BUILDING CODE ENERGY PERFORMANCE TRAJECTORY PROJECT

FINAL REPORT

July 2018

# Built to Perform

## An industry led pathway to a zero carbon ready building code

asbec
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 to accelerate the transition to net zero emissions by 2050 for Australia and our region. 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 the 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 Sustainable Buildings Research Centre at the University of Wollongong (UOW).

## Supporters

The project is steered by an ASBEC Task Group comprising government, industry and academic stakeholders and chaired by Prof Tony Arnel, a former long-term Board member of the Australian Building Codes Board (ABCB), President of the Energy Efficiency Council and Global Director of Sustainability at Norman, Disney and Young.

**RACV** is a lead project sponsor. RACV is proud to offer their members products, services and benefits in the areas of motoring and transport, the home and travel and entertainment.

Other project supporters include:

- A range of industry and non-government organisations including Air Conditioning and Mechanical Contractors Association, Australian Building Sustainability Association, Australian Institute of Refrigeration Air Conditioning and Heating, Australian Passive House Association, Australian Steel Stewardship Forum, Australian Windows Association, Chartered Institute of Building, Consult Australia, Cooperative Research Centre 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, Sustainable Buildings Research Centre, University of Wollongong, Standards Australia, University of Melbourne, and Vinyl Council of Australia; and
- Government organisations and departments, including ACT Environment, Planning and Sustainable Development Directorate, City of Sydney, Commonwealth Department of the Environment and Energy, NSW Office of Environment and Heritage, QLD Department of Natural Resources, Mines and Energy, QLD Department of Environment and Science, QLD Department of Housing and Public Works, QLD Department of State Development, Manufacturing, Infrastructure and Planning, SA Department of Energy and Mining, 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 societal cost-benefit analysis, and ASBEC, ClimateWorks and the delivery partners gratefully acknowledge the generous and highly valuable input they have provided throughout the project.

## Project funders:

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# Executive Summary

Improved energy performance of buildings presents a win-win-win opportunity, reducing stress on the electricity network, offering bill savings, supporting a least-cost pathway to a zero carbon built environment, and improving health and resilience outcomes for households and businesses.

The National Construction Code is a ready-made policy instrument to influence the operational energy use of new buildings and major renovations. The Code regulates the building 'envelope' and fixed equipment, including heating and cooling equipment, lighting and hot water. Over time, improvements to the Code can have a significant impact since more than half the buildings expected to be standing in 2050 will be built after the next update of the Code in 2019. Increased minimum energy requirements in the Code are essential to address market failures in the delivery of higher performance buildings that have seen a widening gap between industry leaders and minimum requirements.

As a signatory to the Paris Climate Change Agreement, Australia has committed to reducing economy-wide greenhouse gas (GHG) emissions by 26 to 28 per cent below 2005 levels by 2030. The Australian Sustainable Built Environment Council's (ASBEC) *Low Carbon, High Performance* roadmap found that actions to reduce emissions from the building sector (including new and existing buildings), could deliver 28 per cent of Australia's 2030 emissions reduction target. This report, prepared by ASBEC and ClimateWorks Australia, builds on *Low Carbon, High Performance* to investigate opportunities for the Code to contribute to the decarbonisation of Australia's economy in line with the Paris Agreement. It recommends the establishment of a transition plan to make the Code 'Zero Carbon Ready'.

**A Zero Carbon Ready Code would maximise the potential for new construction to cost-effectively contribute to achieving the overarching zero carbon goal, and prepare buildings built today for the 2050 zero carbon environment in which they will ultimately be operating.**

Implementing this recommendation would mean moving away from ad-hoc, periodic updates whereby the ambition of performance targets is re-debated every few years, causing ongoing uncertainty for industry. This report recommends defined targets and a timeline for progressive Code upgrades to hit those targets, as well as an established process for tracking progress and adjusting targets to accommodate future advances in technology and design approaches. Shifting to this approach would provide the regulatory certainty that industry requires to plan and invest time and effort in research and development to bring new technologies to market and deliver higher building energy performance at a lower cost. It would also help unlock the potential for the Code to deliver emissions reductions in line with the Paris Agreement.

The report outlines a set of energy performance targets for different building types across different climates, based on societal cost-benefit analysis of energy efficiency and on-site renewable energy opportunities. The goal of the analysis is to assess the contribution that the Code could make towards achieving GHG emissions reductions in line with overarching zero carbon targets.

**The analysis shows that by 2030, even conservative improvements in Code energy efficiency requirements could deliver between 19 and 25 per cent of the energy savings required to achieve net zero energy in new residential buildings, 22-34 per cent of the required energy savings for commercial sector buildings, and 35-56 per cent for public sector buildings.**

Achieving these targets could reduce household bills by up to $900 per year for each household, while saving thousands of dollars each year across a whole non-residential building. This could also reduce electricity network investments across Australia by $7 billion between now and 2050. These benefits more than offset the upfront costs, noting that electricity market reforms would be required to enable network savings to be passed through to individual building occupants. Achieving the targets could also deliver 15 million tonnes of cumulative emissions reductions to 2030, and 78 million tonnes to 2050.

In order to achieve zero carbon buildings, residual energy use would need to be addressed through a combination of on-site renewable energy, improvements in energy efficiency of plug-in appliances and decarbonisation of centralised grid electricity supply. Additional analysis undertaken for this report highlights that there is significant and economically attractive opportunity for on-site renewable energy generation to meet remaining energy demand (see Section 2). Capturing the full potential of on-site renewables could get detached and attached homes all the way to net zero energy, and the rest of the modelled buildings between 10 and 85 per cent of the way there.

Urgent action is needed to unlock these opportunities. This report recommends the following three actions:

### RECOMMENDATION 1:
### Commit to a Zero Carbon Ready Building Code.

The COAG Energy Council and Building Ministers Forum should commit to deliver a ‘Zero Carbon Ready’ Code. This would mean setting energy efficiency targets in the Code at least as stringent as the conservative energy efficiency targets in this report (excluding renewable energy potential), introducing net energy targets (including renewable energy potential), and establishing a clear set of rules and processes for implementation and adjustment of the targets in the Code.

### RECOMMENDATION 2:
### Deliver a step change in 2022.

The COAG Energy Council and Building Ministers Forum should jointly agree to task the Australian Building Codes Board (ABCB) to deliver a step change in the energy requirements in the 2022 Code, with a strong focus on residential standards and a further incremental increase in non-residential standards.

### RECOMMENDATION 3:
### Expand the scope of the Code and progress complementary measures.

The COAG Energy Council and Building Ministers Forum should jointly establish work programs that investigate expanding the scope of the Code to prepare for future sustainability challenges and opportunities, including health, peak demand, design for maintainability, provision for electric vehicles and embodied carbon. The Building Ministers Forum and COAG Energy Council should also progress measures to complement the Code and drive towards zero carbon new and existing buildings.

