BUILDING CODE ENERGY PERFORMANCE TRAJECTORY PROJECT

INTERIM REPORT

February 2018

The Bottom Line

The household impacts of delaying improved energy requirements in the Building Code

AUSTRALIAN SUSTAINABLE BUILT ENVIRONMENT COUNCIL

ClimateWorks AUSTRALIA

About Us

Project partners

The project is a partnership between ASBEC and ClimateWorks Australia.

The **Australian Sustainable Built Environment Council (ASBEC)** is the peak body of key organisations committed to a sustainable built environment in Australia. ASBEC members consist of industry and professional associations, non-government organisations and government and academic observers who are involved in the planning, design, delivery and operation of Australia's built environment.

ASBEC provides a collaborative forum for organisations who champion a vision of sustainable, productive and resilient buildings, communities and cities in Australia.

ClimateWorks Australia is an expert, independent adviser, acting as a bridge between research and action to enable new approaches and solutions that accelerate Australia's transition to net zero emissions by 2050. It was co-founded in 2009 by The Myer Foundation and Monash University and works within the Monash Sustainable Development Institute.

In the pursuit of its mission, ClimateWorks looks for innovative opportunities to reduce emissions, analysing their potential then building an evidence-based case through a combination of robust analysis and research, and clear and targeted engagement. They support decision makers with tailored information and the tools they need, as well as work with key stakeholders to remove obstacles and help facilitate conditions that encourage and support Australia's transition to a prosperous, net zero emissions future.

Technical partner and sponsor

The **Cooperative Research Centre for Low Carbon Living (CRCLCL)** is a national research and innovation hub for the built environment, funded by the Australian Government's Cooperative Research Centres Programme. The CRCLCL is leading and providing funding for technical analysis for the Building Code Energy Performance Trajectory Project.

The CRCLCL brings together industry and government organisations with leading Australian researchers to develop new social, technological and policy tools for reducing greenhouse gas emissions in the built environment. It seeks to grow industry confidence to invest in low carbon innovations, providing evidence to inform best practice Australian building codes and standards.

Delivery partners

The Building Code Trajectory Project is being delivered in partnership with CSIRO, Energy Action (EA), Strategy. Policy. Research. (SPR) and the University of Wollongong (UOW).

Supporters

The project is steered by an ASBEC Working Group comprising government, industry and academic stakeholders and chaired by Tony Arnel, a former Board member of the Australian Building Codes Board (ABCB), Chair of the Energy Efficiency Council and Global Director of Sustainability, NDY.

RACV is a lead project sponsor. RACV is one of Australia's largest membership organisations, serving more than 2.1 million members in the areas of mobility, home and leisure, delivering products and services, and advocating on their behalf.

Other project supporters include:

- A range of industry organisations including Australian Institute of Refrigeration Air Conditioning and Heating, Australian Windows Association, Consult Australia, CRC for Low Carbon Living, Energy Efficiency Council, Engineers Australia, Facility Management Association of Australia, Green Building Council of Australia, Insulation Australasia, Insulation Council of Australia and New Zealand, Property Council of Australia, and Vinyl Council of Australia; and
- Government departments, including ACT Environment, Planning and Sustainable Development Directorate, NSW Office of Environment and Heritage, QLD Department of Energy and Water Supply, QLD Department of Environment and Heritage Protection, QLD Department of Housing and Public Works, QLD Department of Infrastructure, Local Government and Planning, SA Department of Environment Water and Natural Resources, SA Department of Premier and Cabinet, and Victorian Department of Environment, Land, Water and Planning

The project has established two Technical Advisory Groups (one for the residential sector and one for non-residential buildings) comprising relevant experts in building design, construction and operation, energy performance in buildings, building energy modelling and cost-benefit analysis, and ASBEC, ClimateWorks and the delivery partners gratefully acknowledge the generous and highly valuable input they have provided throughout the project.

One-Page Summary

The National Construction Code is a ready-made policy instrument to influence the energy efficiency of new buildings and major renovations. Improved building energy efficiency presents a win-win-win solution, reducing stress on the electricity network and supporting a least-cost pathway to decarbonisation while also delivering cost savings and improved comfort to households and businesses. Improvements to the Code can have a large impact because new construction adds up fast: More than half of the buildings expected to be standing in 2050 will be built after the next update of the Code in 2019.

The Building Code Energy Performance Trajectory Project is an industry-led initiative seeking improvements to the energy requirements in the Code. This Interim Report presents preliminary results, focusing on short-term improvements to residential requirements. A Final Report will be published in mid-2018 focused on the establishment of a long-term trajectory for Code energy requirements for both residential and non-residential buildings.

Results

- There are immediate and cost-effective opportunities to improve energy efficiency requirements in the Code. Reducing air leakage is a major opportunity for many building types assessed, along with ceiling fans and roof insulation in some cases. Across a range of climate zones and building types, these measures could individually deliver bill savings of up to $150 per household per year, with savings more than offsetting additional capital costs.
- Combined, cost-effective measures could reduce energy consumption for heating and cooling by an estimated 28 to 51 per cent across a range of housing types and climates. This is equivalent to between 1 and 2.5 stars on the NatHERS scheme. In most jurisdictions, implementing these improvements would mean setting minimum requirements at the equivalent of 7 star NatHERS or higher.
- Implementing these opportunities across projected new buildings and renovations could save an estimated $1.2 billion to 2050 through avoided and deferred network investments, and deliver an estimated 10.8 million tonnes of cumulative emissions reductions to 2050, more than the annual emissions of Victoria's Loy Yang B coal-fired power station.
- Just three years' delay could lock in an estimated $1.1 billion in unnecessary energy bills for the projected half a million homes that will be built in the meantime, and 3 million tonnes of additional emissions to 2050.
- A high level assessment of rooftop solar PV indicates that it is now highly financially attractive at the household level, although it does not deliver a range of other benefits provided by energy efficiency.

Recommendations

- **Recommendation 1:** States, Territories and the Commonwealth should commit to harmonised strengthening of residential energy requirements in the Code by 2022 at the latest, or sooner. Individual States, Territories or local governments could show leadership by piloting strengthening standards by at least the equivalent of 1 star NatHERS in the meantime.
- **Recommendation 2:** States, Territories and the Commonwealth should introduce market transformation initiatives to reduce the cost of key energy saving technologies identified in this report, and improve industry capability in best practice building design for energy efficiency.
- **Recommendation 3:** States, Territories and the Commonwealth should commit to introducing renewable energy requirements in the Code (alongside optimal minimum efficiency requirements) and develop an implementation strategy that addresses the issues highlighted in this report.
- **Recommendation 4:** States, Territories and the Commonwealth should commit to improving Code compliance through:
  - Funding significant upgrades to NatHERS, including upgrades to enable improved assessment of air tightness;
  - Reviewing residential compliance pathways, including investigating the potential to replace or limit the use of Deemed to Satisfy and Reference Building methods; and
  - Improved monitoring and enforcement, including compliance audits and nationally standardised post-construction measures to verify as-built compliance.

CALL FOR FEEDBACK

ASBEC and ClimateWorks welcome feedback on the preliminary results presented in this Interim Report.

For any contributions, please contact:

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Executive Summary

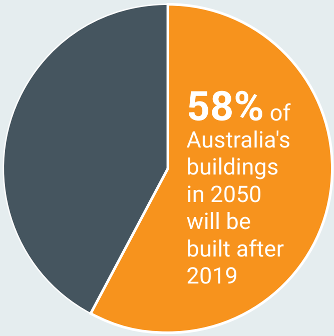
The National Construction Code is an important policy lever

The National Construction Code is a ready-made policy instrument to influence the energy efficiency of new buildings and major renovations. Improved building energy efficiency presents a win-win-win solution, reducing stress on the electricity network and supporting a least-cost pathway to decarbonisation while also delivering cost savings and improved comfort to households and businesses.

The Building Code Energy Performance Trajectory Project (the Trajectory Project) is an industry-led effort to support improvements to these energy requirements, which sit within the National Construction Code. Improvements to the Code can have a large impact because new construction adds up fast: more than half of the buildings expected to be standing in 2050 will be built after the next update of the Code in 2019[1].

The Code energy requirements have not been updated since 2010, while electricity prices have almost doubled over the past decade[2]. This Interim Report focuses on opportunities to improve the energy efficiency of residential buildings in the short-term, and estimates the cost of further delaying improvements to the Code energy requirements for homes. A Final Report to be published in mid-2018 will focus on establishing a long-term trajectory for Code energy requirements in both residential and non-residential buildings.

Share of 2050 building stock expected to be built after 2019



Low energy homes can improve comfort and living affordability, while delivering least-cost emissions reductions.

Already high - and rising - house prices, and the flow-on impacts on rental pricing, are exerting significant financial stress on households, particularly in the context of low real wage growth. Rising energy prices are adding to the burden. The average Australian family now spends around $2,115 on household electricity and gas costs per year[3]. This adds up to almost $20 billion across the whole economy[4]. Low-energy homes can reduce living costs, empowering inhabitants to put money that would otherwise have been spent on energy bills towards essential expenses, and investment in additional energy efficiency improvements which further reduce living costs.

Housing that is less reliant on air conditioning on hot days also puts less stress on the electricity grid, reducing the need for network upgrades and lowering electricity costs for everyone.

If a single household cuts their peak demand by one kilowatt (kW) - equivalent to the power used to run a small oil heater - this would save almost $1,000 in required investment in electricity system infrastructure, thus reducing electricity prices for everyone[5].

The cost-effective energy efficiency opportunities identified in this report would deliver an estimated financial benefit of $1.2 billion nationally by 2050 in the form of avoided or deferred network investments.

Energy efficient homes can also provide a comfortable refuge that improves health and wellbeing, particularly during cold winters and on extremely hot days. This is becoming increasingly important, given projected increases in the regularity and severity of extreme heat days in the future[6], with some of Australia's biggest cities likely to experience 50 degree days by 2050[7].

Our preliminary results show that the proposed cost-effective improvements to energy requirements could deliver 10.8 million tonnes of cumulative emissions reductions to 2050, more than the annual emissions of Victoria's Loy Yang B coal-fired power station. This assumes that the electricity system transitions to net zero emissions by 2050, in line with Australia's commitments under the Paris Agreement on climate change. If this transition occurs more slowly, the benefits of reducing energy use in buildings are greater. With no change to current policy, the proposed Code updates could deliver up to 19 million tonnes of emissions reductions, more than the total emissions from Loy Yang A, Victoria's largest power station.[8]

Without improvements in household energy efficiency, additional emissions reductions would be required in other sectors of Australia's economy that may not be as cost-effective or immediately achievable. This would lead to a higher overall cost to the economy of decarbonising.

Improved energy efficiency requirements in the Code could reduce energy consumption from heating and cooling by 28 to 51 per cent across a range of housing types and climates.

This study assessed a range of simple energy efficiency opportunities (see Appendix B for a full list) across three building types (detached, attached and apartment), and three climate zones covering Australia's largest population centres. It sought to identify improved energy efficiency measures for which the capital cost is outweighed by financial benefits ('cost-effective') from a societal perspective over the lifetime of the relevant building elements, in most cases a 10-15 year period. It considered opportunities to improve efficiency of the building 'fabric' (walls, ceilings, windows etc) and fixed equipment (hot water, lighting), but not plug-in appliances, which are regulated separately. A number of improvement opportunities remain under investigation. The analysis used conservative assumptions[9] and focused on simple lowest common denominator opportunities to improve energy efficiency. Importantly, the analysis did not consider opportunities for accelerated adoption of best practice building design for energy efficiency, such as optimal building orientation and window placement. While accelerated adoption of best practice design approaches may deliver a more optimal outcome, these approaches are currently far from mainstream, and this analysis sought to identify material improvements that are possible even without best practice design.

The most cost-effective energy efficiency opportunities identified include[10]:

- **Reduced air leakage**, which can be achieved at low cost through improved workmanship to prevent loss of conditioned indoor air and infiltration of unwanted outside air;
- Increasing **roof insulation** for detached housing; and
- Using **ceiling fans** in warm and hot climates to reduce the need for air conditioning.

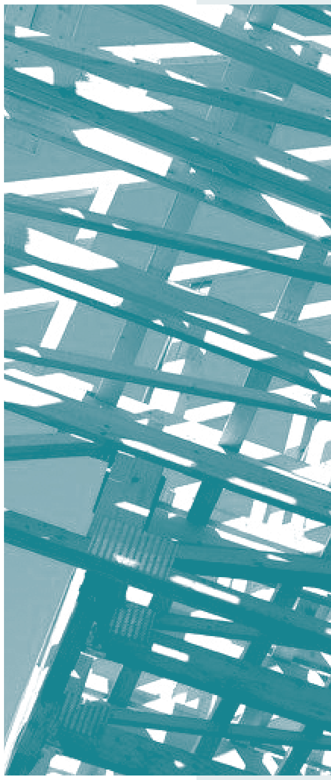
Each of these measures individually were found to reduce household energy bills by between $45 and $150 per year, with savings more than offsetting additional capital costs.

It was found that even without accelerated adoption of best practice building design and at today's energy prices, these cost-effective measures when combined could today deliver an improvement equivalent to between 1 and 2.5 stars according to the Nationwide House Energy Rating Scheme (NatHERS)[i]. This would reduce energy consumption from heating and cooling for the average home by between 28 and 51 per cent. In most jurisdictions, implementing these improvements would mean setting minimum requirements at the equivalent of 7 star NatHERS or higher[11].

Best practice design, accelerated industry learning and government initiatives to support market transformation could unlock even greater opportunities to improve energy performance.

The opportunities described above were found to be most cost-effective with current energy prices and technology costs. A range of other opportunities could become cost-effective if energy prices increase, or technology costs come down. Additional opportunities that have a significant energy impact but were not assessed to be cost-effective on current economic assumptions include:

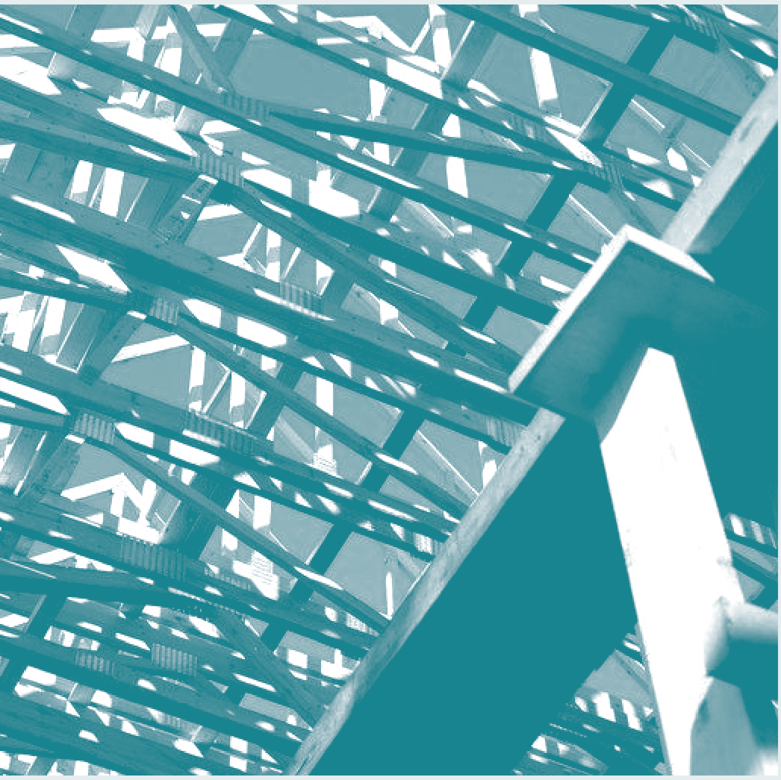
- Increased requirements for **wall insulation** (particularly in cooler climates);
- Stronger specifications for **window performance**;
- Installation of **roller shutters** and **larger eaves** in certain orientations (particularly in warmer climates);
- Increased **thermal mass**;
- Tighter standards for **lighting**; and
- Improved efficiency of **domestic hot water** systems.



i The extent of the opportunity varies by building type and climate zone. For the apartment archetype in climate zones 2 and 5, the costs of energy performance measures were found to outweigh the benefits based on current economic assumptions. The analysis approach is conservative as it only looks at individual apartment dwellings, and additional opportunities would likely be identified if a whole apartment building was modelled; see section 2.2 for further details.

In addition, numerous studies show that with best practice design for energy efficiency, such as proper orientation, sizing and placement, additional low-cost or even negative-cost improvements in energy efficiency are possible[12].

There is a role for government, working with industry groups, to support market transformation initiatives focused on (i) reducing the cost of these key technologies, for example through research, development and deployment funding and (ii) supporting industry learning and improvement in building design and construction for energy efficiency.



A high level assessment of rooftop solar PV indicates that it is now highly financially attractive at the household level, although it does not deliver the range of other benefits provided by energy efficiency.

A high level analysis of rooftop solar PV was undertaken for the detached and attached building types[13]. Solar PV systems are already more cost-effective than most of the energy efficiency opportunities identified in this analysis, using today's energy prices and feed-in tariffs for unused energy sold back to the grid. This creates a case for the introduction of renewable energy requirements for new homes in the Code. Renewable energy requirements will be particularly important if the Code moves towards requiring net zero energy or emissions homes, including to offset the energy consumption of in-home appliances. A number of implementation issues would need to be addressed in order to incorporate solar PV into the Code - these are considered briefly in section 4 of this report, and will be considered further in the Final Report.

