with other thermal energy efficiency outcomes, with flexibility around meeting an energy usage budget. Appliances must also be sized correctly, for example space conditioning should have sufficient capacity to meet the likely energy loads for the home. Where no appliance is specified, a default appliance should be assumed to avoid attempts to bypass requirements.

NCC 2022 should also consider changes to building sealing, ventilation, lighting, and split heating and cooling load limits, whilst ensuring there are no adverse impacts on condensation and indoor air quality. Industry-led analysis has identified benefits of improving building sealing and lighting. Given ventilation issues raised prior to NCC 2019, increasing building sealing was not considered in the Trajectory for Low Energy Homes project. However, NCC 2022 changes should consider increasing building sealing while managing ventilation issues more broadly, and consider opportunities to tighten split heating and cooling requirements. Lighting changes should be considered from 2025, after the introduction of increased Minimum Energy Performance Standards for lighting from 2020.

The NCC should not be considered a standalone mechanism and other initiatives, including for existing homes, should be progressed. The NCC offers an established mechanism to ensure energy efficiency improvements are being implemented at the point when they are most cost effective (i.e. before construction has happened). However, to support the cost effective delivery of energy efficiency outcomes for households, a range of policies and initiatives are needed. This includes continuing to strengthen NEPP measures, such as improving training and compliance, making choice easier for consumers, energy ratings and disclosure, etc.

Existing (pre-energy efficiency standards) homes offer the greatest potential for energy efficiency improvements and options for improving these homes should be considered by the Council in 2019. Early modelling indicates that by improving the performance of existing buildings by a relatively small amount, the energy savings and benefits roughly double. For example, improving the existing housing stock by just 1 per cent could deliver an additional $1.5 billion in net present value. However, further investigation is needed to identify the policy opportunities that could best harness these potential savings. It is therefore proposed investigations be undertaken for Council consideration in late 2019.

Australian governments should continue to improve the energy efficiency of existing homes through state and territory initiatives. There are a number of state and territory initiatives that aim to improve the energy efficiency of existing homes. These measures are at various stages of implementation, with many being used to inform other COAG Energy Council measures.

BASED ON THE RECOMMENDATIONS NOTED PREVIOUSLY, A POTENTIAL TRAJECTORY FOR LOW ENERGY HOMES IS:

EXISTING BUILDINGS

2019: Measures for existing buildings considered and trajectory updated

Timelines for measures for existing buildings to be considered at the end of 2019

NEW BUILDINGS

2018

Initial trajectory set and changes to the National Construction Code (NCC) 2022 agreed

2022

- Expand the NCC objective;
- Introduce an energy (and carbon) usage budget that includes appliances already covered by the NCC (hot water, pool pumps, and lighting), adds a new requirement for space conditioning, and increases thermal efficiency requirements up to 7 stars equivalent in some climates;
- Ensure homes are 'ready' to accommodate on-site renewable energy generation, storage and electric vehicles;
- Introduce whole-of-home tools and a simple elemental pathway to verify compliance;
- Consider opportunities for building sealing, while addressing any ventilation and condensation impacts;
- Progress measures outside the NCC.

2025

- Increase thermal and appliance energy efficiency where cost effective;
- Consider opportunities to increase lighting energy efficiency;
- Consider increasing the scope to include all fixed appliances and potentially electric vehicles.
- Consider further opportunites for renewable energy to lower energy usage where practical, cost effective and additional to other energy efficiency measures.

2028

- Changes from 2028 should progress triennial revisions to buildings energy efficiency that ensure provisions keep pace with changing technologies and energy prices to facilitate progress towards zero energy (and carbon) ready homes.
- Progress measures outside the NCC.

Zero energy (and carbon) ready buildings

* Zero energy (and carbon) ready buildings have an energy efficient thermal shell and appliances, have sufficiently low energy use and have the relevant set-up so they are 'ready' to achieve net zero energy (and carbon) usage, if they are combined with renewable or decarbonised energy systems on-site or off-site.

Introduction

Energy efficiency in residential buildings plays an important role in lowering energy bills for households, ensuring energy security and affordability, and addressing climate change. It also improves the comfort and health of occupants, saves energy and reduces wastage for the wider economy, and reduces the risk of blackouts by reducing peak demand.

The National Energy Productivity Plan (NEPP), agreed by the COAG Energy Council (the Council) in 2015, aims to improve Australia's energy productivity by 40 per cent between 2015 and 2030. This will reduce costs for households, while improving Australia's competitiveness and growing the economy and jobs. The NEPP also supports the Australian Government's commitment under the Paris Agreement to reducing greenhouse gas emissions to 26–28 per cent below 2005 levels by 2030.

The NEPP takes a whole-of-system approach to energy policy and covers electricity, gas and transport fuels. It includes:

- Energy market reforms to promote consumer choice and increase competition and innovation in the energy market; and
- Energy efficiency measures that support better energy use in buildings, equipment and vehicles.

Under NEPP Measure 31, 'Advance the National Construction Code', the Council agreed to consider opportunities to increase minimum requirements in the NCC to achieve better energy efficiency outcomes for Australia's buildings. Energy efficiency requirements in the NCC are a key mechanism for delivering the NCC's 'Sustainability' goal, while also supporting its 'Health' and 'Amenity' goals. The Council recognised that capturing this opportunity could likely result in very strong productivity and emissions reductions benefits. This is reflected by strong calls from energy consumer groups and parts of the building and building products sectors, to improve the energy efficiency of Australian buildings for the benefit of householders.

By the end of 2018, Council agreement is needed on the policy direction for achieving better energy efficiency outcomes for Australia's households and the proposed measures to be included in the NCC 2022. This will inform the Building Ministers' Forum and the Australian Building Codes Board (ABCB) of what should be investigated for the 2022 update of the NCC and the potential scope and stringency levels of energy efficiency provisions.

In late 2017, the Trajectory for Low Energy Homes project commenced by establishing a Stakeholder Reference Group to collaborate on the opportunities for transitioning towards low energy homes, advise on modelling methodologies for testing these opportunities and identify changes for the 2022 update of the NCC. Over 220 stakeholders were engaged through this process, consisting of representatives from a range of sectors including: building and property, appliance and technology, energy supply and distribution, household energy consumer advocacy groups, academia and different levels of government. Over 100 written submissions were received from this group, which has been invaluable in developing options that offer benefits to households while being both cost effective and minimising burden on industry. A summary of feedback received is at Appendix A.

This Report is designed to bring together the findings from the Trajectory for Low Energy Homes project. Opportunities for energy efficiency have been identified throughout the building system, from thermal performance to appliance energy usage and renewables. This Trajectory provides a long-term, nationally consistent approach to energy efficient homes while maintaining sufficient flexibility for regional or jurisdictional circumstances. It outlines the energy improvements in the building sector to date; benefits from improving the energy efficiency of homes; the need for further energy efficiency improvements; policy options for new homes and recommended stringency changes to the NCC; and preliminary options for improving the energy efficiency of existing homes. Further details on the scope of the Trajectory for Low Energy Homes project is at Appendix B.

Energy improvements in the building sector to date

Australia's residential building sector is large and growing. The residential building sector is responsible for around 11 per cent of Australia's emissions[1] and 23 per cent of electricity use.[2] In 2016 there were over 9 million homes. Of these, 72 per cent are separate houses while the remaining consist of other forms of dwellings such as flats, apartments, semi-detached, row housing or town housing.[3]

Australia has made important progress in residential building energy performance. To date:

- New homes have improved considerably over the years, becoming more energy efficient. For example, in Victoria a sample of energy rated houses constructed prior to 1990 was found to have an average House Energy Rating of around 1.5 stars. Following the introduction of insulation standards for new homes in 1991, homes constructed between 1990 and 2005 averaged around 3 stars.[4] Today, new homes are required to meet the equivalent of 6 stars or greater in most states and territories.
- More than one in five Australian houses now have solar panels installed on their roof – the highest rate per capita in the world.[5]
- Appliances and equipment used within households have significantly improved too. This is largely due to the Equipment Energy Efficiency (E3) program and the Greenhouse and Energy Minimum Standards (GEMS) Act (and its state and territory predecessors), which sets minimum energy performance standards, requires energy rating labelling, and delivers education and training.
- Split system air conditioners are now 50 per cent more efficient than they were in 2001.
- 27 per cent less energy is used by lighting since the phase out of inefficient lighting in 2009 and technological advances in LEDs.

In considering building energy efficiency policy going forward, an important issue in Australia has been the increasing number of apartments being built. While this initial trend has eased in the last year, Figure 1 shows that compared with seven years ago, apartments are making up a greater proportion of new homes.[6] Therefore the energy efficiency of apartments is of growing importance, especially where retrofits to apartments are comparatively more difficult than detached homes.

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1 Department of the Environment and Energy, National Inventory by Economic Sector 2016: Australia's National Greenhouse Accounts, February 2018. Residential direct emissions (non-transport) is 13.3 Mt CO2-e and residential indirect emissions (electricity) is 45 Mt CO2-e - combined together 58.3 Mt CO2-e. This compares to total emissions of 533 Mt CO2-e.

2 Department of the Environment and Energy, Australian Energy Statistics, January 2017, Table F. Figures is based on 2015-16 share of electricity.

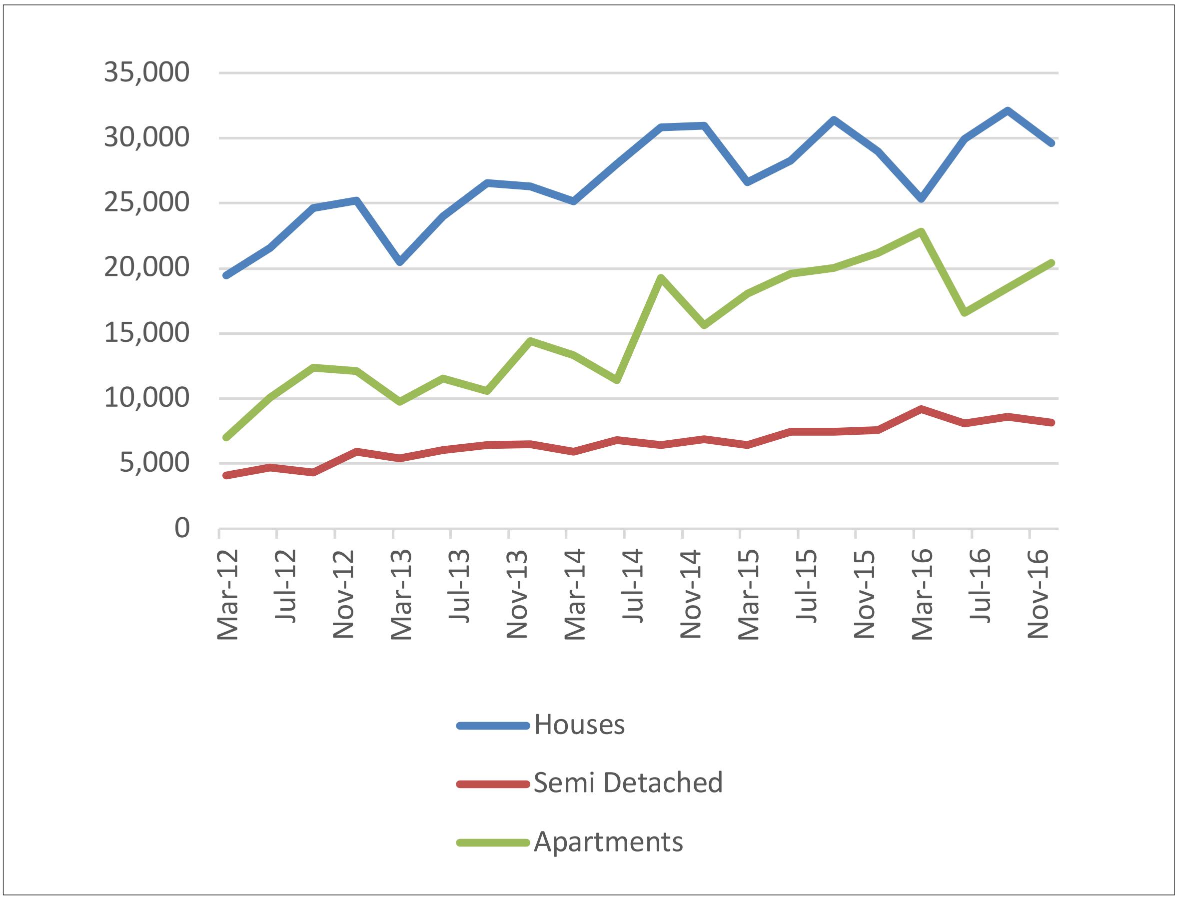
3 www.abs.gov.au/ausstats/abs@.nsf/mf/2024.0

4 Energy Efficiency Upgrade Potential of Existing Victorian Houses, September 2016, page 6

5 www.cleanenergyregulator.gov.au/About/Pages/News%20and%20updates/NewsItem.aspx?ListId=19b4efbb-6f5d-4637-94c4-121c1f96fcfe&ItemId=417

6 www.commsec.com.au/content/dam/EN/ResearchNews/ECOReport.20.11.17_Biggest%20homes_size-fall.pdf

Figure 1: Number of new apartments compared to detached homes in Australia



Source: Housing Industry Association

Benefits of improving the energy efficiency of homes

Homes that are energy efficient work better with the climate they are in and maximise the opportunities of each component of the building. Features of an energy efficient home can include: the building being orientated with windows that capture the sun to keep the home warm in winter and/or have shading devices and openable windows to keep the home cool in summer; use appropriate materials and insulation; and have energy efficient appliances to minimise the use of energy. In addition, photovoltaic (or solar) panels can generate electricity on site and batteries can store the energy for use at times when the sun is not shining.

Lower energy bills for households

Most of the energy used in Australia comes from electricity, natural gas and wood. Electricity represents 50 per cent of energy used in Australian households and is a large component of the household budget.[7] A 2017 CHOICE Consumer Pulse survey found that electricity is households' number one cost-of-living concern, with 82 per cent of people stating that they were concerned or very concerned about their electricity bill. Electricity has been the number one cost-of-living concern in almost every period since CHOICE began conducting the survey in 2014.[8]

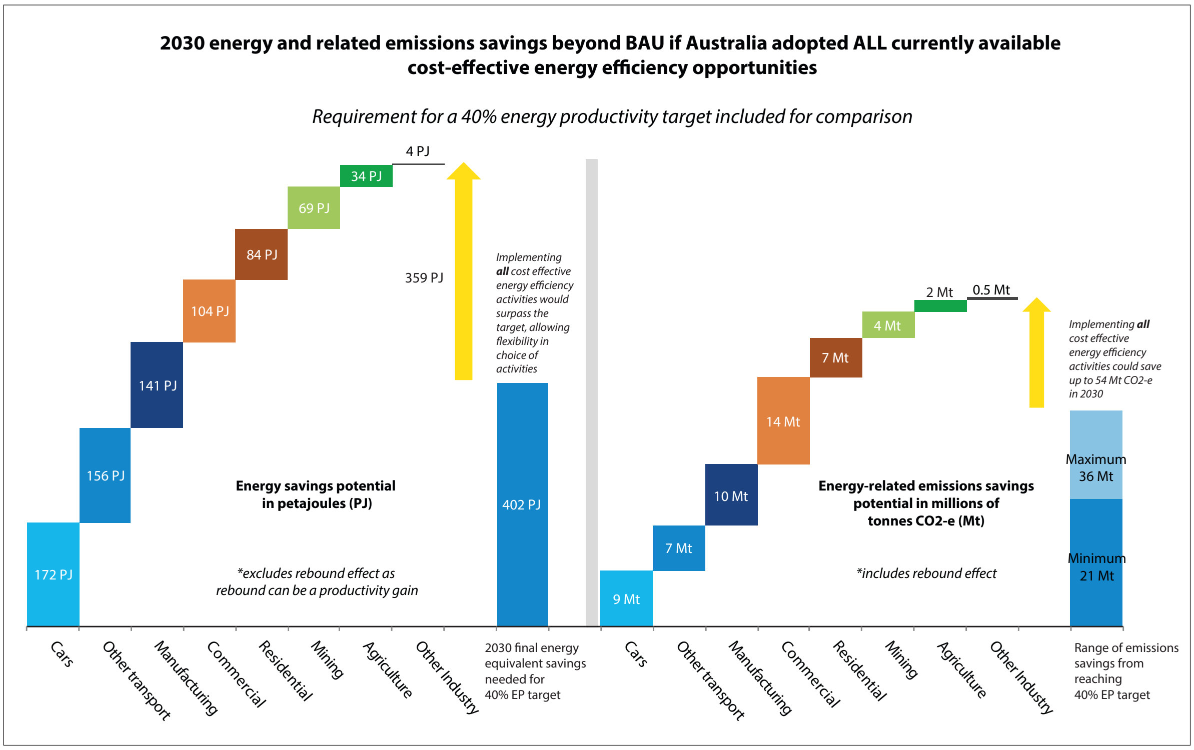
Energy efficient homes can reduce energy costs to consumers and protect against rising electricity prices. For example, in the ACT retrofitting a home with insulation, draught proofing and using efficient appliances can typically save consumers about $700 per year and reduce energy use by up to 50 per cent annually. In this same instance, installing a solar hot water system can increase the savings to about $1,500 and reduce energy use by about 80 per cent annually.[9] Similar results have been found in Victoria, where households can save up to 45 per cent on their energy bills by insulating ceilings, walls and floors alone.[10]

Save energy (reduce wastage) for the wider economy

Large amounts of energy is wasted through inefficient buildings, appliances and practices. The NEPP identified the considerable contribution the residential building sector can contribute to reducing Australia's energy productivity by 40 per cent by 2030, as demonstrated in Figure 2.[11] Capturing this opportunity will enhance economic growth through increased productivity; improve energy security by reducing energy demand; and defer the need for increasing energy supply.

7 www.energymatters.com.au/energy-efficiency/
8 CHOICE, CHOICE Consumer Pulse: Australians' Attitudes to Cost of Living 2014-2017, August 2017, pages 4-5
9 www.environmentcommissioner.act.gov.au/__data/assets/pdf_file/0006/590829/ocse_factsheet_retrofit_050710.pdf
10 www.sustainability.vic.gov.au/You-and-Your-Home/Building-and-renovating/Planning-and-design/Build-for-energy-efficiency
11 COAG Energy Council, National Energy Productivity Plan 2015-2030, December 2015, page 13

Figure 2: Energy productivity opportunities identified in the National Energy Productivity Plan



Source: COAG Energy Council, National Energy Productivity Plan 2015-2030

Improved health and comfort levels for occupants

Energy efficient buildings can be more comfortable and, with appropriate ventilation, can create conditions that support improved occupant health and well-being, particularly among vulnerable groups such as children, the elderly and those with pre-existing illnesses. Benefits can include improved physical health such as reduced symptoms of respiratory and cardiovascular conditions, rheumatism, arthritis and allergies, and improved mental health (reduced chronic stress and depression).[12] This is especially the case where inefficient existing homes have their building shell upgraded through features such as insulation, draught sealing and window protection. A New Zealand study found that occupants of insulated houses are about half as likely to report respiratory symptoms as those in uninsulated houses.[13]

Cold weather contributes towards 6.5 per cent of all deaths in Australia and hot weather contributes towards a further 0.5 per cent of deaths. More people die of cold-related illnesses in Australia than in Sweden.[14] While current NCC requirements address many of these issues, there are still further opportunities for improvement, particularly for older existing homes.

12 International Energy Agency, *Capturing the Multiple Benefits of Energy Efficiency*, 2014, page 22

13 The Lancet, Volume 386, Antonio Gasparrini, Yuming Guo, Masahiro Hashizume, Eric Lavigne, Antonella Zanobetti, et al, *Mortality risk attributable to high and low ambient temperature: a multicountry observational study,* 2015, pages 369-75, page 4

14 www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)62114-0/fulltext, page 372

Improved resilience to extreme weather and blackouts (peak demand)

Extreme weather events can impact our homes and well-being, with some of the key risks coming from floods, heatwaves, bushfires, hotter and drier conditions, and more intense storms and cyclones.

Homes are responsible for around 23 per cent of electricity use,[15] with households contributing disproportionately to electricity demand during critical peak events. This is especially the case during hot weather, where significant demand is placed on the electricity system due to the increased use of air conditioners.[16] The duration, frequency and intensity of extreme heat events is also projected to increase,[17] with the resulting high electricity demand expected to continue to place pressure on the electricity grid.

Energy efficient homes reduce stress on the electricity grid during times of peak demand. Almost $1,000 in electricity system infrastructure could be saved for each household that cuts their peak demand by one kilowatt through good design and efficient appliances[18] – the power used to run an air-conditioner in one room.[19] This could reduce electricity prices for everyone. In the short term, reducing peak demand reduces consumption when wholesale electricity prices are high, the savings of which can flow through to consumers.

Reduced carbon emissions

The residential buildings sector is responsible for around 11 per cent of Australia's greenhouse gas emissions.[20] This consists of emissions from source fuels such as coal and gas for electricity generation, and direct use of gas for heating and cooking. A CSIRO study conducted in 2014 found that greenhouse gas emissions were 7 per cent lower over a year for a five-star or higher-rated home than lower rated homes.[21]

Where homes rely on grid electricity that includes fossil fuels, improving homes further, particularly through a whole of building approach, can deliver additional and substantial reductions in carbon emissions.

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15 Department of the Environment and Energy, *Australian Energy Statistics*, January 2017, Table F. Figures is based on 2015-16 share of electricity.