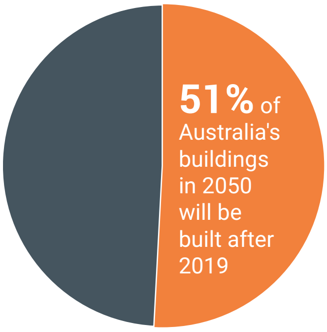
| GLOSSARY | |
|---|---|
| ABCB | Australian Building Codes Board |
| ASBEC | Australian Sustainable Built Environment Council |
| BCR | Benefit-cost ratio |
| CRC | Cooperative Research Centre |
| COAG | Council of Australian Governments |
| Code energy requirements | Minimum energy requirements in the National Construction Code |
| Energy efficiency targets | Targets for energy performance to be included in the Code, excluding any on-site renewable energy generation |
| NatHERS | National House Energy Rating Scheme |
| NEEBP | National Energy Efficient Building Project |
| NEPP | National Energy Productivity Plan |
| Net energy performance | Annual energy consumption of a building minus the annual on-site renewable energy generation |
| Net energy targets | Targets for net energy performance to be included in the Code, accounting for on-site renewable energy generation |
| Net societal benefit | The total social benefits of an action, minus the total social costs, without considering the distribution of benefits and costs (e.g. between the individual taking the action and broader society). |
| Net zero energy | The annual on-site renewable energy generation is equal to or more than the annual energy consumption |
| RIA | Regulatory Impact Assessment |
| Zero carbon | Refers to a building with no net annual greenhouse gas emissions resulting from on-site energy or energy procurement (Scope 1 and Scope 2) from its operation[1] |
| Zero Carbon Ready Code | A Building Code that maximises the cost-effective potential for new construction to contribute to achieving the overarching zero carbon goal |

# 1. The case for forward energy targets

Improved energy performance of buildings presents a win-win-win opportunity, reducing stress on the electricity network, offering bill savings, supporting a least-cost pathway to decarbonisation and improving health and resilience outcomes for households and businesses. The Australian Sustainable Built Environment Council (ASBEC) has convened a broad coalition of built environment sector industry groups to develop, in partnership with ClimateWorks Australia, forward targets and trajectories for the energy requirements in the National Construction Code.

Buildings consume over half of Australia's electricity[2], and are a key driver of peak demand across the electricity grid. The operation of buildings also contributes almost a quarter of national greenhouse gas emissions[3]. New construction adds up fast: 51 per cent of the buildings expected to be standing in 2050 will have been built after the next update of the National Construction Code in 2019 (see Figure 1)[4]. Reducing the energy consumption of new buildings is an important part of the solution to transitioning to a zero carbon energy system.

**FIGURE 1: Share of 2050 building stock expected to be built after 2019**[i]



This report presents the final results of the Building Code Energy Performance Trajectory Project (the Trajectory Project), which aims to support governments to adopt medium-term targets and trajectories for Code energy requirements. The report sets out a series of feasible forward pathways for Code energy requirements that cover a range of building types and climates across Australia, which provide a benchmark for governments to support the adoption of targets for future revisions of the Code.

This introductory section (Section 1) sets out the rationale for the introduction of forward targets and trajectories for energy requirements in the National Construction Code. Section 2 summarises the targets that this study found would deliver net societal benefits for various building types across different Australian climates, while Sections 3 and 4 provide specific recommendations for the implementation of targets and trajectories in the Code.

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[i] Estimating future construction rates is highly uncertain. The estimation presented here differs from the figure presented previously by ASBEC and ClimateWorks as it now draws on updated Australian Bureau of Statistics data.

## 1.1 Role of the National Construction Code

**The National Construction Code is a ready-made policy instrument to influence the energy performance of new buildings and major renovations.**

The National Construction Code (the Code) sets minimum requirements for all new buildings and major renovations in Australia, and includes requirements for energy efficiency. The Code energy requirements cover heating and cooling performance of the building envelope, lighting energy efficiency, and energy efficiency of large fixed equipment such as air conditioning and lifts; however, the Code does not cover smaller appliances such as refrigerators or computers, nor does it cover the procurement of energy from off-site sources (for example, through renewable energy power purchasing agreements).

It is a model code (with no legal force) developed and maintained by the Australian Building Codes Board (ABCB) under an Inter-Governmental Agreement, and given legal force through State and Territory legislation. Each jurisdiction may elect to apply the Code with amendments, to suit their own context[5]. The Code applies at the point of design and construction, the easiest and cheapest time to deliver energy performance outcomes.

## 1.2 The benefits and costs of high-performance buildings

**Low-energy, high performance buildings can deliver lower bills, reduced burden on the electricity grid, greater resilience to temperature extremes and healthier, more comfortable spaces for people to live and work.**

Energy is inextricably linked to living affordability and the costs of doing business. Retail electricity prices for households and small businesses have increased by 80 to 90 per cent over the past decade, while electricity prices for some medium and large businesses have doubled, or even tripled, in the past two years alone[6]. Low-income households and small businesses are particularly vulnerable to price increases - for example, low-income households spend up to five times more (as a proportion of disposable income) on electricity than higher-income earners[7]. Higher energy prices have also had a detrimental impact on the international competitiveness of larger Australian businesses[8].

**As a proportion of their disposable income, low-income households spend up to five times more as a share of their disposable income on electricity than higher-income earners.**

While individual households and businesses have very limited influence on the unit price of energy, there are concrete actions that can be taken to reduce overall energy bills by improving building energy performance, particularly during the design and construction of new buildings and major renovations. If the energy efficiency targets in this report are implemented in the Code, residential energy bills could be reduced by $18.9 billion, and non-residential bills could be reduced by $7.8 billion, between now and 2050.

These benefits more than offset the upfront costs, noting that electricity market reforms would be required to enable network savings to be passed through to individual building occupants.

The increases in retail electricity prices over the past decade have been driven primarily by higher electricity network costs[9]. Improving energy efficiency and installing on-site generation with storage each reduce the burden buildings place on the grid. These measures reduce the investment required in transmission and distribution networks to deliver electricity during periods of peak demand (for example, air conditioning demand peaks in the afternoons and early evenings on hot days when businesses are still operating and people are returning from work)[10].

If a single building cuts its peak demand by one kilowatt (kW), equivalent to the power used to run a small oil heater, it is estimated this will save almost $1,000 in required investment in electricity system infrastructure, reducing electricity prices for everyone[11]. Implementation of the energy efficiency targets identified in this report would deliver an estimated financial benefit of $6.9 billion nationally by 2050 in the form of avoided or deferred network investments.

**Cutting peak demand by just one kilowatt, the equivalent power used to run a small oil heater, can save almost $1,000 in investment in electricity system infrastructure, reducing electricity prices for everyone.**

It is important to note that the energy market currently does not provide a mechanism for most building owners and occupiers to directly recover the financial benefits they provide to the market by lowering their peak demand. To address this, the Australian Energy Market Commission (AEMC) Power of Choice review is leading to new rules that are intended to better incentivise individual consumers to reduce their peak electricity demand, including peak demand tariffs[12].