It is important to note that solar PV systems have a much shorter lifespan than the building itself, and on-site renewables do not deliver the same comfort, health and resilience benefits as energy efficiency measures. In addition, improving energy efficiency first means that smaller solar PV systems are needed to meet a home's energy demand, reducing the cost of investing in such systems to reach net zero energy or net zero carbon. Accordingly, leading building designers adopt a 'fabric first' approach which prioritises efficiency of building 'fabric' first, followed by energy efficiency of equipment, appliances and on-site generation. For this reason, it is recommended that new homes continue to be required to meet a minimum level of fabric energy efficiency (e.g. through a NatHERS star rating) in line with the recommendations above.

Delaying improved energy requirements for housing could lock in an estimated $1.1 billion in unnecessary energy bills for Australian households to 2050, along with 3 million tonnes of additional greenhouse gas emissions.

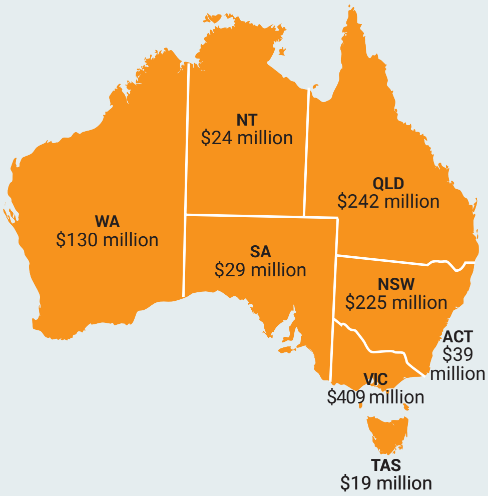
The Australian Building Codes Board is currently undertaking an update of the National Construction Code energy requirements for 2019. Improvements to the energy requirements for residential buildings are being proposed, including separate limits for heating and cooling and more detailed requirements for building sealing. However, there is no proposal to upgrade the stringency of the Code energy requirements for residential buildings in order to reduce the regulated level of allowable energy consumption.

The next opportunity to update the Code will not be until 2022, at which point it will have been 12 years since the last increase in energy requirements for houses and apartments.

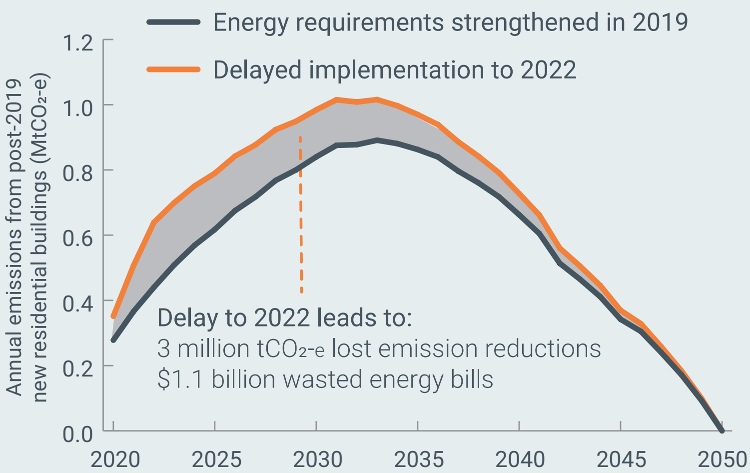
Between 2019 and 2022, an estimated half a million new dwellings will be built, many to 2010 minimum requirements[14]. These homes will still be standing in 2050 and beyond, at which point Australia will need to be at or near net zero emissions.

A three year delay would lead to an estimated $1.1 billion in unnecessary household energy bills by Australian households to 2050, while locking in $530 million in unnecessary network investments and 3 million tonnes of additional greenhouse gas emissions. When capital costs are taken into account, this amounts to $104 million net additional energy costs to 2050.

The cost of delay, by state and territory (cumulative additional energy bills to 2050)



The national emissions cost of delay

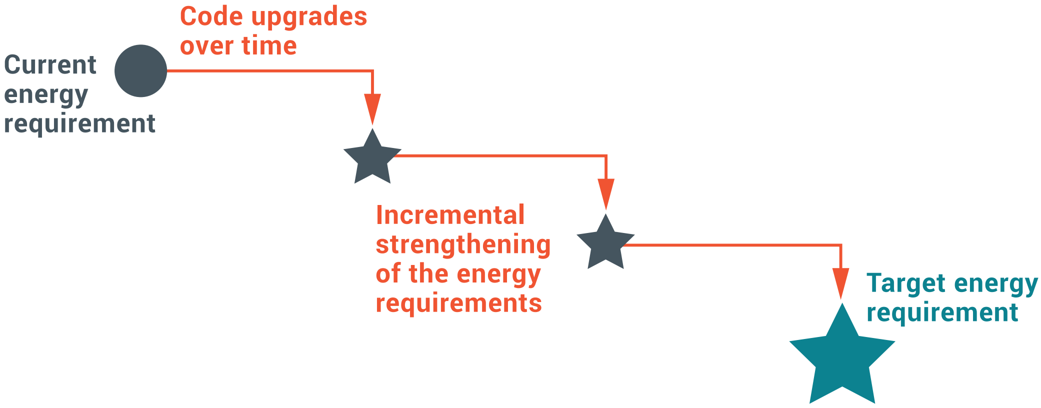


The next phase of this project will propose the establishment of forward trajectories for Code energy requirements, in order to spur innovation and investment in low energy building design and construction.

The next phase of the Trajectory Project will seek the establishment of long-term targets and a pathway, or forward trajectory, for improvements in Code energy requirements, as illustrated below. Planning steady improvements in energy requirements will deliver energy savings and emissions reductions, provide certainty for planning and investment, enable innovation and encourage the achievement of energy performance above and beyond current requirements[15].

This Interim Report presents initial results for the residential sector, complementing similar analysis already completed for non-residential buildings for the Australian Building Codes Board. Moving forward, the project will develop forward trajectories for eight building types (three residential and five non-residential) across four climate zones[ii]. Adopting forward trajectories will deliver the long-term certainty needed to spur industry investment and innovation, and help avoid further delays in Code updates in the future. Final results will be presented in a Final Report, due for publication in mid-2018.

Illustrative forward trajectory for Code energy requirements



ii The Interim Report includes analysis for climate zones 2 (e.g. Brisbane), 5 (Sydney, Perth) and 6 (Melbourne), and the Final Report will include climate zone 7 (Hobart, Canberra). There is also the potential for the Trajectory Project to include two additional climate zones in northern Australia, climate zones 1 (Darwin) and 3 (Alice Springs). If this additional scope is confirmed by the project partners, the results for these two climate zones will be included in the Final Report.

Summary of preliminary results - Identified cost-effective measures

Detached house

- **Require ceiling fans for climate zones 2 and 5**
  $50-$80 yearly energy bill savings per household
- **Increased roof insulation for all climate zones**
  $45-$80 yearly energy bill savings per household
- **Improved air tightness for all climate zones**
  $50-$150 yearly energy bill savings per household

Attached house

- **Require ceiling fans for climate zone 2**
  $50 yearly energy bill savings per household
- **Improved air tightness for climate zone 6**
  $115 yearly energy bill savings per household

Single Apartment#

- **Improved air tightness for climate zone 6**
  $130 yearly energy bill savings per household

* Equivalent NatHERS Star ratings assume that NatHERS is updated to enable higher air tightness to be credited, and assume a common 6 Star baseline across different jurisdictions.

^ Assumes limited technology cost/performance improvements, and no adoption of best practice building design for energy efficiency. More opportunity above 6 Star is likely to exist if these factors are considered.

A single, mid-level apartment was assessed in order to apply results to different sized towers. Results were averaged across four orientations. This does not account for whole-building opportunities, or insulation in ceilings or above basement car parks. Top and bottom apartments are likely to have more opportunity for improvement, and analysis of more apartment building types would likely find more opportunities.

1. Introduction

The Australian Sustainable Built Environment Council (ASBEC) and ClimateWorks Australia are working together to develop an industry-led forward trajectory for energy requirements in the National Construction Code. The Building Code Energy Performance Trajectory Project (the Trajectory Project) aims to support governments to adopt long-term targets and trajectories for the Code energy requirements. Ultimately, the adoption of long-term targets and forward trajectories for the Code energy requirements will:

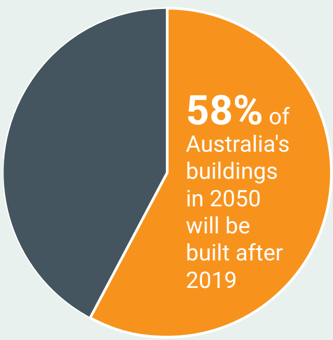
- Catalyse market transformation in the sector by providing a strong regulatory signal and guidance on the direction for future requirements, stimulating investment and innovation in low-energy building design, construction, materials and technologies; and
- Deliver higher performing buildings, resulting in improved energy productivity, more efficient use of energy infrastructure, energy cost savings, emissions reductions and improved health and comfort for building occupants.

1.1. The role of the National Construction Code

Australia needs a National Construction Code with strong energy standards.

Construction of new buildings adds up fast: an estimated 58 per cent of Australia's expected building stock in 2050 will be built after 2019[16]. New and renovated buildings with higher energy performance will eventually transform the built environment by increasing the average energy efficiency of the entire building stock[17].

FIGURE 1: Share of 2050 building stock expected to be built after 2019



The National Construction Code is a ready-made policy instrument to influence the energy performance of new buildings and major renovations. The Code sets minimum requirements for all new building work in Australia, and includes requirements for energy efficiency. It is a model code developed and maintained by the Australian Building Codes Board (ABCB) under an intergovernmental agreement, and enforced by the States and Territories through implementing legislation. Each jurisdiction may elect to apply the Code with amendments, to suit their own context[18].

Mandatory minimum standards, including standards for new construction in the Code, are a crucial part of a holistic package of policy measures needed to save energy and rapidly decarbonise Australia's built environment (see Figure 2). Mandatory minimum standards are particularly important because voluntary action has proven insufficient to deliver significant improvements in energy performance across the market as a whole. The ASBEC *Low Carbon, High Performance* report indicates that over a decade period, advances in energy efficient design and construction approaches enabled market leaders to achieve large improvements in energy performance. Over the same period the market as a whole improved only two per cent for commercial buildings, and five per cent for residential[19] (Figure 3). This is despite considerable effort being invested in information campaigns, incentives and other non-regulatory measures, and suggests that a regulatory signal is required.

FIGURE 2: Mandatory minimum standards, including the Code, are just one part of a suite of complementary market transformation measures[20]

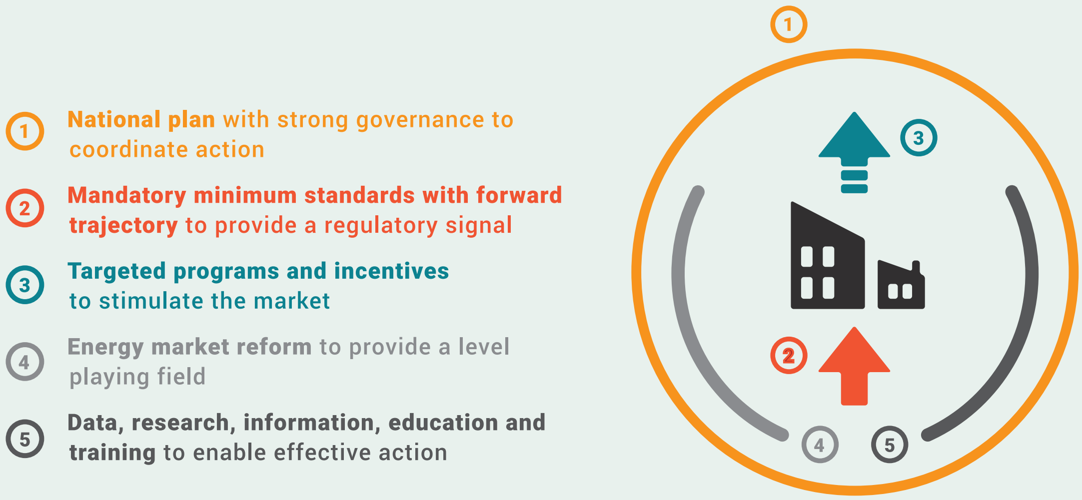
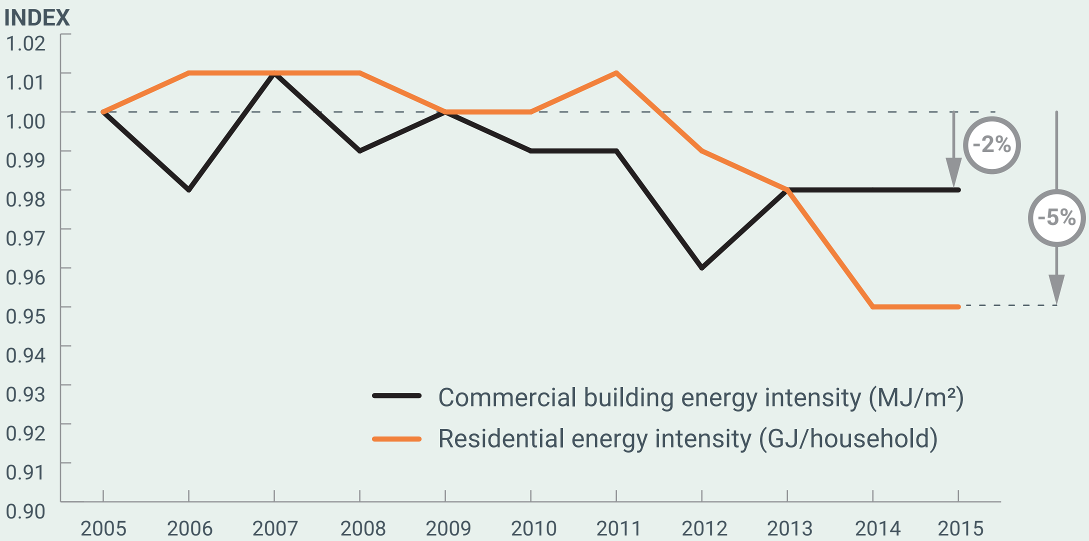


FIGURE 3: Evolution of the average energy intensity of commercial and residential buildings between 2005 and 2015. From *Low Carbon, High Performance* (2016)



While the Code is an important lever for improving building energy performance, it is important to note that the Code only regulates building 'fabric' and fixed equipment for new homes and renovations. For residential buildings, the Nationwide House Energy Rating Scheme (NatHERS) that is commonly quoted to describe the star rating of a building only covers the heating and cooling performance of the building fabric; additional requirements for fixed equipment such as lighting are set out in the Code separate to NatHERS requirements. For non-residential buildings, Code compliance can also be achieved in part through the use of on-site energy generation.

Other significant energy sources and energy efficiency opportunities, most importantly plug-in appliances and occupant behaviour, are not regulated by the Code and are therefore not in the scope of this report. Likewise, retrofitting of existing homes is outside the scope of the Code and this report. A range of other measures beyond the Code will be required in order to fully unlock the energy and emissions potential in the built environment, as outlined in the *Low Carbon, High Performance* report.

1.2. The focus of this report

This Interim Report presents preliminary results focused on opportunities to improve the energy efficiency of residential buildings in the short-term.

This report explores the opportunity for short-term cost-effective improvements in Code energy requirements for residential buildings. The analysis for this report takes a conservative approach, as it assumes no significant changes in design practices. A conservative approach has been taken in recognition of the fact that while accelerated adoption of best practice design approaches may deliver a more optimal outcome, these approaches are far from mainstream, and material improvements are possible even without best practice design. The analysis is also conservative because it does not quantify a number of important benefits of efficient homes (due to a lack of resources to do so) and because it adopts a number of conservative assumptions (due to the highly contested nature of these assumptions). Improved design, less conservative assumptions or quantification of broader benefits could deliver more energy efficiency, at lower cost and with higher benefits than those presented in this report. A number of short-term energy efficiency opportunities in residential buildings remain under investigation, and results presented here are preliminary - final results will be published in the Final Report (see below).

The focus on residential buildings in this report complements the current proposal by the ABCB to strengthen the energy requirements for commercial buildings in the 2019 update of the Code, and improve the energy requirements for residential buildings to include separate limits for heating and cooling and more detailed requirements for building sealing. However, no increase in the stringency of residential standards is currently planned for the 2019 Code, meaning the next opportunity will not be be until the next Code update in 2022.

A Final Report presenting final results and focusing on the long-term trajectory for Code energy requirements for both residential and non-residential buildings (see the Planning for the Future section) is expected to be published in mid-2018.

2. The Opportunity

Energy is inextricably linked with broader affordability issues facing Australian households. High house prices and rental costs exert significant financial stress on households, and rising energy prices are adding to the burden[21]. While individuals have very limited influence on housing affordability, there are concrete actions that can be taken to improve building energy performance and reduce energy use, particularly during the design and construction of new buildings and major renovations. Energy performance can be improved through energy efficiency measures that reduce the energy required to run a home, combined with on-site solar photovoltaic (PV) electricity generation. The benefits of energy performance can flow on to the broader economy, with growing uptake of new technologies supporting new jobs in manufacturing and in the building and construction industry[22]. The Trajectory Project represents an industry-led effort to encourage the development of better quality homes that are more comfortable, safer in extreme weather, lower cost and lower emissions.