16 This issue is addressed in the 'Impacts on Electricity Networks' section

17 CSIRO, Bureau of Meteorology, *Australia's Changing Climate*, 2016, page 1

18 Australian Sustainable Built Environment Council Interim Report Key Messages, 5 February 2018

19 www.solarpanelsphotovoltaic.net/power-consumption-101-typical-household-appliances/

20 Department of the Environment and Energy, *Australia's National Greenhouse Accounts: National Inventory by Economic Sector 2016*, February 2018

21 CSIRO, *The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings*, December 2013, page 14

The need for further energy efficiency improvements

While Australia has made important progress towards building more energy efficient homes, there are a number of reasons for taking further action.

Industry is seeking certainty

In developing this Report, Australian Government officials engaged with more than 250 stakeholders from a range of sectors. The overwhelming majority of stakeholders indicated the need for policy certainty for the residential building sector. A summary of feedback received is at Appendix A.

Research has also found that clear direction for the residential building sector can help industry to plan, innovate and invest with confidence and certainty,[22] particularly as the property and building products industry both have long lead times.

Homes impact on electricity network reliability

While energy efficient homes can reduce stress on the grid, they can also exacerbate impacts on the electricity grid depending on the combination of thermal efficiency and appliances. For example, Australians have been installing air conditioners and photovoltaic (solar power) systems at a rapid rate, causing supply and demand challenges to the electricity grid.

Around one million air conditioners are sold in Australia per year, with an estimated stock of almost 12 million in 2014.[23] This growth in household air conditioning is the major contributor to peak electricity demand, especially on hot summer afternoons. Peak demand growth has been a key driver of investment in generation and network capacity. For example, in New South Wales, peak demand events occurring for less than 40 hours per year (or less than 1 per cent of the time) accounted for around 25 per cent of retail electricity bills. The growth in household air conditioning is the major contributor to this pattern.[24]

Energy efficient design, measures, and behaviours can reduce the need for air conditioning. This includes insulating ceilings, walls and floors; shading windows from the summer sun; closing curtains to keep heat out, etc. At the same time, rooftop solar systems are playing an increasingly important role in reducing air- conditioning and other loads on the grid, particularly during heatwaves and summer demand peaks. Similarly, photovoltaic (PV) systems represent an important source of energy affordability for consumers, enabling them to access the benefits of technologies such as air conditioning without facing excessive electricity bills.

22 Low Carbon Living CRC, *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment,* March 2017, page 10

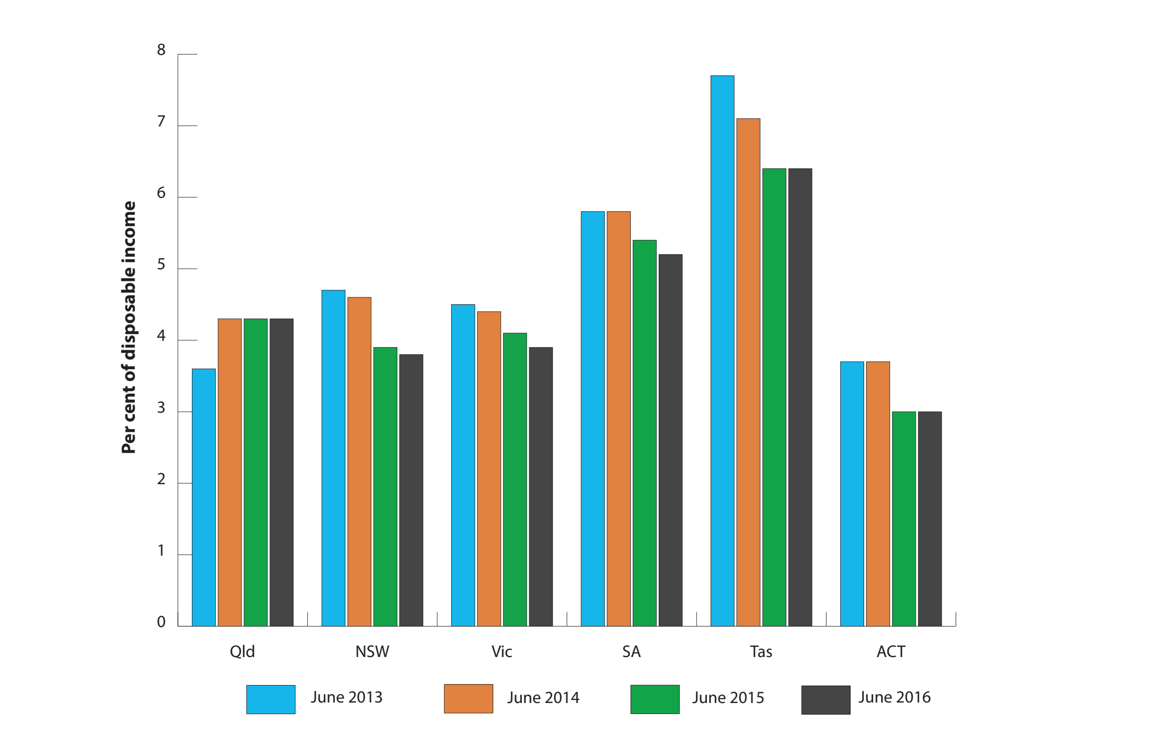
23 Department of Industry, Innovation and Science, *E3 Consultation Regulation Impact Statement – Air Conditioners and Chillers*, February 2016, page 1

24 Productivity Commission, *Electricity Network Regulatory Frameworks Productivity Commission Inquiry Report Volume 1*, No. 62, 9 April 2013, pages 16-17

Vulnerable consumers are being negatively impacted

Energy affordability snapshots for a typical low income household are provided in Figures 3 and 4. Research conducted by the Australian Energy Regulator found that while electricity became more affordable for a typical low income household in NSW, Victoria and South Australia in 2016, it remained unchanged elsewhere in Australia.[25] Gas affordability fluctuated markedly, with improvements in NSW, no change in Queensland and the ACT, and deteriorations in Victoria and South Australia.[26] The data in both Figures accounts for available concessions and rebates.

Figure 3: Energy bill burden for low income households - electricity[27]



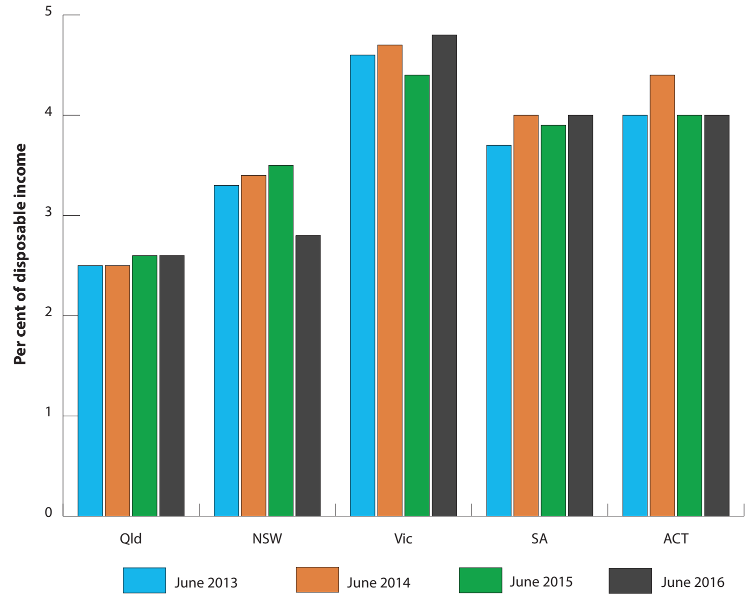
Source: Australian Energy Regulator

25 Australian Energy Regulator, *State of the Energy Market*, May 2017, page 147

26 ibid.

27 Energy charges are based on the median market offer. Disposable income for a low income household is that of the lowest two deciles, excluding the first and second percentile. Electricity consumption is the average for low income households in each jurisdiction. Gas consumption is the average for all households. Australian Energy Regulator, *State of the Energy Market*, May 2017, page 151

Figure 4: Energy bill burden for low income households – gas



Source: Australian Energy Regulator

Low-income householders are particularly vulnerable to energy affordability - spending up to five times more of their disposable income on electricity than high-income earners.[28] A study by KPMG found that in 2015/2016 around 160,000 households were disconnected for non-payment of their electricity or gas bill - up approximately 47 per cent since 2009/10.[29] In some states there has been a threefold increase in electricity disconnections as a result of non-payment due to hardship since 2008.[30] Others are forced to ration energy, foregoing heating or cooling and risking their health and wellbeing.[31]

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28 Australian Competition & Consumer Commission, *Retail Electricity Pricing Inquiry Preliminary Report*, 22 September 2017, page 14
29 KPMG, *Quantifying the Cost of Customers Experiencing Difficulties in Paying Energy Bills*, November 2016, page 1
30 Consumer Action Law Centre, *Heat or Eat: Households should not be forced to decide whether they heat or eat,* August 2015, page 6
31 Australian Council of Social Service, *Energy Efficiency & People on Low Incomes*, 2013, page 1

Australia is falling behind internationally on energy efficiency

In 2018 Australia ranked 18th out of 25 of the world's top energy-consuming countries – dropping two places from the previous Scorecard in 2016. The Scorecard provides a score for each country's efficiency efforts over four categories: buildings, industry, transportation, and overall national energy efficiency progress. Australia was strongest in building energy efficiency due to its building codes, commercial building labelling program, and appliance and equipment labelling. However, Australia's score for residential building codes has decreased from the previous year, suggesting that further work is needed in this area.[32]

Buildings are long-lived

The average life of a brick home is 88 years and a timber home is 58 years.[33] There are approximately 200,000 new homes built each year[34] (houses and apartments combined) and at current rates of construction, modelling in this Report estimates approximately 45 to 55 per cent of Australia's building stock in 2050 will be built after the next update of the NCC in 2019. Decisions that are made about homes today will therefore continue to have consequences for decades. It is also more cost effective to design and build these homes to be energy efficient now, rather than seeking to address any deficiencies via retrofits.

The NCC, as a key tool for delivering improvements to the energy efficiency of new homes and homes that have major refurbishments, has not changed since 2010 in relation to the stringency of standards to be met. It is therefore important to consider updating the NCC to reflect changes in building practices, advances in building products and technology, falling costs for renewable energy, improvements in energy efficient appliances and batteries, rising energy prices, and issues that impact on energy system reliability and costs. This will ensure new homes, and major refurbishments, are implementing all cost effective opportunities available and locking in these benefits for decades to come.

32 American Council for an Energy-Efficient Economy, *The 2016 International Energy Efficiency Scorecard*, June 2018, page 91 & American Council for an Energy-Efficient Economy, *The 2018 International Energy Efficiency Scorecard*, June 2018, page 104

33 Mark Snow & Deo Prasad, *Climate Change Adaptation for Building Designers: An Introduction*, EDG 66 MSa, February 2011, page 9

34 www.hia.com.au/-/media/HIA-Website/Files/IndustryBusiness/Economic/fact-sheet/window-into-housing.ashx?la=en&hash=984BFC3393B3F2F997E099A71545B151044C2B50

Market failures and barriers prevent change without government action

There are over 9 million homes in Australia, many of which use more energy than necessary and are more expensive to operate. This is due to a range of market failures and barriers that impact on the ability of households and businesses to choose cost effective energy efficiency improvements. The most recognised market failures and barriers consist of:

- ***Information*:** Energy efficiency is highly technical and collecting and understanding investment pay back information necessary to make fully informed decisions is difficult and time consuming.[35] While consumer attitudes on energy efficiency may be changing, a survey that was conducted in 2014 found that "house buyers are largely uninterested in energy efficient outcomes".[36] Many industry professionals have noted this translates into limited demand for efficiency features, a preference for lower capital cost or for more desirable aesthetic features (larger floor area, better kitchen, etc.), and a practical inability for consumers to hold the building supply chain to account for energy performance shortfalls.[37]
- ***Split incentives:*** These occur when one party accrues the costs (that is, up-front capital investment), while the other party receives the benefits (for example, lower energy bills).[38] This creates conflicting motivations and incentives between the builder and home owner, the real estate agent and the buyer and/or seller, or the tenant and the owner. For example, owner households have significantly higher rates of insulation, window treatments and solar electricity or hot water systems than renter households.[39]
- ***Capital Constraints:*** The RIS for proposed NCC energy efficiency changes in 2010 identified that some studies considered capital constraints to be an additional barrier. Energy efficiency investments require up-front capital (or financing) while the benefits of lower energy use accrue over time and often during a period that is not aligned with the financing period.[40]

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35 Australian Building Codes Board, *Final Regulation Impact Statement: Proposal to Revise the Energy Efficiency Requirements of the Building Code of Australia for Residential Buildings,* December 2009, page 43

36 Pitt&Sherry: *National Energy Efficient Building Project Final Report*, November 2014, page ix

37 Pitt&Sherry: *National Energy Efficient Building Project Final Report*, November 2014, page 44

38 Australian Building Codes Board, *Final Regulation Impact Statement: Proposal to Revise the Energy Efficiency Requirements of the Building Code of Australia for Residential Buildings,* December 2009, page 43

39 www.abs.gov.au/ausstats/abs@.nsf/Lookup/4670.0main+features100042012#Energy

40 Australian Building Codes Board, *Final Regulation Impact Statement: Proposal to Revise the Energy Efficiency Requirements of the Building Code of Australia for Residential Buildings,* December 2009, page 43

Policy options for improving energy efficiency

In conducting the Trajectory project a range of policy options were identified through research and by stakeholders. A summary of feedback received from stakeholders is at Appendix A.

Recognising that cooperation with industry is vital to the success of any policy, some notable considerations raised by stakeholders included:

- Consumer groups are strongly advocating for an increase in the performance standards for new and existing homes, citing health impacts as well the potential to significantly reduce household bills. They stressed, however, that care must be taken to avoid locking homes into particular fuel types, so households always have opportunities to replace appliances with more efficient models and are not faced with large replacement and disconnection costs. They have called for the COAG Energy Council to also commit to a national plan to address energy efficiency for existing homes, as these offer the greatest potential for energy efficiency improvements.
- 27 industry members of ASBEC support its industry-led analysis with ClimateWorks through the *Built to Perform* report, which was released in 2018. It recommended governments commit to a Zero Carbon Ready Building Code; deliver a step change to the NCC in 2022; and expand the scope of the NCC and progress complementary measures. Their analysis showed that by 2030, improvements in the NCC energy efficiency requirements could deliver between 19 and 25 per cent of the energy savings required to achieve net zero energy in new residential buildings.
- Some building industry groups indicated support for setting a target and considering a more holistic approach to energy efficiency for residential buildings, including the use of on-site renewables. However they raised concerns with increasing requirements for the thermal performance of new homes in 2022. The building industry also indicated that any proposals need to be simple and straightforward while having flexibility for tailor-made design solutions. Feedback was therefore supportive of an approach similar to the NSW BASIX[41] tool that allows for a do-it-yourself approach or a first principle tailor-made design. In terms of broader matters, they believe it is important that any proposed changes consider what impact these may have on broader building code compliance and that the analysis should consider all types of residential buildings.
- Some gas industry groups questioned the need for the NCC to have requirements for appliances and do not believe that renewable energy should be required in the NCC. They strongly supported the NCC should remain fuel neutral and allow for changes in technology and the decarbonisation of the gas network over time. However it was noted by others in the gas industry that if a requirement is introduced for appliances, the energy rating of flued gas room heaters should be practically capped at 5.0 stars, while ducted (whole of house) gas heaters should incrementally increase from 4.0 to 5.0 stars to allow for a smooth market transition.

The following options, along with the details outlined in the following Chapters, are considered to offer benefits to households while being both cost effective and minimising burden on industry.

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41 The NSW Building Sustainability Index (BASIX) tool checks elements of proposed design against sustainability targets.

Establishing a trajectory

This project recognises strong calls from energy consumer groups and many in the building and building products sectors to improve the affordability of operating new and existing buildings. While this project has identified potential opportunities to improve the affordability of powering new homes, industry has sought greater certainty over the ultimate outcome being pursued. As such, it is recommended that a trajectory towards 'zero energy (and carbon) ready homes' should be set.

Zero energy (and carbon) ready homes have an energy efficient thermal shell and appliances, have sufficiently low energy use and have the relevant set-up so they are 'ready' to achieve net zero energy (and carbon) usage annually if they are combined with renewable or decarbonised energy systems either on-site or off-site. The United States Department of Energy has developed a Zero Energy Ready standard,[42] while a Zero Energy Ready standard is being considered by Canada.[43]

This trajectory would encourage and support industry and the community to adopt more energy efficient design and construction practices, select and install more energy efficient appliances, ensure the building is low energy, highly comfortable, healthy and climate resilient for occupants, and be 'ready' to connect to renewable energy systems when appropriate.

Establishing a trajectory and providing advanced notice of future requirements is especially important as the building and manufacturing sector are subject to long lead times to adjust to any changes. Governments around the world have begun to adopt long-term strategies to deliver highly energy efficient buildings. In many countries, such as the European Union, Japan and Korea, this includes setting national energy efficiency or building sector zero energy or zero carbon targets or goals.

Setting a definitive target for the Australian residential building sector is challenging, as there are many variables that are involved. For example, initial modelling conducted by AECOM indicated that it may be cost effective to achieve a zero energy (or carbon) home for detached houses, however this is more difficult to achieve for apartments due to their smaller roof area for renewable energy generation. Internationally there have also been concerns raised about a performance gap, where buildings are designed to use zero energy, but in actual operation they consume significantly more energy than had been predicted. The concept of achieving zero energy (and carbon) 'ready' buildings can address some of these issues.

Updating each triennial revision of the NCC

Energy efficiency provisions should be substantially updated in NCC 2022 and 2025, before reverting to triennial revisions that ensure provisions keep pace with changing technologies. This would provide greater certainty to industry than the current ad hoc approach and reduce the need for larger NCC changes in the future.

The NCC is an important and established mechanism to deliver minimum performance for the energy efficiency of new homes. Energy efficiency requirements aim to meet the NCC's health and sustainability goals. There are considerable opportunities to increase energy efficiency in the 2022 and 2025 updates to the NCC. Longer term, there should be an expectation of regular adjustments to the annual energy budget to accommodate improvements in appliance performance and changing technologies over time.

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42 www.energy.gov/sites/prod/files/2014/04/f15/doe_zero_energy_ready_home_requirements_rev04.pdf

43 *Pan-Canadian Framework on Clean Growth and Climate Change: Canada's Plan to Address Climate Change and Grow the Economy,* 2016, *page 17*

Aligning the NCC to the trajectory and outlining the step changes for future NCC requirements could encourage the achievement of energy performance beyond current requirements. This has been observed in Denmark where a pathway set in 2010 specified a series of incremental increases in the stringency of building requirements for 2010, 2015 and 2020. When the 2010 minimum requirements were in force, 15 to 20 per cent of Danish building investors elected to build to 2015 or 2020 requirements.[44]

Progressing other initiatives

Whilst application of the NCC aims to improve supply of residential buildings that meet minimum acceptable standards, it is limited to the existing rate of new building and home renovation work that occurs each year.[45] To achieve a transition to zero energy (and carbon) ready homes, a suite of policies is needed.

A number of policy initiatives are currently being progressed and will need to continue to be implemented in collaboration with industry and consumers. These include measures identified in the NEPP and initiatives being implemented by state and territory governments (these are outlined in the following Chapters). However, aligning these initiatives to the trajectory and identifying opportunities for upgrading and improving existing homes requires further investigation.

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44 Energy Efficiency Watch, *Energy Efficiency Policies in Europe: Case Study – Danish Building Code*, 2017, page 2

45 International Partnership for Energy Efficiency Cooperation, *International Review of Regulatory Policies*, 2017, page 25

Opportunities for the NCC and new homes

In conducting the Trajectory project a range of options were identified for improving the NCC and new homes. These are discussed in Appendix C. This section outlines recommendations resulting from this analysis and broad stakeholder consultation.

Based on modelling undertaken for the Trajectory, the recommendations for updating the NCC in 2022 alone could deliver energy savings for households of 1,181 PJ by 2050 (134 PJ to 2030) (see Figure 5) and save 50.9 Mt of carbon by 2050 (6.6 Mt to 2030). This would deliver a net financial benefit to households of $1.7 billion by 2050. Noting conservative capital cost assumptions used in the modelling, even a 2.5 per cent reduction in capital cost could increase the net benefit to $1.9 billion. In addition, a modest uptake of renewable energy generation could increase the net benefit to over $5 billion (see Table 1).