**Achieving the energy efficiency targets proposed in this report could reduce residential energy bills by $18.9 billion, and non-residential bills by $7.8 billion, between now and 2050.**

In addition to financial savings, growing evidence shows that Australia's buildings can significantly improve their occupants' health and wellbeing if energy performance, comfort and resilience outcomes are targeted effectively in a building's design and construction. Low-energy design and construction is important for building resilience into the operation of businesses and keeping homes comfortable and safe in a changing climate. Low-energy housing has also been demonstrated to reduce stress associated with affordability issues[13]. These benefits apply not only to where we live, but to where we work, study and learn. Numerous case studies from around the world have reported improved productivity and reduced sick days when upgrading to 'green' offices[14], while comfortable indoor temperatures in schools have been shown to contribute to better student performance and healthier work environments for teachers[15].

The benefits of the energy efficiency targets set out in this report could be delivered at a construction cost premium of between 1 and 4 per cent of typical construction costs for detached homes, and around 1-2 per cent for commercial office buildings[16]. Further details on the construction cost premiums for the modelled building types are provided in Appendix A.

The Code gives significant flexibility to designers to achieve its energy requirements in a range of ways. Leading designers have shown that with close attention to building design, very high energy performance can be delivered at low cost. The upfront cost figures in this report provide a conservative estimate of upfront costs, assuming limited industry adjustment and adaptation to reduce costs.

Improving the energy performance of buildings is not just about the environment. The benefits of lower-energy buildings to people are clear: better living affordability, a less expensive electricity network, and improved health outcomes.

# 1.3 Market failures and progress to date

## While market leaders are driving world-class innovation in low-energy buildings, a range of barriers have limited progress across the rest of the market.

Market leaders in Australia are demonstrating world-class commitment to sustainability in the built environment. Property companies and fund managers in Australia and New Zealand have been outperforming the rest of the world for the past seven years in commercial office sustainability, according to the Global Real Estate Sustainability Benchmark (which is based in part on measured and publicly disclosed energy performance)[17]. Recent years have seen leaders commit to net zero emissions targets. For example:

* AMP Capital Wholesale Office Fund, one of the largest wholesale property fund managers in Australia and New Zealand, is targeting net zero emissions by 2030 across its $4.7 billion portfolio[18];
* Investa, one of Australia's largest owners and managers of institutional grade office real estate, is pursuing a net zero emissions target by 2040 across its office portfolio and business operations[19];
* Dexus, a real estate investment trust with $26 billion worth of assets spanning commercial office, retail and healthcare, has committed to a net zero target across their business by 2030[20];
* Mirvac, a property group managing over $18 billion worth of assets across office, retail and industrial sectors, has committed to reaching net positive carbon emissions by 2030[21];
* The GPT Group is working to achieve a net zero emissions target across its $18 billion property portfolio before 2030[22];
* Lendlease's wholesale commercial property trust, Australian Prime Property Fund Commercial, has set an ambitious target of net zero emissions by 2025[23]; and
* Monash University has committed to net zero carbon emissions by 2030[24].

In the residential sector, although the minimum requirement in many parts of Australia is for housing to be designed to the equivalent of a heating and cooling efficiency of 6 Stars under the Nationwide House Energy Rating Scheme (NatHERS), almost nine per cent of housing designs across Australia are at 7 Stars and above. The proportion of ratings at these levels are particularly high in the Australian Capital Territory (21 per cent), Northern Territory (20 per cent) and Queensland (25 per cent)[25].

However, a range of persistent barriers and market failures have prevented broader uptake of these better practices across the building sector. As a result, progress in improving energy performance in the built environment has been limited to a small segment of market leaders. For example, a ClimateWorks review of the progress being made in the building sector towards a low carbon economy, released in 2013, found that new commercial office buildings with a Green Star rating had, on average, half the emissions intensity of new office buildings built to minimum Code energy requirements[26].

While some gap between market leaders and the market average is expected, these barriers and market failures explain why most buildings are built to minimum standards despite the existence of feasible and cost-beneficial upgrades as demonstrated by the leaders. Barriers can be categorised as follows[27]:

* **Capability:** Home buyers, tenants and businesses often lack appropriate data, information and skills, which can undermine their ability to fully realise the benefits of low-energy buildings when making decisions to buy or rent a property; and
* **Motivation:** Internal and external factors can have a strong influence on the motivation of home buyers, tenants and businesses to consider investing in a high-performance building, regardless of financial attractiveness and capability. These include 'split incentives' between tenants and landlords, and a lack of awareness of the non-energy benefits of energy efficiency.

Energy requirements in the Code have not shifted substantially in a decade, which is a contributing factor to these market failures that have seen a widening gap between industry leaders and minimum Code requirements. Increased energy requirements in the Code are essential to address such market failures in the delivery of higher performance buildings. As discussed below, a forward plan for introducing more ambitious Code energy requirements, implemented in a manner that provides consistency and certainty to industry and consumers, will help ensure that the full potential of the Code to drive improvements is realised and accelerates the adoption of new technologies and design and construction practices across the market as a whole[28].

## 1.4 The case for trajectories and targets

### Because buildings are long-lived assets, a delay in upgrading Code requirements locks in higher energy use and emissions for decades.

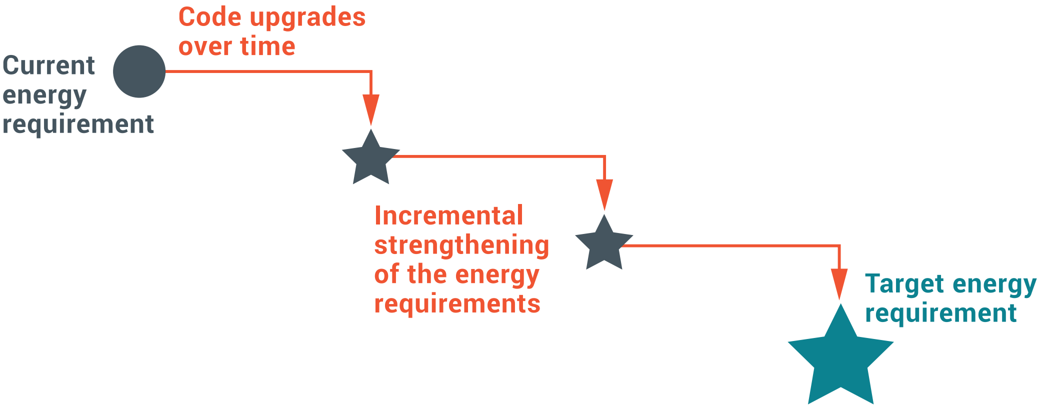
An estimated 1.1 million homes and 42 million square metres of non-residential floor space are expected to be built between 2022 and 2025. These buildings will remain standing for decades to come, and without expensive retrofits, they will be using more energy than they should. Just three years' delay in the implementation of the energy efficiency targets recommended in this report could lock in, between now and 2030, $2 billion in residential energy bills, $620 million in non-residential energy bills and $930 million of additional network investments.