2.1. The benefits of low-energy homes

There are significant opportunities for improved energy requirements to save money for households and improve living affordability.

The energy used in Australian buildings is costly to households and businesses. Retail electricity prices have increased for households by 80 to 90 per cent over the past 10 years[23]. The average Australian family now spends around $2,115 on household electricity and gas costs per year[24], adding up to almost $20 billion across the whole economy[25]. Significant cost savings on electricity and gas bills can be achieved for households through more efficient house design and construction: *Low Carbon, High Performance* shows that, in total, over $16 billion in savings for households can be achieved between 2016 and 2030 by improving the performance of residential buildings in Australia[26]. These savings are particularly important for low-income households to preserve household budget for food and other essential expenses[27], as low-income households spend up to five times more of their disposable income on electricity than high-income earners[28]. These savings could also empower households to invest in additional improvements in energy performance, leading to further savings in the future.

Low energy buildings reduce the burden on the electricity system, delivering lower electricity prices for everyone.

Buildings consume over half of Australia's total electricity[29], so reducing building energy use can also benefit the electricity grid. Improving energy efficiency and installing on-site generation with storage both reduce the burden buildings place on the grid. Increasingly, smart heat pumps, smart swimming pool pumps, solar PV and batteries can enable households to participate in demand response programs that reduce energy consumption at peak periods. Efficiency, on-site generation and demand management measures avoid transmission and distribution network costs, particularly the cost of delivering electricity during periods of peak demand (e.g. during heatwaves, in the afternoons and early evenings when businesses are still operating and people are returning from work)[30]. Reducing demand also reduces the amount of new large-scale renewable energy generation infrastructure required to achieve net zero emissions, lowering the cost of meeting Australia's commitments under the Paris Climate Change Agreement.

If a single household cuts their peak demand by one kilowatt (kW), equivalent to the power used to run a small oil heater, this is estimated to save almost $1,000 in required investment in electricity system infrastructure, reducing electricity prices for everyone.

The cost-effective energy efficiency opportunities identified in this report would deliver an estimated financial benefit of $1.2 billion nationally by 2050 in the form of avoided or deferred network investments.

Low-energy design and construction is important for keeping homes comfortable, healthy and safe in a changing climate.

Growing evidence shows that Australia's buildings can significantly improve their occupants' health and wellbeing by providing comfortable indoor environments.

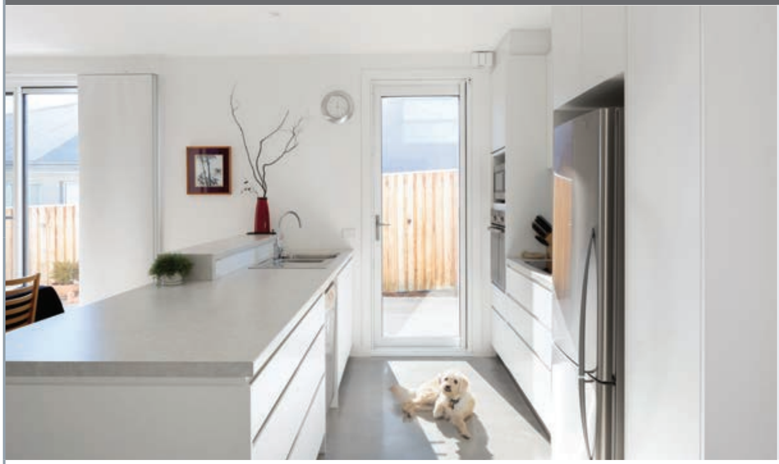
Both hot and cold weather are recognised as major contributors to poor health and even premature deaths[31]. The health impacts of heatwaves in particular could increase as the climate changes, with Australia's capital cities projected to potentially experience 50 degree days by 2050[32]. Rising electricity prices may lead to some households to ration their use of air conditioning[33], and many existing air conditioners could even fail on the hottest days[34], presenting a health risk for Australia's most vulnerable populations[35]. Increased hospital admissions during extreme weather events also leads to greater pressure on health and emergency services and on government health budgets[36].

Quality housing design and construction can keep indoor temperatures safe and comfortable for occupants in both the heat and the cold (see Box 1 for examples in colder climates). The broader benefits of low-energy homes, including health benefits, have been demonstrated by multiple studies in Australia and abroad[37]. For example, delivering household energy efficiency programs can improve residents' general satisfaction with their comfort and the quality of their living space while reducing social isolation, with residents more likely to host friends and family when their home is more comfortable[38]. Research currently underway in the UK suggests that residents of low-energy houses are highly satisfied with comfort levels of their homes[39]. In Australia, initiatives to improve household energy efficiency have been shown to reduce stress levels and improve comfort[40]. During heat waves, homes that are designed to maintain comfortable temperatures without air conditioning can not only keep residents cool and save on energy bills, but also avoid further raising local temperatures with the hot air produced by air conditioning units[41].

The scope of the Trajectory Project analysis has not included the health, comfort, safety and resilience benefits of improved energy efficiency, resulting in a potentially conservative outcome. Though quantifying the impacts of these non-energy, non-financial benefits can be challenging, they are important to consider in regulatory analysis[42], and robust tools to assess them are currently available[43].

Further research to quantify broader benefits of energy efficiency is likely to reveal that higher levels of energy efficiency are cost-effective if these benefits are included, compared with analysing energy efficiency on financial grounds alone.

Box 1 Keeping warm and managing condensation in a cold climate



Size: *113 square metres*

Construction cost: *$2,500 per square metre*

Year of construction: *2014*

Location: *Canberra ACT (climate zone 7)*

NatHERS rating: *7.9 stars*

Stray Leaf House

Stray Leaf House is designed to make the most of the sun's warmth in the winter, with living spaces oriented to the north and features like double glazing, concrete floors and a well-sealed internal building shell to retain heat. Internal condensation is not an issue because exhaust fans are used to extract moist air from wet areas when cooking or washing, and the internal surfaces of the well-insulated building shell, including PVC-framed double glazing, rarely reach temperatures low enough for water vapour to condense. Window sizes and locations were cleverly selected to bring in daylight only where needed, resulting in a warm and naturally well-lit home with only an 18 per cent window-to-wall ratio.

This study was contributed by Light House Architecture and Science.

Size: *240 square metres*

Construction cost: *$1,771/ square metre*

Year of construction: *2016*

Location: *Somers VIC (climate zone 6)*

NatHERS rating: *9.1 stars*

Annual energy bills: *Estimated at between $300 and $700*

Ocean View Crescent

Well-sealed homes can require little or no mechanical heating, even in cold climates. Ocean View Crescent, winner of the 2017 Best Sustainable Home Award from Master Builders Association of Victoria, has been constructed to a level of air tightness 90 per cent better than average Australian homes. In its first winter since construction, the temperature never dropped below 16 degrees Celsius, even on cold winter mornings.

This study was contributed by Nick Wootton.

2.2. Short-term opportunities to strengthen energy requirements

The Trajectory Project has identified cost-effective opportunities to strengthen energy requirements by between 28 and 51 per cent for selected housing types and climates.

The analysis for the Trajectory Project was completed across three building types:

- Detached, single-storey house;
- Attached, two-storey townhouse or terrace house; and
- Single apartment[iii];

and for three climate zones covering Australia's largest population centres:

- Climate zone 2 - Warm humid summer, mild winter (e.g. Brisbane);
- Climate zone 5 - Warm temperate (e.g. Sydney, Adelaide, Perth); and
- Climate zone 6 - Mild temperate (e.g. Greater Western Sydney, Melbourne).

Analysis is planned for climate zone 7 (cool temperate, e.g. Canberra, Hobart), with modelling results to be included in the Trajectory Project Final Report. The Trajectory Project team is also exploring avenues to extend the modelling to climate zones 1 and 3 (which include Darwin, northern Western Australia, Alice Springs and far north Queensland).

The analysis sought to identify improved energy efficiency measures for which the capital cost is outweighed by financial benefits from a societal perspective over the lifetime of the relevant building elements, in most cases a 10-15 year period. It considered a range of opportunities to improve energy performance which are detailed in Appendix B.

Using conservative economic assumptions and even without considering best practice design approaches, the improvements could be achieved through:

- **Reduced air leakage**, which can be achieved at low cost through improved workmanship to prevent unwanted infiltration of outside air, and escape of conditioned indoor air (see Box 2);
- Increasing **roof insulation** for detached housing; and
- Using **ceiling fans** in warm and hot climates to keep home occupants cool so as to reduce the need for air conditioning.

For the building types and climate zones where they have been found to be 'cost-effective', each of these measures individually were found to reduce household energy bills by between $45 and $150 per year, with savings more than offsetting additional capital costs.

Preliminary results suggest that when combined, the cost effective measures could reduce energy consumption for heating and cooling by an estimated 28 to 51 per cent across the various building types and climate zones. This approximates to the equivalent of a 1 to 2.5 Star improvement on the Nationwide House Energy Rating Scheme (NatHERS), which calculates a Star rating based on the predicted heating and cooling energy of a home. For most jurisdictions, this means that it would be cost-effective to set minimum thermal performance requirements equivalent to 7 star NatHERS[iv].

The potential for these measures to improve energy efficiency cost-effectively varies by building type and location, as illustrated in the graphic on page 12. For the apartment

archetype in climate zones 2 and 5, the costs

iii The apartment analysis presented in this Interim Report are focused on individual apartments and not whole apartment buildings. Common areas are excluded from the analysis discussed here, but common area requirements are included in the broader Trajectory Project as part of the commercial building analysis. Results will be presented in the Final Report.

iv Equivalent NatHERS Star ratings assume that NatHERS is updated to enable higher air tightness to be credited, and assume a common 6 Star baseline across different jurisdictions.

of energy performance measures were found to outweigh the benefits based on current economic assumptions. The project looked at only a single, mid-level apartment dwelling averaged across four different orientations in order to expand the applicability of the results to apartment towers of different sizes. However, this approach is conservative as it does not allow for opportunities for whole-building design responses such as trade-offs in different orientations, or ceiling insulation and insulation above a basement car park. It also does not account for the variability in performance across different apartment dwellings in the one dwelling. The lower-rated apartments in a building are likely to have greater opportunities for improvement than the higher-rated apartments. The Trajectory Project scope was limited to one apartment archetype; analysis of a diverse range of whole apartment buildings of different geometric forms would likely lead to the identification of further cost-effective opportunities for apartments.

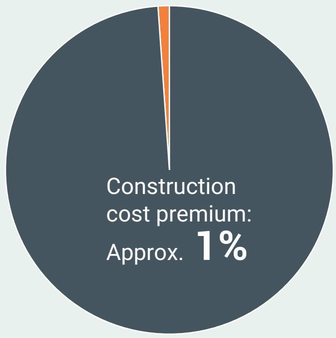
Variations for different climate zones and building types are summarised in Appendix B, and discussed in further detail in the Interim Technical Report, available on the ASBEC and ClimateWorks websites[44].

The estimated construction cost premium[v] associated with these changes ranges between $656 to $3,000.

For detached homes, the estimated cost premium translates to approximately $12 to $17 per square metre, which amounts to just 1 per cent of typical construction costs[vi].

Looking at it another way, the estimated cost premium is approximately equivalent to a single month of house price rises.[45] Costing details are summarised in Appendix B. It is possible that the cost premium determined by this analysis is overstated, as industry may respond to strengthened energy requirements by modifying housing design and construction to reduce the impact on total construction costs[46].

FIGURE 4: Incremental increase in capital cost (for the detached house archetypes) compared with typical construction cost



v The cost premium for each individual measure is calculated as the upfront capital costs of the measures, minus savings associated with downsizing heating and cooling equipment and network benefits associated with reduced peak demand.

vi Average construction costs are difficult to determine, but industry consultation suggests a range of between $1,500 per m^2 for volume built homes and upwards of $4,000 per m^2 for custom architect-designed homes.

A major opportunity to strengthen Code energy requirements is to introduce performance standards and verification requirements for air leakage.

The Code requires residential buildings to include construction features that minimise air leakage[47]. It sets out specific requirements for common air leakage points in a building to be sealed, including exhaust fans, windows and doors. However, the Code does not set a minimum overall air leakage performance level that needs to be achieved.

Until recently there had been relatively little practical testing of the air tightness of Australian dwellings. However, standard 'blower door' testing from 2015 in capital cities around Australia found that newly constructed buildings (less than three years old) had an average air leakage rate of approximately 15 air changes per hour at 50 pascal pressure (ACH@50Pa, a standard measure for air tightness)[48]. These homes have been assumed as representative of those currently being built to current Code requirements. In order to properly assess the opportunity for improved air tightness, the Trajectory Project modelling assumes approximately 15 ACH@50Pa as the base case air leakage benchmark for the residential archetypes modelled.

The modelling results suggest that, for the archetypes and climate zones included this project, there may be significant opportunities to cost-effectively improve energy performance by improving air tightness to around 6 ACH@50Pa. Potential measures to achieve this improvement include:

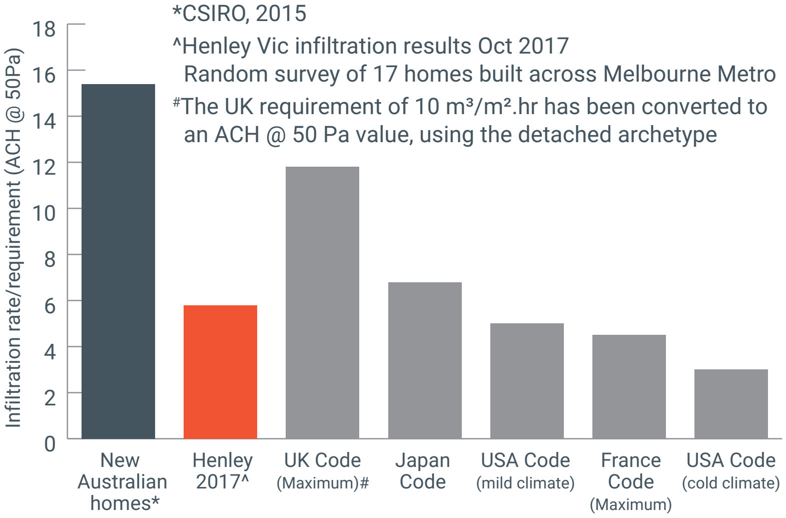
- Undertake research on existing housing to identify the building sealing measures required to achieve improved air tightness performance levels. If there are measures required to achieve better air tightness that are not currently in the Code, consider including these in the Deemed to Satisfy Code building sealing requirements; and/or
- Increase the minimum NatHERS Star rating requirement (or equivalent, e.g. BASIX in New South Wales) as recommended in this report, and provide an option for project teams to achieve this rating by inputting a lower air leakage into the NatHERS software. This strategy would require NatHERS energy rating software to be enhanced to enable project teams who achieve higher than the mandatory level of air tightness to be rewarded for this in the calculation of their star ratings (see section 4.4 for further details on this recommendation).

An air leakage rate of 6 ACH@50Pa as modelled is a reasonable level for the Code to target in the short term. The CSIRO study found that 18 per cent of the houses tested were already at less than 8 ACH@50Pa, and around one third were less than 10 ACH@50Pa, even in the absence of specific infiltration rate requirements[49] This level of air tightness is also comparable with international standards and is what some leading builders have stated they are achieving as standard practice (see Box 2). At this level of air tightness, indoor moisture and pollutant levels can be managed by effective ventilation fans in the kitchen and bathroom - heat recovery ventilation is not generally needed to ensure energy efficient fresh air delivery at this level[50].

Box 2
Beating the leaks - boosting home comfort and energy performance at low cost

Reducing air leakage is one of the most cost-effective ways to improve home comfort and energy performance. Australian buildings are extremely leaky when compared to the rest of the world (see Figure 5), although there is wide variability, between 1.4 and 39 air changes per hour[51]. This is perhaps in part a result of our relatively moderate climate, but also the fact that, unlike many of our international peers, the National Construction Code does not set a quantified minimum.

FIGURE 5: Comparison of different countries' building code infiltration requirements for residential buildings with measured results

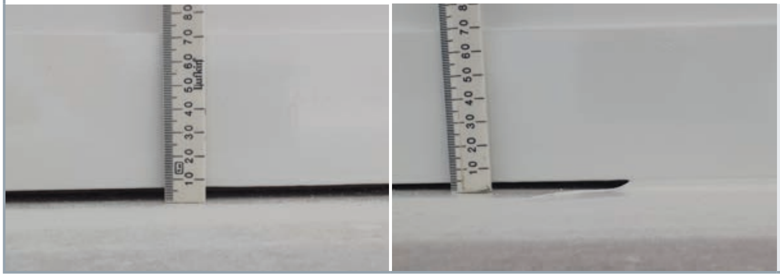


Leading builders such as Henley Properties have shown that achieving sensible levels of air tightness is possible without any additional construction cost.

"Henley is able to achieve air tightness levels of five air changes per hour easily, robustly, reliably and repetitively with simple construction practices, fixtures, fittings and materials and at zero additional cost"

Adam Selvay, Energy and Sustainability Manager, Henley Properties

Henley Properties is able to achieve these higher levels of air tightness using relatively simple measures such as sealing skirting boards and walls to floors, and effective sealing of ducting connections.



Skirting board prior to sealing (left) and during sealing (right) to demonstrate how sealing can remove the gap between the skirting board and the floor, leading to lower air leakiness.