Figure 5: National Residential Sector Energy Savings

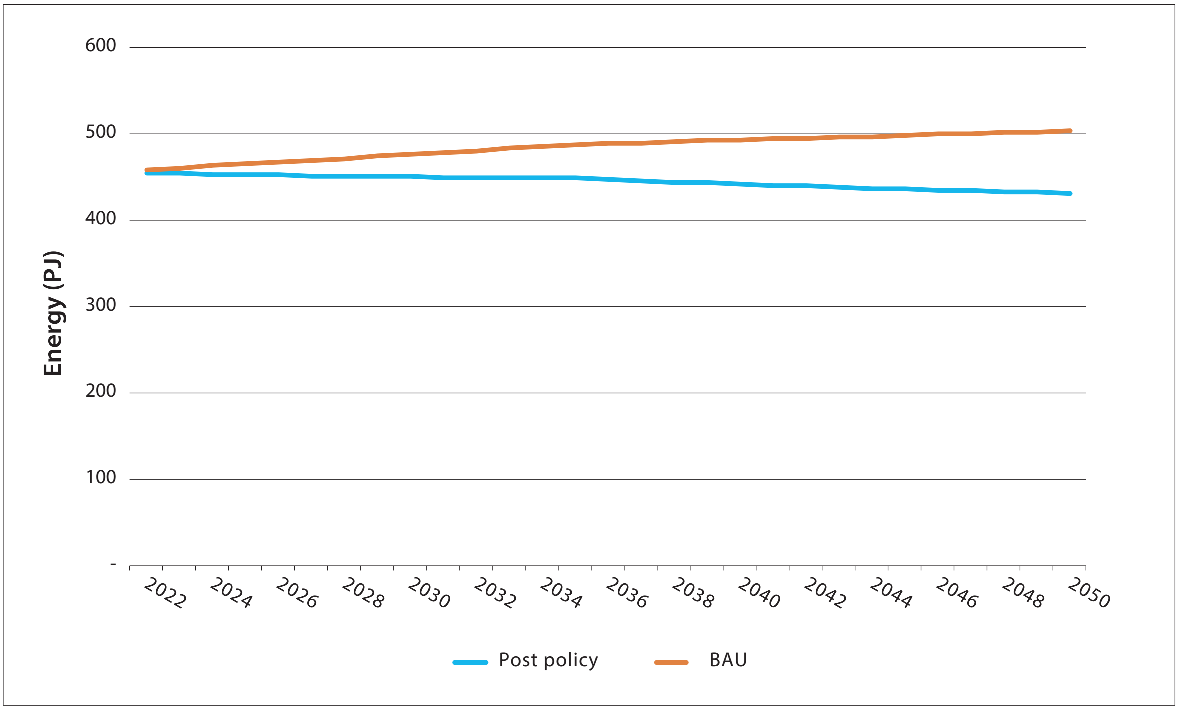

Table 1: Net Present Value of NCC 2022 changes to 2050

	Tailored Approach		Tailored Approach + 2.5% Cost Improvement		Tailored Approach + 10% PV from 2022	
NPV	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio
Australia	*$1,744.78*	*1.22*	*$1,939.03*	*1.25*	*$5,129.58*	*1.61*

Setting a broader objective for energy efficiency provisions in the NCC

The NCC provides the minimum necessary requirements for safety, health, amenity and sustainability in the design and construction of new buildings (and new building work in existing buildings) throughout Australia. In some cases it may also apply to new building work in existing homes. Energy efficiency requirements in the NCC are a key mechanism for delivering the NCCs 'Sustainability' goal, while also supporting its 'Health' and 'Amenity' goals.

The current Energy Efficiency Performance Provision in the NCC states the objective is "to reduce greenhouse gas emissions".[46] While this statement does not place a legal obligation on industry, it sets the policy intent of the energy provisions in the NCC.

The energy efficiency objective in the NCC should reflect the broader policy objectives of energy efficient homes. A narrow climate policy objective especially disadvantages comfort and resilience benefits of improved thermal performance. The policy intent of including energy efficiency requirements in the NCC is, at a minimum, to meet the NCC goals of sustainability, health and amenity. More broadly, the objective is primarily to improve energy efficiency and reduce energy, which has benefits for energy bills, health, resilience and emissions reduction. Therefore the NCC energy efficiency objective should be reviewed to better capture the broad objectives of:

- Lower energy bills for households;
- Save energy (reduce wastage) for the wider economy;
- Improve comfort levels for, and potentially the health of, occupants;
- Improve resilience to extreme weather and blackouts (peak demand); and
- Reduce carbon emissions.

Increasing the building (thermal) and services requirements in the NCC

This project has identified opportunities for energy efficiency improvements throughout the building system, from thermal performance to appliance energy usage and renewable energy. For clarity, these have been specified with regards to their equivalent NatHERS star rating performance and a sample of appliances that could together meet an overall annual energy budget. Setting a final requirement in the NCC would require rigorous further analysis through a RIS to ensure an overall net benefit of greater than 1:1. Other appliances and fuel options with equivalent performance to these should also be allowed and the overall energy usage budget should be influenced by increases in thermal performance beyond minimum requirements, where they reduce space conditioning loads.

Based on feedback received throughout the Trajectory project, a number of scenarios were considered for increasing the building (thermal) and services provisions in the NCC. These are outlined in Attachment C.

46 Australian Building Codes Board, *NCC 2016 Building Code of Australia – Volume Two*, page 86

Class 1 dwellings and Class 3 dwellings

Findings from the various options modelled indicate it is cost effective from 2022 for new Class 1 dwellings to be built to at least:

- Between 6.5 and 7.0 NatHERS stars equivalent in NCC climates 6, 7 and 8;
- 6.5 stars equivalent in NCC climates 1 and 5;
- Up to 6 stars equivalent in NCC Climates 2, 3 and 4
(noting many homes in these climates currently have credits available to build below 6 stars); and
- Total combined energy usage budget for the building and services of 115MJ/m2 equivalent. This was found to be suitable in most climates modelled, however further analysis is needed to determine the final energy usage budget, as it will need to be set at a level that allows for both high efficiency heat pump and high efficiency gas technologies, and be based on geographical and climatic conditions.

In implementing the above requirements for the 2022 NCC update, thermal requirements should be increased to the extent possible while still obtaining an overall net benefit from the measures. Prioritising thermal performance aims to maximise comfort and climate resilience objectives that are difficult to quantify through the RIS process.

Setting climate specific thermal requirements aims to increase national consistency in the adoption of energy efficiency provisions under the NCC. The variation between climates in what was found to be cost effective for households reflects the large variation in climates across Australia. Larger benefits are gained from thermal shell efficiency improvements in Australia's more extreme climate locations (cold or hot), but not in the more temperate climate locations. It is therefore proposed requirements for thermal performance should be based on climate locations and this be further considered as part of the RIS for NCC 2022.

One outcome of this approach is that there would be climate specific variations in energy efficiency requirements within each jurisdiction. Where jurisdictions consider this variation may pose issues for compliance and messaging, NCC 2022 could consider alternate opportunities for varying requirements by jurisdiction rather than climate.

In addition, the optimal thermal performance was found to vary within NCC climate zones. This was especially the case for NCC climate zones 1, 3 and 4, which span the vast majority of Australia. Therefore it is recommended the RIS considers opportunities for each climate to move to up to 7 stars to ensure an optimal outcome is achieved. Improvements not found to be cost effective in 2022 should then be reconsidered again in NCC 2025. While further national increases in thermal performance beyond NCC 2022 may or may not be cost effective in 2025, the move to climate-specific requirements may see localised opportunities that offer a net benefit.

This scenario was found to deliver potential bill savings to new home buyers and their renters of over $650 each year in colder or tropical climates, such as Canberra, Townsville and Darwin, and around $170 each year in more temperate climates, such as Sydney, Melbourne and Adelaide (see Table 2 below). Adding on an average $4,500 to the overall build cost of a new home is small, as it is less than 1 per cent of the national median house sale price of $686,200 in June 2018.[47] However, the capital costs could be less based on research that found the costs of moving up a star could be as low as $18/m^2.[48]

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47 ABS - 6416.0 - Residential Property Price Indexes: Eight Capital Cities, March 2018

48 Moreland Energy Foundation, *Changes Associated with Efficient Dwellings project –Final Report*, May 2017, page 5

An evaluation of capital cost impacts following 2010 changes to the NCC showed that modelled capital cost increases are representative of actual impacts. The RIS for 2010 changes to energy efficiency provisions in the NCC identified that changes would add between $500 and $4,100 to the cost of a new home.[49] A post implementation evaluation of these costs found a median price impact of $2,700, while noting that in reality, house prices vary greatly and 'much of this variation – perhaps most of it – is unrelated to energy performance'.[50] Given the impact on house prices is likely minor when compared with market driven house price fluctuations, the modelling does not consider any reduction in new home constructions as a result of energy efficiency changes in NCC 2022.

The potential energy savings and costs of this scenario in each capital city based on 2018 energy prices and capital costs are summarised in Table 2. Note: the actual payback periods will be notably shorter than appears in this table, as energy prices are forecast to increase over time while capital costs fall, and policy options are not expected to be implemented until at least 2022.

Low appliance capital costs in Melbourne and Canberra are due to the comparatively lower cost of installing 10kW of split systems when compared with ducted gas heating in the base case.

Table 2: 2018 potential household energy bill savings and capital cost in each capital city for Class 1

	NCC Climate	Annual Energy Bill Saving (2018)	Additional Capital Cost (2018)
Darwin	1	$897	$5,564
Brisbane	2	$475	$4,880
Sydney	5	$203	$3,636
Adelaide	5	$179	$3,863
Perth	5	$294	$3,940
Melbourne	6	$141	$3,741
Canberra	7	$770	$950
Hobart	7	$319	$4,796

49 Australian Building Codes Board, *Final Regulation Impact Statement: Proposal to Revise the Energy Efficiency Requirements of the Building Code of Australia for Residential Buildings,* 2009, page 99

50 Moreland Energy Foundation, *Changes Associated with Efficient Dwellings Project –Final Report*, May 2017, pages 5-6

Dwellings modelled with the proposed thermal performance increases were found to consume under 115MJ/m² per year or 13KJ/m² per hour in all climate zones except NCC Climates 1, 3 and 4, when paired with appliances that are cost effective for households (for comparison, the annual energy budget requirement proposed for Class 2 common areas in NCC 2019 is 30KJ/m² per hour). However, energy usage in NCC climate zones 1, 3 and 4 was far more variable within each climate zone, which is expected given they each span most of Australia. For example, Darwin consumed 50 per cent more energy than Townsville, despite both being in NCC climate zone 1. In addition, NCC climate zone 8 was not modelled given the relatively few dwellings constructed in this climate. Based on these findings, it is proposed some further work be conducted to establish a methodology for quantifying an annual energy budget for NCC climate zones 1, 3 and 4, and these energy usage budgets are further considered in the RIS for NCC 2022.

The cost effective appliances used to establish the energy usage budget consisted of a total of 10kW worth of 4 star split system air conditioners, heat pump hot water and an allowance for lighting, cooking and plugged loads. Testing also found that, once adjusted based on the relative carbon intensity of different fuel sources (see the following section on Remaining Fuel Neutral), an energy load of under 115MJ/m² could also be achieved through combinations of 5 star gas space heating and 5 star gas water heating systems, or 4 star split systems with high efficiency heat pump water heating. However, further analysis is needed on alternative high efficiency technologies in all climate zones, including high efficiency ducted reverse-cycle air conditioning and high efficiency "all gas" appliance options. It is likely the energy usage budget will need to be adjusted to accommodate such technologies across the different geographical and climatic zones. This work should be considered as part of the RIS for NCC 2022.

Table 3: Indicative appliance performance for NCC 2022

	Current minimum available performance	Current typical sold appliances	Proposed NCC 2022 appliances
Space conditioning	Electric resistance heaters, 1 star air conditioning and 4 star gas heating	Equivalent to 3.5 star air conditioning and 4 star gas heating	Equivalent to 4 star air conditioning and 5 star gas heating
Hot water	Electric resistance and 4 star gas storage	Electric resistance and 5 star gas instant (gas boosted solar in Vic)	Equivalent to a climate appropriate heat pump or 5 star gas instant
Lighting	Halogen (to be phased out from 2020)	LED, CFL and halogen	No change in NCC (halogens to be phased out from 2020)
Cooking	Electric or gas (no minimum)	Electric or gas (no minimum)	Not specified in NCC
Plugged appliances	Various	Various	Not specified in NCC

When the total costs and savings were modelled to 2050 from increasing the thermal performance of Class 1 dwellings and improving the appliances in a whole-of-house approach, the result delivered a net financial benefit to households as shown in Table 4.

Sensitivity testing showed that Class 1 dwellings are relatively sensitive to the starting capital costs associated with the thermal and appliance upgrades. While NSW achieved a small net cost, even a 2.5 per cent reduction in

capital cost assumptions produced a positive outcome. The conservative cost assumptions used in this modelling was repeatedly raised as a concern by stakeholders throughout consultation and any RIS should include further review of capital cost assumptions.

Table 4: Sector impacts in each jurisdiction for Class 1 dwellings to 2050

			+ 2.5% Cost Improvement		+ 10% PV from 2022	
NPV	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio
NSW	-$45.81	0.98	$2.24	1.00	$519.51	1.31
VIC	$42.77	1.02	$87.42	1.05	$559.35	1.34
QLD	$450.35	1.21	$502.80	1.25	$953.60	1.43
SA	$50.42	1.10	$62.69	1.13	$211.05	1.47
WA	$797.38	1.85	$820.64	1.90	$1,186.89	2.29
TAS	$1.13	1.01	$5.01	1.03	$20.99	1.14
NT	$111.40	2.53	$113.22	2.59	$137.84	2.72
ACT	$239.31	8.29	$240.12	8.50	$265.94	8.10
Australia	*$1,646.95*	*1.22*	*$1,834.15*	*1.25*	*$4,198.52*	*1.53*

Note: The NPVs and Savings to Cost Ratio are based on a 7 per cent discount rate. Figures are indicative and this will need to undergo a RIS process to assess the full costs and benefits associated with the proposed changes.

Opportunities for renewables in the NCC are considered later in this report, but modelling indicates Class 1 results are sensitive to the addition of PV with even a small increase in the uptake of PV, i.e. 10 per cent, more than doubles the projected Net Present Value (NPV).

Class 2 dwellings and Class 4 parts of a building

Modelling to date for Class 2 apartments has found it cost effective at the national level to build to at least an equivalent performance of:

- 7 star average and 5.5 star minimum in NCC climates 7 and 8;
- 6.5 star average and 5.5 star minimum in NCC climates 1, 4, 5 and 6;
- 6 star average and 5 star minimum in NCC climates 2 and 3; and,
- A total combined energy usage budget for the building services that requires appliances equivalent to 5 star gas heating or 4 star space conditioning, and 5 star gas instant or electric resistance hot water systems.

In implementing the above requirements for the 2022 NCC update, thermal requirements should be increased to the extent possible while still obtaining an overall net benefit from the measures. The RIS should consider opportunities for each jurisdiction and climate to move to up to 7 stars average requirements for sole-occupancy units in a Class 2 building, with minimum requirements for any sole-occupancy unit 1 star below average requirements. Improvements not found to be cost effective in 2022 should then be reconsidered again in NCC 2025. Prioritising thermal performance aims to maximise comfort and climate resilience objectives that are difficult to quantify through the RIS process.

On average, Class 2 apartment buildings were found to perform very similar to the proposed requirements for Class 2 common areas in NCC 2019 of 30KJ/m^2 per hour, while noting the differing software and assumptions used for this modelling. Therefore there may be scope to harmonise these requirements. Apartments were modelled to have the following average energy usage, when paired with 5kW of 4 star split air conditioning systems, electric hot water and an allowance for lighting, cooking and plugged loads:

- Under 245MJ/m^2 per year or 28KJ/m^2 per hour in climate zones 5, 6 and 7;
- Under 265MJ/m^2 per year or 30KJ/m^2 per hour in climate zone 2 and 4, as well as in Tasmania;
- Again, an annual energy budget could not be determined in climate zone 1 due to large variation in energy usage, while climate zones 3 and 8 were not modelled in this project.

The slightly higher energy load in Hobart when compared with Canberra (both of which are in climate zone 7), appears due to the assumption that apartments in Hobart have no gas usage. Testing found that, once adjusted based on the relative carbon intensity of different fuel sources (see the following section on Remaining Fuel Neutral), apartments with gas cooking achieve a lower annual energy budget than those with a small electric resistance hot water system. A test using gas hot water also achieved the annual energy budgets.

Analysis found that apartments built to this standard could offer both a modest cost and saving, as outlined in Table 5. This is due to many apartments in a complex already meeting the requirement, which reduces the average cost and savings per apartment. Apartments also have a smaller size and energy consumption when compared with Class 1 dwellings.

Table 5: 2018 potential average apartment energy bill savings and capital cost in each capital city

	NCC Climate	Annual Energy Bill Saving (2018)	Additional Capital Cost (2018)
Darwin	1	$168	$379
Brisbane	2	$47	$841
Sydney	5	$32	$151
Adelaide*	5	Excluded	Excluded
Perth **	5	$0	$0
Melbourne	6	$70	$196
Canberra	7	$21	$200
Hobart	7	$67	$143

** **Excluded:** Note that while energy loads for South Australia have been modelled for the purposes of comparing with other locations, potential costs and savings were excluded. Refer to the RIS titled: Increasing the energy efficiency requirements for Class 2 residential buildings, completed as a jurisdiction based variation to the National Construction Code, commencing 1 July 2019.*

*** Energy efficiency increases in Perth were not found to be cost effective.*

When the total costs and savings were modelled to 2050 of increasing the thermal performance of Class 2 dwellings up to a 7 star average equivalent in some locations based on climate, and improving the appliances in a whole-of-house approach, the result delivered a positive impact overall as shown in Table 6.

While results were mixed for some locations, the very small costs and benefits for this scenario mean the results are within a margin of error and inconclusive. Further modelling is needed in the RIS to determine the net benefit of this scenario. Results for Class 2 have little sensitivity to changes in capital cost, given the smaller capital costs when compared with changes to Class 1 homes. The introduction of on-site renewables does provide a strong positive NPV result at the national level, while noting both physical (limited roof space) and strata issues with introducing renewables for Class 2 buildings. Opportunities for renewables in the NCC are considered later in this report.

Table 6: Sector impacts in each jurisdiction for Class 2 dwellings to 2050

			+ 2.5% Cost Improvement		+ 10% PV from 2022	
NPV	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio
NSW	$40.58	1.78	$41.82	1.82	$303.05	4.50
VIC	$109.33	4.20	$110.13	4.31	$304.24	5.23
QLD	-$16.99	0.86	-$14.00	0.88	$142.31	2.03
SA	*Excluded	*Excluded	*Excluded	*Excluded	*Excluded	*Excluded
WA	-$50.32	0.34	-$48.45	0.34	$35.63	1.53
TAS	$2.55	5.50	$2.57	5.63	$5.28	4.67
NT	$9.19	5.41	$9.24	5.54	$15.81	4.04
ACT	$3.49	1.99	$3.57	2.04	$22.23	4.32
Australia	$97.83	1.34	$104.88	1.37	$931.06	3.11

Note: The above NPVs are based on a 7 per cent discount. Figures are indicative and this will need to undergo a RIS process to assess the full costs and benefits associated with the proposed changes.

**** Excluded:*** *Note that while energy loads for South Australia have been modelled for the purposes of comparing with other locations, potential costs and savings were excluded. Refer to the RIS titled: Increasing the energy efficiency requirements for Class 2 residential buildings, completed as a jurisdiction based variation to the National Construction Code, commencing 1 July 2019.*

Setting a performance requirement in the NCC

Volumes 1 and 2 of the NCC, while organised differently, currently set energy efficiency performance requirements for homes based on 'Building' (thermal) and 'Services' (appliances) requirements. In addition, Volume 3 sets performance requirements for heated water services. Services requirements primarily relate to lighting and pool pump energy usage, while Volume 1 also captures requirements for Class 2 common areas.

Climate or jurisdiction-specific requirements

It is recommended that a climate or jurisdiction-specific annual energy budget should be quantified as an energy efficiency performance requirement in the NCC. This should consist of the energy usage from appliances already considered in the NCC (lighting, water heating and pool pumping), with the addition of space conditioning, which should also be influenced by increases in thermal performance beyond minimum requirements, where they reduce space conditioning loads.

While this report found total home energy usage (including cooking and plugged appliances) of 115MJ/m^2 for Class 1 and up to 265MJ/m^2 for Class 2 could be achieved for many climates, specific values for NCC 2022 should be developed as part of the NCC change process that achieve the thermal and appliance performance outcomes specified in the previous section on increasing the building (thermal) and services requirements in the NCC.

Also, based on the large variation identified in energy usage within each climate zone, further analysis is needed on whether the NCC climate zone boundaries require adjusting, or additional zones added to reduce this variation in energy requirements. This is particularly the case in northern Queensland, which consistently required less energy than Darwin and Broome, all of which are in climate zone 1. Consideration should also be given to whether requirements should vary by jurisdiction rather than climate zone, simplifying compliance for industry.

In addition to the annual energy budget, a thermal performance requirement should be retained. Under this project, quantifying a single thermal load requirement was not achieved and it was more successful to model requirements in each climate zone by NatHERS star bands. This is due to thermal load allowances under NatHERS star bandings varying considerably within each NCC climate. Therefore retaining a qualitative requirement is recommended, which aims to tailor to thermal needs of each climate and enable homes to be designed appropriate for their climate.

Remaining fuel neutral

Consultation with industry has highlighted the importance of setting an energy performance requirement that is fuel neutral. While some stakeholders proposed a shift towards full electrification, the NCC should remain flexible to the changing costs, emissions and energy efficiency of different fuel types over time. Analysis of possible metrics was tested with stakeholders and many considered that a carbon metric offered the best potential to remain fuel neutral. This is reflected in current water heating provisions in NCC Volume 3, BP2.8, which has requirements for CO_2-e per MJ.

However, it is proposed that a delivered energy metric is most appropriate for measuring energy efficiency requirements in the NCC, consistent with those already proposed for Class 2 common areas in Section J (measured in KJ/m^2 per hour). Alternatively, Section J could be redefined in a MJ/m^2 per year value to maintain consistency with existing residential thermal requirements. Both metrics would be mathematically identical in

practice and should not impact on the outcome. This project has primarily reported in MJ/m^2, although consideration of reporting in KJ/m^2 per hour and demonstrating this is achieved, could benefit in delivering on the peak demand objective.