### Well-designed and implemented targets for minimum energy requirements will drive innovation and investment in new practices and technology.

Specific and time-bound targets provide guidance as to when, how and to what degree energy requirements will change over time. Forward targets that set out the allowable levels of energy consumption for new buildings and major renovations over subsequent upgrades to the Code (as illustrated in Figure 2) – well in advance of each Code upgrade cycle – would provide a regulatory signal to consumers and industry that would encourage 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[29].

**Just three years' delay in implementing the energy efficiency targets recommended in this report could lock in $2.6 billion in wasted energy bills and $930 million of additional electricity network investments to 2030.**

FIGURE 2: Illustrative forward trajectory for Code energy requirements



Jurisdictions around the world have set ambitious and time-bound energy performance targets for new construction[30]. When combined with effective complementary measures and good design practices, a set pathway for progressively strengthening energy targets can provide certainty for planning and investment, enable innovation and encourage the achievement of energy performance above and beyond current requirements[31]. The latter effect has been observed in Denmark, where a pathway set in 2010 specified a series of incremental increases in the stringency of energy requirements for 2010, 2015 and 2020. Even when “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[32].

## 1.5 Transition to a net zero emissions economy

**Australia needs to accelerate its transition to net zero emissions, and many of the lowest cost, shovel-ready opportunities can be found in the design and construction of new buildings.**

As a signatory to the Paris Climate Change Agreement, Australia has committed to reducing economy-wide greenhouse gas emissions by 26 to 28 per cent below 2005 levels by 2030, which equates to approximately 272-287 million tonnes of carbon dioxide equivalent ($MtCO_2$-e)[33]. A number of States and Territories have also committed to ambitious emissions reduction targets beyond 2030, including net zero emissions by 2050 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[34].

Unlike some sectors such as aviation, steel and cement production and long-haul freight, the buildings sector does not require fundamental transitions and research and development to produce new technologies that substantially reduce emissions. For the building sector as a whole (including new and existing buildings), improving energy efficiency while encouraging fuel switching and on-site renewable energy generation could deliver 28 per cent of Australia's 2030 emissions reduction target through measures that are technologically proven and commercially available today[35]. Strengthened energy efficiency targets for new buildings, as recommended in this report, could deliver 14.7 million tonnes of emissions savings to 2030, and 78.3 million tonnes to 2050. This assumes rapid grid decarbonisation in line with a smooth transition to net zero emissions by 2050. If the grid decarbonises more slowly, the emissions savings from the proposed Code changes would be significantly higher, up to 21.4 million tonnes by 2030 and 147 million tonnes by 2050. Greater emissions reductions could be unlocked if renewable energy requirements are introduced in the Code and the full technical potential for solar PV on new buildings, as presented in this report, is achieved.

If the energy performance of buildings is not improved as suggested in this report, more action would be needed in other sectors, including the electricity sector. Reducing demand also reduces the amount of new large-scale renewable energy generation infrastructure required. The Code energy efficiency changes proposed in this report would reduce energy demand by 24 percent by 2030, and 28 percent by 2050. This is important considering the already large scale of investment that will be required to transition to a net zero emissions electricity grid while meeting the increase in demand for electricity from future electrification of transport and industry.

As is the case with energy bill savings and electricity network investments, delaying the implementation of the energy efficiency targets recommended in this report would lock in emissions that could have been avoided. A three-year delay would lock in 9 MtCO2-e of emissions to 2030 and 22 MtCO2-e to 2050, which would require more to be done by existing buildings or other sectors of the economy.

> **The term 'Zero Carbon Ready' describes a Code that maximises the cost-effective potential for new construction to contribute to the overarching zero carbon goal.**

## A ‘Zero Carbon Ready’ Building Code will prepare buildings built today for the future zero carbon environment in which they will still be operating.

The National Construction Code is an important contributor towards achieving emissions reductions in line with the overarching zero carbon targets. The term 'Zero Carbon Ready' describes a Code that maximises the cost-effective potential for new construction to contribute to achieving the overarching zero carbon goal.

The goal of the Trajectory Project has been to assess how much contribution the National Construction Code could make towards achieving emissions reductions in line with overarching zero carbon targets. To achieve this goal, this report assesses how far each building type in each climate zone could get towards net zero energy on-site through energy efficiency and on-site renewables. ‘Net zero energy’ here means that the building uses less energy over the course of the year than it generates on-site.

# 2. Energy targets

The report outlines a set of feasible energy efficiency targets for Code energy requirements and potential net energy targets. This section summarises targets for different building types across a range of climate zones.

There are numerous opportunities available today to improve the energy performance of buildings, which in turn can deliver net benefits to society[ii]. The updates proposed by the ABCB for the 2019 Code target a number of these opportunities for non-residential buildings. The Interim Report for this project found that simple measures such as improving air tightness also deliver net societal benefits in many cases for housing[36]. As technology evolves and the costs of current leading-edge technology reduces through scalability and industry learning, many more opportunities are expected to deliver net societal benefits.

The Code is currently on a three-yearly upgrade cycle. This report proposes a set of energy efficiency targets for different buildings types that could be implemented in the Code. The basis of the analysis is a conservative projection for medium-term trends in construction costs, energy prices, technological changes and other economic factors. The analysis covers the time period over which the next five Code updates will take place, from now until 2034. It sought to answer the following question: “What is the maximum level of energy performance that can be achieved in the future (without fundamental change in building designs) while delivering net societal benefits?” for different building types in different climate zones.

The results presented in this report provide an industry-led evidence base intended to support further government policy development. The Trajectory Project is not intended to replace the regulatory or policy making processes required to implement targets, trajectories and updated Code requirements. Under NEPP Measure 31, Australian Governments are investigating options for advancing the residential and commercial buildings energy efficiency measures in the National Construction Code, including consideration of possible trajectories. The intent of this report is to present illustrative pathways showing what is feasible, and to provide recommendations that would enable implementation of targets.

This report proposes energy efficiency targets and sets out the potential for net energy performance for climates across Australia, covering most State and Territory capital cities. Targets relevant to tropical and arid regions of northern Australia (including Darwin, northern Western Australia, Alice Springs and far north Queensland) will be published in a separate northern Australia report.

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[ii] Measures are considered to deliver net benefits to society if the capital cost is outweighed by the financial benefits from a societal perspective over the lifetime of the relevant building elements, in most cases a 10-15 year period.

## 2.1 Targets and forward trajectories for Code energy requirements

The Trajectory Project analysis clearly identifies minimum energy efficiency targets and trajectories that vary by building type and climate.

The Trajectory Project analysed eight building ‘archetypes’ across four climate zones, each of which was modelled in four orientations. While it was not possible to fully capture the diversity of Australia's buildings, the archetypes were developed to cover a range of typical attributes of common building types as a proxy for the entire building stock. The modelled building archetypes were:

- 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 were selected based on the locations of major population centres (see Figure 3):

- 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).