Best practice design, accelerated industry learning and government initiatives to support market transformation could unlock even more opportunities to improve energy performance.

The analysis undertaken for this first stage of the Trajectory Project takes a conservative approach. It assumes no significant changes in design, and simply investigates the costs and benefits of adding energy-saving components to typical housing types. Numerous studies have demonstrated that best practice building design with a focus on energy efficiency can significantly improve energy performance at low or even negative cost (see Box 3 for some examples). Best practice building design includes proper orientation and shading to avoid unwanted heat coming into the building in summer while maximising light and heat gain and retention in winter, considered selection of window size and placement, and natural ventilation when appropriate. However, this approach is not necessarily mainstream practice across much of the housing industry - for example, anecdotal evidence suggests that some volume home builds are designed to meet minimum energy requirements in a manner that is insensitive to orientation and climate zone[53].

In addition to this, the analysis assumes no complementary initiatives such as technology research and development support or industry training and education, which could significantly reduce the cost of achieving higher energy efficiency. Further, the analysis does not quantify the health and resilience benefits of energy efficiency; if these are incorporated, energy efficiency measures are likely to prove much more cost-effective, especially in the context of rising temperatures and projected increases in extreme weather.

The results of this analysis are therefore likely to overestimate the costs to achieve this level of energy efficiency, and at the same time underestimate the potential 'cost-effective' improvements in the energy requirements in the Code. In other words, the energy-saving components analysed are likely to be even cheaper and deliver more benefits than this analysis suggests.

The conservatism of this analysis means that even more energy efficiency improvements are likely to be cost-effective. For example, if higher industry learning rates occur, or government introduces market transformation initiatives to help improve learning rates and reduce costs, additional improvements in the energy performance could be achieved in residential buildings.

Of the other measures assessed, the following were found have the greatest energy impact, and could become cost-effective if costs reduced or electricity prices and related costs (including network costs and the social cost of carbon) increased:

- Increased requirements for **wall insulation** (particularly in cooler climates);
- Stronger specifications for **window performance**;
- Installation of **roller shutters** and l**arger eaves** in certain orientations (particularly in warmer climates);
- Increased **thermal mass**;
- Tighter standards for **lighting**; and
- Improved efficiency of **domestic hot water** systems.

In the next phase of this project, the impact of changes in construction and energy costs over time will be used to determine if and when the above measures could be incorporated into the Code energy performance trajectory, and what complementary market transformation interventions might be required to achieve the desired reductions in construction costs. Section 5. Next Steps provides further details on the approach for the forward trajectory analysis.

Box 3 Delivering extraordinary performance for an ordinary price

Size: *152 square metres*

Construction cost: *$1,579 per square metre*

Year of construction: *2013*

Location: *Perth, WA (climate zone 5)*

NatHERS rating: *10 stars*

Annual net energy consumption: *Approximately 17kWh per square metre – Comparable with the requirements of Passive House*

Annual energy bills: *Josh's House imports less than 10 per cent of the electricity of a typical Australian home from the grid, saving the occupants an estimated $1,500 per year.*

Josh's house

Josh's house demonstrates that high energy performance can be achieved for the cost of a typical build. Paying careful attention to building orientation and design means that no air conditioning is required even in Perth's hot climate. The owner, Josh Byrne, is now communicating his experiences to demonstrate that highly energy efficient homes can be highly liveable and built at a comparable cost to standard houses.

This study was contributed by Josh Byrne & Associates.

Size: *136 square metres*

Construction cost: *Approximately $1,400 per square metre (Melbourne example)*

Location: *Melbourne, Victoria (climate zone 6) and Canberra, ACT (climate zone 7)*

NatHERS rating: *8 stars*

Annual energy bills: *Estimated to be $84 per year without solar PV, and $0 per year with a 3kW solar system.*

High Performance House

High Performance House Done Dirt Cheap is a house design demonstrating the potential to achieve extremely high energy performance on a tight budget. Constructed at three locations to a NatHERS 8 Star standard, the house's size and orientation is carefully designed to keep indoor temperatures comfortable in all seasons. During their first winter in the home, the residents of one house in Canberra didn't turn on their heating once, even when temperatures outside reached minus 10 degrees Celsius.

This study was contributed by F2 Design.

Size: *3 x 120 square metre townhouses, each with 30 square metres of garden space, along with a shared front productive garden*

Construction cost: *The project is yet to go to tender, however to achieve its financial accessibility aims, is targeting construction at $2,000 per square metre, subject to final specification and negotiations with a preferred builder.*

Year of construction: *Under construction*

Location: *Melbourne, Victoria (climate zone 6)*

NatHERS rating: *8 stars*

Davison Street Collaborative

The Davison Street Collaborative demonstrates how innovative business models can bring down the cost of building low-energy homes. In the project's 'Collaborative Housing' model, a Joint Venture proposal created by HIP V. HYPE utilising design-thinking principles, people pool their resources to develop three townhouses on one inner-city block. This model results in lower costs as financial returns are diverted directly to the people collaborating on the project rather than a third-party developer. The model also gives the people collaborating more control over the design and construction of their home, resulting in greater end-user focus.

This study was contributed by HIP V. HYPE.

2.3. The transition to net zero emissions by 2050

Australia needs a rapid transition to net zero emissions, and many of the lowest cost, shovel-ready opportunities are in the design and construction of new homes.

Australia's commitment to the Paris Agreement means taking action to reach net zero emissions by around 2050. A number of States and Territories have also committed to ambitious emissions reduction targets, including net zero emission targets in South Australia, the ACT, Victoria, NSW, Tasmania and Queensland. Achieving this level of emissions reduction relies on four pillars of decarbonisation: improving energy efficiency, implementing low carbon electricity, electrification and moving away from fossil fuels, and reducing non-energy emissions[54].

Buildings currently account for almost a quarter of Australia's annual emissions[55], with residential energy use responsible for approximately half of the total emissions in the buildings sector[56]. Decarbonising buildings is essential to reduce Australia's overall emissions cost-effectively. ClimateWorks' analysis of least-cost, feasible pathways to achieve deep decarbonisation suggests that residential buildings must contribute at least seven per cent of Australia's efforts to reach net zero emissions by 2050, equivalent to 1,720 million tonnes of cumulative emissions reductions by 2050[57].

Without improvements in household energy efficiency and a shift to all-electric homes (see Box 4), additional emissions reductions would be required in other sectors of Australia's economy that may not be as cost-effective or immediately achievable. This would lead to a higher overall cost to the economy of decarbonising.

Our results show that the proposed short-term improvements in energy requirements could deliver 10.8 million tonnes of emissions reductions to 2050, more than the annual emissions of Victoria's Loy Yang B coal-fired power station.[58] This assumes a rapid decarbonisation of the electricity grid, in line with a smooth transition to net zero emissions nationally by 2050. This would require new policies which to date have proven extremely challenging to implement at the national level. In the event of slower, 'business-as-usual' grid decarbonisation, the proposed improvements could deliver up to 19 million tonnes of emissions reductions to 2050.[59]

Further emissions reduction opportunities in buildings are expected to become cost-effective in the future with the right combination of policy measures, and this will be investigated in the Trajectory Project Final Report.

Box 4 Gas and New Construction

The analysis for this report assumes that all newly constructed buildings will be 'all electric'. Research shows that this is currently more cost-effective than installing gas connections in new buildings[60]. This is because electric heating and hot water technology is becoming increasingly efficient, so despite gas being cheaper per unit of energy than electricity, electric appliances have lower running costs than their gas-powered counterparts. Retail gas prices have significantly increased in most states since 2006[61], making gas increasingly unaffordable for households. An all-electric approach would also reduce the cost of building homes in new suburbs, as it avoids the need for costly new gas infrastructure to be built.

Phasing out gas in buildings is needed over the long term to meet Australia's commitment to net zero emissions by 2050 under the Paris Climate Change Agreement, as electricity generation transitions towards low carbon energy sources and becomes less emissions-intensive than gas[62]. Coupled with current concerns about domestic gas supply, increasing Australia's gas demand through new buildings does not add up.

The all-electric scenario modelled here does not necessarily preclude future regulations from allowing buildings to connect to 'zero net emissions' gas (such as biogas) if this option becomes more available and cost-effective. It also does not preclude the use of alternative fuels such as wood if it can be demonstrated that this is consistent with a long term net zero emissions target. Further work is required to investigate the role of non-electric energy sources in building regulations and in the transition to net zero emissions.

3. The Cost of Delay

Delaying improved energy requirements for housing locks in higher energy costs for Australian households.

The Australian Building Codes Board is currently undertaking an update of the National Construction Code energy requirements for 2019. Strengthening the energy requirements for commercial buildings is being proposed for Section J of the 2019 Code. Adjustments to the energy requirements for residential buildings are also proposed for the 2019 update to make the requirements clearer and easier to comply with. This includes proposals for separate limits for heating and cooling to encourage balanced climate-responsive design, tighter controls on alternative compliance methods (including Verification Using a Reference Building) and more detailed requirements for building sealing. However, there is no proposal to upgrade the stringency of the Code energy requirements for residential buildings, in order to reduce the regulated level of allowable energy consumption.

The next opportunity to update the Code will come in 2022, at which point it will be 12 years since energy requirements were last increased for houses and apartments. Between 2019 and 2022, an estimated 500,000 dwellings will be built, many to 2010 minimum requirements[63]. These homes will still be standing in 2050 and beyond, when Australia will need to be at or near net zero emissions nationally, and regardless, is expected to be experiencing an increase in extreme weather associated with climate change.

To delay an update from 2019 to 2022 would lock in the construction of less affordable housing with higher running energy costs. The associated carbon emissions would make it harder for Australia to meet its emissions reduction obligations. It also locks in the need to build additional expensive electricity network infrastructure and generation capacity that wouldn't otherwise be needed. This would represent a missed opportunity for Australia to become a world leader and act on delivering better housing and lower emissions.

This delay would lead to an estimated $1.1 billion in unnecessary household energy bills by Australian households to 2050, while locking in $530 million in unnecessary network investments and 3 million tonnes of additional greenhouse gas emissions. When capital costs are taken into account, this amounts to $104 million net additional energy costs to 2050.

Analysis for the Trajectory Project estimates the household energy bill cost of delaying strengthened energy requirements from 2019 to 2022 at $1.1 billion nationally.

FIGURE 6: The national emissions cost of delay

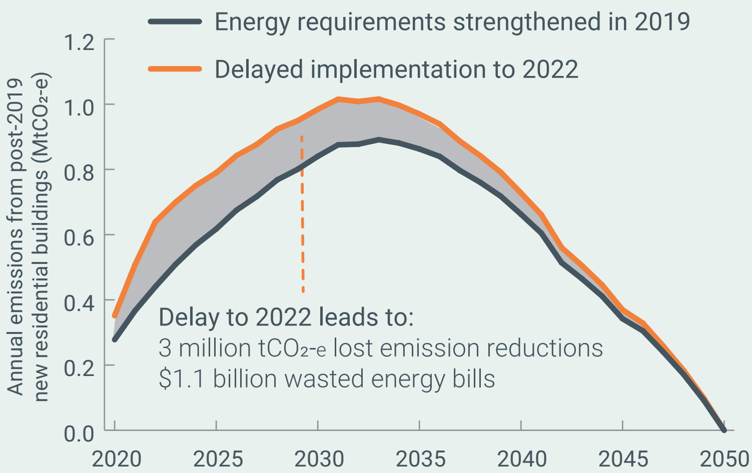
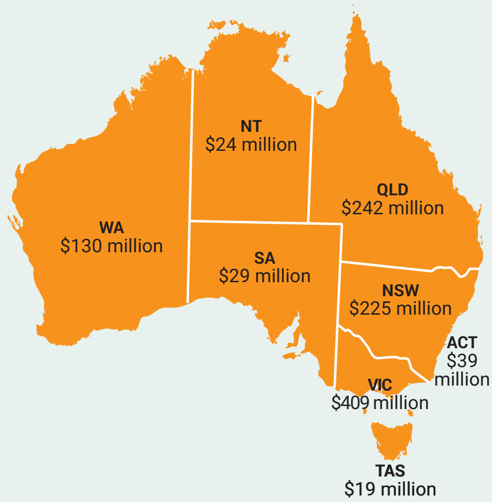
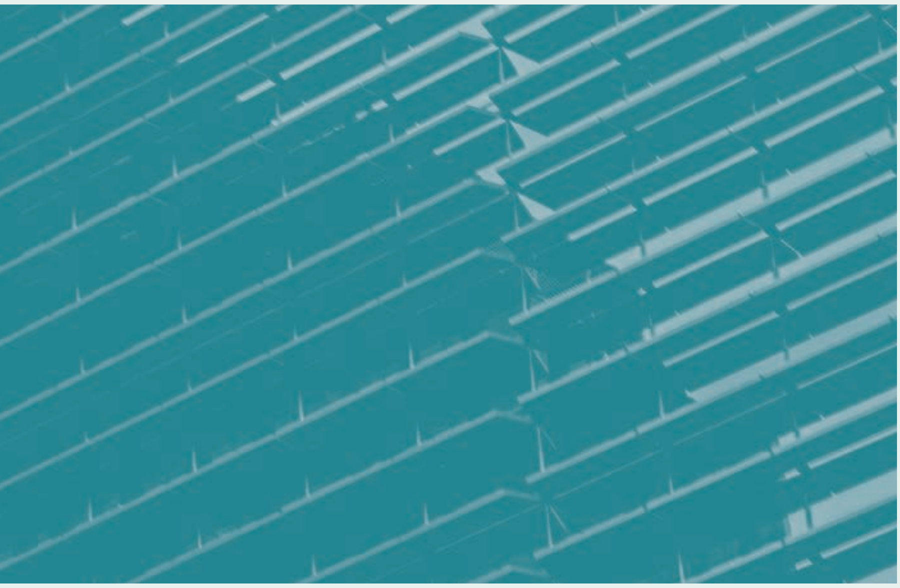


FIGURE 7: The cost of delay, by state and territory





4. Recommendations

Capturing the opportunity described above requires the effective implementation of stronger energy requirements in the Code and a range of complementary measures. This section sets out the key recommendations of the Building Code Energy Performance Trajectory Project Interim Report.

4.1. Strengthening residential energy requirements

RECOMMENDATION 1: States, Territories and the Commonwealth should commit to harmonised strengthening of residential energy requirements in the Code by 2022 at the latest, or sooner. Individual States, Territories or local governments could show leadership by piloting strengthening standards by at least the equivalent of 1 star NatHERS in the meantime.

Moves to strengthen residential energy requirements should be coordinated across jurisdictions, and States, Territories and the Commonwealth should commit resources and actions to deliver harmonised changes by 2022, or sooner. However, an increase in the Code energy requirements for residential buildings is not currently being pursued for the 2019 update of the Code.

Previous research suggests that savings of between eight per cent and 49 per cent would be cost-effective by 2020[64], and the preliminary results presented in this Interim Report suggest that, with the exception of single apartments in warmer climates, energy requirements for homes could be strengthened by at least between 28 and 51 per cent cost-effectively today (equivalent to 1 to 2.5 Star NatHERS).

The cost of delaying action, estimated at $1.1 billion in energy bills nationally creates a case for individual States, Territories or local governments to take the lead and pilot increased energy requirements before 2022. Moves by States and Territories to strengthen energy requirements prior to 2022 can act as a pilot for updating requirements nationally, and build the evidence base for harmonisation of requirements in 2022 and beyond. Jurisdictions that pilot the strengthening of standards prior to 2022 would also benefit from a housing stock that is prepared for future national regulatory changes.

This 'piloting' approach is achievable given enforcement of the Code is legislated at the state or territory level, and indeed, past improvements in the energy requirements have been led by individual states, with the Code following at a later stage.

As part of any regional pilot, supporting analysis would be required to adapt this analysis to the characteristics of different housing markets, including typical construction costs, construction materials and particular issues faced by each market. For example, commentators have highlighted the need for more appropriate architecture in Darwin that adequately responds to its tropical climate[65] (Box 5 provides two examples of homes that are designed to remain comfortable in Australia's hot northern climates). On the other hand, new home-owners in Tasmania have expressed concerns about the regular build-up of internal condensation due to construction practices that are not responsive to the state's colder climate, leading to mould and related issues (note that there is no evidence to suggest that this issue is related to energy regulations)[66]. Likewise, while new housing construction in most markets is dominated by brick veneer walls, wall construction can have a big impact on a building's thermal mass properties and therefore energy performance; for example, housing in northern Queensland utilises concrete blockwork, while Western Australian housing often uses double-brick construction[67].

Box 5 - Climate-responsive design in the heat

Size: *220 square metres*

Construction cost: *Comparable to regional average*

Year of construction: *2013*

Location: *Townsville (climate zone 1)*

NatHERS rating: *10 stars*

Innovation House 1

Building low-energy housing in Northern Australia requires an understanding of energy demand, solar generation and electricity network performance specific to tropical climates. Townsville's Innovation House 1 is the first 10 star NatHERS display home in the Australian tropics, with a design that responds to its location and climate. The house creates comfortable indoor areas with low energy use by utilising climate-responsive strategies such as lightweight building construction with insulation in the walls, roof and ceiling, large 900mm eaves on all sides, ceiling fans and timber louvres that allow ventilation while blocking out the sun. Innovation House 1 is the first step in socialising the Innovation House process, which aims to walk communities through the necessary change to enable them to improve their lives with better housing solutions.