To accommodate different fuel sources, the proposed annual energy budget could include a conversion factor for different fuels based on their relative carbon intensity. This approach is similar to that applied to the South Australian Retailer Energy Efficiency Scheme,[51] while focussing the conversion factor on carbon intensity gives an equivalent outcome to the carbon metric often favoured by stakeholders. In addition to electricity and natural gas, stakeholders highlighted the importance of conversion factors for bottled gas, biogas and wood, to ensure other appliances and fuel options with equivalent performance are allowed under NCC 2022. If adopted, the conversion factors should be updated with each triennial revision of the NCC to reflect relative changes in carbon intensity of each of these fuel sources over time, especially noting ongoing work to decarbonise electricity and gas networks.

As a guide, the conversion factors shown in Table 7 were developed based on the forecast relative carbon intensity of different fuels in 2022. This is based on national average carbon intensity, which may differ from specific regions around Australia based on the fuel mix of electricity. Consideration should be given to a jurisdiction based conversion factor for NCC 2022.

Under these factors, both electric and gas appliance configurations were found to satisfy the indicative annual energy budgets of $115MJ/m^2$ for Class 1 dwellings or up to $265MJ/m^2$ for Class 2 dwellings.

Table 7: Fuel Conversion Factors

Fuel Type	Conversion Factor[52]
Electricity	1.000
Natural Gas and LPG	0.239
Wood and Biomass	0.006

For example, based on the above conversions, $100MJ/m^2$ of natural gas usage would contribute $20.3MJ/m^2$ towards the total annual energy budget, while the equivalent usage of wood would contribute only $0.5MJ/m^2$ towards the total annual energy budget. While this approach could incentivise wood, a rapid uptake is not expected given its higher ongoing running costs. Further analysis will be needed to establish the actual conversion factors that are appropriate.

51 SA Department of State Development, *Consultation Paper on Proposed REES Thresholds, Metrics and Activity Specifications,* August 2014, page 8

52 Conversions are based on the Australia's emissions projections 2016, forecast electricity combined scope 2 and 3 emission factors EFs in 2022-23 of 214.7 kg CO2-e/GJ and the Commonwealth National Greenhouse Accounts Factors 2017, natural gas distributed in a pipeline emissions of 51.4 kg CO2-e/GJ (table 2) and dry wood of 1.2 kg N2O/GJ (table 1)

Accounting for larger or smaller homes

In quantifying the performance requirement, further analysis is needed to ensure small homes are not disadvantaged despite using less energy, which is the key objective. While energy usage from space conditioning and lighting can reasonably be assumed to vary with the size of the home, changes in hot water, cooking and plugged appliance usage varies with the number of household occupants. There is a risk that a MJ/m^2 requirement may make it comparatively more difficult to achieve compliance for a smaller home than a larger home, which is inconsistent with the objectives to lower household energy usage and bills.

The NatHERS pathway currently seeks to manage this risk through an area correction factor for space conditioning. For other appliances, this risk could be managed by not introducing cooking and plugged loads into the overall energy requirement in NCC 2022 and reducing the annual energy budget accordingly. This would have minimal impact on the built outcome as there are limited opportunities for energy savings in cooking, and plugged loads are not covered by building regulations in most jurisdictions. However, this issue may need to be reconsidered in the future if any requirement is considered to offset total home energy usage with renewables.

Verifying compliance and including whole of building tools in the NCC

The NCC is a performance based code, whereby the mandatory performance requirement specifies the minimum level of performance for energy efficiency provisions (among others), which can be satisfied by:

- A Deemed-to-Satisfy Elemental pathway, which consists of prescriptive examples of materials, products, design factors, construction and installation methods and if followed in full are deemed to comply with the Performance Requirements of the NCC; or
- A Deemed-to-Satisfy NatHERS pathway, which consists of a modelled approach and if the NatHERS star rating is achieved it is deemed to comply with the Performance Requirements of the NCC; or
- A Performance Solution, such as Verification Using a Reference Building, which is any solution that can meet the Performance Requirements, other than a Deemed-to-Satisfy Solution.

Deemed-to-satisfy: elemental

For 2022 the simplest form of implementation for the increased requirements is through updating existing thermal verification methods, redefining the hot water provisions around the new energy metric, and extending Deemed-to-satisfy (DtS) Elemental provisions to cover space conditioning energy usage. A maximum wattage per m^2 of capacity or kWh/m^2 energy usage could be considered for residential space conditioning requirements. When combined with existing lighting and pool pump verification methods, this approach offers clarity for industry and building certifiers.

While industry has expressed support for including an elemental approach to verification in NCC 2022, many called for provisions to be simplified to improve clarity and compliance. However simplification of the thermal DtS elemental provisions could potentially result in large variation in performance. To maintain the policy objectives, these risks could be managed by having the provisions simplified and set at a point that ensures if there is variation of performance it primarily results in over-performance rather than under performance. For example, variations in thermal performance could be reduced by requiring a proportion of living area and kitchen glazing to face within 30 degrees of north.

A risk that requires further consideration under a DtS elemental approach is how compliance can be assured. Building plans may need to document the maximum allowed system for the home. Consideration must also be given to options that prevent the delay of installation until after the final building inspection, in order to avoid having to meet the minimum requirements. This could be managed through requiring homes to meet a higher thermal performance requirement where they do not intend to have space conditioning, to ensure health and comfort is maintained for occupants.

Deemed-to-satisfy: NatHERS

Many in industry have sought greater flexibility to find innovative solutions to meet the minimum requirements. This is most effectively achieved through the use of whole-of-home modelling tools. Therefore, the DtS NatHERS verification pathway should be expanded to capture the services performance requirements through NatHERS accrediting whole-of-home modelling tools.

There are already a number of whole-of-home modelling tools that exist in the market that have incorporated NatHERS thermal performance modelling into their methodology, as set out below. These tools could potentially be used for regulatory use under the DtS NatHERS verification pathway. A review of these tools would ensure they produce equivalent building outcomes to those assumed when setting the performance requirement, noting the proposed annual energy budget has been established based on different settings to those currently used by NatHERS in regulation mode (refer to Appendix C for details).

The following tools could be considered to verify compliance with NCC 2022 requirements, with an immediate focus on ensuring solar passive design, space conditioning, hot water and lighting, in order to deliver a whole-of-home modelling verification method for 2022.

- BASIX – Introduced by the NSW Government in 2004, BASIX is a web-based planning and regulatory assessment tool. BASIX has broad industry support as a regulatory tool in NSW and could be adapted for national use. While it sets minimum required reductions of greenhouse gas emissions (GHG-e) from all new residential buildings in NSW, outputs could also display modelled energy loads. BASIX also mandates the minimum thermal performance from the building fabric, based on NatHERS assessments or a do-it-yourself approach.
- AusZEH – Developed by CSIRO, this tool is an expansion of AccuRate (currently the NatHERS Benchmark Tool) and can assess the thermal shell, appliances and on-site renewable energy supply system.
- The Scorecard – The Victorian Residential Efficiency Scorecard is a voluntary home energy rating tool. This Victorian Government program is about to undergo testing in all capital cities, supported by the NEPP. The Scorecard is being developed such that it recognises NatHERS ratings, and rates homes on a 10-star scale, representing average energy cost. It covers thermal performance, fixed appliances and solar PV. Hot weather rating, ratings for main home features and upgrade options are also included. The Scorecard can be used for new homes, renovations, or existing homes where information can be discovered on walk through. This creates a simpler version of a rating than NatHERS, but has been correlated against NatHERS to confirm the two tools are consistent, such that a home with a good NatHERS building shell rating should also rate well under the Scorecard building shell elements.
- Other NatHERS tools – CSIRO is currently working with third party software tool providers to develop new whole-of-house modelling tools.

Apartment building common areas should continue to be progressed as part of increases to commercial energy efficiency requirements. Verifying energy efficiency requirements for apartment building common areas are currently achieved through an elemental approach. The NABERS for Apartment Buildings tool presents an opportunity to offer a performance based approach to verifying compliance with common area requirements through a base building commitment agreement. Performance requirements should continue to increase with commercial provisions. One approach could be to leverage the NABERS for Apartment Buildings tool, while ensuring the tool's carbon outputs deliver on a possible energy (and carbon) performance requirement in the 2022 update to the NCC.

- NABERS for Apartment Buildings – Introduced by the NSW Government in 2018, NABERS for Apartment Buildings provides operational performance ratings for shared assets. NABERS ratings use measured and verified building information, such as utility bills, and converts it into a performance rating from one to six stars for the shared services of the apartment.

Opportunities for renewables in the NCC

In addition to being zero energy (and carbon) ready, new homes should have the capability to accommodate on-site renewable energy generation and storage, by considering infrastructure (such as electrical conduit) and ensuring adequate roof spaces, pitch and orientation available for future placement of infrastructure (eg. PVs). Where practical and cost effective, opportunities should also be considered for setting an even tighter annual energy (and carbon) usage budget for Class 1 and 3 buildings, and Class 2 common areas, with flexibility to achieve the additional performance through on-site renewables (possible with batteries) as well as increased thermal or appliance efficiency. For example, the energy usage budget could be tightened from 115MJ to 100MJ and the extra 15 MJ achieved by increased thermal efficiency beyond the minimum thermal requirement, increased efficiency of appliances, or through on-site renewable energy generation (note: this is an example only and the actual energy usage budget will be determined based on the outcomes of a RIS). Decarbonisation of the gas and LPG sectors could also assist in meeting a more stringent annual energy (and carbon) usage budget by reducing the gas conversion factors.

This should not allow any trading off renewable generation against the thermal or appliance efficiency requirements in previous recommendations, to ensure that renewable energy is not a pathway to facilitate lower performing buildings. On this basis, introducing ten per cent renewable energy offset could offer a large increase in net financial benefit for households of $4.2 billion and provide greater flexibility in cost effectively meeting the energy efficiency requirements.

However, further analysis is needed before renewable energy is introduced into the NCC. One consideration will be ensuring the renewable industry is equipped to meet any increased demand. In 2017, there were approximately 1.7 million rooftop solar systems in the National Electricity market, up from 14,000 in 2008.[53] This is an average of around 170,000 new systems each year and growing. With 108,000 new detached houses forecast to be built in 2022, a rapid uptake of solar amongst these new homes could pose considerable risks for the solar industry to meet this demand, if they are to maintain quality and safety.

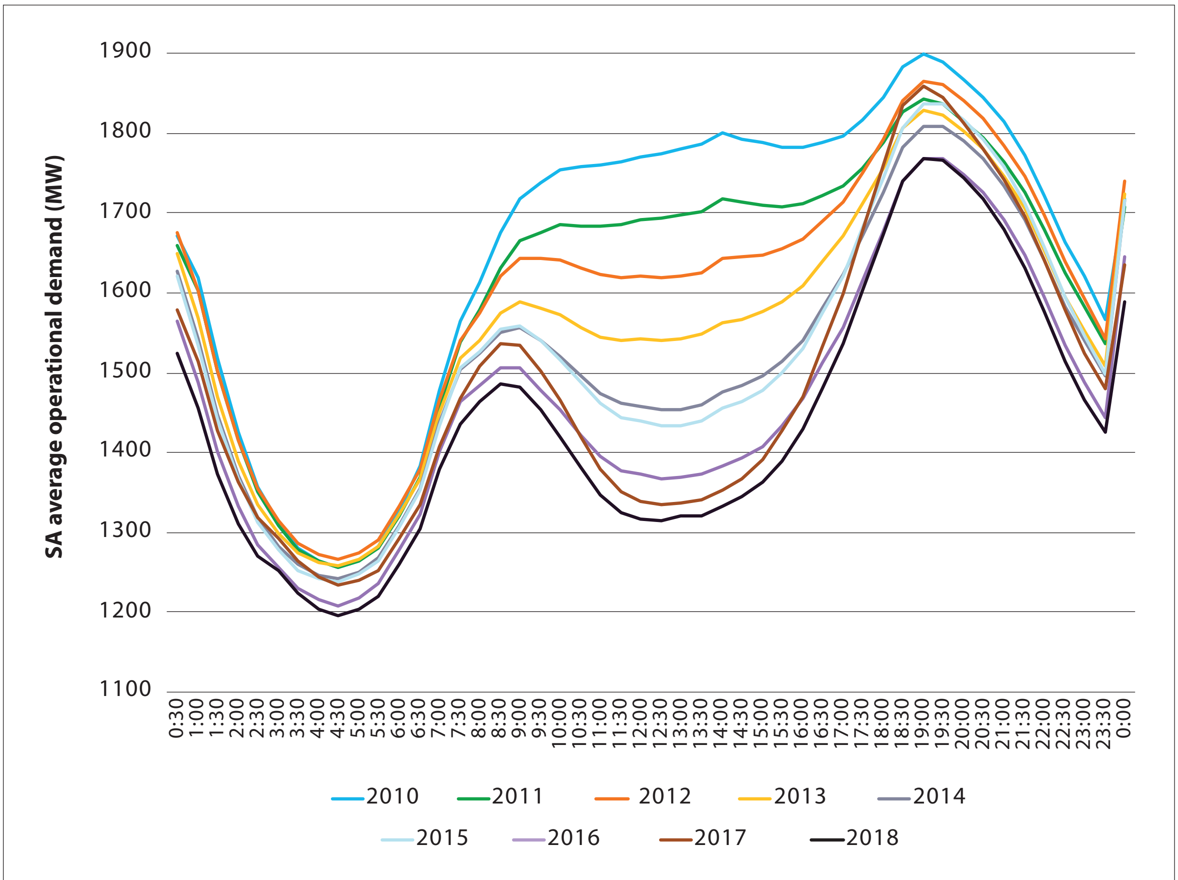
Consideration should also be given to whether renewable energy requirements would drive a shift to full electrification and the potential grid impacts from doing this. The output from solar generation peaks during the middle of the day when residential electricity demand tends to be quite low. This can lead to load shifting

53 Australian Energy Market Operator, AEMO observations: Operational and Market Challenges to Reliability and Security in the NEM, March 2018, page 19

challenges where batteries are not installed.[54] In California, the Public Utilities Commission has been leading studies on grid integration costs, which can be quite significant.[55] In 2018, the Australian Energy Market Operator (AEMO) found the uptake of solar in South Australia has greatly reduced average daily electricity demand while having only a modest impact on peak demand (Figure 6).[56] It found these low demand periods can create challenges for maintaining minimum levels of generation available to respond to peak demand and at some levels may cause voltage changes. The NCC can assist by improving climate resilience of homes through improved thermal performance and appliance energy efficiency, which can reduce peak demand. Greater analysis should also be undertaken on the role of batteries to reduce peak demand.

Time-of-use pricing is being rolled out throughout Australia, which may reduce this risk to some degree, however solar access, the relative economics of requiring solar for gas-powered homes given relatively lower feed-in tariffs and the ability of apartments to offset energy usage onsite, are also challenges that need to be overcome.

Figure 6: Effect of rooftop solar on SA average grid electricity demand



Source: Australian Energy Market Operator

54 www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

55 See more information at: www.cpuc.ca.gov/ZNE/

56 Australian Energy Market Operator, AEMO Observations: Operational and Market Challenges to Reliability and Security in the NEM, March 2018, page 6

Opportunities for building sealing, ventilation, lighting, split heating and cooling, and electric vehicle charging requirements

There are potentially additional opportunities for improving the performance of buildings that have not been modelled as part of this report. It is proposed these be considered as part of the RIS process.

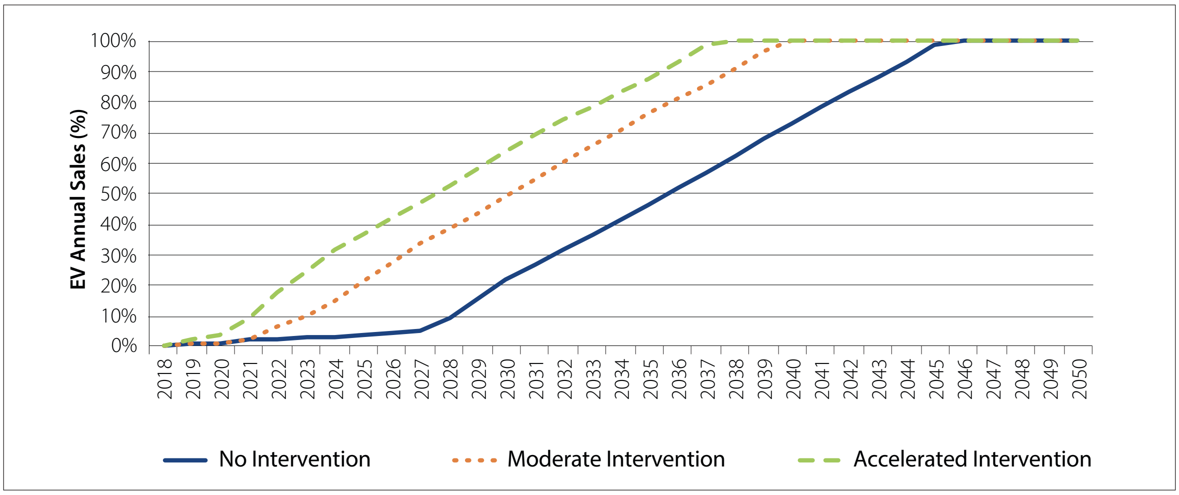
The ASBEC and ClimateWorks *Built to Perform* report considered some of the lowest cost opportunities for improving thermal performance were through increasing building sealing. This should be investigated for NCC 2022, while ensuring there are no adverse impacts on condensation and indoor air quality. This would include the ABCB continuing to review and monitor ventilation issues more broadly following on from their proposed changes to the NCC in 2019 in relation to this issue.

The modelling for this project assumed households install LED lighting as a base case assumption for new housing, while the *Built to Perform* report considered there are opportunities to support this outcome by lowering maximum energy usage per m^2 in the NCC. This should be considered as part of the NCC update in 2025, which should stage changes in energy efficiency requirements for lighting through the NCC in alignment with the Minimum Energy Performance Standards (MEPS) being introduced through the Greenhouse and Energy Minimum Standards Act. In April 2018, COAG Energy Council agreed to improve lighting energy efficiency regulation by phasing out inefficient halogen light bulbs and introducing MEPS for LED light bulbs in line with European Union standards, from 2020.

Based on the substantial benefits identified in the RIS for including requirements for split heating and cooling loads in the NCC 2019 version, there are potentially additional benefits for further increases to these load limits from what has been modelled in this Report. This should also be considered as part of the RIS process for NCC 2022.

For electric vehicles, the 2018 Australian Electric Vehicle Market Study by the Australian Renewable Energy Agency, the Clean Energy Finance Corporation and Energeia, found electric vehicles could make up 50 per cent of new car sales in 2030 under a moderate government intervention scenario (see Figure 7). NCC 2022 changes should consider fitting garages and car parking facilities with an electrical conduit and placement for future provision of electric vehicle charging infrastructure, especially for Class 2 apartments where the cost of retrofitting could be particularly high given the high electrical loads needed to charge multiple vehicles concurrently.

Figure 7: Forecast annual electric vehicle sales



Source: Energeia Modelling

Other initiatives for new homes

Stakeholder feedback has frequently commented that changing requirements in the NCC in 2022 is not enough to meet the desired objectives. Other measures are needed to support industry and ensure compliance outcomes.

In mid-2017 the Building Ministers' Forum tasked Professor Peter Shergold AC and Ms Bronwyn Weir to undertake an assessment of the effectiveness of compliance and enforcement systems for the building and construction industry across Australia. They found that jurisdictions and industry bodies have been facing growing challenges in ensuring effective compliance with, and enforcement of, the NCC.

These findings were consistent with a study conducted in 2014, which found that many stakeholders in the building industry, representing professions throughout the supply chain, acknowledged skills gaps within their own ranks.[57] These were attributed to a lack of training, mandatory accreditation and auditing / compliance checking by regulators. The NCC itself was also considered to be excessive in its complexity.[58]

NEPP Measure 32: Increasing Compliance with the NCC

This Trajectory for Low Energy Homes, and the work of the Buildings Ministers' Forum, should be supported through governments working with industry to educate and train participants in the building supply chain to deliver energy efficiency outcomes.

Through NEPP Measure 32, Australian governments have been collaborating with industry to improve compliance with current building energy efficiency regulation through the:

- Provision of information, education and training to lift the capabilities of all relevant professionals and trades involved in the whole building development lifecycle (such as through the *Your Home* initiative); and
- Development of tailored compliance tools for building certifiers and government regulatory agencies to meet specific state and territory regulatory and administrative needs.

Further research

Stakeholders have also raised a range of additional areas that would benefit from further research.
This includes:

- Consideration of buildings being resilient in heatwaves and maintaining comfortable temperatures within the home.
- Climate files used in assessment tools that are based on future climate forecasts.
- Embodied energy and lifecycle impacts and considerations.