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. Modelling for Climate Zones 1 (hot humid summer, warm winter, e.g. Darwin, Broome, Cairns, Townsville) and 3 (hot dry summer, warm winter, e.g. Alice Springs) is underway and the results will be published in a separate Northern Australia report.

FIGURE 3: Australian climate zones

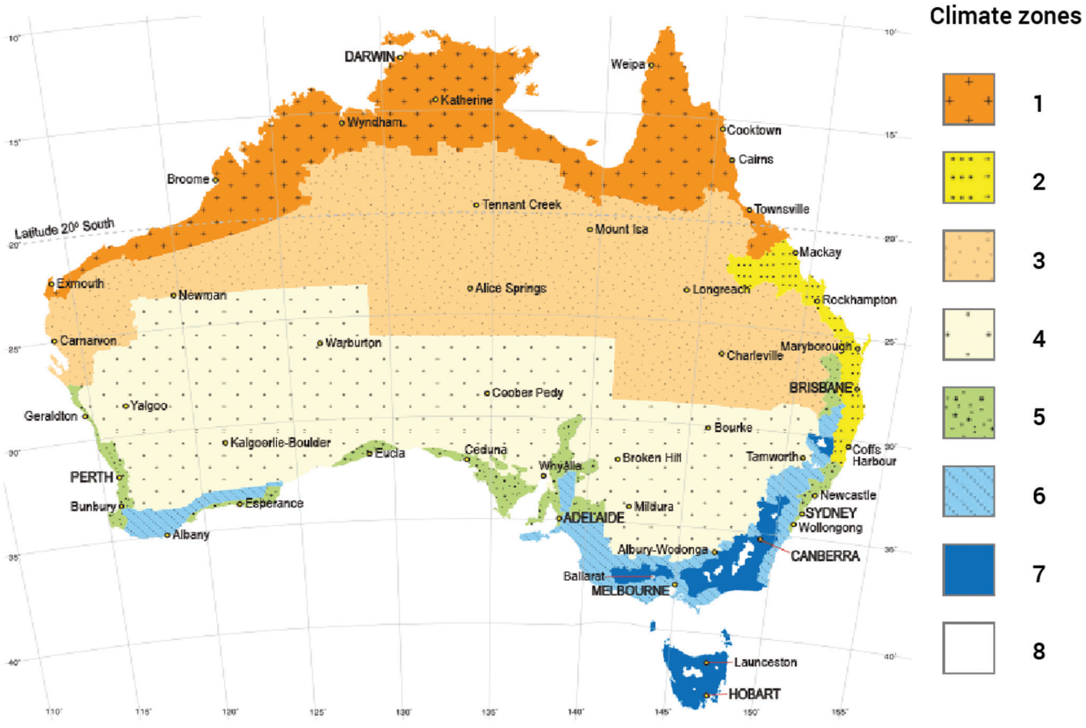


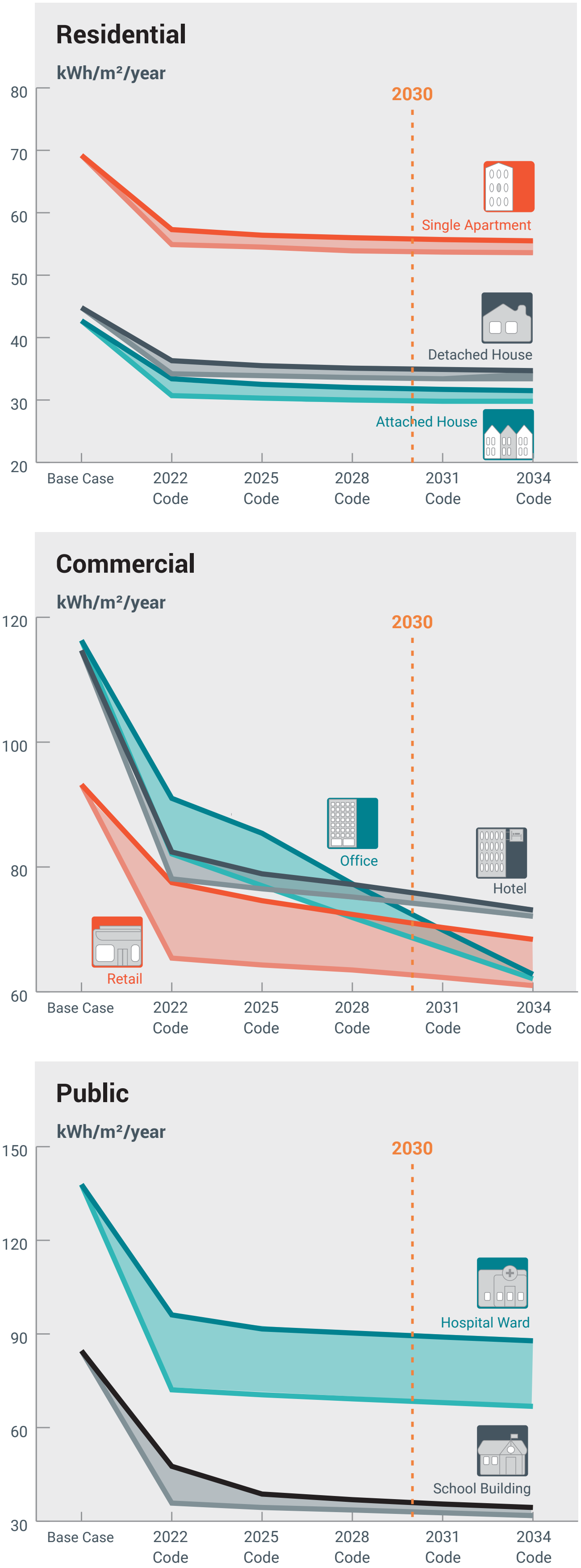
Image source: http://www.yourhome.gov.au/introduction/australian-climate-zones

For each building archetype in each climate zone, two different sets of targets and forward trajectories were determined as follows:

- **Conservative scenarios:** These include energy efficiency targets and the potential for net energy performance through on-site renewables (assumed to be solar PV, taking into account average consumption profiles and available roof space). All of these targets and performance levels were set at a level at which societal benefits outweigh the capital costs; and
- **Accelerated deployment scenarios:** The energy efficiency targets include all measures that are deemed to provide a material energy benefit, and assume faster deployment of energy efficiency technologies. The identified potential for net energy performance in these scenarios assumes that the entire available roof area of each building archetype is covered with solar PV, allowing for maintenance access and installation angle for panels. Based on our analysis, the benefits of achieving these targets would not outweigh the capital costs on current economic projections. However, the cost of achieving these accelerated trajectories could be lower if the industry adapts to energy efficiency measures faster than assumed or if government implements market transformation measures, such as research and development, to reduce the cost of key technologies (see Section 4.6 for further details).