This study was contributed by Dr Wendy Miller, Queensland University of Technology, and Finlay Homes.

Size: *165 square metres*

Year of construction: *2013*

Location: *Karratha, WA (climate zone 1)*

NatHERS rating: *8.1 stars*

Pilbara Vernacular House

Keeping homes cool in some of Australia's hottest towns can be challenging and expensive. The Pilbara Vernacular House defies these trends using a number of design features that help keep indoor temperatures comfortable. The house is designed to capture breezes and direct cooler air to bedrooms using breezeways, 'wind scoops' and 'wind blades'. The highly reflective roof, deep eaves, and secondary parasol roof over the living area also help keep internal temperatures down. And when temperatures in the Pilbara soar, a central air conditioned living room provides a cool refuge as it's protected by the other, external living spaces. *This study was contributed by Josh Byrne & Associates. Image courtesy VAM Media*

4.2. Market transformation

RECOMMENDATION 2: States, Territories and the Commonwealth should introduce market transformation initiatives to reduce the cost of key energy saving technologies identified in this report, and improve industry capability in best practice building design for energy efficiency.

This analysis assumes limited improvement in technology cost or performance, and no adoption of best practice building design for energy efficiency, despite numerous studies showing that with smarter design, such as proper orientation and selection of window sizes and placement, additional low-cost or even negative-cost improvements in energy efficiency are possible[68].

There is a role for government, working with industry groups, to support market transformation initiatives. Market transformation refers to the use of a targeted suite of measures to ensure that high-performance building designs and technologies continue to improve and reduce in cost, and in the long term, to move them out of market niches and into the mainstream without the need for ongoing policy intervention[69]. The goal of market transformation in the context of building energy performance is to deliver low-energy, low-cost and comfortable buildings as the mainstream through new technology and innovative design and construction practices.

Market transformation initiatives should focus on:

1. Reducing the cost of key technologies identified in section 2.2 of this report as having a significant energy impact but not currently cost-effective, for example through research, development and deployment funding; and
2. Supporting industry learning and improvement in building design and construction for energy efficiency, for example through training and accreditation programs for builders, architects and building designers, as well as ancillary service providers such as real estate agents. Providing real estate agents with the skills to sell high energy performance housing can educate their customers[70] and spur increased demand for higher performing buildings[71]. Information-sharing of case studies, template design briefs, demonstration projects, home-builder shows and even mainstream television programs can also translate information from leaders to the rest of the field, supporting the transition towards stronger requirements in future Code updates.

4.3. Renewables in the Code

RECOMMENDATION 3: States, Territories and the Commonwealth should commit to introducing renewable energy requirements in the Code (while retaining minimum efficiency requirements) and develop an implementation strategy that addresses the issues highlighted in this report.

A high level analysis of rooftop solar PV was undertaken for the detached and attached building types[72]. On this high level analysis, solar PV systems are already more cost-effective than most of the energy efficiency opportunities identified in this analysis, using today's energy prices and feed-in tariffs for unused energy sold back to the grid. Further details on the solar PV analysis are provided in Appendix B.

This analysis suggests that there is a case for the introduction of renewable energy requirements for new homes in the Code. Including renewable energy requirements will be particularly important if the Code moves towards requiring net zero energy or emissions homes, including to offset the energy consumption of in-home appliances. Although the Trajectory Project analysis focused on solar PV, the opportunities to incorporate renewables into the Code need not be limited to any particular technology.

It is important to note that renewable energy generation systems such as solar PV have a much shorter lifespan than the building itself, and on-site renewables do not deliver the same comfort, health and resilience benefits as energy efficiency measures. In addition, improving energy efficiency first means that smaller renewable generation systems are needed to meet a home's energy demand, reducing the cost of investing in such systems to reach net zero energy. Accordingly, leading building designers adopt a 'fabric first' approach which prioritises efficiency of building 'fabric' first, followed by energy efficiency of equipment, appliances and on-site generation. For this reason, it is recommended that new homes continue to be required to meet a minimum level of fabric energy efficiency (e.g. through a NatHERS star rating) in line with the recommendations above.

In addition, a number of implementation issues would need to be addressed in order to incorporate solar PV into the Code, including:

- Alternatives for households that do not have access to solar energy or appropriate roof area to support solar PV installations. This may come in the form of exemptions or allowances for these households to purchase near-site or off-site renewable energy instead.
- Finance mechanisms to help reduce the burden of upfront capital costs. This may include extending Environmental Upgrade Finance or similar to the residential sector - under Environmental Upgrade Finance, energy retrofits are financed by a lender via the local council, and the loan is repaid over time via council rates[72]. The Energiesprong model in Europe, which is currently applied to social housing energy retrofits but is looking to expand to other sectors, provides for the capital cost of a retrofit to be repaid to the provider using the money saved from lower energy bills[74].
- Grid integration issues, which have not been considered as part of this analysis. The modelling has not considered current limits on rooftop solar PV connections to the grid[75], or the potential future costs of integrating increasing amounts of rooftop solar PV into the electricity network.

There are a number of precedents internationally of jurisdictions that have included on-site renewable energy generation in mandatory building codes. Building standards in California, United States, require all buildings to be 'solar ready'[76]. Houses must set aside a dedicated 'solar zone' on the roof with appropriate access to sunlight and designed to accommodate a solar PV system, with the minimum size of the solar zone set according to the total roof area and other energy efficiency factors. For apartment buildings and non-residential buildings with limited roof area, the solar zone can be located on another structure up to 250 feet from the building. The City of Santa Monica, California, building code amends the statewide energy standards by requiring a minimum amount of solar PV to be installed on the building: set at 1.5 watts per square foot (W/ft2) of floor area for one- and two-family dwellings (equivalent to 16 W/m2), and 2 W/ft2 (equivalent to 21.5 W/m2) for larger buildings[77]. The US Department of Energy's Zero Energy Ready Home PV-Ready Checklist also sets minimum sizes and design conditions for a 'PV-ready' rooftop zone[78]; Oregon is one state that has adopted this approach by requiring all new residential buildings to meet the Zero Energy Ready Standard by 2023[79]. These case studies can provide a starting point for including solar PV requirements in Australia's National Construction Code.

4.4. Code compliance

RECOMMENDATION 4: States, Territories and the Commonwealth should commit to improving Code compliance through:

- Funding significant upgrades to NatHERS, including upgrades to enable improved assessment of air tightness;
- Reviewing residential compliance pathways, including investigating the potential to replace or limit the use of Deemed to Satisfy and Reference Building methods; and
- Improved monitoring and enforcement, including compliance audits and nationally standardised post-construction measures to verify as-built compliance.

Significant upgrades to NatHERS are recommended, including to enable improved assessment of air tightness.

The most significant opportunity for improved energy efficiency identified in this analysis was reduced air leakage, however this opportunity could not be easily modelled using NatHERS software. In practice, this means that developers are unable to receive credit for improving air tightness to high levels when demonstrating Code compliance through obtaining a NatHERS star rating.

NatHERS software currently allows a number of air leakage points (such as downlight holes) to be inputted. It then calculates an air leakage rate based on these air leakage points. However, advice from industry stakeholders suggests that the software may not comprehensively cover the many air leakage points found in typical homes. This could be resolved by increasing the minimum NatHERS Star rating requirement (or equivalent, e.g. BASIX in New South Wales) as recommended in this report, and provide an option for project teams to achieve this rating provided the project team verifies that the specified air leakage rate is achieved post-construction - for example, this could be mandated by the NatHERS certificate awarded during design. Air leakage verification is in place in jurisdictions internationally; for example, the United Kingdom's Building Regulations require a minimum of 10ACH@50Pa to be verified post-construction by providing certification to local authorities no later than seven days after ventilation testing is completed[80]. Project teams could then choose to achieve the higher NatHERS Star rating (using an updated version of NatHERS software that rewards better infiltration performance) by improving and verifying air leakage performance or by using other strategies. The NatHERS Administrator should be funded to deliver this update as a matter of urgency.

In the course of this project, a range of other potential areas of improvement with the NatHERS framework were identified, which are detailed in the Interim Technical Report. Funding should be provided for further updates to the NatHERS framework to pursue these additional improvements.

There are indications that existing options to demonstrate compliance with the Code may require review.

The Code provides a range of options to developers to demonstrate compliance with the Code, of which the most commonly used are:

- Deemed to Satisfy (DtS) elemental pathway, which requires new homes to meet a series of individual requirements for different building elements, similar to a checklist;
- NatHERS star rating (6 stars in most jurisdictions), which can be used to demonstrate compliance with the building 'fabric' efficiency requirements relating to heating and cooling. This is complemented by additional requirements for fixed equipment, such as lighting; and
- Verification Using a Reference Building, whereby the new home must be shown through energy modelling to perform at least as well as a hypothetical reference building built to DtS elemental requirements.

While not core to the scope of this project, a number of issues have been raised with these compliance pathways, including:

- Different compliance pathways may deliver significantly different energy outcomes. The intention of the Code is that all compliance methods should deliver buildings that, on average, achieve a similar level of energy performance. Anecdotal feedback from some industry stakeholders suggests that the DtS compliance pathways may enable buildings performing well below the 6 star NatHERS standard to comply. Our analysis provides some evidence to support this. In brief, the models constructed for this project were based on typical house designs, modified to comply with the DtS elemental requirements. The analysis found that for the most part, the base case models were broadly equivalent to the 6 Star NatHERS standard. However, it was found that a base case model for the detached archetype in climate zone 5 (e.g. modelled in Sydney) could be built to comply with the DtS elemental requirements while achieving an approximate 5 Star NatHERS level. The fact that a typical detached house design can be modelled to perform at approximately 1 Star below minimum NatHERS standards while still meeting the DtS elemental requirements may point to a broader issue;

- Assessing potential changes to the DtS elemental requirements is extremely challenging, because the energy and therefore cost impact of different measures is highly dependent on building design and site characteristics, both of which are highly variable. The use of a rating tool such as NatHERS helps to avoid this issue by setting a normalised performance benchmark that allows project teams flexibility in their design approaches to suit the site and climate; and
- As energy requirements increase, it is possible that none of the existing compliance pathways will be capable of supporting the delivery of higher levels of energy performance. The DtS elemental requirements are unlikely to provide sufficient flexibility to support higher levels of energy performance. A rating tool such as NatHERS provides this flexibility, allowing the developer to adopt a least-cost solution for achieving energy requirements by adjusting the variables in the modelling tool until the desired outcome is reached. Performance-based approaches, like the NatHERS 6 star standard, are generally believed to encourage industry innovation, as developers test what measures are possible using the tool, and innovate to reach cost-effective solutions[81]. However, the current NatHERS framework would require updates (including those relating to infiltration as discussed above, and potentially to cover other energy uses in a 'whole of house' approach) in order to support higher levels of energy performance.

These issues require further investigation. It is recommended that a review of compliance pathways be undertaken, including investigation of the option of removing or limiting the availability of the DtS elemental pathway (e.g. making it available only for small projects or extensions) in favour of one or more approved, fit-for-purpose rating tools.

Requiring the use of one or a limited number of compliance pathways (and approved rating tools) would also:

- **Support tool maintenance and upgrades.** Most rating tools are financially supported by revenue from certificate issuances. Limiting compliance pathways to one or more approved tools will help ensure that they have sufficient revenues to invest in appropriate updates and improvements over time. Without this financial stability, there is an increased risk of developers being able to 'game' a tool to produce cheaper, less efficient house designs;
- **Support regulatory analysis.** As discussed above, different compliance pathways may produce different results, across different building types in different climates, depending on their assumptions and modelling algorithms. The Commercial Building Disclosure program requires the use of a single tool (NABERS) in the commercial office sector, and a similar approach that mandates the use of a particular modelling tool could be taken for Code compliance in the residential sector. A potential opportunity could lie in the NABERS for Apartment Buildings tool, which is a pilot tool being developed for apartment common areas and due for public release in mid-2018[82]; and
- **Support compliance monitoring and enforcemen**t. Successful rating tools sit within a broader governance, monitoring and compliance framework, including panels for review and audit of ratings. The governance framework around NABERS provides a good example.

Immediate action is required to address non-compliance and under-compliance with energy requirements, but this should not delay cost-beneficial Code changes.

It is widely acknowledged that non-compliance with the Code is an ongoing issue[83]. Non-compliance and under-compliance is unlawful. It undermines the rights of building purchasers and occupants who are not receiving what they are legally entitled to receive under the Code, and provides an unfair advantage to operators who cut corners over those who meet required standards. This issue must clearly be addressed as a matter of urgency. However, the fact that some operators are failing to comply with the regulations should not prevent implementation of cost-beneficial and achievable strengthening of the energy requirements.

Improving the energy efficiency requirements in the Code needs to work hand-in-hand with improvements in compliance and enforcement. There are ongoing efforts to improve Code compliance, such as the National Energy Efficient Building Project (NEEBP). This initiative should be fully resourced, and further work will be required to ensure Code updates are accompanied by effective and practical measures to ensure compliance. It is recommended that the NEEBP be complemented by initiatives to strengthen the evidence base around the extent of compliance in the industry, such as an independent national audit of a representative sample of all building forms, the findings of which can inform systemic reforms of compliance and enforcement regimes in Australia.

Monitoring and enforcement systems should also be improved by State and Territory-based regulators. This may include tailoring the frequency and timing of building surveyor audits to allow proper verification of efficiency measures, as it is difficult or impossible to check certain measures once the building is complete[84]. The industry has suggested that this could include random audits to improve standards throughout the construction process[85]. An independent assurance regime for building surveying could be implemented to avoid conflicts of interest arising from developers appointing their own building surveyor during the appointment of building surveyors[86]. Enforcement activities should also be effectively resourced, and meaningful penalties and remedies should be put in place for non-compliance, with clear and enforceable legal accountability[87].

A key area for reform is how buildings are verified post-construction. States and Territories could explore **introducing nationally-standardised measures for all buildings to verify 'as built' compliance**, which will help address the gap that can exist between efficiency elements proposed during the design phase and their implementation during construction. For example, mandating blower-door testing to verify air tightness would address the highly variable rates of air leakage observed in new buildings[88].

Compliance and enforcement issues must clearly be addressed as a matter of urgency. However, the fact that some operators are failing to comply with the regulations should not prevent implementation of cost-beneficial and achievable strengthening of the energy requirements.

5. Next Steps: The Forward Trajectory

Phase two of this project will investigate pathways to improve energy requirements over future Code upgrades towards a long-term target of net zero buildings. Results from this trajectory analysis will be presented in a Final Report, due for publication in mid-2018. The sections below describe the analysis that will be undertaken for the Final Report.

5.1. The case for targets and a forward trajectory

A well designed and implemented long-term target and forward trajectory for the Code energy requirements will provide the certainty industry requires to encourage innovation and investment in new practices and technology.

Jurisdictions around the world have set ambitious and time-bound energy performance targets for new construction[89]. In the residential sector, the State of California in the United States is aiming for all new residential buildings to be net zero energy by 2020; while Finland required all new residential buildings to meet Passive House standards by 2015. Across all building types, Sweden requires all new buildings to be net zero energy by 2020; Germany requires all new buildings to operate with zero fossil fuels by 2020; the City of Boulder, Colorado, in the United States has set a target of net zero energy for new buildings by 2031; and Canada is targeting net zero energy for all new buildings by 2050. No such targets have yet been legislated for new buildings in Australia.

A forward trajectory with clear targets provides guidance as to when, how and to what degree energy requirements should be changed over time. Key components of a forward trajectory should include:

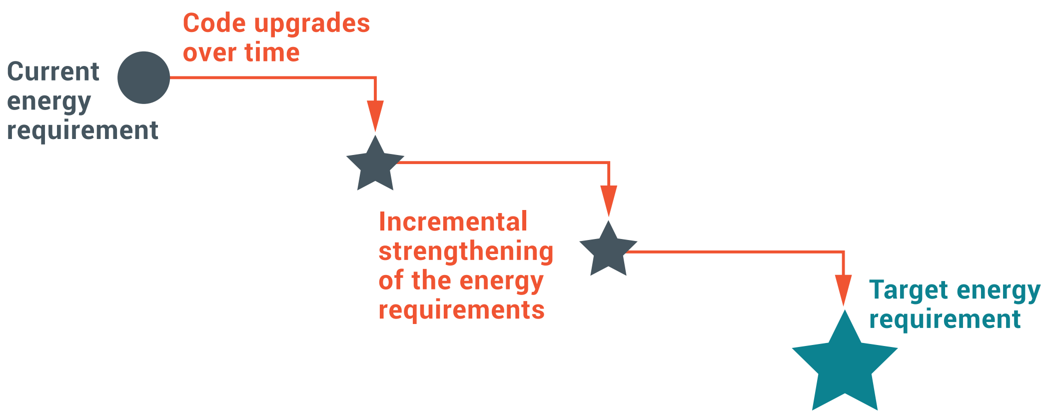
Without this policy certainty, Code upgrades can be ad hoc, and stakeholder consultation processes take place without common ground rules, increasing the potential for "discretionary interventions in the decision-making process"[90]. The absence of such policy clarity may, in part, explain the delay since the last strengthening of Code energy requirements in 2010, and the fact that no update in stringency of residential energy requirements is expected until at least 2022[91].