57 Pitt&Sherry: National Energy Efficient Building Project Final Report, November 2014, pages 44-45
58 ibid.

Options for existing homes

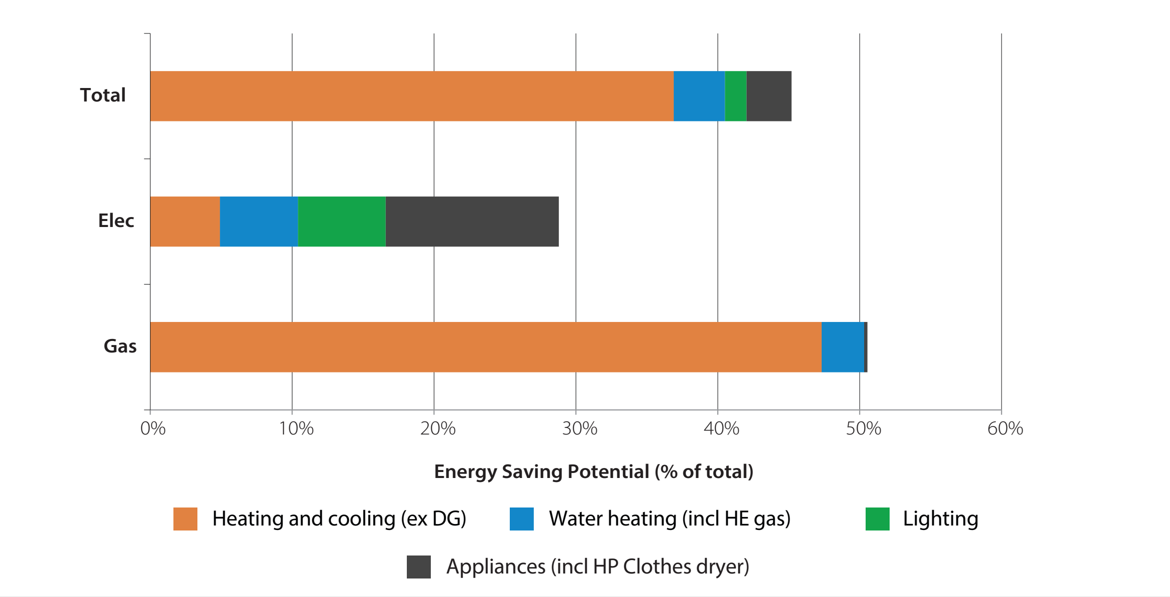
While in some cases the NCC may apply to new building work in existing homes, most existing homes will not be impacted by changes in the NCC. Existing homes represent the largest potential for energy savings in the residential sector. Based on modelling at Appendix C, approximately 55 per cent of Australia's total residential building stock is forecasted to be impacted by proposed NCC changes by 2050. This leaves an estimated 7 million homes not impacted by the NCC – resulting in missed opportunities to harness further energy savings.

The vast majority of Australia's housing was built before the introduction of minimum energy efficiency regulations for residential buildings in 2005. This means existing (pre-2005) housing will continue to pose large energy costs, health and emission issues for households, regardless of minimum standard increases in the NCC.

A 2015 study of 60 existing (pre-2005) houses by Sustainability Victoria found the average House Energy Rating (HER) of houses constructed prior to 1990 was around 1.5 Stars and the average HER of the houses constructed between 1990 and 2005 was around 3 Stars – considerably less efficient than the 6 Star houses constructed today. These existing houses had inefficient thermal performance, and the lighting and appliances were considerably less energy efficient than new lighting and appliances available today.[59] The average cost of increasing the performance of these houses to an equivalent 5 Star rating was between $11,405 and $24,742. The average cost of upgrading the pre-and post-1990 houses was similar.[60]

Sustainability Victoria's analysis showed that the total energy saving potential from energy efficiency measures modelled was 45.2 per cent of total energy use, 50.5 per cent of total gas use and 28.8 per cent of total electricity use, as demonstrated in Figure 8.[61]

Figure 8: Estimated energy saving potential of study houses



Source: Sustainability Victoria

59 Sustainability Victoria, Energy Efficiency Upgrade Potential of Existing Victorian Houses, December 2015, page 6
60 Sustainability Victoria, Energy Efficiency Upgrade Potential of Existing Victorian Houses, December 2015, page 7
61 Sustainability Victoria, Energy Efficiency Upgrade Potential of Existing Victorian Houses, December 2015, page 8

Based on initial modelling conducted as part of this Report (outlined in Appendix C), by improving the performance of existing buildings by a relatively small amount, the energy savings and benefits nearly double. For example, by improving the existing house stock by just 1 per cent could deliver an additional $1.5 billion in net present value. Note, this initial analysis has not captured all of the potential savings from Australian government initiatives outlined in the following section.

Current NEPP measures

NEPP measures that are currently being implemented to improve existing buildings that are relevant to this Trajectory include:

Measure 2.1: Market mechanisms to capture societal benefits - Jurisdictional schemes

Jurisdictional energy savings schemes reduce household energy bills, reduce greenhouse gas emissions and put downward pressure on demand in the wholesale energy markets. Australian governments have been working together to improve and maximise the benefits to consumers from the respective energy savings or energy efficiency schemes. This includes aligning activities and reducing red tape where appropriate, while ensuring that schemes continue to deliver the high quality outcomes, and further expand opportunities for consumers to reduce their energy costs, and continue to grow jobs and skills in each state or territory's energy efficiency sector.

Measure 3: Making choice in energy services easier

Australian governments recognise the current market transition with increasing choice in energy services, tariffs and technologies can provide strong consumer benefits. However, this greater choice also increases complexity and could increase risks of bill shock for some consumers. Choice needs to be supported by the right tools and customer information to avoid adverse impacts.

Australian governments have been working on a number of projects that support the improvement of tools to help simplify energy choices and continue to spur innovation in terms of energy products and services.

Measure 4: Supporting best practice services for vulnerable consumers

Low-income consumers are particularly vulnerable in the transitioning energy market. They are facing a combination of rising energy prices, low wage growth, and have a limited capacity to address the increased complexity of decisions in regards to energy usage. This risks further increasing the likelihood that low-income consumers will experience energy poverty unless they receive support specifically tailored to their needs.

Australian governments have been working with Energy Consumers Australia and other stakeholders to reduce the barriers to vulnerable consumers effectively engaging with energy productivity measures and services.

Measure 5: Improving residential building ratings and disclosure

Most Australians are unaware of how their homes perform, the benefits of energy efficiency, and the options for improvements. Home buyers and renters need better information about their home's energy performance when they are choosing homes or renovating, expressed in terms of their likely energy bills, comfort and liveability. It is also important for the building sector to have easy to use, clear and comparable tools. Building on the COAG Energy Council's agreement to a national collaborative approach to residential building ratings and disclosure, jurisdictions are sharing information about existing and proposed schemes in each jurisdiction to inform future policy development, including testing Victoria's Residential Efficiency Scorecard assessment tool.

Measure 30: Delivering a new Equipment Energy Efficiency (E3) prioritisation plan

Through the E3 program, governments are increasing the energy efficiency of new appliances and equipment through mandatory energy performance standards and the energy rating label. Appliance regulations save the average Australian household between $140 and $220 on their electricity bill each year (about 10 to 15 per cent of the average annual bill).

The E3 work program has been prioritised to ensure that opportunities to save energy, lower energy costs for households and business and reduce greenhouse gas emissions, are realised as soon as possible. The E3 work program includes new and enhanced regulations for air conditioners, domestic refrigerators and freezers, hot water systems, industrial products, lighting, non-domestic fans, refrigerated storage and display cabinets, swimming pool pumps and televisions.

Finkel 6.6: Improving access for low income households to distributed energy resources and energy efficiency programs

The Independent Review into the Future Security of the National Electricity Market (the Finkel Review) Recommendation 6.6 identified the need to improve access for low income households to distributed energy resources and energy efficiency programs. Recognising that many jurisdictions already have measures in place to support low income consumers, Australian governments are working to consolidate jurisdictional learnings, summarising existing measures at the Commonwealth, state, and territory levels, and identifying opportunities for further action.

Current state and territory measures

State and territory governments also have a range of initiatives to improve existing buildings that are relevant to this Trajectory. These include:

Australian Capital Territory:

- NEPP Measure 2.1: The ACT Energy Efficiency Improvement Scheme has new residential heating "heat pump" upgrade activities along with ongoing LED commercial lighting upgrade activities.
- NEPP Measure 4: Following the successful ACT Public Housing trial program in 2017-2018 to upgrade heating and hot water systems, a new ACT (Public) Housing program will upgrade and replace heating systems with high efficiency reverse cycle air conditioning heat pumps, with demand response capability, over the next 5 years in a percentage of ACT's public housing.
- NEPP Measure 4: The Actsmart - Low Income Solar program has had strong take up, while the Actsmart low income household programs continue to deliver.
- NEPP Measure 11: The ACT Government has begun a three year Innovative Financing project to reduce barriers to utilising smart financing for energy efficiency upgrades in the ACT.
- NEPP Measure 13: The ACT's Next Generation Energy Storage program continues to have good take up and is driving investment in "smart batteries" across the ACT. This has led to an energy distributor partnering with the ACT Government and 400 households, who now own "smart" batteries mainly through this ACT program, to participate in a city wide virtual battery demand response trial.
- NEPP Measure 31: The first ACT "gas free" all electric, solar PV new residential suburb trial has been announced.
- The ACT is also reviewing its existing residential energy efficiency disclosure scheme and investigating options for improving the energy efficiency of rental accommodation in the Territory.

New South Wales

The NSW Government Climate Change Fund is funding the following initiatives:

- $15 million for up to 3,400 low-income households opting to receive a 2.5 kW solar power system if they forgo their low income household rebate.
- $24.5 million for more than 20,000 low-income renters to upgrade lighting, heating and hot water systems.
- $50.2 million for up to 16,500 dwellings in community, public and Aboriginal housing to upgrade items such as heating, cooling, hot water, lighting, insulation, sealing and solar PV; up to 4,500 energy hardship customers to receive solar PV systems and improve energy use knowledge; at least 23,000 households to replace old inefficient fridges and TVs with new energy efficient models.
- $30 million for up to 140,000 households to upgrade fixed appliances such as lights or heaters.

South Australia

- Retailer Energy Efficiency Scheme (REES): This scheme is trialling the Victorian Residential Efficiency Scorecard as part of the REES low income audits targets.
- Household Storage Subsidy Scheme: $100 million will support the installation of approximately 40,000 energy storage systems in South Australian homes, assisting customers to access the benefits of battery storage technology.

Tasmania

- The $40 million Tasmanian Energy Efficiency Loan Scheme provides no-interest-loans of up to $10,000 for households and small businesses to purchase energy efficient equipment and appliances.
- The $750,000 On-farm Energy Audit and Capital Grant Program provides up to $20,000 for farmers to undertake audits of stationary energy uses and/or irrigation systems and to co-fund energy efficient capital upgrades.
- A business and government energy efficiency audit program to assist small and medium sized businesses and government agencies better understand their energy use and access funding support for capital upgrades.

Victoria

- The Victorian Energy Upgrades program provides households (and businesses) with access to discounts for a range of energy efficient products. The program works by setting a state-wide target for energy savings that results in a range of energy-efficient products and services being made available to homes and businesses at a discount.
- Through the Solar Homes program, rebates are available for around 24,000 eligible households to install solar photovoltaic panels on their home. From 19 August 2018 eligible households will only have to pay 50 per cent of the cost of a solar panel system, up to a maximum rebate of $2,225. The rebate is available through Solar Victoria. In addition, a rebate of $1,000 for the purchase and installation of solar hot water systems is available for around 6,000 eligible households.
- $16.9 million has been invested towards a number of programs to retrofit the homes of 3,300 low income households. One program is Healthy Homes that provides free home energy upgrades to up to 1000 vulnerable Victorians who live with complex healthcare needs, and have low incomes, in Melbourne's western suburbs and the Goulburn Valley.
- The Victorian Residential Efficiency Scorecard is a voluntary home efficiency rating tool. Householders who are interested in understanding more about the energy performance of their home can contact a private provider and arrange for a rating assessment. The provider collects data on site and calculates a star rating. With the help of the Scorecard tool, the assessor can also offer suggestions for cost effective energy improvements to the home.

Queensland

Queensland has a number of programs targeting low income householders, including:

- Solar for Renters: $4 million program that is scheduled to commence in 2019 providing rebates to landlords to install solar PV systems on their rental properties.
- Energy Savvy Families: Provides digital meters to eligible low-income families in regional Queensland, together with energy efficiency information to help them gain a greater understanding of when and how they use their electricity. They are investing a further $4 million to extend the program to a further 4000 low-income households.
- Solar for public housing trial: Indigenous Community Lockhart River is benefiting from a 200 kilowatt rooftop solar farm with a battery storage system which has been integrated into the diesel-powered network. The rooftop solar farm provides 10 per cent of the community's electricity supply and aims to offset thousands of litres of diesel fuel usage with cheaper solar electricity. The Cairns and Rockhampton

Sunny Savers trial has over 800 public housing tenants signed up to benefit from a solar power purchase agreement to access cheaper solar electricity. Participants in the Sunny Savers trial can save up to $250 on their annual electricity bill. The Logan part of the trail is expected to the rolled out in 2019.

- Interest Free Loans for Solar and Storage: This program includes up to 3500 solar assistance packages offering an interest free loan of up to $4500 over seven years to eligible households. Eligible households must have spent over $1000 in the last six months on electricity, and be receiving Family Tax Benefit B.

Other opportunities identified through consultation

In addition to the previously noted Measures, advocacy groups have called for consideration of other policies to improve existing buildings some of which include:

- Introducing mandatory energy efficiency standards for rental properties, phasing in rooftop solar systems, and provision of tax incentives to support upgrades;
- Investing in best practice energy efficiency and renewable energy for all new public housing builds;
- Funding ongoing programs for low-income and disadvantaged households to provide access to energy-efficient knowledge, products and renewable energy;
- Prioritising renewable energy and energy efficiency for remote Indigenous communities; and
- Piloting new technologies.

Based on initial findings from the modelling in this report, existing (pre-2005) homes offer the greatest potential for energy efficiency improvements. However, due to time limitations for this trajectory project, further investigation is needed to identify the policy opportunities to harness these potential savings from existing homes. It is therefore proposed this investigation be undertaken and presented to the Council for consideration in late 2019.

Appendix A: Summary of consultations

In developing the Trajectory for Low Energy Homes, an extensive consultation process was undertaken. A Stakeholder Reference Group (SRG) was established to discuss possible policy options for the trajectory. The SRG comprised of 198 industry stakeholders and 76 government stakeholders. Five teleconferences and eight workshops were held in a number of Australian cities, while one-on-one meetings with stakeholders were held where requested to discuss details specifically relevant to their organisation and/or industry.

The purpose of the SRG was to ensure the final policy measures are acceptable and suitable for implementation. More than 100 written submissions were received on a variety of issues. Below is a small collection of quotes received on key issues.

The Problem

The majority of feedback received throughout the process agreed there needs to be stronger energy efficiency measures for Australia's residential buildings.

> *"Reducing peak demand has overall system benefits through lower wholesale, transmission and distribution network costs. Therefore, ensuring that minimum standards also contribute to reducing peak demands should be included."*
>
> *"The energy efficiency of the home should be focussed on the building envelope but also consider life cycle energy of different materials within the building envelope."*
>
> *"The NCC should also explore adaptation of Australian households to heat waves."*
>
> *"Improved energy efficiency can provide significant benefits to people on low incomes, such as lower energy bills, improved health and wellbeing, increased resilience to climate change, while also reducing emissions."*

The inclusion of existing homes was raised by a large number of stakeholders, as were measures for rental homes and those with low-incomes.

> "*Ultimately the target for the sector should cover all homes – new and existing. While the draft paper focuses on the 52 per cent of residential buildings that will be built after 2019, the fact remains that almost half of 2050 buildings exist now. These must be dealt with to achieve any meaningful energy and carbon reductions from this sector."*
>
> *"…The trajectory must include measures that aim to increase standards of existing housing stock, which include the dwellings of low income and disadvantaged households."*
>
> *"The trajectory must include measures that aim to increase standards of existing housing stock over time to minimise market distortions and potential perverse incentives, as well as address equity concerns."*
>
> *"…There would be far greater gains to be had by tackling energy efficiency upgrades for existing housing stock rather than seeking to further increase standards for our already highly efficient housing stock built to current 6-star standards"*

Target and Metric

Most stakeholders were seeking a target and longer term direction for buildings, with incremental changes along the way.

> *"The trajectory should include incremental increases to the minimum energy performance requirements over the next 25 years, starting with a +1 Star rise to the 6 Star minimum at the earliest opportunity."*

> *"I feel the current target of 7 – 8 star energy rating is a good start for the next ten years and finally heading to 8 – 10 star and zero carbon should be the total aim of the next 20-30 years."*

> *"Minimum standards should be ratcheted up over time, to keep up with technological advances and – hand in hand with education and promotion of the benefits of passive design and energy efficiency – community standards."*

> *"The range of objectives for the housing sector – lower bills, improved health and comfort, improved resilience during extreme weather and blackouts, reduced carbon emissions – suggests a dual target that embraces these objectives."*

> *"It should apply to all buildings new and existing with a clear pathway and aspirational goals available for those wishing to jump ahead."*

> *"Providing clear trajectories for improving energy efficiency and performance of the Commercial and Residential construction sectors will deliver a level of certainty regarding future NCC changes that will enable industry to adapt and implement the changes required to deliver future, Code-compliant buildings. This approach would provide the certainty industries like ours…need to innovate and invest, so as to supply economically the products higher performing buildings need, and thereby support a rapid and least cost national transition to net zero."*

Stakeholder views were mixed on whether targets and the NCC should be fuel neutral.

> *"The performance metric should not prescribe specific energy sources. The ability to comply with the metric should be the key consideration – not how the compliance is achieved."*

> *"The use of renewable gas, including biomethane and biopropane, is growing overseas, and its use can affect building design, especially when it is produced on-site from household waste."*

> *"The need to shift to all electric housing should be emphasised given the GHG intensity of electricity is going down."*

> *"Care must be taken to avoid locking households into particular fuel types so that households are not left with appliances that they cannot replace with more efficient models, unless they switch to an alternative fuel type and thus potentially face increased replacement and disconnection cost."*

> *"… Any future NCC changes should not seek to provide an advantage to one technology/energy source over another. Rather the NCC should just set a benchmark on energy usage or a performance/output that building services needs to achieve"*

Scope of the NCC

Opinions on the scope of the NCC were mixed, while some stakeholders agreed that appliances and renewable energy should be included in the scope, others disagreed.

> *"Renewable energy should be included but its inclusion should not come at the expense of energy efficiency, particularly thermal performance. Renewable energy systems should only be installed where it is appropriate, including not installing them where there is extensive shading and/or inappropriate orientation."*
>
> *"Appliance (i.e. non-thermal) related energy use should be considered at least for major and/or fixed appliances which are decided at build stage (e.g. hot water, lighting, potentially white goods if offered as part of a home sale 'package')."*
>
> *"On-site renewable energy generation and storage**:** Should be included as these affect energy usage, costs and emissions. However, we do not support substitution of an increased minimum thermal energy rating with solar PV or storage."*
>
> *"In considering the inclusion of any specific technologies such as solar or storage… does not support the mandating of specific technologies but prefers a performance-based approach, where any eligible, minimum quality technology can be used to meet a particular performance requirement (above a minimum thermal rating baseline)."*
>
> *"Changes to the NCC should focus on thermal performance and not home-owner behaviours and lifestyle choices… therefore appliances should not be within scope."*

Implications for Stakeholders

While attributable quotes have not been included, most industry stakeholders were cautious and wanted to ensure sufficient time to transition.

> *[Stakeholders] "need to be supported to build up their capacity. They also need to be given an adequate timeframe to adapt to the regulatory changes."*
>
> *"… Further changes for the NCC for both Commercial and Residential buildings every three years shows a lack of understanding and appreciation for the challenges faced by industry to implement significant ongoing changes"*

Potential Costs and Energy Savings

Stakeholders raised concerns around risks to realising modelled energy savings:

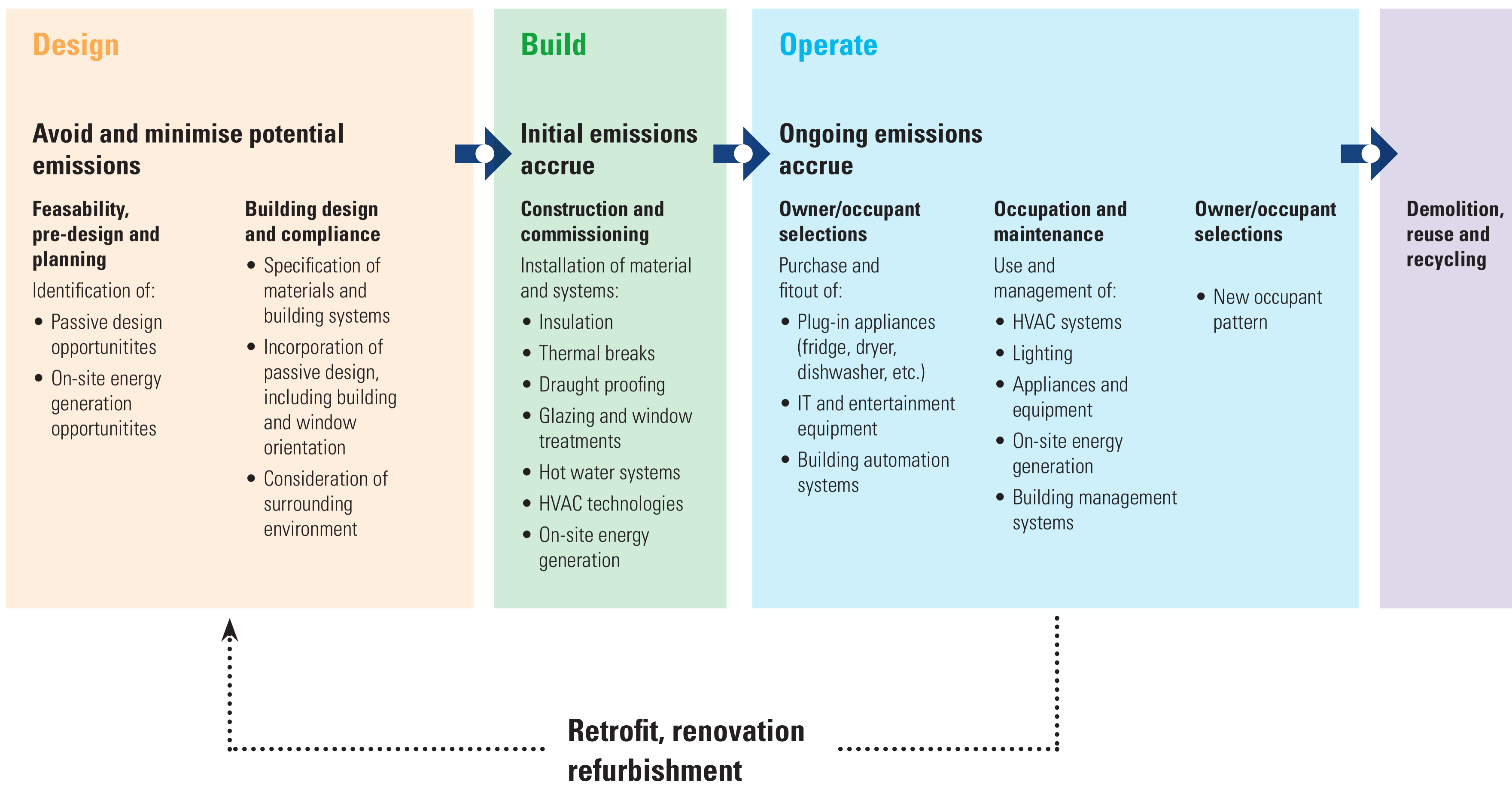
> *"Delaying upgrades would be costly… just three years' delay from 2022 to 2025 could lock in $2 billion in residential energy bills and $930 million of additional network investments between now and 2030."*
>
> *"The timeframes will depend upon the political commitment, scale of resources allocated, incentives provided for the building industry to change, and scale of 'consumer pull' that can be mobilised by promotion, information and incentives."*
>
> *"There is currently a lack of compliance checks to ensure houses are built to the standards they say they are."*

Appendix B: Scope for the Trajectory for Low Energy Homes

The stages of a home that have been considered as part of this Trajectory project are outlined in Figure 9. This consists of:

- **Design or retrofit stage.** Key decisions about designing to suit the climate, the size, orientation, construction materials and type and choice of fixed appliances, can all promote energy efficiency or 'lock in' poor performance for many decades to come.
- **Build stage.** Compliance with the original design, the quality of the build, and the quality of installation of insulation, draught sealing, fixed appliances and lighting can all impact on whether the building performs as planned.
- **Operate stage.** How occupants manage the home and use appliances and lighting will determine the actual energy performance and comfort of the home.