The conservative and accelerated deployment energy efficiency scenarios for each building type are illustrated in Figure 4. These summary trajectories are averaged across all climate zones. Further detail is provided in the body of this section[iii] and in Appendix A of this report. A separate Technical Report, published by the CRC for Low Carbon Living and available on the ASBEC and ClimateWorks websites, provides technical details underpinning the analysis[37].

FIGURE 4: Summary of proposed energy targets for the Code, under the conservative (darker line) and accelerated deployment (lighter line) scenarios.



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[iii] For simplicity, the summary results presented in the body of this report are relevant for new construction in 2030 (i.e. the potential energy efficiency targets in the 2028 Code). This aligns with the timelines for the National Energy Productivity Plan and Australia's 2030 commitment under the Paris Climate Change Agreement.

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

This project calculated energy efficiency targets by identifying a set of design, technology and construction measures deemed to deliver net societal benefits for the particular building archetypes and climates modelled. However, the project takes a conservative approach that assumes typical mainstream building designs are retained, without inclusion of best practice design for energy efficiency. Improving the design of a building is often the lowest-cost option to improve energy performance, but assessing the impacts of best practice design was not included within the scope of this project.

Although the selected measures provide an illustration of how energy efficiency and net energy targets could be achieved and how individual Code requirements could be updated, the targets are intended to be applied in a way that does not favour particular technologies over others. It is recommended that the Code maintains this technological neutrality to provide designers and builders with flexibility in their choice of technologies and design approaches to meet the targets. Stronger targets, combined with this flexibility, are expected to encourage best practice design approaches as designers and builders seek the lowest-cost approach to meeting the targets.

Although learning rates for some fixed equipment, lighting and solar PV have been assumed based on available evidence,  for most other measures the economic analysis has not accounted for the accelerated technological progress and cost reductions that forward targets are likely to deliver.

In relation to upfront costs, this study assumes the capital cost of identified energy-saving measures are simply added to the cost of construction. This is likely to overestimate the actual cost of increased energy performance. For example, a study for the Commonwealth Department of the Environment and Energy led by Moreland Energy Foundation found significant variability in construction cost increases and learning rates after the introduction of the NatHERS 6 Star minimum requirement in 2010. This suggests that strengthened energy requirements are not strongly correlated with increased costs, and that there are strong drivers of construction costs that are unrelated to energy performance[38].

In addition to this, the analysis assumes no implementation of 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 (see Section 4 for further discussion).

Further, the analysis does not quantify the health and resilience benefits of energy efficiency; if these were to be 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 of achieving increased energy performance and at the same time, underestimate the potential benefits. In other words, the energy-saving components analysed are likely to be even cheaper and deliver more benefits than this analysis suggests.

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**The energy-saving components analysed are likely to be even cheaper and deliver more benefits than this analysis suggests.**

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The conservative nature of this analysis means that energy efficiency improvements beyond those modelled in this report could be achievable. The accelerated deployment trajectories provide some indication of the opportunities if costs decrease; however, even this analysis remains conservative and it is recommended that the targets be reviewed over time as new evidence emerges (see Section 4).

# Residential buildings

Strengthening the energy efficiency requirements of the Code could deliver between 19 and 25 per cent of the energy savings required to achieve net zero energy in new residential buildings by 2030, compared with a baseline that complies with the deemed-to-satisfy (DtS) requirements of the 2016 Code[39]. This could be achieved through simple measures such as:

- Improving air tightness;
- Including double glazed windows;
- Increasing insulation;
- Installing adjustable outdoor shading or larger eaves;
- Including ceiling fans; and
- Increasing the efficiency of air conditioning, lighting and domestic hot water systems.

Assuming minimal industry learning and conservative projections of technology cost and performance improvements, the upfront cost associated with these improvements would be approximately $6,800 for the modelled apartment archetype ($89 per square metre), $8,000 for the attached housing archetype ($63 per square metre) and $14,000 for the detached housing archetype ($74 per square metre). These upfront costs would be more than offset by the energy bill savings, reduced spend on heating, cooling and ventilation equipment, and electricity network savings.

Under the accelerated deployment scenarios, changes to the Code energy efficiency requirements could deliver 22-30 per cent of the required energy savings. This could be achieved through accelerated deployment of higher performance windows or more efficient air conditioning, lighting and domestic hot water equipment.

The remaining task to reach net zero energy in residential buildings would need to be addressed through a combination of best practice design, on-site renewable energy, voluntary measures to improve energy efficiency, strengthened standards for items outside the Code (such as plug-in appliances) and decarbonised electricity supply.

Analysis of on-site renewable energy potential shows that there is the potential for both detached and attached housing to reach net zero energy through a combination of strengthened Code energy requirements and rooftop solar PV generation as early as 2022. By 2030, with projected cost reductions in solar PV, the potential would increase further; if grid integration and other challenges can be resolved, there is the potential for a single-storey detached house to generate over three times its annual energy use through solar PV, while a two-storey attached house could generate one-and-a-half times its energy use.

The potential for apartments is less significant; by 2030 an apartment in a mid-rise building could potentially generate one-tenth of its annual energy use via rooftop solar PV, although accelerated commercialisation of building-integrated solar PV could unlock additional opportunity for apartment buildings (this was not considered in the analysis for this report).

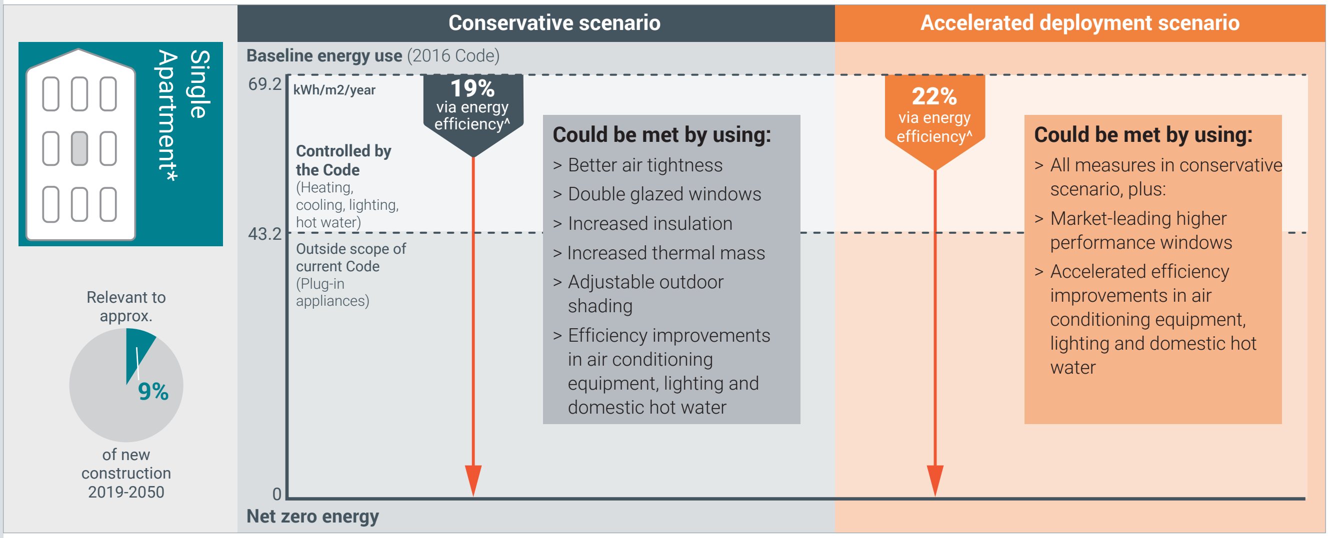
Determining the optimal balance between on-site renewables and other measures requires consideration of the issues outlined in Section 4.