As shown in Figure 8, a trajectory can take the form of energy performance targets that incrementally reduce along a pathway towards an end goal. A trajectory that sets out the allowable levels of energy consumption for new construction over subsequent upgrades to the Code – well in advance of each Code cycle – provides a regulatory signal to consumers and industry that encourages innovation and investment in new technology, design and construction practices. This is particularly important for innovations that require a long lead-time, such as the development of new products by manufacturers, as it allows the industry to plan ahead for future regulatory requirements[vii].

vii Feedback from stakeholders suggests that a lead time of at least three to four years is required to bring new window products to market.

When combined with effective complementary measures and good design practices, a trajectory can provide certainty for planning and investment, enable innovation and encourage the achievement of energy performance above and beyond current requirements[92]. The latter effect has been observed in Denmark, where a trajectory implemented in 2010 specified a series of incremental increases in the stringency of the energy requirements for 2010, 2015 and 2020. Even when the "class 2010" minimum requirements were in force, 15 to 20 per cent of Danish building investors elected to build to "class 2015" or "class 2020" requirements[93].

FIGURE 8: Illustrative forward trajectory for Code energy requirements



5.2. Purpose of the trajectory analysis

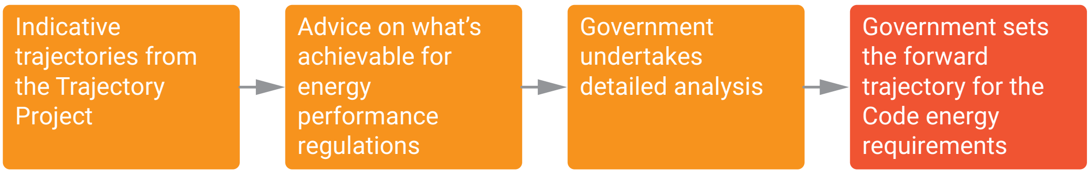
The trajectory analysis will propose an ambitious and achievable long-term trajectory for energy requirements in new construction.

This project will determine a forward trajectory for different building types that includes recommendations for a potential long-term target, a clear and efficient process for Code updates, the associated research and analysis required for each update, and necessary complementary measures. The basis of the trajectory analysis is a set of scenarios for long-term trends in construction costs, energy prices, technological changes and other economic factors. The analysis answers the question "What energy requirement could be cost-effective?" for different building types and for each consecutive iteration of the Code energy requirements.

The results of the trajectory analysis should provide an evidence base for government policy makers indicating a long-term direction for the Code with sufficient evidence to support a high level commitment alongside further detailed investigation. The Trajectory Project is not intended to replace the regulatory processes required to set performance requirements in government policy. Rather, the intent of the Trajectory Project is to present illustrative pathways showing what is feasible for Code energy requirements under a set of assumptions about the future economic environment, and to provide recommendations for complementary policy measures that would enable the implementation of the forward trajectory. The Trajectory Project can inform follow-up policy analysis and engagement by government, including detailed Regulatory Impact Statements.

Successful implementation of a forward trajectory relies on an effective policy framework with clear objectives and processes for setting energy requirements. Recommendations on objectives and targets will be detailed in the Final Report.

FIGURE 9: Purpose of the Trajectory Project analysis



5.3. Approach to the trajectory analysis

In July 2017, ASBEC and ClimateWorks undertook stakeholder engagement through workshops in Melbourne and Sydney and written responses to an Issues Paper[94], with participation from builders, designers and architects, engineering consultants, government, building ratings administrators and product suppliers. The primary outcome from this stakeholder engagement was the development of a refined set of objectives for the Code energy requirements, and a set of principles for the development of a long-term target and forward trajectory. A summary of the stakeholder consultation is provided in Appendix A.

This project will use these principles to determine forward trajectories and long-term targets for eight building model 'archetypes' across four climate zones. In addition to the three residential archetypes discussed in this Interim Report, the broader project is analysing five non-residential building archetypes. The eight building archetypes have been developed to cover typical, average attributes of buildings in Australia's building stock. Overall, the set of models cover a range of geometric properties ranging from low to high surface area to volume ratio, and covers models where heating and cooling energy is dominated by internal loads (such as heat from people and equipment) and those dominated by facade loads (the transfer of heat between the inside and outside of the building). The modelled building archetypes are:

- For residential buildings:
  - Detached, single-storey house;
  - Attached, two-storey townhouse or terrace house; and
  - Apartment.
- For commercial and other non-residential buildings:
  - Office tower;
  - Hotel tower;
  - Medium retail shop;
  - Hospital ward; and
  - School.

The four climate zones have been selected based on the locations of major population centres:

- Climate zone 2 - Warm humid summer, mild winter (e.g. Brisbane);
- Climate zone 5 - Warm temperate (e.g. Sydney, Adelaide, Perth);
- Climate zone 6 - Mild temperate (e.g. Greater Western Sydney, Melbourne); and
- Climate zone 7 - Cool temperate (e.g. Canberra, Hobart). Modelling results will be included in the Final Report.

The project team recognises that design principles and associated energy efficiency opportunities for buildings in the tropics are unique when compared with the rest of the country. The team is actively exploring avenues to extend the modelling to climate zones 1 and 3 (which include Darwin, northern Western Australia, Alice Springs and far north Queensland), but in the meantime will estimate energy opportunities and costs based on results from the modelled climate zones.

There is evidence that a lack of consideration of unintended consequences can lead to perverse outcomes, particularly in housing. The trajectory analysis will consider mould and condensation in particular, by setting practical limits on some technological and design improvements, such as requiring mechanical ventilation to be installed in housing when air leakage falls below a certain threshold. The trajectory analysis will also utilise a future climate scenario in the modelling to determine the impacts of a changing climate on building energy consumption.

Further details on the modelling methodology for the trajectory are provided in the Interim Technical Report, available on the ASBEC and ClimateWorks websites.

FIGURE 10: Australian climate zones

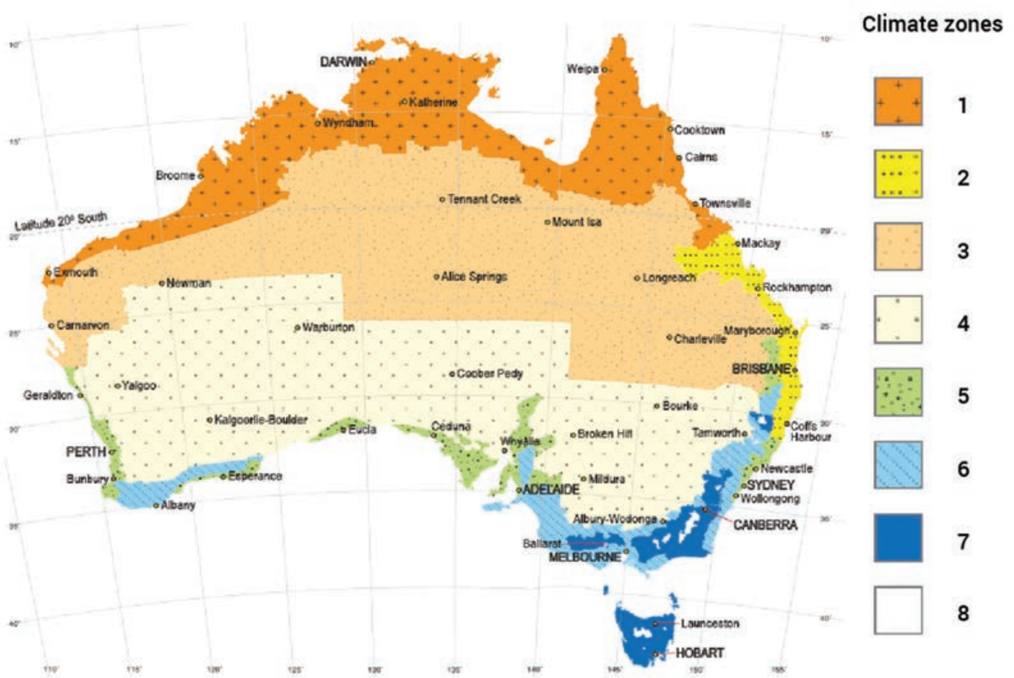
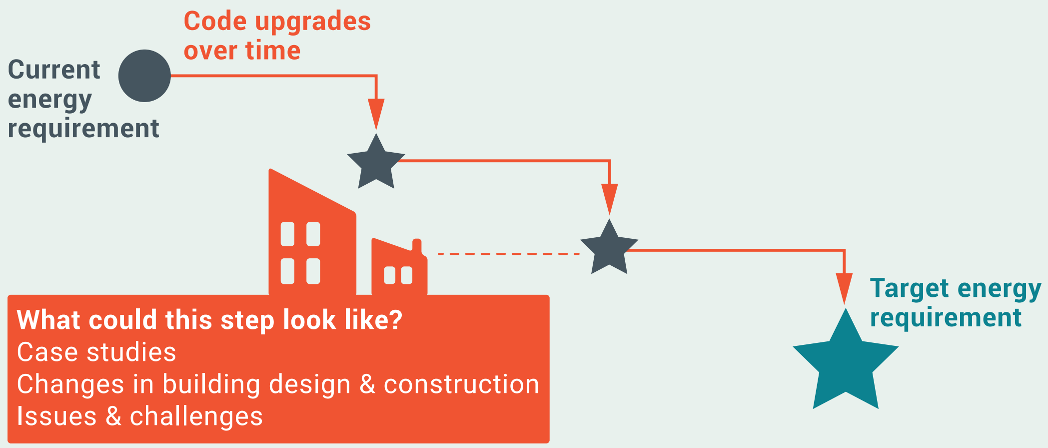


Image source: http://www.yourhome.gov.au/introduction/australian-climate-zones

5.4. Call for case studies

The trajectory analysis will be complemented by a broad selection of real life case studies that illustrate how buildings are already meeting future energy requirements cost-effectively and without compromising occupant expectations (see Figure 11). Some examples of low-energy housing have already been included in this Interim Report and in Appendix C.

FIGURE 11: Case studies will illustrate how buildings are already meeting future energy requirements today



The project team intends to present a number of different building case studies that provide a snapshot of leading low-energy buildings across all sectors, sizes, locations and energy performance levels (ranging from just above current requirements, to net zero energy or carbon). The purpose of these case studies is to:

- **Demonstrate feasibility**: Show that future energy performance levels proposed by the Trajectory Project - both the end targets and the steps along the way - are achievable and cost-effective across a range of building types, climate zones, sites/orientations and business models (e.g. large developers, volume builders, small home builders);
- **Highlight challenges and solutions:** Explore the challenges faced by project teams in achieving high energy performance, and how these were overcome, with a particular focus on known technical issues (e.g. condensation and ventilation) and on the experience of builders;
- **Highlight the non-energy benefits:** Demonstrate the multiple benefits of high energy performance including cost savings and health improvements; and
- **Profile innovative design approaches**: Profile innovative design strategies taken to achieve higher energy performance levels in different building types and climate zones, while maintaining or improving amenity for occupants.

ASBEC and ClimateWorks welcome any case studies of buildings across all sectors that profile how future energy requirements are being met today.

Box 6 - A comfortable home with very low energy bills

Reservoir House

When the owners were designing their house in Melbourne's northern suburbs, they asked for a home that was comfortable with minimal energy bills. This brief was met by Habitech's Reservoir House design, which incorporates solar passive principles including carefully designed window shades and a retractable awning. The house was built to be very airtight and well insulated at relatively low cost using innovative 'structural insulated panels'. A year's worth of data logging shows that the house has better energy performance than what's required by the international Passive House standard, leading to energy bills of only $560, and a 7.6kW rooftop solar PV array means that Reservoir House is a net energy exporter.

This study was contributed by Habitech Systems and 8020green.

Size: *150 square metres*

Construction cost: *$3,300 per square metre*

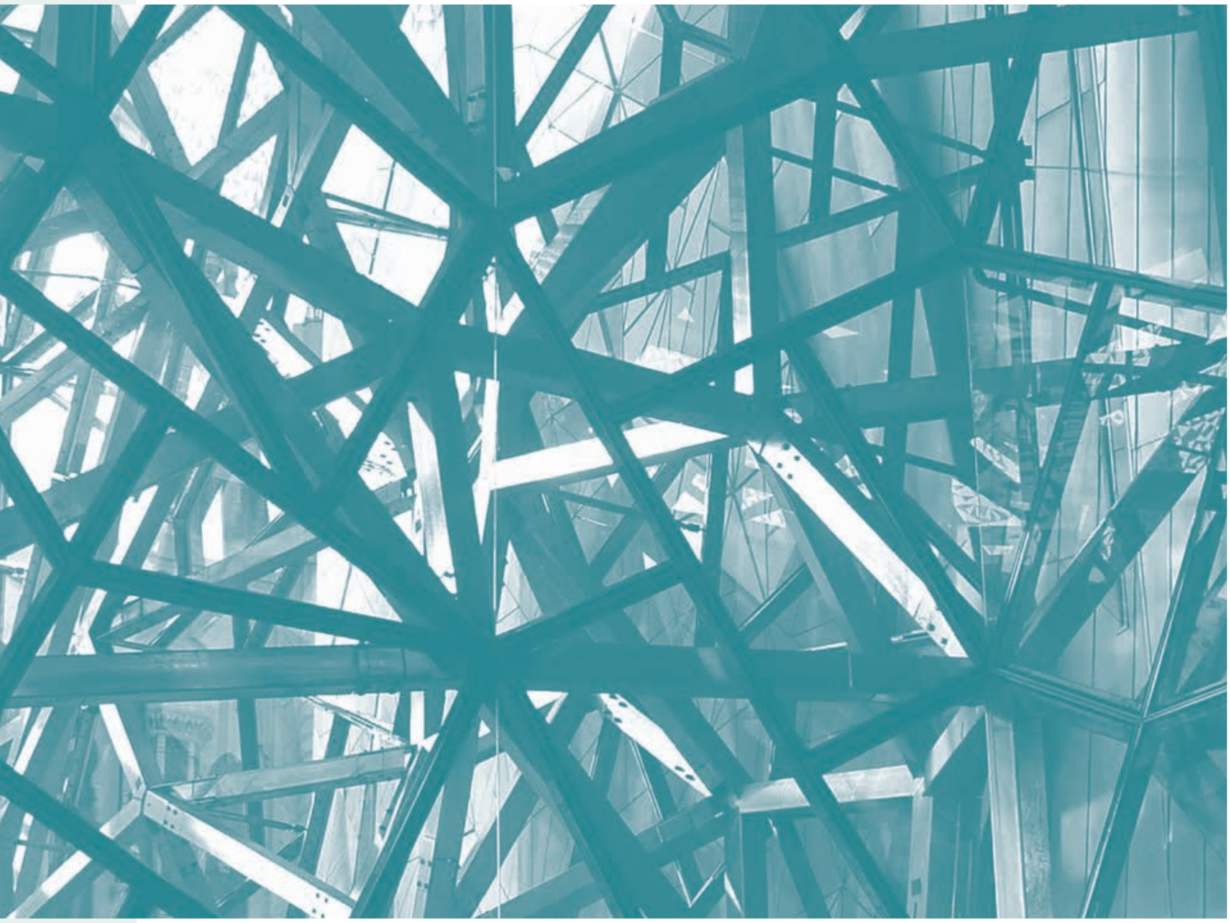
Year of construction: *2015*

Location: *Melbourne (climate zone 6)*

NatHERS rating: *Estimated 9.0 stars (based on metered electricity data)*

Annual net energy consumption: *8.5 kWh per square metre – Significantly better than the requirements of Passive House*

Annual energy bills: *$560*



Endnotes

[1] Based on floor area across all building sectors, given currently expected growth rates and allowing for refurbishment/rebuild of 1 per cent of the stock each year, in addition to net stock growth.

[2] Based on Australian Bureau of Statistics data and adjusted for inflation. Australian Competition and Consumer Commission (2017). *Retail Electricity Pricing Inquiry - Preliminary Report*, p.12.

[3] Australian Bureau of Statistics. (2017, 2017-09-13). *6530.0 - Household Expenditure Survey, Australia: Summary of Results, 2015-16.*

[4] Australian Alliance for Energy, P. (2016). *A roadmap to double energy productivity in the Built Environment by 2030*, p.10. Figure calculated based on original figure of $380 million spent per week.

[5] According to estimates undertaken by CSIRO for this project.

[6] Climate Council (2017). Cranking up the intensity: Climate change and extreme weather events. Available online: https://www.climatecouncil.org.au/uploads/1b331044fb03fd0997c4a4946705606b.pdf .

[7] Lewis, S. C., King, A. D., & Mitchell, D. M. (2017). Australia's unprecedented future temperature extremes under Paris limits to warming: Australia's future extremes. *Geophysical Research Letters*. doi:10.1002/2017GL074612, p.9.

[8] Clean Energy Regulator data from 2015-16 estimates that Loy Yang B power station produced 9.6 million tonnes of emissions in that year, while Loy Yang A power station and mine produced 18.4 million tonnes. Clean Energy Regulator (2017). Electricity sector emissions and generation data 2015-16. Available online: http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/electricity-sector-emissions-and-generation-data/electricity-sector-emissions-and-generation-data-2015-16"

[9] See Section 2 and Appendix B for details.

[10] The list of cost-effective measures by building type and climate zone is presented in Appendix B

[11] Equivalent NatHERS ratings assume that NatHERS is updated to enable higher air tightness to be credited. See section 2.2. for more detail.

[12] Moreland Energy Foundation. (2017). *Changes Associated with Efficient Dwellings - Final Report*, prepared for the Department of the Environment and Energy, p.5; Sustainability House. (2012). *Identifying Cost Savings through Building Redesign for Achieving Residential Building Energy Efficiency Standards.*

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[14] Estimates by Strategy. Policy. Research. for this project.