Figure 9: Key stages in a building's lifecycle that influence a home's performance



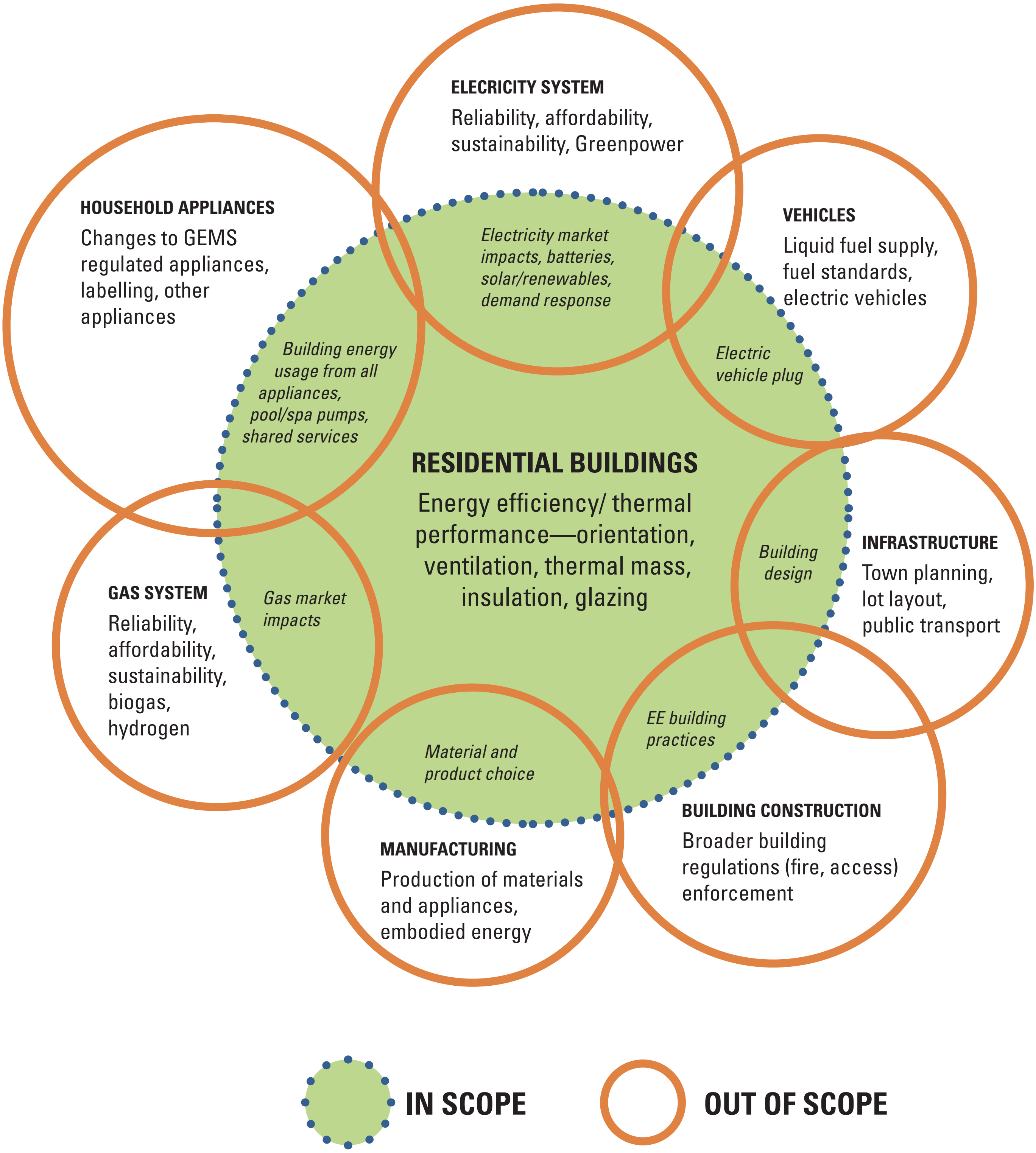
Changes can be made to one or multiple components in a home to deliver the intended outcomes. For example, actions that could be taken to reduce energy bills include:

- The energy efficiency of the building shell could be improved to reduce the amount of energy needed to keep the home at a comfortable temperature; or
- The energy efficiency of fixed heating and cooling appliances (or systems, if central units) could be improved to reduce the amount of energy being used to keep the home at a comfortable temperature; or
- Renewable energy (photovoltaic, or solar panels) could be used to generate energy on site - reducing the amount of electricity being drawn from the electricity grid and reducing energy bills, partly by offsetting electricity use and partly from income earned from exported electricity.

Any one of these individual actions could reduce energy bills, however in many cases the most cost-effective or ideal solution may be a combination of these actions, particularly as some actions can deliver additional benefits (improving the thermal shell can improve the comfort of a house and also reduce peak energy loads on the hottest and coldest days) or create additional complications (generating excess energy on-site at non-peak times can potentially cause problems for the electricity grid).

The components of a home that have been considered to be in and out of scope of this project are outlined in Figure 10.

Figure 10: Components in and out of scope when developing the Trajectory



The rationale for what is in scope and out of scope of this project is:

- Consideration of the performance of the thermal shell is in scope, as it is core to any home. This consists of the solar passive elements, including orientation, ventilation, thermal mass, insulation and glazing.
- Energy use from fixed appliances, pool/spa pumps and shared services, or the factors associated with their installation, are in scope of this project as they impact on the performance of the home. However, reducing energy usage from individual appliances is achieved through other projects such as the GEMS.
- Consideration of electricity and gas market impacts by incorporating batteries, solar and renewable energy generation and demand response as part of the building are in scope of this project. However, considering initiatives for the overall energy system is out of scope, as this is captured under broader government energy policies.
- Consideration of material and product choice is within scope in so far as it impacts on energy usage, but the manufacturing and production of materials and appliances, including their embodied energy, is out of scope, as this is a complex area and would be better considered in the future when time permits.
- Energy efficiency building practices and how they interact with other requirements will be considered. However, initiatives for the broader building construction items such as fire, access, health and enforcement of regulations are beyond scope, as these are managed through other processes.
- Consideration of building design and orientation is in scope as it impacts on the thermal shell, but town planning, lot layout or public transport is out of scope, as the responsibility for these items is spread across a range of different stakeholders that would be better considered in the future when time permits.
- Allowing for future electric vehicles is in scope with consideration given to the inclusion of a charge point, but electric vehicles or other vehicle types are out of scope, as electric vehicle technologies are still evolving and further research is required when time permits.

Appendix C: Costs and benefits analysis

Modelling to support the Trajectory for Low Energy Homes has been undertaken in two stages:

Stage 1: Whole of House Analysis Stage. AECOM conducted modelling to:

- Establish a baseline for Australian dwellings, including thermal performance and appliances.
- Model the energy performance of these dwellings (houses and apartments) and possible cost-effective options for increasing their energy performance.

Stage 2: Cost-Benefit Analysis Stage. Modelling was conducted as outlined in this paper, which sought to:

- Aggregate AECOM's individual dwelling results to a national level.
- Project findings into the future, based on different scenarios.

Establishing a baseline

In early 2018, AECOM was engaged to develop a base typology for a typical new Class 1 dwelling (houses) and Class 2 dwelling (apartments), including thermal performance and appliances. Base building designs and specifications can be found at Annex C1, with baseline appliances at C2.

As all 69 Climate Zones identified by NatHERS were unable to be accounted for, AECOM started by analysing the bundled Climate Zones identified in "NatHERS Star bands for proposed 2015 version of Chenath including new weather data" by Tony Isaacs Consulting, Floyd Energy and Pitt & Sherry (2014). Their reporting found the 69 distinct climate zones could be grouped into 13 different climates founded on their similar resultant ratings. This was based on modelling completed over a range of housing types and climates.

Following this, a cross sectional analysis against jurisdictions and housing stock was completed for each type of development in order to understand the type of housing being represented in each location.

Most existing and new Class 2 developments were found to be located in cities; and therefore Class 2 analysis is in keeping with these climate zones. This finding is likely to maintain relevance into the future as the world's population becomes increasingly urban. In 1960, 34 per cent of the total global population lived in urban areas, increasing to more than half of the population (54.5 per cent) in 2016. By 2030 the projected urban population is predicted to reach 60 per cent. The trends are observable in cities with 1 million inhabitants to those with 10+ million. In 2016, 23 per cent of the world's population lived in cities with at least 1 million inhabitants. This is projected to increase to 27 per cent by 2030.[62]

Class 1 dwellings designs were taken from the 2013 RMIT University study titled "Development of Representative Dwelling Designs for Technical and Policy Purposes". This study sought to develop a set of statistically robust, up-to-date, government endorsed dwelling designs to represent the most typical characteristics of recent residential buildings. This work is still considered representative of the bulk of new Class 1 dwellings currently being built around Australia by volume builders. Available house plans from the largest of these builders throughout different locations have been analysed against the proposed single storey four bedroom floor plan and found to be very similar.

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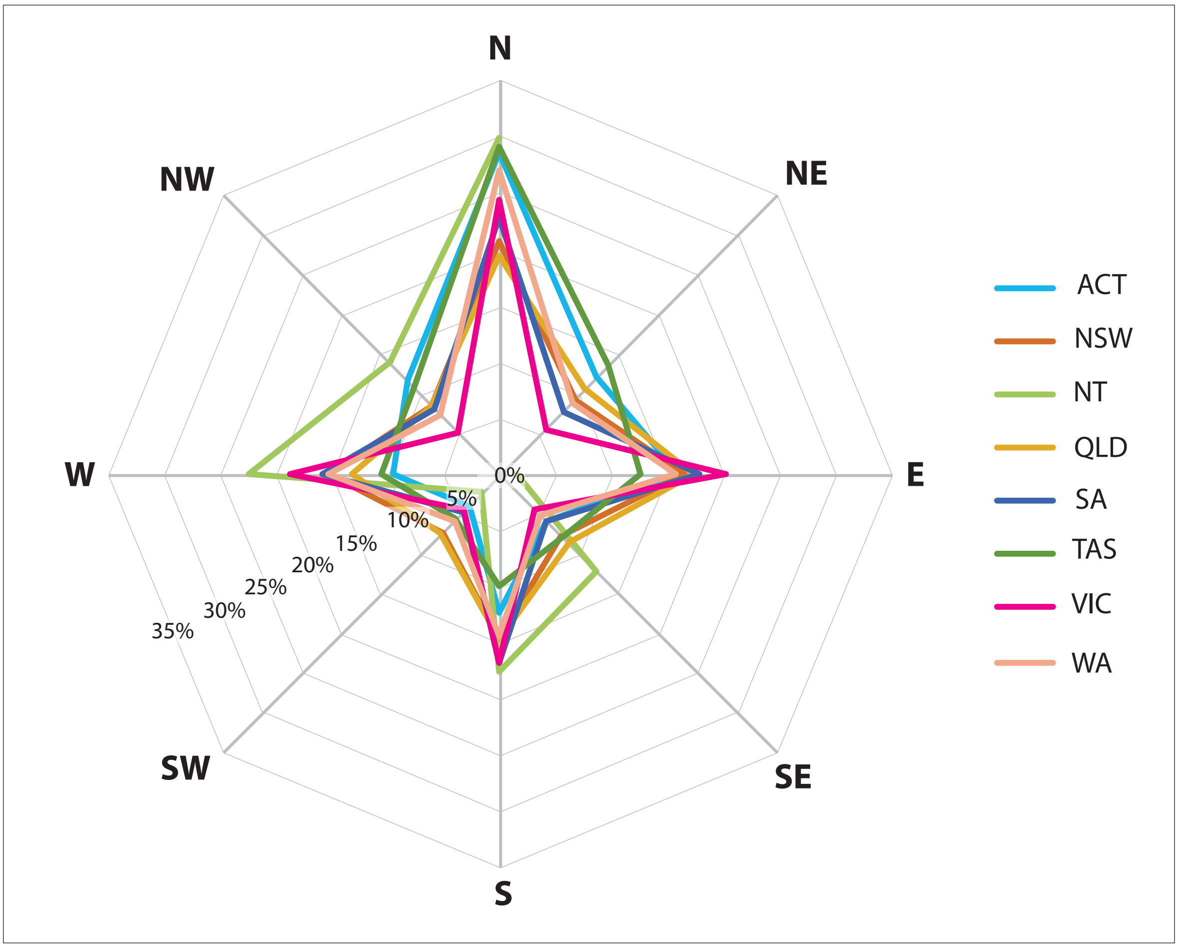
62 United Nations, *The World's Cities in 2016 Data Booklet*, 2016, page 3

Dwellings have been oriented north, as the data from the NatHERS portal indicates the glazing orientation per living/kitchen area across all states is predominantly north (north-east to north-west) (see Figure 11).

Figure 11: Glazing orientation per living/kitchen area per state for new Class 1 dwellings (percentage of all windows)



Source: AECOM analysis of NatHERS portal data

Building specifications were developed based on an analysis of data in the NatHERS portal, which specifies a breakdown of building construction in areas across Australia. All other elements of the home were assumed to meet minimum regulatory requirements.

The NatHERS portal data indicates that dwellings average 0.1 to 0.4 stars above the minimum regulatory requirements for Class 1 dwellings and 0.3 to 1 star above for Class 2 apartments. Where necessary, base case dwellings were de-rated below average ratings to give confidence that at least half of dwellings built today outperform the base case and can be assumed to have a lower compliance cost (and energy saving) than modelled under
this work.

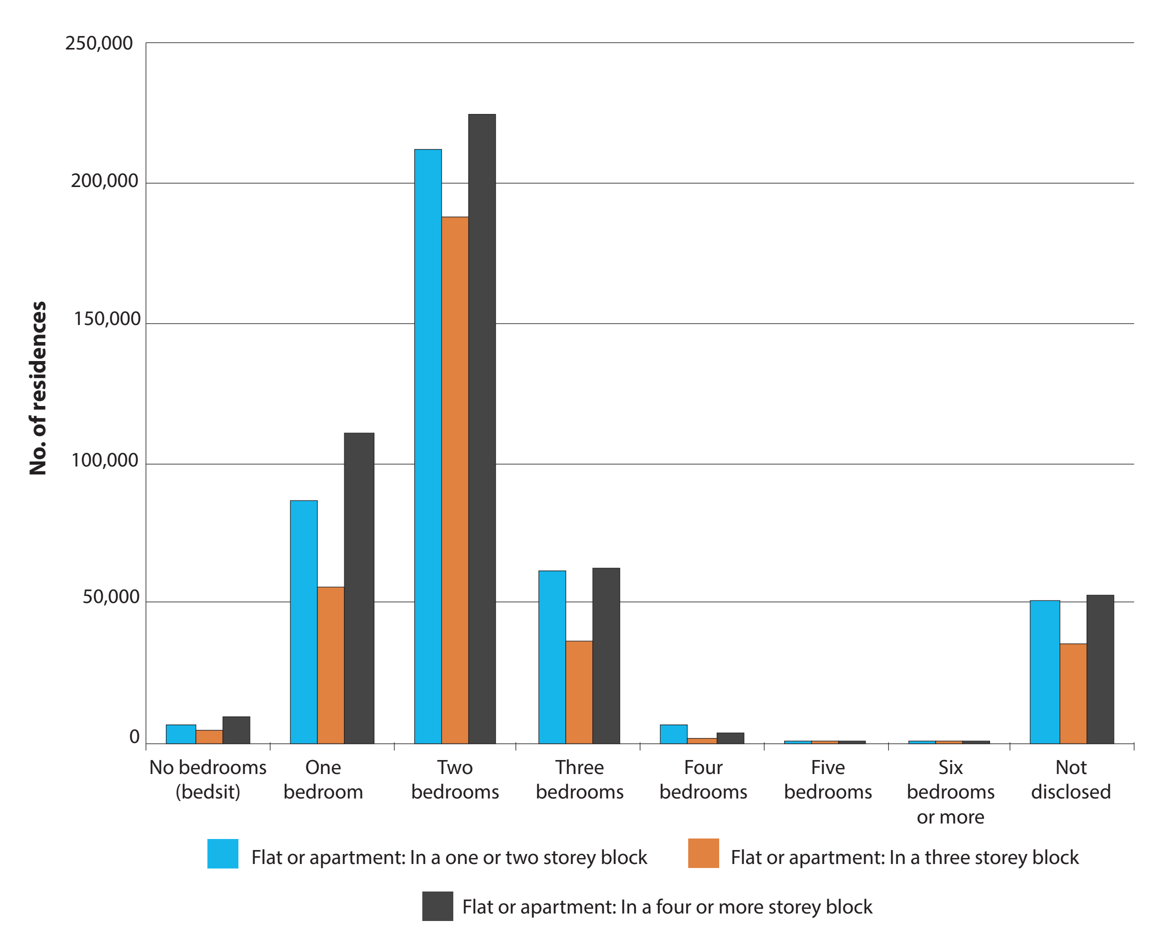
For Class 2 apartments, an entire typical floor plate was used as a case study (rather than an individual apartment/unit) to allow for greater stock representation. Each floor plate was modelled on a middle floor and on the top floor.

In accordance with the 2016 census, two bedroom Class 2 residences in Australia represent over half of the market (52 per cent); with the majority of the remainder of the market being made up of one bedroom apartments (21 per cent) and three bedroom apartments (13 per cent) (Figure 12).

In addition to ensuring the floor plate represented the Australian Bureau of Statistics' distribution of apartment sizes, the following elements were also included following an analysis of a number of Class 2 apartment designs throughout Australia:

- Typically combined kitchen/living area with full width and full height glazing (kitchen located furthest from the window);
- Balcony adjoining living area with overshadowing from above balcony (or other external shading on top level);
- Bedrooms with smaller full height glazing (width: 30-50 per cent of wall); and
- Bathrooms located internally to the apartment or closest to the core.

Figure 12: Breakdown of number of bedrooms per apartment



Source: AECOM analysis of Census 2016 data

Baseline appliances were taken from the Residential Baseline Study model, developed for the Department of the Environment and Energy. Where two prominent technologies were observed, such as double glazing versus single glazing in Hobart, the most common specification was selected.

For appliances, specifications varied by location, generally including either gas instant or electric storage hot water, paired with either ducted gas heating plus air conditioning or reverse cycle air conditioning. LED lighting was assumed in all cases.

Modelling was then undertaken using the AusZEH software with the following adjustments from those assumed under NatHERS, in order to better understand the likely energy savings from any changes:

- The occupancy profile and thermostat settings were modified by averaging all day and weekday profiles to better match the Composite Weekday Profile identified in the Residential Baseline Study.
- Cooling thermostat settings were matched to the Residential Baseline Study.

The effect of these changes was to reduce energy usage during the day (due to reduced occupancy), while increasing cooling energy usage (due to lower thermostat settings). The net effect was to reduce potential energy savings in cold climates, while increasing savings in hot climates, when compared with NatHERS settings.

Modelling was undertaken to increase the energy performance of these model houses and apartment blocks through adjusting thermal performance and appliance features. The capital costs and the energy bills savings for households and apartment occupants were then estimated, in order to estimate the cost effectiveness for households from the upgrades.