**Case study:** Innovation House 1

Townsville's Innovation House was the first 10 star as-designed NatHERS rated house in the Australian tropics. The house uses simple features to maximise its energy efficiency, such as careful orientation to capture the predominant breezes in the area, large eaves for shading, ceiling fans and a light-coloured roof and walls which reflect much of the sun's heat away from the house. Collectively these design features reduce the need for use of air conditioning. 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.

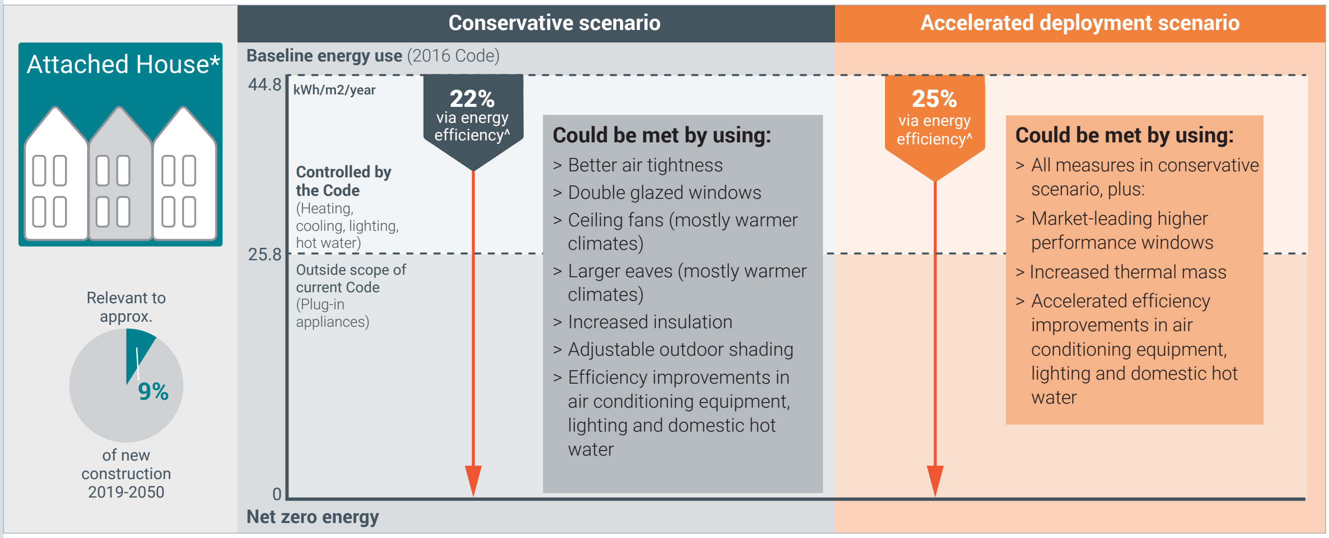
*This case study was contributed by Dr Wendy Miller, Queensland University of Technology, and Innovation House.*

# POTENTIAL 2030 ENERGY TARGETS - Residential buildings



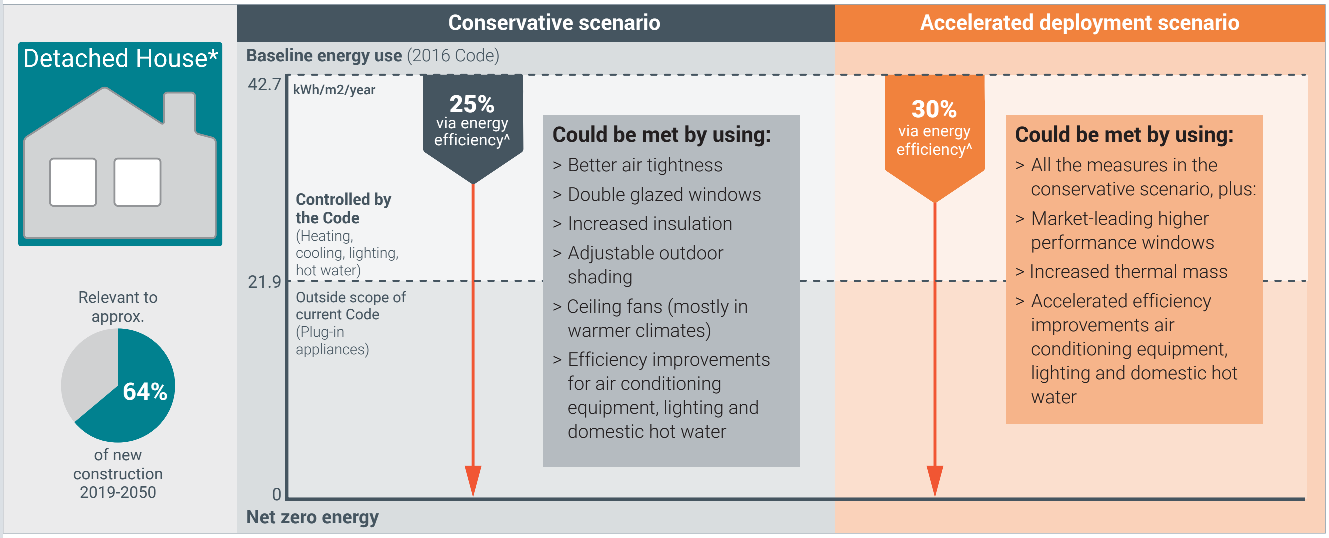
**Could be met by using:**
- > Better air tightness
- > Double glazed windows
- > Increased insulation
- > Increased thermal mass
- > Adjustable outdoor shading
- > Efficiency improvements in air conditioning equipment, lighting and domestic hot water

**Could be met by using:**
- > All measures in conservative scenario, plus:
- > Market-leading higher performance windows
- > Accelerated efficiency improvements in air conditioning equipment, lighting and domestic hot water



**Could be met by using:**
- > Better air tightness
- > Double glazed windows
- > Ceiling fans (mostly warmer climates)
- > Larger eaves (mostly warmer climates)
- > Increased insulation
- > Adjustable outdoor shading
- > Efficiency improvements in air conditioning equipment, lighting and domestic hot water

**Could be met by using:**
- > All measures in conservative scenario, plus:
- > Market-leading higher performance windows
- > Increased thermal mass
- > Accelerated efficiency improvements in air conditioning equipment, lighting and domestic hot water



**Could be met by using:**
- > Better air tightness
- > Double glazed windows
- > Increased insulation
- > Adjustable outdoor shading
- > Ceiling fans (mostly in warmer climates)
- > Efficiency improvements for air conditioning equipment, lighting and domestic hot water

**Could be met by using:**
- > All the measures in the conservative scenario, plus:
- > Market-leading higher performance windows
- > Increased thermal mass
- > Accelerated efficiency improvements air conditioning equipment, lighting and domestic hot water

**The gap to net zero energy can be met** by a combination of best practice design, on-site renewable energy, improved appliance efficiency and decarbonised grid electricity supply.