[15] Harrington, P., & Toller, V. (2017). *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, p.10.

[16] Based on floor area across all building sectors, given currently expected growth rates and allowing for refurbishment/rebuild of one per cent of the stock each year, in addition to net stock growth.

[17] This has been observed in some countries that have mandated high energy requirements for a long period of time - see International Energy Agency (2008). *Energy efficiency requirements in building codes, energy efficiency policies for new buildings*, p15.

[18] A summary of how the Code is administered and the variations in Code energy requirements is provided in ASBEC & ClimateWorks Australia (2016), *Building energy performance standards project: Issues Paper*, pp.5-10.

[19] ASBEC (2016). *Low Carbon, High Performance*, pp.35-36.

[20] Adapted from the recommended five policy areas in ASBEC (2016). *Low Carbon, High Performance*.

[21] ME (2017). *Household Financial Comfort Report: Twelfth Survey published Jun 2017*, p.7.

[22] Energy Efficiency Council. (2016). *Australian Energy Efficiency Policy Handbook*, p.11.

[23] Based on Australian Bureau of Statistics data and adjusted for inflation. Australian Competition and Consumer Commission (2017). *Retail Electricity Pricing Inquiry – Preliminary Report*, p.12.

[24] Australian Bureau of Statistics. (2017, 2017-09-13). *6530.0 – Household Expenditure Survey, Australia: Summary of Results, 2015–16.*

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[42] Isaacs, T., Pears, A.M. (2016) *How cautious analysis could lead to 'do nothing' policy: A case study of the 6-star housing Regulation Impact Statement*, p.13.

[43] For example, Energy Consumers Australia has released the report *Multiple Impacts of Household Energy Efficiency: An Assessment Framework* (2017), which provides a guide for policy makers and practitioners to assess the wide range of benefits that can result from improved household energy efficiency.

[44] Accessible via www.asbec.asn.au and www.climateworksaustralia.org.au.

[45] The nationwide mean value of residential dwellings (for all building types) rose from $490,800 in September 2011 to $637,400 in September 2016, an increase of $146,600 over five years. This is equivalent to an average monthly price rise over that five year period of $2,443. This is based on the Total Value of the Dwelling Stock (TVDS) data from the Australian Bureau of Statistics *6416.0 - Residential Property Price Indexes: Eight Capital Cities, Sep 2017*.

[46] Isaacs, T., Pears, A.M. (2016). *How cautious analysis could lead to 'do nothing' policy: A case study of the 6-star housing Regulation Impact Statement*, pp.5-6.

[47] The National Construction Code Volume 2 (2016), clause P2.6.1.(f) states that "A building must have, to the degree necessary, a level of thermal performance to facilitate the efficient use of energy for artificial heating and cooling appropriate to...the sealing of the building envelope against air leakage"

[48] Ambrose M.D.; Syme, M. (2015), p.26. The study found that, based on blower door testing of 134 homes across all of Australia's capital cities except for Darwin, the mean air tightness was 15.4 air changes per hour (ACH) at 50 Pa, and the median air tightness was 13.3 ACH at 50 Pa.

[49] Ambrose M.D.; Syme, M. (2015), p.28.

[50] Based on feedback from industry stakeholders consulted for the Trajectory Project. The US standard ASHRAE 62.2 outlines a performance-based trade-off between air tightness and air quality, and could potentially be modified to suit Australian climates. Internationally, mechanical ventilation is generally required in jurisdictions where air tightness of less than 5 ACH@50Pa is required by regulations: Dewsbury, M. *et al.* (2016), *Scoping Study of Condensation in Residential Buildings*, p.43.

[51] Ambrose M.D.; Syme, M. (2015), p.25.

[52] Moreland Energy Foundation. (2017). *Changes Associated with Efficient Dwellings - Final Report*, prepared for the Department of the Environment and Energy, p.5; Sustainability House. (2012). *Identifying Cost Savings through Building Redesign for Achieving Residential Building Energy Efficiency Standards.*

[53] Moreland Energy Foundation. (2017), p.23.

[54] ClimateWorks Australia (2014). *Pathways to Deep Decarbonisation in 2050*, p.17.

[55] ASBEC (2016). *Low Carbon, High Performance*, p.26.

[56] ASBEC (2016). *Low Carbon, High Performance*, p.27.

[57] Unpublished ClimateWorks analysis as part of its *Pathways to Deep Decarbonisation in 2050* report, 2014. Includes measures relating to energy efficiency, fuel-switching and decarbonisation of electricity supply.

[58] Clean Energy Regulator data from 2015-16 estimates that Loy Yang B power station produced 9.6 million tonnes of emissions in that year. Clean Energy Regulator (2017). Electricity sector emissions and generation data 2015-16. Available online: http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/electricity-sector-emissions-and-generation-data/electricity-sector-emissions-and-generation-data-2015-16

[59] The 'business-as-usual' grid decarbonisation trajectory assumes a 26 percent emissions reduction from the grid by 2030 on 2005 levels, then emissions continue to decline after 2030 at a comparable rate.

[60] Alternative Technology Association (2014). *Are we still cooking with gas? Report for the Consumer Advocacy Panel*. Note that research was conducted across 'most gas pricing zones in the NEM (National Electricity Market)', so excludes homes in Western Australia and the Northern Territory. The modelling is currently being updated and is likely to find that all-electric new homes are even more cost-effective if solar PV systems and higher gas prices are taken into account (ATA, 2017 - ReNew Economy article). Analysis found that for new and existing homes not currently connected to gas, choosing efficient electric space heating (multiple reverse cycle air conditioners, sized to house), hot water (heat pump large) and cooking (electric oven, induction cooktop) is more cost-effective than connecting gas.

[61] Greenwood, O. (2016) *Gas Price Trends Review*, prepared for the Commonwealth Department of Industry Innovation and Science, p.6.

[62] ClimateWorks, A. (2014). *Pathways to Deep Decarbonisation in 2050*, p.25.

[63] According to estimates by Strategy. Policy. Research. for this project.

[64] pitt&sherry. (2016). *Pathway to 2020 for Increased Stringency in New Building Energy Efficiency Standards: Benefit Cost Analysis: 2016 Update for Residential Buildings*, prepared for the Department of Industry, Innovation and Science,

[65] Damjanovic, D. (2017) *Why is Darwin dominated by air conditioned, concrete-bunker-type houses?* Available online: http://www.abc.net.au/news/2017-10-31/curious-darwin-top-end-housing/9098446.

[66] Dewsbury, M., Law, T., Henderson, A. (2016). *Final report - Investigation of destructive condensation in Australian cool-temperate buildings,* University of Tasmania.

[67] Based on feedback from Trajectory Project stakeholders.

[68] Moreland Energy Foundation. (2017). *Changes Associated with Efficient Dwellings - Final Report*, prepared for the Department of the Environment and Energy, p.5; Sustainability House. (2012). *Identifying Cost Savings through Building Redesign for Achieving Residential Building Energy Efficiency Standards.*

[69] Harrington, P., & Toller, V. (2017). *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, p.50.

[70] CSIRO's Centre for Liveability Real Estate provides training for real estate agents to become 'Liveability Real Estate Specialists', giving real estate agents the tools to identify and highlight property features that improve energy efficiency and comfort. The Centre for Liveability Real Estate (2017) Become a Liveability Real Estate Specialist, 2017. Available online: https://liveability.com.au/lres/.

[71] Study found that 89% of housing consumers surveyed would be more likely to rent or purchase a house that they were told was more energy efficient. Adams, H., Clarke, M., & Potts, J. (2016). *Enhancing the Market for Energy Efficient Homes: Implementing a national voluntary disclosure system for the energy performance of existing homes*, p.10.

[72] While this study has not considered solar PV for apartments, previous analysis for the City of Sydney has shown that it's technically feasible even for high-rise apartment buildings to reach net zero energy in Australia, through passive design and building-integrated solar PV technology. See pitt&sherry (2016). *Accelerating Net-Zero High-Rise Residential Buildings in Australia - Final Report,* prepared for the City of Sydney.

[73] Better Building Finance. Environmental Upgrade Finance: How it works. Retrieved 11 January, 2018, from http://betterbuildingfinance.com.au/how-it-works/.

[74] Energiesprong Foundation. Energiesprong Explained. Retrieved 11 January, 2018, from http://energiesprong.eu/about/.

[75] Stakeholder feedback provided for this project suggests that for many homes the local electricity distribution network service provider (DNSP) currently sets a 5 kW limit for solar PV systems connected to the grid.

[76] For details, refer to Section 110.10 'Mandatory Requirements for Solar Ready Buildings in California Energy Commission (2016). *Building Energy Efficiency Standards for Residential and Nonresidential Buildings Title 24 Part 6*, pp.1 16-118.

[77] For details, refer to Chapters 8.106.055 and 8.106.080 of City of Santa Monica (2017). *Santa Monica Municipal Code - Article 8 Building Regulations.* Available online: http://www.qcode.us/codes/santamonica/

[78] PV-Ready Checklist available at https://energy.gov/sites/prod/files/2015/05/f22/PV-Ready%20Checklist.pdf

[79] State of Oregon (2017). *Executive Order No. 17-20 Accelerating Efficiency in Oregon's Built Environment to Reduce Greenhouse Gas Emissions and Address Climate Change*, p.5.

[80] Note that in developments of greater than 2 buildings, 3 units or 50% of each dwelling type must be tested. The infiltration requirements can also be met by demonstrating that the Dwelling Carbon Dioxide Emission Rate is lower than the Target Carbon Dioxide Emission Rate. *The Building Regulations 2010: Conservation of fuel and power* (2016) Chapter London: NBS. p.20

[81] Harrington, P., & Toller, V. (2017). *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, p.30.

[82] NABERS. NABERS for Apartment Buildings. Sydney: Available online: https://nabers.gov.au/public/WebPages/DocumentHandler.ashx?docType=3&id=1195&attId=0 [Accessed 30 January 2018].

[83] pitt&sherry. (2014). *National Energy Efficient Building Project*, prepared for the South Australian Department of Economic Development, p.x.

[84] pitt&sherry. (2014), p.xvi

[85] Aliento, W. (2017) *24 ways to improve the building industry*. Available online: https://www.thefifthestate.com.au/innovation/building-construction/24-ways-to-improve-the-building-industry/96553.

[86] Suggested by Trajectory Project stakeholders, and industry including Aliento, W. (2017) *24 ways to improve the building industry*. Available online: https://www.thefifthestate.com.au/innovation/building-construction/24-ways-to-improve-the-building-industry/96553.

[87] Australian Institute of Building Surveyors (2017) *AIBS Policy - Building Regulatory Reform in Australia*, p.12.

[88] Ambrose M.D., Syme, M. (2015). *House Energy Efficiency Inspections Project – Final Report*, prepared for the Department of Industry, Innovation and Science. p.29.

[89] For a summary, see ASBEC & ClimateWorks Australia (2016). *Building Code Energy Performance Trajectory Project: Issues Paper*, pp. 10-11.

[90] Harrington, P., & Toller, V. (2017). *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, p.99.

[91] Australian Building Codes Board (ABCB) (2016). *NCC 2019 Energy Efficiency Provisions at a Glance*. Retrieved from www.abcb.gov.au/Resources/Publications/EducationTraining/NCC-2019-Energy-Efficiency-Provisionsat-a-glance.

[92] Harrington, P., & Toller, V. (2017). *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, p.10.

[93] Energy Efficiency Watch (2014). *Energy efficiency policies in Europe: Case Study - Danish Building Code*, p.2.

[94] Available at http://www.asbec.asn.au/research-items/building-code-energy-performance-trajectory-issues-paper/.

Appendices

Appendix A: Consultation Summary

This appendix summarises the main outcomes from the stakeholder consultation undertaken by the Australian Sustainable Built Environment Council (ASBEC) and ClimateWorks Australia in July 2017 for the Building Code Energy Performance Trajectory Project. Approximately 50 people attended the workshops across the four sessions, with representation from builders, designers and architects, engineering consultants, government, building ratings administrators and product suppliers. Approximately 25 written responses to the Issues Paper were also received, including responses from local governments, state government departments, product suppliers, contractors, building owners, architects and developers.

Setting targets

The most significant change in the approach taken by the project team in response to stakeholder feedback is in the definition of the target for new building performance. Prior to undertaking stakeholder consultation, the intention was to set a measurable and easy-to-communicate target (such as 'net zero energy' or 'net zero carbon') that defines the endpoint of an NCC energy performance trajectory. However, the project team is proposing to move away from a 'net zero'-style target due to the following feedback from stakeholders:

- Energy is an appropriate metric
- However, not all buildings can achieve net zero energy or carbon onsite; and
- The NCC does not, and is unlikely to, regulate offsite energy procurement.

Instead, we have proposed a set of principles and a process for target-setting that will guide the modelling for this project, and which should be codified to guide future regulatory analysis and updates. For each of the eight building archetypes, we will apply the proposed target-setting principles to determine a target using an energy metric, along with illustrative trajectories towards the target. This will provide evidence-based guidance to government and industry as to the NCC energy requirement improvements that should be targeted. The target-setting processes and principles will be set out in further detail in the Final Report published in 2018.

Other stakeholder feedback

In addition to the modified target-setting process, the main feedback items from stakeholders were:

- Objectives were proposed for buildings energy policy and the energy requirements of the Code. This will set out in further detail in the Final Report published in 2018;
- It is important to model the energy, costs and benefits under the following climate zones:
  - Climate zone 1 (which includes Darwin, Cairns & Townsville); and
  - Climate zone 7 (which includes Canberra, Hobart, Ballarat, Bathurst);

  in addition to those climate zones already proposed to be modelled:
  - Climate zone 2 (Brisbane, Gold Coast);
  - Climate zone 5 (Sydney, Adelaide, Perth, Newcastle, Wollongong); and
  - Climate zone 6 (Melbourne, Western Sydney);

  In response to the stakeholder consultation, the project team has secured funding to model climate zone 7 and is actively seeking support to model climate zones 1 and 3; and
- It was clear from the consultation undertaken by the project team that parallel 'practitioner' streams of engagement with builders and architects/designers are needed for the development of the trajectory, to complement the modelling approach (and associated consultation). The project team is currently seeking advice on appropriate strategies for these focused practitioner engagement streams.

Appendix B: Summary of Technical Assumptions and Results

This appendix summarises the key assumptions and modelling results relating to the Trajectory Project analysis. Further details on the methodology and results are provided in the Interim Technical Report available on the ASBEC and ClimateWorks websites.

Overview of modelling methodology

The Trajectory Project residential modelling presented in this Interim Report followed four steps:

- Establish baseline consumption of each building archetype (detached house, attached house, apartment) in each climate zone (climate zones 2, 5 and 6);
- Estimate the energy and cost savings associated with individual measures where each measure is varied independently;
- Assess the costs and benefits of each measure from a society perspective;
- Select the 'cost-effective' measures for further analysis; and
- Estimate the combined impact of the set of cost-effective measures.

Technical assumptions

The following measures were modelled individually:

- External wall insulation;
- External wall surface colour;
- Roof type;
- Roof surface colour;
- Roof openness (for ventilation);
- Roof insulation;
- Under slab insulation;
- Ceiling fans;
- Infiltration;
- Eave extension;
- Roller shutters; and
- Thermal mass - floor and walls.

The results in this Interim Report are based on assessment of measures that are cost-effective when considered individually. Further work will be done by the Trajectory Project team to analyse the interactions between measures when they are applied together. The team is also undertaking ongoing analysis of glazing opportunities, which have been excluded from the results presented here. These updated results will be presented in the Final Report to be published in mid-2018. However, this follow-up analysis will not impact on the cost-effectiveness of each individual measure.

Economic assumptions

The economic analysis is based on a benefit cost methodology that is informed by the Australian Government's Best Practice Regulation guidelines and Guidance Note on Cost-Benefit Analysis.

Costs for all measures are developed based on contractor and quantity surveyor pricing, retail and trade pricing, and the 2017 edition of the Rawlinson's Australia Construction Handbook.

A discount rate of seven per cent is used.

The national electricity prices are derived from previous work by CSIRO completed for the Electricity Network Transformation Roadmap (the Roadmap). A key feature of the Roadmap scenario was that the electricity sector does more than its proportional share of current national abatement targets (i.e. achieving 40% below 2005 levels by 2030) and accelerates that trajectory by 2050 to reach zero net emissions. For the electricity sector to achieve net zero emissions by 2050, an implicit carbon price series was used. Assumed to commence in 2020, the carbon price increases from around \$30/tCO2-e to around \$190/tCO2-e by 2050. The national average emission intensity of grid electricity falls from its current level of around 0.78 tCO_2-e/MWh to around 0.09 tCO_2-e/MWh by 2050.

It is likely that energy performance improvements will not only reduce energy consumption but also demand on the network during peak periods. To estimate potential savings from deferred network augmentation, an estimate of average augmentation costs were sourced from Roadmap scenario modelling outputs, adjusted for the level of overcapacity in current infrastructure. On this basis the indicative network augmentation cost is modelled as being $963/kW to around $905/kW by 2050 reflecting recent Australian Energy Regulator (AER) determination decisions and assumed continued productivity improvements.