Outcomes from the 7 star house analysis – Class 1 Dwellings (houses)

The first modelling scenario saw a 1 star NatHERS increase in star ratings to the base case. For NCC climates 1 and 2, the current credits in the NCC of up to 1 NatHERS star have been retained. A summary of capital city NatHERS ratings relative to the base case is in Table 8. The full list of star rating increase for each of the locations used in the model for the 7 star house analysis are presented in Annex C3.

Table 8: The star rating increases applied in a selection of locations in the 7 star house analysis

		Class 1 – Houses	
Capital City	**NCC Climate Zone**	**Base Case Star Rating**	**New Star Rating**
Darwin	1	5.4	6.0
Brisbane	2	4.6	6.0
Sydney	5	5.5	7.0
Adelaide	5	6.1	7.1
Perth	5	6.2	7.0
Melbourne	6	6.3	7.0
Canberra	7	6.5	7.1
Hobart	7	6.2	7.0

To achieve a 7 star rating, the houses were generally upgraded with additional insulation and/or improved windows, either low-e or double glazing as appropriate for the climate (see Annex C3). Note that these costs are conservative, as it can be expected that designs improve over time to partially offset the need for higher cost building elements. This project took an elemental approach to improving thermal performance, as customised redesign could not be undertaken given the number of homes modelled.

In addition, appliances were upgraded with a total of 10kW worth of 4 star split system air conditioners and heat pump hot water. Modelling assumed a fixed rate for building sealing and energy usage for lighting, cooking and plugged loads across all Class 1 scenarios. As costs are sourced from Rawlinson's data, they represent the custom design end of the market and are likely to be well above the volume home market supply contract prices. Therefore costs can be considered conservative, with actual costs likely to be lower than presented in this report.

A summary of upgrade costs and annual energy bill savings in each capital city is in Table 9. The low appliance capital costs in Melbourne and Canberra are due to the comparatively lower cost of installing the 10kW of split system air-conditioners when compared with ducted gas heating and ducted air conditioning in the base case.

Table 9: Estimates of the 2018 capital costs and energy bill savings for houses, with electric upgrades only

	NCC Climate Zone	Capital Costs – Thermal Upgrades ($)	Capital Costs – Appliance Upgrades ($)	Total Capital Costs ($)	Annual Energy Bill savings ($)
Darwin	1	$ 1,356	$ 1,960	$ 3,316	$700
Brisbane	2	$ 7,444	$ 1,960	$ 9,404	$511
Sydney East	5	$ 8,186	$ 1,960	$ 10,146	$225
Adelaide	5	$ 5,681	$ 1,960	$ 7,641	$237
Perth	5	$ 5,219	$ 1,960	$ 7,179	$310
Melbourne	6	$ 4,443	-$ 702	$ 3,741	$141
Canberra	7	$ 1,652	-$ 702	$ 950	$770
Hobart	7	$ 4,263	$ 2,533	$ 6,796	$349

The figures in Tables 8 and 9 apply to 2018 prices, with energy prices expected to rise over time while costs are expected to fall (see the following section on Cost Benefit Analysis Underlying Methodologies and Assumptions).

When aggregated, findings of just this scenario found the net present value gave mixed results at a discount rate of 7 per cent (Table 10). This rate was selected as it was the base case used in the 2010 RIS. Mixed results primarily related to the comparatively lower energy savings potential in temperate climates. Tasmania may also be impacted by changes in modelling occupancy settings that reduce the modelled energy savings. Given the neutral results, Tasmania may offer a net benefit following further analysis of different dwellings and user profiles.

It is worth noting that while some jurisdictions did not achieve a net benefit greater than 1:1 overall, there were locations within that jurisdiction where it was cost effective to move to equivalent of 7 stars. This was the case in climate zones 6, 7 and 8.

Table 10: Net Present Value (NPV) to 2050 from the 7 Star House analysis, with electric upgrades only

	7 Star		7 Star with 2.5% Improvement in Upgrade Costs	
	$ million	Savings to Cost Ratio	$ million	Savings to Cost Ratio
NSW	-$1,593.8	0.56	-$1,462.1	0.59
VIC	-$69.9	0.96	$88.2	1.05
QLD	-$968.8	0.74	-$891.1	0.76
SA	-$264.4	0.70	-$258.5	0.71
WA	-$345.7	0.84	-$340.4	0.84
TAS	-$57.6	0.75	-$49.3	0.78
NT	$101.0	2.68	$111.8	2.84
ACT	$239.3	8.29	$243.7	7.88
Australia	-$2,959.9	0.76	-$2,557.7	0.80

Outcomes of tailored climate analysis – Class 1 Dwellings

Due to the variability in the results across regions, a new scenario was modelled that adjusted the thermal performance to each location. Appliances were unchanged from the 7 star analysis. The tailored climate analysis recognised that temperate climates generally offered lower energy savings and longer payback periods for households. As such, a revised approach was modelled with the following assumptions:

- Between 6.5 and 7.0 NatHERS stars in NCC climates 6, 7 and 8;
- 6.5 stars in NCC climates 1 and 5; and
- Up to 6 stars in NCC Climates 2, 3 and 4 (noting many homes in these climates currently have credits available to build below 6 stars).

A summary of capital city NatHERS ratings relative to the base case is in Table 11.

Table 11: Star rating increases applied in a selection of locations in the tailored climate analysis

		Class 1 – Houses	
Capital City	**NCC Climate Zone**	**Base Case Star Rating**	**New Star Rating**
Darwin	1	5.4	6.5
Brisbane	2	4.6	5.2
Sydney	5	5.5	6.5
Adelaide	5	6.1	6.6
Perth	5	6.2	6.7
Melbourne	6	6.3	7.0
Canberra	7	6.5	7.1
Hobart	7	6.2	6.7

A summary of upgrade costs and annual energy bill savings in each capital city is in Table 12.

Table 12: Estimates of 2018 capital costs and energy bill savings under Increase 2 scenario for houses, with electric upgrades only

	NCC Climate Zone	Capital Costs – Thermal Upgrades ($)	Capital Costs – Appliance Upgrades ($)	Total Capital Costs ($)	Annual Energy Bill savings ($)
Darwin	1	$3,604	$1,960	$5,564	$897
Brisbane	2	$2,920	$1,960	$4,880	$475
Sydney East	5	$1,677	$1,960	$3,637	$203
Adelaide	5	$1,903	$1,960	$3,863	$179
Perth	5	$1,980	$1,960	$3,940	$294
Melbourne	6	$4,443	-$702	$3,741	$141
Canberra	7	$1,652	-$702	$950	$770
Hobart	7	$2,262	$2,533	$4,796	$319

To compare energy usage of different fuel sources, the model was re-run using a 5 star gas heating system and gas boosted solar hot water. While carbon intensities are forecast to change over time, a test was undertaken when gas energy usage was adjusted based on the forecast relative carbon intensity in 2022, as outlined in Table 13.

Table 13: Fuel Conversion Factors

Fuel Type	Conversion Factor[63]
Electricity	1.000
Natural Gas and LPG	0.239
Wood and Biomass	0.006

Once the fuel conversion factor is applied, gas cases generally had a comparable or lower adjusted energy load when compared against the electricity case (Table 14). This suggests that any annual energy budget should be set based on the higher electricity adjusted energy load, allowing for both fuel sources to meet the requirements.

63 Conversions are based on the Australia's emissions projections 2016, forecast electricity combined scope 2 and 3 emission factors EFs in 2022-23 of 214.7 kg CO2-e/GJ and the Commonwealth National Greenhouse Accounts Factors 2017, natural gas distributed in a pipeline emissions of 51.4 kg CO2-e/GJ (table 2) and dry wood of 1.2 kg N2O/GJ (table 1)

Table 14: Comparison of adjusted energy loads for electricity and gas appliance scenarios

	NCC Climate Zone	Annual energy usage – Electricity scenario (MJ)	Adjusted energy usage - Electricity scenario (MJ)	Adjusted energy usage - Electricity scenario (MJ/m^2)	Annual energy usage – gas scenario (MJ)	Adjusted energy usage - gas scenario (MJ)	Adjusted energy usage - gas scenario (MJ/m^2)
Sydney	5	20,105	20,105	108	24,153.8	18,861	101
Melbourne	6	19,174	18,507	99	31,719.0	18,558	100
Canberra	7	21,472	21,472	115	38,551.4	20,791	112

When aggregated nationally, this scenario gave a positive net present value in all jurisdictions with the exception of NSW (Table 15).

Table 15: Net Present Value (NPV) to 2050 from the tailored climate analysis, with electric upgrades only.

	$million	Savings to Cost Ratio
NSW	-$45.8	0.98
VIC	$42.8	1.02
QLD	$450.4	1.21
SA	$50.4	1.10
WA	$797.4	1.85
TAS	$1.1	1.01
NT	$111.4	2.53
ACT	$239.3	8.29
Australia	$1,647.0	1.22

The results of the tailored climate analysis indicate that building thermal performance requirements should vary by climate to ensure optimal outcomes are achieved.

Outcomes of tailored climate analysis – Class 2 Apartments

Due to the variability in the results for Class 1 homes, Class 2 apartments were modelled with varying performance across climate regions:

- 7 star average and 5.5 star minimum in NCC climates 7 and 8;
- 6.5 star average and 5.5 star minimum in NCC climates 1, 4, 5 and 6; and
- 6 star average and 5 star minimum in NCC climates 2 and 3.

To achieve the target thermal performance, the apartments were generally upgraded with additional insulation and/or improved windows, either low-e or double glazing as appropriate for the climate (see Annex C4). In addition, appliances were upgraded with a total of 10kW worth of 4 star split system air conditioners. Modelling assumed a fixed rate for building sealing and energy usage for lighting, electric hot water, cooking and plugged loads across all class 1 scenarios.

A summary of average capital city NatHERS ratings relative to the base case is in Table 16.

Table 16: Star rating increases applied in a selection of locations in the tailored climate analysis

		Class 2 – Apartments	
Capital City	NCC Climate Zone	Base Average Star Rating	New Average Star Rating
Darwin	1	6.0	6.5
Brisbane	2	5.0	5.5
Sydney	5	5.9	6.4
Adelaide	5	6.1	6.6
Perth	5	6.4	6.9
Melbourne	6	6.2	6.7
Canberra	7	6.6	7.1
Hobart	7	6.5	7.0

A summary of upgrade costs and annual energy bill savings in each capital city is in Table 17 below.

Table 17: Estimates of 2018 capital costs and energy bill savings for apartments, with electric upgrades only

	NCC Climate	Total Capital Costs ($)	Annual Energy Bill savings ($)
Darwin average	1	$379	$168
Brisbane average	2	$841	$47
Sydney East average	5	$151	$32
Perth average	5	$0	$0
Melbourne average	6	$196	$70
Canberra average	7	$200	$21
Hobart average	7	$143	$67

To compare energy usage of different fuel sources, the model was re-run using a centralised gas hot water system. Once the fuel conversion factor was applied, gas cases were found to have lower adjusted energy load when compared against the electricity case (Table 18). This is due to the comparable performance of electric and gas options modelled, coupled with the discount applied to gas during the adjustment. This suggests that any annual energy budget should be set based on the higher electricity adjusted energy load, allowing for both fuel sources to meet the requirements. Note this may change as carbon intensities of different fuels change over time.

Table 18: Comparison of adjusted energy loads for electricity and gas appliance scenarios

	NCC Climate Zone	Annual energy usage – Electricity scenario (MJ)	Adjusted energy usage – Electricity scenario (MJ)	Adjusted energy usage – Electricity scenario (MJ/m^2)	Annual energy usage – gas scenario (MJ)	Adjusted energy usage – gas scenario (MJ)	Adjusted energy usage – gas scenario (MJ/m^2)
Sydney average	5	19982	19466	249	22,763.9	16253	208
Melbourne average	6	19629	19122	245	22,411.0	15909	204
Canberra average	7	19769	19281	247	22,550.7	16069	206

When aggregated nationally, this scenario gave a positive net present value at a national level, but mixed results at the jurisdictional level (Table 19).

Table 19: Net Present Value (NPV) to 2050 from the tailored climate analysis, with electric upgrades only NPV

	$million	Simple Savings to Cost Ratio
NSW	$40.6	1.78
VIC	$109.3	4.20
QLD	-$17.0	0.86
SA	$*Excluded	*Excluded
WA	-$50.3	0.34
TAS	$2.6	5.50
NT	$9.2	5.41
ACT	$3.5	1.99
Australia	*$97.8*	*1.34*

**Excluded*: Note that while energy loads for SA have been modelled for the purposes of comparing with other locations, assessing potential net benefits was excluded. Refer to the RIS titled: Increasing the energy efficiency requirements for Class 2 residential buildings, completed as a jurisdiction based variation to the NCC, commencing 1 July 2019.*

Outcomes of Cost-Benefit Analysis

This section provides an understanding of the impact to the cost-benefit of the three scenarios. These scenarios are as follows:

- Tailored Approach
- Tailored Approach with 2.5% Improvement in Capital Cost
- Tailored Approach with 10% PV from 2022

Scenarios 2 and 3 test the sensitivity of the results in key areas, the results of which provide indications of which elements are significant and therefore require robust testing going forward. Below are the comparative results for the modelling for Class 1, Class 2, and combined new dwellings.

Table 20: Scenario Results for New Class 1 Dwellings

			Tailored Approach + 2.5% Cost Improvement		Tailored Approach + 10% PV from 2022	
NPV	**$m**	**Savings to Cost Ratio**	**$m**	**Savings to Cost Ratio**	**$m**	**Savings to Cost Ratio**
NSW	-$45.81	0.98	$2.24	1.00	$632.96	1.31
VIC	$42.77	1.02	$87.42	1.05	$657.37	1.34
QLD	$450.35	1.21	$502.80	1.25	$953.60	1.43
SA	$50.42	1.10	$62.69	1.13	$245.36	1.47
WA	$797.38	1.85	$820.64	1.90	$1,272.56	2.29
TAS	$1.13	1.01	$5.01	1.03	$23.29	1.14
NT	$111.40	2.53	$113.22	2.59	$142.06	2.72
ACT	$239.31	8.29	$240.12	8.50	$271.33	8.10
Australia	*$1,646.95*	*1.22*	*$1,834.15*	*1.25*	*$4,198.52*	*1.53*

The results in Table 20 above show that Class 1 dwellings are relatively sensitive to the starting capital costs associated with the thermal and appliance upgrades. New South Wales, Victoria, South Australia, and Tasmania are particularly sensitive. Class 1 results are also quite sensitive to the addition of PV with even a small increase in the uptake of PV, i.e. 10 per cent PV, more than doubles the projected NPV. There is enough evidence at the national level to suggest that it is all three scenarios will provide a strong positive NPV result.

Table 21: Scenario Results for New Class 2 Dwellings

	Tailored Approach		Tailored Approach + 2.5% Cost Improvement		Tailored Approach + 10% PV from 2022	
NPV	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio
NSW	$40.58	1.78	$41.82	1.82	$344.44	4.50
VIC	$109.33	4.20	$110.13	4.31	$327.62	5.23
QLD	-$16.99	0.86	-$14.00	0.88	$162.38	2.03
SA	*Excluded	*Excluded	*Excluded	*Excluded	*Excluded	*Excluded
WA	-$50.32	0.34	-$48.45	0.34	$49.22	1.53
TAS	$2.55	5.50	$2.57	5.63	$5.60	4.67
NT	$9.19	5.41	$9.24	5.54	$16.76	4.04
ACT	$3.49	1.99	$3.57	2.04	$25.04	4.32
Australia	*$97.83*	*1.34*	*$104.88*	*1.37*	*$931.06*	*3.11*

The Class 2 results in Table 21 suggest there is very little sensitivity to the starting capital upgrade costs. This is due to the relatively low level of savings generated for every dollar of capital upgrades compared to the Class 1 dwellings. However, Class 2 dwellings are very sensitive to PV with a 10 per cent uptake yielding a tenfold improvement of the NPV. Scenarios 1 (tailored approach) and 2 (tailored approach + 2.5% cost improvement) do not provide evidence of a positive or negative NPV result even at the national level and are therefore inconclusive. Scenario 3 (tailored approach + 10 % PV) does provide a strong positive NPV result at the national level.

Table 22: Scenario Results for Combined

	Tailored Approach		Tailored Approach + 2.5% Cost Improvement		Tailored Approach + 10% PV from 2022	
NPV	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio	$m	Savings to Cost Ratio
NSW	-$5.23	1.00	$44.07	1.02	$977.40	1.46
VIC	$152.10	1.08	$197.56	1.11	$984.99	1.49
QLD	$433.36	1.19	$488.80	1.23	$1,115.97	1.47
SA*	$50.42	1.10	$62.69	1.13	$245.36	1.47
WA	$747.06	1.74	$772.19	1.78	$1,321.78	2.22
TAS	$3.68	1.02	$7.57	1.05	$28.90	1.17
NT	$120.60	2.61	$122.46	2.68	$158.82	4.39
ACT	$242.79	7.68	$243.69	7.88	$296.37	7.48
Australia	*$1,744.78*	*1.22*	*$1,939.03*	*1.25*	*$5,129.58*	*1.61*

As Table 22 shows, whilst there is a degree of sensitivity associated with improving the upgrade costs, there is a much higher sensitivity associated with PV. Given the PV increase is set at 10 per cent, which is very low, there is an argument that the modelled costs for purchase and installation would be an underestimate due to the lack of efficiencies of scale. As an additional level of sensitivity the costs of the PV was doubled and the results still came back positive. Going forward both of these elements (improving upgrade costs and adding PV) need to be refined as they have significant impact on the results. However, all three scenarios at the national level, and combining Class 1 and Class 2 new dwellings, provide strong evidence of a positive NPV result if implemented.

Cost Benefit Analysis Underlying Methodologies and Assumptions

In simplistic terms, the cost benefit analysis takes the modelling results that AECOM provided and multiplies the number by the appropriate annual number of households over time, thus measuring the national impact over time. The impacts measured are broadly: savings less costs resulting in benefit (positive or negative). The savings come from a reduction in energy consumption, which in turn determines the financial and emissions savings; these are deemed to be ongoing. The costs arise from the initial additional capital expenditure and additional compliance costs; these are deemed to be once off.

As the policy evaluation period is to 2050 there are many factors that will reasonably change over time and this also needs to be incorporated into the model. These include:

- Number of Class 1 and Class 2 dwellings further split into new and existing.
- Cost of energy by fuel type and jurisdiction.
- Emissions rate of electricity by jurisdiction.
- Capital costs by type of appliance and thermal upgrade.

Number of Households by Jurisdiction

The total number of residential households at the jurisdictional level in the model is based on the Australian Bureau of Statistics (ABS) household and family projections Series II.[64] The current release of ABS household and family projections (2011) projects out to 2036. As this policy is being modelled out to 2050 it is necessary to extend the projection an additional 14 years. Figure 13 shows the projections most closely approximate a linear progression and extending the projections using a linear equation is reasonable.

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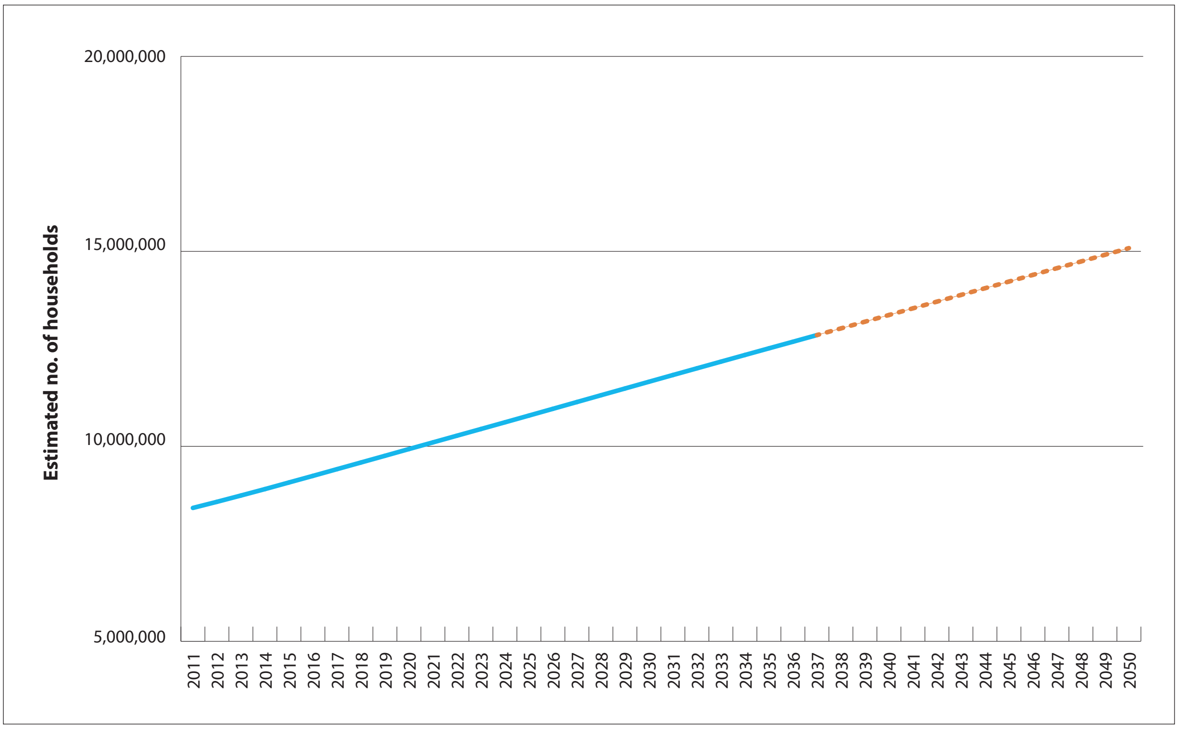
64 Australian Bureau of Statistics report 32360DO001_20112036 *Household and Family Projections, Australia, 2011 to 2036, Series II*

Figure 13: Extension of ABS projections for the number of households[65]



Number of New Dwellings

New builds were determined by the year on year growth of households using ABS 'number of households' data. The methodology assumed that all new builds are started and completed within the listed year.