An additional allowance was made for the reduction in air conditioning system costs from reduced peak heating or cooling load. The incremental cost of air-conditioning has been modelled based on a brief study of the cost of split system air-conditioners. Based on this, an incremental air-conditioning cost saving of $230/kWth was included.

A measure is deemed 'cost-effective' if it has a benefit cost ratio to society at least 1 over a 15-year period.

Key results

Table B1 summarises the measures that were determined to be cost-effective for each archetype in each climate zone, and the associated costs and benefits. The cost premium for each individual measure is calculated as the upfront capital costs of the measures, minus savings associated with downsizing heating and cooling equipment and network benefits associated with reduced peak demand.

TABLE B1: Costs and benefits of the individual measures that were deemed to be cost-effective

Archetype	Climate zone	Cost-effective measures	Annual energy saving (kWh/annum)	Average annual energy cost saving ($/annum, 2017 prices)	Network saving ($, 2017 prices)	Cost premium ($, 2017 prices)	Annual net benefit to society ($/annum, 2017 prices)	Societal Benefit-cost ratio
Detached	2	Improved air tightness	226	$58	$444	$570	$172	5.53
		Require ceiling fans	314	$81	$12	$1,027	$21	1.3
		Increased roof insulation (to R5.2 total)	173	$45	$178	$3,724	$23	1.25
	5	Improved air tightness	190	$49	$364	$570	$69	2.82
		Require ceiling fans	182	$47	$1,001	$313	$936 (High net savings due to high network benefit)	Negative cost (due to network benefit outweighing capital cost)
		Increased roof insulation (to R5.82 total)	222	$57	$415	$3,736	$129	2.38
	6	Improved air tightness	572	$147	$107	$800	$82	2.53
		Increased roof insulation (to R5.82 total)	316	$81	$424	$3,736	$230	3.46
Attached	2	Require ceiling fans	197	$51	$76	$656	$18	1.42
	5	-	-	-	-	-	-	-
	6	Improved air tightness	442	$114	$102	$800	$57	2.07
Apartment	2	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-
	6	Improved air tightness	508	$131	$20	$800	$17	1.32

For the Single Apartment archetype in climate zones 2 and 5, energy savings were found to be achievable if air tightness was improved and roller shutters are included on certain orientations. However, based on current economic assumptions it was found that in these cases the costs outweigh the benefits. The project looked at only a single, mid-level apartment dwelling averaged across four different orientations in order to expand the applicability of the results to apartment towers of different sizes. This approach is conservative as it does not allow for opportunities for whole-building design responses such as trade-offs in different orientations, or ceiling insulation and insulation above a basement car park. It also does not account for the variability in performance across different apartment dwellings in the one dwelling. The lower-rated apartments in a building are likely to have greater opportunities for improvement than the higher-rated apartments.

The Trajectory Project scope was limited to one apartment archetype. It is recommended that more detailed follow-up projects analyse a diverse range of whole apartment buildings of different geometric forms, which would likely lead to the identification of further cost-effective opportunities for apartments.

Table B2 summarises the initial results when the measures from Table B1 are combined into a single model. As noted above, these results are preliminary, and follow-up analysis will investigate the interactions between measures to ensure that the benefit-cost ratio when multiple measures are combined falls within a benefit-cost ratio of between 1 and 1.5.

All of the measures included in Table B2 relate to heating and cooling energy performance of a home, so all energy savings are converted to an equivalent improvement in Star rating under the Nationwide House Energy Rating Scheme (NatHERS). NatHERS calculates a Star rating based on the predicted heating and cooling energy of a home. It doesn't cover all energy requirements in the Code, such as lighting.

TABLE B2: Preliminary results when the measures from Table B1 are combined in a single model, for each archetype in each climate zone

Archetype	Climate zone	Total energy saving (kWh/annum)	Equivalent NatHERS Star rating change	Total energy saving (% of heating and cooling)	Cost premium ($)
Detached	2	353	+2.5	51%	$2,697
	5	339	+2.3	51%	$2,915
	6	441	+1.5	42%	$2,154
Attached	2	194	+1.9	40%	$656
	5	-	-	-	-
	6	441	+1.2	37%	$800
Apartment	2	-	-	-	-
	5	-	-	-	-
	6	288	+1.3	35%	$800

Table B3 summarises the results of the solar PV analysis. The sizing of the solar PV systems for the Trajectory Project analysis assumes that up to half of all north, east and west-facing roof areas can be used. This amounted to an 11.5 kW system for the detached house archetype (approximately $30,000 capital cost) and 4.5 kW for the attached house ($8,600 capital cost). The benefit cost analysis for solar PV was conducted under a 'full export' scenario (where all electricity generated is exported and the owner receives a feed-in tariff) and a 'full internal use' scenario (where it is assumed that all electricity generated is used on-site). The results indicate that under current economic assumptions, solar PV is cost-effective to the point where approximately 60 per cent (for climate zone 2) to 70 per cent (for climate zones 5 and 6) of generated electricity is exported. This issue will be investigated further in the second phase of the project, as will the solar PV opportunities for apartments, with the results to be presented in the Final Report.

The modelling has not considered current limits on rooftop solar PV connections to the grid, or the potential future costs of integrating increasing amounts of rooftop solar PV into the electricity network. Stakeholder feedback provided for this project suggests that for many homes the local electricity distribution network service provider (DNSP) currently sets a 5 kW limit for solar PV systems connected to the grid.

TABLE B3: Results of the solar PV economic analysis

Archetype	Climate zone	Benefit cost ratio - full export	Benefit cost ratio - full internal use
Detached	2	0.60	1.88
	5	0.54	1.70
	6	0.53	1.68
Attached	2	0.60	1.88
	5	0.54	1.70
	6	0.53	1.68

The analysis details summarised in this appendix only relate to the results summarised in the Interim Report. Further details on the modelling methodology, assumptions and results for all measures tested are provided in the Interim Technical Report, available on the ASBEC and ClimateWorks websites.

Appendix C: Detailed case studies

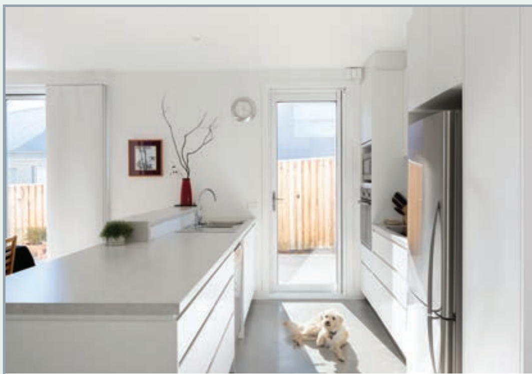
Josh's house

Josh's House shows the potential for very high performing homes to be constructed at little or no extra cost. The project built two houses on a Perth block, achieving a 10 Star NatHERS rating without straying from 'conventional' building materials.

The homes are oriented east-west to make the most of the sun's warmth in winter, while avoiding too much heat gain in summer by using shading and eaves on the north windows. Minimal windows on the eastern and western sides also reduce heat gain in the summer. The internal materials of each house have been carefully selected to maintain stable indoor temperatures in summer and absorb the sun's warmth in winter. These benefits are also enhanced by well-insulated walls and ceilings, ensuring the temperature inside is comfortable all year round. These features and the 3kW rooftop solar system make the house extraordinarily cheap to run, saving the family over $1,500 in electricity bills every year.

Josh's House has an integrated system for recording household data, such as temperature and energy use, and serves as an exemplar of the potential for 'regular' homes to be extremely efficient and affordable.

This study was contributed by Josh Byrne & Associates.



Stray Leaf House

The Stray Leaf House was designed to be a comfortable, affordable home for its retired residents, who spend much of the day at home. This meant that it was very important that the house maintained warm indoor temperatures even during Canberra's cold winters months. Light House Architecture and Science achieved this through a combination of design features that make the most of the sun's energy and minimise unwanted heat loss.

The thermal mass of the concrete floors helps to reduce temperature fluctuations. Making the most of the northern orientation and designing appropriately sized eaves allows high levels of passive solar heating in winter while shading the floors in summer. Heat loss in winter (and heat gain in summer) is minimised by high levels of insulation in the walls and ceilings, as well as double glazed windows and a well-sealed internal building shell.

Internal condensation is not an issue because exhaust fans are used to extract moist air from wet areas when cooking or washing, and the internal surfaces of the well-insulated building shell, including PVC-framed double glazing, rarely reach dew point (the temperature at which water vapour condenses).

These features all create a home that is cosy and cheap to run. Energy efficient equipment such as an evacuated tube solar hot water system and a 1.5kW photovoltaic system mean that in summer power bills can be as little as a third of that of typical one person households in the area.

This study was contributed by Light House Architecture and Science.


Davison Street Collaborative

The Davison Street Collaborative is a ‘Collaborative Housing’ project, bringing multiple people together to construct three townhouses on a single site in inner-city Melbourne. The project aims to fill a gap in the Australian housing market: the construction of quality townhouses in suburban infill developments. The Collaborative Housing model involves multiple individuals, couples or families - ‘Collaborators’ - coming together to jointly purchase a site and develop it into multiple homes. The Collaborators enter into an agreement to form a Joint Venture company, a legal entity that binds Collaborators together. The Joint Venture engages HIP V. HYPE’s management services to manage the procurement process and mitigate development risk on behalf of the Joint Venture including site identification, acquisition, enabling Collaborator input through the design process, bank finance and building works. Then, once the buildings are finished, the financial loans will be transferred to each Collaborator who will take up individual mortgages. This results in a lower mortgage for Collaborators than a traditional build by as much as 20 per cent (depending on the rate of return required by the bank) as financial returns are diverted to people collaborating, rather than a third-party developer.

The Collaborative Housing model has the added benefit of building a community through the project procurement process and delivering housing with an end user design focus. As the ‘developers’ of the project, the Davison Street Collaborators have greater oversight of the design and construction, leading to more informed decisions being made through the eyes of an end user and owner, leading to more comfortable homes with lower running costs that are suited to their personal needs. By pooling their resources, the Collaborators can access comfortable, sustainable townhouse style homes in an inner-city suburb in which house prices are becoming increasingly unaffordable.

Sustainability and passive thermal design underpin every element of the project, which is being designed and constructed under the management of HIP V. HYPE Development in collaboration with HIP V. HYPE Sustainability and Archier Architects. An airtight building envelope along with double glazed, timber-framed windows ensure that unwanted heat loss and gain is minimised. Inside, cross ventilation in living areas and energy recovery ventilation is designed to ensure fresh air is provided to the building occupants. Ceiling fans will be provided to cool bedrooms and living areas on hot days, and a heat pump hydronic heating system will efficiently keep the houses warm during cold periods. These heating and cooling measures, along with an all-electric servicing strategy, will dramatically reduce the amount that each household would have otherwise spent on heating and cooling while making each home 'zero carbon ready’. Each house will be equipped with a 4kW solar PV system and battery storage system, which aims to meet 100 per cent of each home’s energy demand and achieve net zero energy on an annual basis.

This study was contributed by HIP V. HYPE.

Ocean View Crescent

Ocean View Crescent demonstrates that airtight, well-insulated homes can dramatically reduce heating and cooling costs. The home's design maximises the opportunity to absorb the sun's warmth, with windows oriented to maximise winter sunlight exposure. High levels of insulation and curtained, double glazed windows help ensure that unwanted heat loss is minimised during cold periods.

The home has a specialised insulated slab, as well as a building wrap on the inside and outside of the walls to make the building airtight. Blower door testing demonstrated that the house is sealed to a level of 1.7 air changes per hour at 50 Pa - around one-tenth of the 'leakiness' of average homes in Australia. Over the winter the temperature inside never dropped below 16 degrees Celsius. Extractor fans in the kitchen and bathroom ensure that moist air is exhausted properly - the owner only experienced slight condensation one day over the winter.

Designing for good ventilation between rooms also keeps temperatures comfortable in summer. The owner manages temperatures in the summer by keeping the doors and windows closed at the hottest times, then opening the house up to let the cool breeze in. During last summer, the hottest temperature reached in the house was 28 degrees Celsius.

The home's electricity needs are also supplemented by a 2.6 kW rooftop solar system. Ocean View Crescent was awarded the 2017 Best Sustainable Home Award by the Master Builders Association of Victoria.

This study was contributed by Nick Wootton, Croft Wootton Construction.

Done Dirt Cheap

This home exemplifies the energy efficiency that can be achieved even on a very limited budget. The design was produced by F2 Design as the winning entry into the Building Designers Association of Victoria 10 Star Challenge to design high-performance homes. The concept has since been tested in three locations in Victoria and the ACT, where it was built to an 8 star NatHERS standard.

The home relies on a number of simple design features that make it extremely low energy and well-ventilated. The building's size and shape is carefully designed to minimise heat loss to the outside environment, and north facing windows direct warmth and daylight inside. This keeps the indoor air temperatures comfortable even during the winter, and warmth is retained using the thermal mass of the concrete slabs and brick walls. The house is well adapted to summertime temperatures as well, with two stories with high level windows allowing warm air to flow outside, ventilating and cooling the house on summer nights.

F2 Design has concluded that the optimal balance between cost-effective construction and energy efficiency for this home is approximately around 8 stars, as this is the level at which all of the building's heating and cooling needs can be generated by on-site renewables. During their first winter in the home, the residents of the 8-star ACT house didn't turn on their heating once, even when temperatures reached minus 10 degrees Celsius.

This study was contributed by F2 Design.

Innovation House 1

Townsville's 'Innovation House 1' demonstrates how climate-responsive design strategies can lead to comfortable, low-energy homes in the tropics.

'Innovation House 1' is a four-person family home that achieved the first 10 star as-designed NatHERS rating in the Australian tropics. The house is built using a lightweight construction with insulation in the walls, ceiling and roof. It is carefully oriented to capture the predominant breezes in the area, and includes timber louvres on the outside walls that allow ventilation while blocking out heat from the sun. Louvres are also incorporated into the front door and in some internal walls to allow better cross ventilation. Large 900mm eaves are constructed on all sides of the house, providing a high level of shading, and a light-coloured roof and walls reflect much of the sun's heat away from the house. Ceiling fans are installed in all main rooms to make indoor areas more comfortable. Collectively these design features reduce the need for using the air conditioners.

Electricity generation from the 5 kW rooftop solar PV system is more than sufficient to meet the family's air conditioning demand during summer, as well as much of the remaining household electricity consumption.

Innovation House 1 is the first step in socialising the Innovation House process by Finlay Homes, which aims to walk communities through the necessary change to enable them to improve their lives with better housing solutions. Innovation House demonstration homes are designed and constructed to respond to the unique needs of each community with respect to good design, energy and water efficiency, technology, health and product selection.

This study was contributed by Dr Wendy Miller, Queensland University of Technology, and Finlay Homes.

Above image courtesy VAM Media

Pilbara Vernacular House

The Pilbara Vernacular House is a demonstration project driven by the WA State Government, exemplifying how smart design can produce homes that are affordable, cool and energy efficient in hot and tropical climate of the north-west.

Preventing heat gain is crucial in a hot climate like Karratha's. The roof of the house is made from highly reflective materials, and deep eaves shade the walls from the hot sun. Ventilation to remove heat is also critical, and this is enhanced in the roof space by a secondary roof and roof cavity, through which airflow is directed to expel heat as it rises from inside the rooms.

The house is oriented to take advantage of north-easterly breezes, which are directed into living spaces using 'wind blades' and 'wind scoops'. Air movement is further enhanced by breezeways that direct air past rooms to cool them. On extremely hot days, an internal, air-conditioned living area acts as an additional refuge. This space efficiently retains its cool temperature when mechanically cooled, as the house's other rooms completely surround and shelter it from the outside air.

This project exemplifies how shading and ventilation are affordable mechanisms to build homes that are well-adapted to some of Australia's hottest climates.

This study was contributed by Josh Byrne & Associates.

Reservoir House

Reservoir House is a home for a family of four in the northern suburbs of Melbourne. The building exemplifies how homes can be built to be comfortable with very low energy bills - in the 2016 winter the average temperature inside hovered around 19 degrees, while the energy bill for the year came to just $560.

The home was designed with passive solar principles in mind. The main living area is located on the northern end of the block to capture the most daylight. The solar heat coming into the house is controlled by window shades and a retractable awning on the north-east corner, which allows in the warmth of the sun during winter but blocks off all sunlight from the main living area during summer.

Structural insulated panels (SIPs) were used to speedily build the home at the same cost as traditional construction, but with significantly higher levels of insulation and airtightness that deliver dramatically improved energy performance and occupant comfort. SIP wall panels are comprised of two rigid panels glued on either side of an insulated foam core. As SIPs are load-bearing, they remove the need for a timber framework on the external walls. The SIPs are also relatively easy to seal, and testing at the end of construction showed that the house achieved an air tightness of 1.15 air changes per hour at 50 Pa - less than one-tenth the 'leakiness' of average housing in Australia. Heat recovery ventilation provides fresh air to the inside of the house while removing moisture, reducing the risk of condensation and mould.

Reservoir House has no gas connection, and therefore has zero on-site carbon emissions from energy. A 7.6 kW solar PV array generates more electricity over the course of the year than is consumed, so the house is a net energy exporter.

This study was contributed by Habitech Systems and 8020green.

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Published by ClimateWorks Australia
Melbourne, Victoria, February 2018

AUSTRALIAN SUSTAINABLE BUILT ENVIRONMENT COUNCIL

ClimateWorks AUSTRALIA
Founding partners Monash University and The Myer Foundation