Class 1 / Class 2 Split

The Housing Industry Association (HIA) provides data on new starts split by detached and multi-units projected out 10 years by jurisdiction. HIA data for the ratio between detached and multi-unit dwellings was used to determine the new dwelling split between Class 1 and Class 2. Currently semi-detached / townhouses were rolled into Class 2.

Number of Existing Dwellings

If new builds are defined as the growth in ABS households (i.e. the total this year minus the total last year) it necessarily means that the existing builds this year must be the same as the total last year.

In the first year of the policy the pool of existing dwellings is determined, as any new dwellings will be built to the new specifications. It is assumed that these existing households will only be brought up to the new specification as they are refurbished. This refurbishment rate is then applied to the established pool of existing dwellings less any that have already been brought up to specification.

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65 Australian Bureau of Statistics report 32360DO001_20112036 *Household and Family Projections, Australia, 2011 to 2036, Series II*

Class 1 / Class 2 Split

In order to split the total existing households into Class 1 and Class 2 a baseline split is established using the 2016 ABS Census. Each year after that the HIA new builds ratio is applied and added to the existing stock to provide a running total of existing split by Class 1 and Class 2. The 2016 ABS Census figures are not yet incorporated into the ABS household projections so the totals calculated will not match. However the ratio of Class 1 and Class 2 provide a reasonable estimate. These ratios are therefore applied to the ABS households previously determined to calculate the existing Class 1 / Class 2 split.

Household split by Climate Zone

The ABS Household Energy Survey provides the number of residential meters in each NCC climate zone by jurisdiction for 2010, 2011, and 2012. In the absence of separate figures for NT and ACT, it was assumed that 75 per cent of the NT is in climate zone 1 and 25 per cent in climate zone 3. 100 per cent of the ACT was attributed to climate zone 7. The ratios across the three years were relatively consistent. Whilst this method of disaggregation is reasonably robust and is acceptable for the current stage of modelling, going forward this should be an area of work to improve the estimate, at the very least some more contemporary data should be sourced.

Scenario Impact Estimates (Electricity, Gas, Costs, Benefits)

Data modelled by AECOM provides all of the impacts at the household level by a selection of NatHERS climate zones. In order to derive the total impact, the AECOM modelled data is mapped from NatHERS climate zones to NCC climate zones and by jurisdiction. In doing this some NCC climate zones occur more than once, in such instances the impacts are averaged. AECOM has not modelled any sites in NCC climate zones 2 and 7 for NSW. For climate zone 2 the Brisbane figures (QLD zone 2) were used as a substitute. For climate zone 7 the Canberra figures (ACT zone 7) were used as a substitute.

Baseline residential energy demand

Estimates for the energy demand by the residential sector were based on forecasts in the *Australian Energy Projections,* and the *Australian Energy Statistics* data. The business as usual (BAU) scenario applied in the model, used energy use by the residential sector between 2010 and out to 2050. Trends in energy use between 2010 and 2016 were based on the Australian Energy Statistics.[66] The projection of energy use out to 2050 adopted the trend line observed in the Australian Energy Projections data.[67] Note that the BAU energy estimates have a fundamentally different basis (top down calculation) compared with the energy savings estimates (bottom up calculation) using a typical household model. These numbers are compared to give a point of reference and contextualisation.

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66 Australian Energy Statistics 2016, table E (www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Australian-energy-statistics.aspx)

67 Department of Industry, Innovation and Science, *Australian Energy Projections to 2049-50*, Table 12, November 2014, page 38

Energy price projections and feed-in tariffs

Energy Price Projections

The electricity price projections are estimated by initially using the Australian Energy Market Commission (AEMC) residential electricity price and then applying an index derived from the Australian Energy Market Operator (AEMO) data. Figures for WA, NT, and ACT required some modifications. WA index is a derivative of the VIC index, based on initial figures using actuals from the WA Department of Treasury.[68] NT index is assumed to be the same as Queensland. ACT index is assumed to be the same as NSW.

Similarly the gas price projections are estimated by starting with gas price estimates provided by the Department of the Environment and Energy and an index using AEMO figures. The WA index is calculated as an average of SA and TAS only, as the starting price of WA is close to both the SA and TAS figures. NT is assumed to be an LPG market. The ACT index is assumed to be the same as NSW.

Whilst for the purpose of this report the above assumptions are deemed to be sufficient, it is recommended that any further reports will need to more accurately represent the projected prices.

Derivation of Feed-in Tariff Projections

Projections on feed-in tariffs have not directly been sourced. For the purposes of this modelling, current jurisdictional feed-in tariff averages are calculated. It is assumed the difference between the average tariff and the full retail rate remains constant over time. A summary of the available feed-in tariffs by jurisdiction was sourced from Solar Choice.[69] For WA the feed-in tariff for the south-western region was used as tariffs differ from region to region.

Calculation of Savings Associated With PV Solar

When PV is included to offset the total energy of the household, not all of the energy consumed occurs during the period of generation. For this reason the energy consumed needs to be split into 'during generation' and 'outside generation'. The proportional split of energy consumed during generation by appliance type is listed in Table 23.

Table 23: Proportional split of energy consumed during generation

Appliance Type	% Energy During Generation
Hot water	90.0%
Cooling	88.0%
Heating	23.5%
Lights	0.0%
All other appliances	29.4%

Energy consumed during the period of solar generation savings are calculated using the full retail rate. For energy consumed outside this period savings are calculated using the feed-in tariff rate.

68 www.treasury.wa.gov.au/Public-Utilities-Office/Household-energy-pricing/Electricity-pricing/#res-ele
69 www.solarchoice.net.au/blog/which-electricity-retailer-is-giving-the-best-solar-feed-in-tariff/

Projections of emissions rates

Emissions related to electricity consumption are predicted to reduce over time. Estimates of these projections by jurisdiction were obtained from the Department of the Environment and Energy. These projections go to 2037 and this report has extended the projections to 2050 using a linear trend. This is believed to be conservative as there is some evidence to suggest the decarbonisation of electricity generation is increasing at an increasing rate.

The emissions rates associated with other fuel sources, namely natural gas and LPG and held constant over time.

Estimation of compliance costs

To improve the potency of the policy, additional compliance checking has been costed. The cost per check was estimated by having someone employed at a salary of $150,000 conducting on average 6 checks per working day, resulting in a cost per check of $104. The model currently assumes that 10 per cent of newly constructed households will be checked each year. A sensitivity check was conducted where the cost was doubled and 100 per cent of builds were checked. Whilst the NPV result was impacted it was still over $1 billion at the national level.

Estimates for Capital Price Trajectories

The CBA model considered the potential price trajectories for the following household features:

- Hot water systems;
- Air conditioning systems;
- Window double glazing;
- Insulation; and
- Solar PV.

Hot water systems

Nominal price estimates were used for several types of residential hot water systems modelled, based on market survey data from the biennial *Household Appliances Market in Australia* studies by BIS Shrapnel. As BIS Shrapnel data is confidential, the price trends applied to that data for hot water systems are presented as equations only, in Table 24. Nominal data from the BIS Shrapnel reports was converted to real prices for $2016, applying an inflation rate of 2.5 per cent. These prices included those for: solar hot water, gas instant hot water, gas storage hot water and electric storage hot water.

Table 24: Potential equations that could be used to extend nominal pricing data in $2016 real terms

Household Feature	Price trend applied		Source
	Equation	R^2	
Solar hot water	$y = 4757.3x^{-0.141}$	0.9113	Extrapolation from BIS Shrapnel
Gas instant hot water	$y = 1642.3e^{-0.015x}$	0.465	Extrapolation from BIS Shrapnel
Gas storage hot water	$y = 1572.2e^{-0.011x}$	0.446	Extrapolation from BIS Shrapnel
Electric storage hot water	$y = 1341.9e^{-0.006x}$	0.5174	Extrapolation from BIS Shrapnel

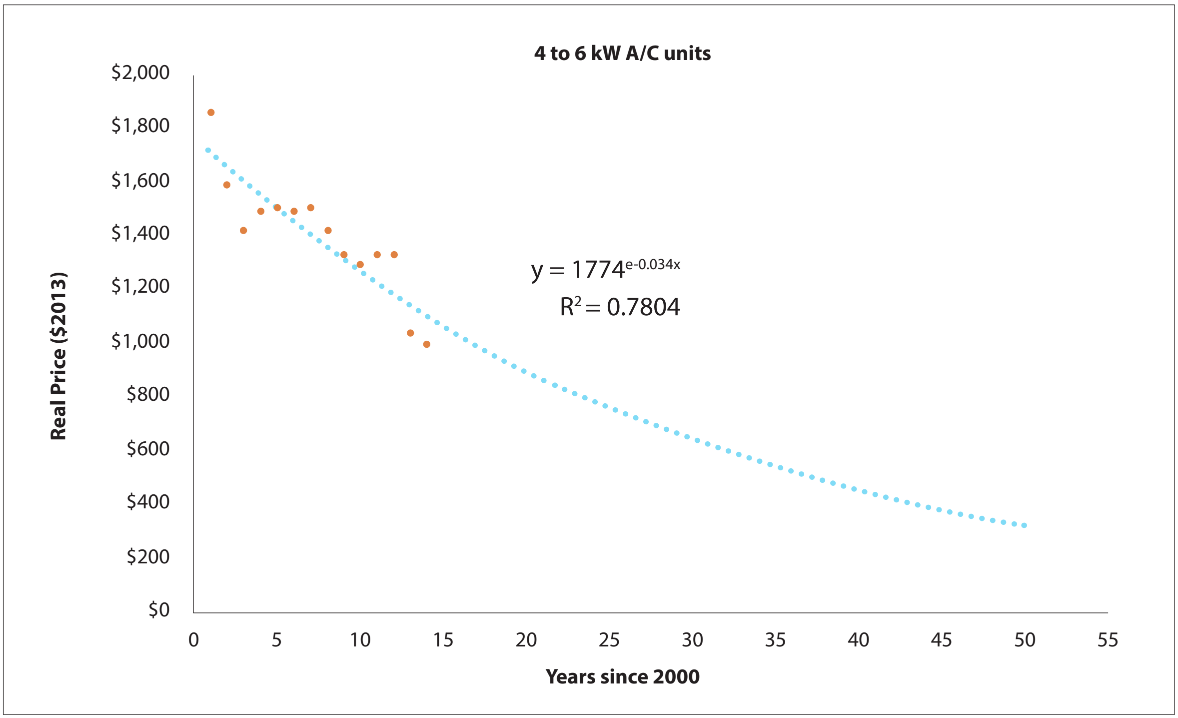
Heat Pump Hot Water Systems

Discussions were held with market experts to estimate trends for prices of Heat Pump hot water systems. Feedback from experts suggested that the prices of heat pump hot water systems have *remained generally static over the past decade*. It is expected that any downward pressure on prices will be driven primarily through an increased uptake and market penetration. The price trend applied to the model for heat pump hot water systems costs was *a real-price increase driven by an inflation rate of 2.5 per cent.*

Air conditioning systems

The company, GfK, collects sales data from large appliance retailers that could form the basis for trends applied to single split-system and reverse cycle air conditioning units. Data between 2003 and 2014 for air conditioning units between 4 – 6kW was projected to 2050, as presented in Figure 14.

Figure 14: A collation of GfK data to estimate the price trends of 4-6kW air conditioning units



Residential Window Glazing

In the absence of Australian glazing price projections, a trend line could be adopted from a Swiss study by the Centre for Energy Policy and Economics. The study by Jakob *et al.* 2002[70] modelled the potential real prices of triple glazed windows, between 2000 and 2030 if market penetration was to increase from below a 10 per cent share to over 70 per cent. The trend for triple glazing was 0.8 per cent per annum in real terms.[71] This was used as an estimate of what price reduction could be experienced for a rapid uptake of double glazing in Australia.

Residential Insulation

Residential insulation was assumed based on analysis by Jakob et al. (2002), which examined the trends in the price of wall insulation of different thicknesses over the period 1980 and 2030, for Switzerland. No Australian data has been found at this stage. Relative to Australian R values, the data shows trends for:

- 12cm= R3.5
- 20cm= R5.5
- 30cm= R8

The model assumed the 20cm / R5.5 scenario was most applicable to Australian buildings. This trend showed a price reduction from about 145 (units uncertain) to 120 (units uncertain) over 30 years. This represents a decline in price of about 18 percent reduction or 0.6 per cent per annum in real terms to 2050.

Solar PV

Estimates for the price of solar PV out to 2050 are available from www.solarchoice.net.au. The trend in prices of solar PV in A$/W was averaged over all cities and all sizes of PV systems. The trend in price reduction from 2012 to the present has been sharp, and is presented in Figure 15.

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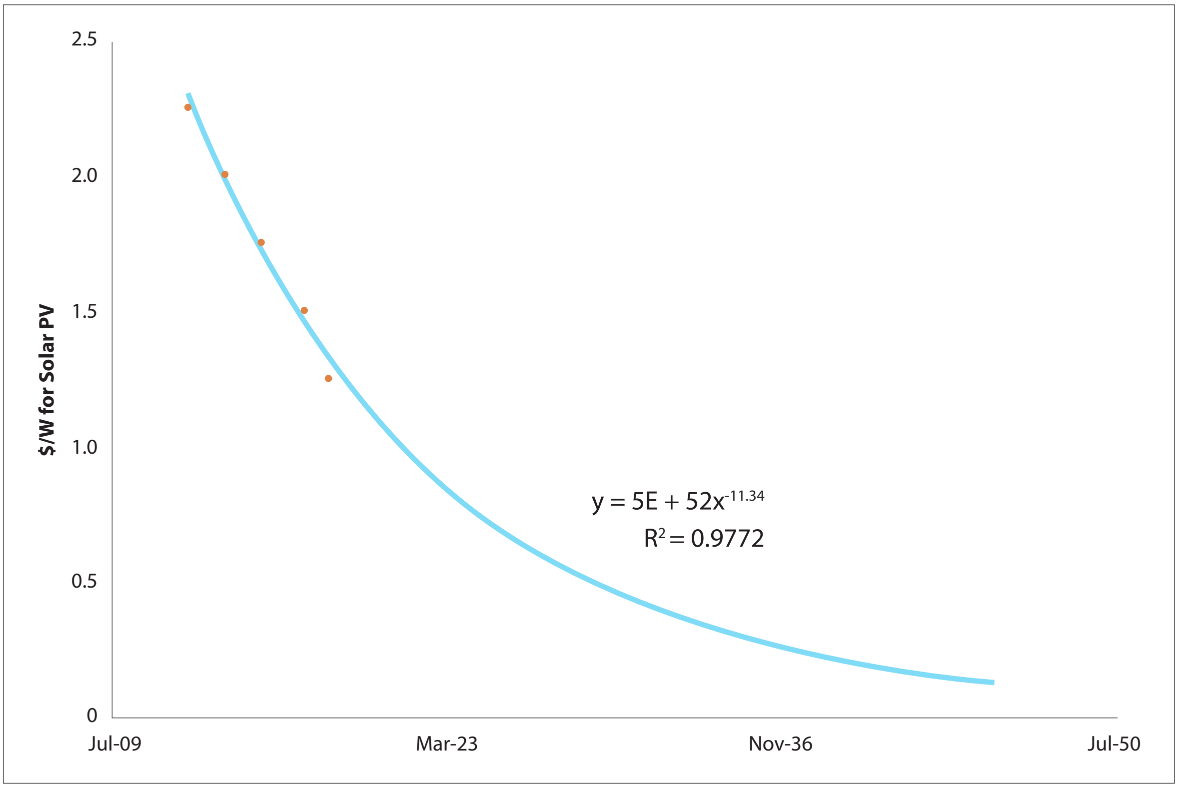
70 www.ethz.ch/content/dam/ethz/special-interest/mtec/cepe/cepe-dam/documents/people/ejochem/Jakob_Jochem_Christen_Grenzkosten_Schlussbericht_Teil1.pdf

71 Cited in Jakob M. and Madlener R., 2003 Exploring experience curves for the building envelope: an investigation for Switzerland for 1970-2020 Centre for Energy Policy and Economics, Swiss Federal Institutes of Technology

Figure 15: Trends in solar PV prices that could be used in a refined model based on data from www.solarchoice.net.au



Appendix D: Acronyms and definitions

ABCB	Australian Building Codes Board. The ABCB is responsible for Australia's national building code.
BMF	Building Ministers' Forum. The BMF is responsible for overseeing governance of the built environment, in relation to policy and regulatory issues impacting the building and construction industries.
Building shell	The key (external) elements of a house, including walls, roof/ceiling, floor and windows.
Carbon dioxide equivalent (CO_2-e)	Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential.
CBA	Cost benefit analysis
Class 1 building	Class 1a — A single dwelling being a detached house, or one or more attached dwellings, each being a building, separated by a fire-resisting wall, including a row house, terrace house, town house or villa unit.
	Class 1b — A boarding house, guest house, hostel or the like with a total area of all floors not exceeding 300m ^{2}, and where not more than 12 reside, and is not located above or below another dwelling or another Class of building other than a private garage.
Class 2 building	A building containing two or more sole occupancy units, each being a separate dwelling.
COAG	Council of Australian Governments. COAG is the peak intergovernmental forum in Australia. The members of COAG are the Prime Minister, state and territory First Ministers and the President of the Australian Local Government Association.
COAG Energy Council	The COAG Energy Council, chaired by the Commonwealth Minister for the Environment and Energy, is the body responsible for supervising and reforming Australia's energy markets.
E3	Equipment Energy Efficiency. The E3 program is a cross jurisdictional program through which the Australian Government, states and territories and the New Zealand Government collaborate to deliver a single, integrated program on energy efficiency standards and energy labelling for equipment and appliances.
Energy efficiency	Using less energy to provide the same service or achieve the same result.
Energy Productivity	Getting more useful energy out of a joule or kilowatt-hour of energy.
GEMS	Greenhouse and Energy Minimum Performance Standards
Heating and cooling load	Annual energy output of heating/cooling devices required to maintain certain thermal comfort conditions inside the home.
kWh	Kilowatt hour (unit of power measurement across time)
m^2	Square metres (unit of area measurement)
MEPS	Minimum Energy Performance Standards. The MEPS scheme applies mandatory minimum performance levels to a broad range of electrical and gas equipment product categories. MEPS typically cover appliances such as refrigerators, air conditioners and televisions.
MJ	Mega joule (unity of energy measurement)

Mt	Mega tonne or million tonnes (unit of measurement)
$MtCO_2e$	Million tonnes of carbon dioxide equivalent (unit of measurement)
NABERS	National Australian Built Environment Rating System is a national rating system that measures the environmental performance of buildings. NABERS provides waste management and indoor-environment quality star-ratings for offices, as well as energy and water ratings, which are also available for hotels, shopping centres and data centres.
NatHERS	Nationwide House Energy Rating Scheme. NatHERS is a star rating system (out of ten) that rates the energy efficiency of a home, based on its design. Its scope is limited to the thermal performance of the building structure and is intended to indicate the heating and cooling requirements. It ex-cludes other home energy use such as hot water, lighting and appliances.
NCC (or the Code)	National Construction Code. The NCC provides the minimum necessary re-quirements for safety, health, amenity and sustainability in the design and construction of new buildings (and new building work in existing buildings) throughout Australia. It covers the Building Code of Australia and Plumbing Code of Australia and is managed by the Australian Building Codes Board. NCC energy efficiency requirements cover heating and cooling performance of the building envelope, lighting, and large fixed equipment (e.g. air condi-tioning and lifts). Smaller appliances (such as refrigerators and computers) are excluded.
Nearly zero energy	Most energy consumption of the building is offset by renewable energy on-site or nearby.
NEPP	National Energy Productivity Plan. The NEPP is a COAG Energy Council agreed package of measures to improve Australia's energy productivity by 40 per cent between 2015 and 2030.
Net zero carbon emissions	All carbon emissions from the building are offset.
Net zero energy	All energy consumption of the building is offset by renewable energy on-site or nearby.
Peak demand	The maximum demand recorded in a given area. In the electricity market, to ensure reliability, supply capacity (generation and network) must be greater than the peak demand.
PJ	Petajoule (measure of thermal energy).
Primary energy	Refers to total energy embodied in the raw sources of energy such as coal, gas and oil.
PV	Solar photovoltaic power (photovoltaics)
Residential build-ings	Residential buildings include detached houses, attached dwellings and buildings containing two or more sole occupancy units.
RIS	Regulatory Impact Statement
Whole-of-House	A 'Whole of House' approach considers solar orientation, built form and ap-pliances. The elements of 'whole of house' energy consumption/greenhouse gas emissions in principle include: Space conditioning energy consump-tion/emissions, fixed appliance energy consumption, portable appliances, and photovoltaics.
Zero energy (and carbon) ready buildings	Zero energy (and carbon) ready homes have an energy efficient thermal shell and appliances, have sufficiently low energy use and have the relevant set-up so they are 'ready' to achieve net zero energy (and carbon) usage annually if they are combined with renewable or decarbonised energy systems either on-site or off-site.

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