Analysis of on-site renewable energy potential shows it could meet approximately:
**10%** of remaining energy use for apartments
**Greater than 100%** of remaining energy use for attached homes
**Greater than 100%** of remaining energy use for detached homes

* Data presented here is an average for this building archetype across the modelled climate zones (2, 5, 6 and 7) for the 2028 Code

^ Percentage reduction is a proportion of whole building energy (or in the case of the apartment, whole-dwelling energy excluding central services), including energy that is currently not in the scope of the Code and needs to be addressed by measures outside the Code

# Commercial buildings

Strengthening the energy efficiency requirements of the Code could deliver between 22 and 34 per cent of the energy savings required to achieve net zero energy in new commercial buildings by 2030, compared with a baseline that complies with the energy requirements proposed for the 2019 Code. This could be achieved through simple measures such as:

- Improving air tightness (combined with overnight ventilation);
- Increasing insulation;
- Increasing thermal mass;
- Installing adjustable outdoor shading; and
- Increasing the efficiency of air conditioning and lighting.

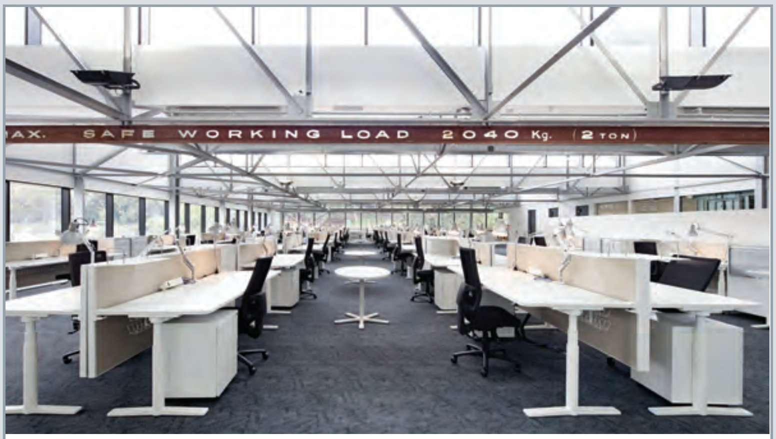
Assuming minimal industry learning and conservative projections of technology cost and performance improvements, the upfront cost associated with these improvements would be approximately $230,000 for the modelled hotel archetype ($128 per square metre), $640,000 for the office archetype ($71 per square metre) and $160,000 for the retail archetype ($171 per square metre). These upfront costs would be more than offset by the energy bill savings, reduced spend on heating, cooling and ventilation equipment, and electricity network savings.

Under the accelerated deployment scenarios, changes to the Code energy requirements could deliver 32-38 per cent of the required energy savings. This could be achieved through accelerated deployment of more efficient chillers, lighting, lifts and commercial-scale electric heat pumps.

The remaining task of reaching net zero energy in commercial sector buildings would need to be addressed through a combination of best practice design, on-site renewable energy, voluntary measures to improve energy efficiency, strengthened standards for items outside the Code (such as plug-in appliances) and decarbonised electricity supply.

Analysis of on-site renewable energy potential shows that by 2030, when combined with strengthened Code energy requirements, there is potential for a low-rise hotel to generate approximately 20 per cent of its annual energy use through rooftop solar and building integrated PV. A mid-rise office building could potentially generate approximately one-third of its energy use and a medium-sized single-storey retail building could generate approximately two-thirds.

Determining the optimal balance between on-site renewables and other measures requires consideration of the issues outlined in Section 4.



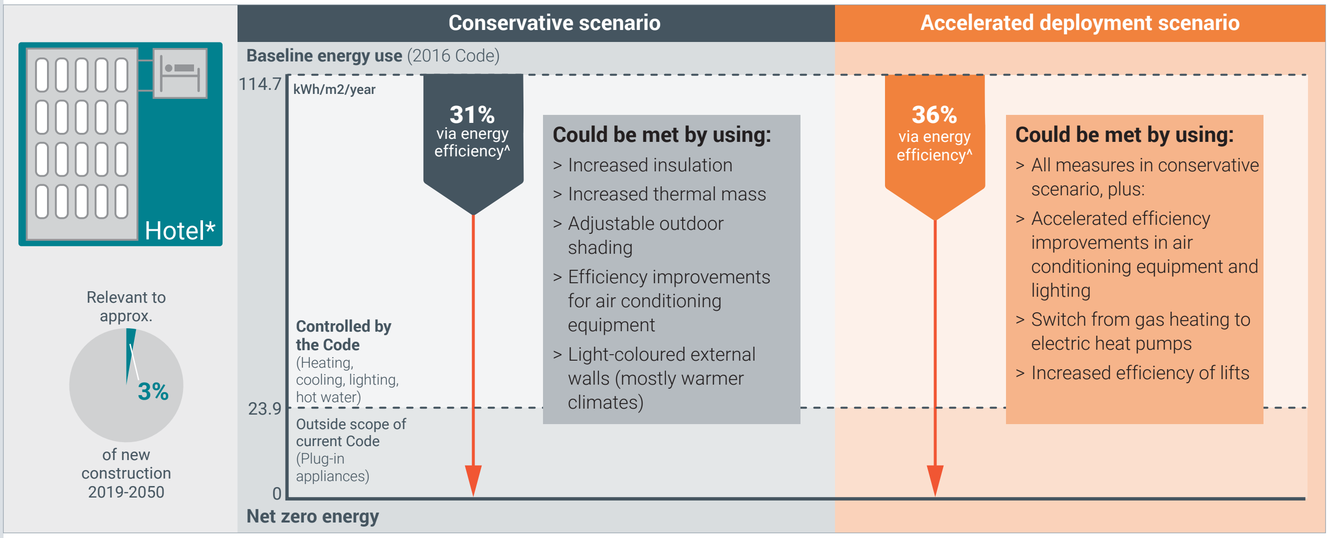
**Case study:**

Monash University Buildings and Property

Completed in 2014, Monash University's Buildings and Property office building in Clayton, Victoria is an industry exemplar of an adaptive reuse project. Formerly an asbestos-clad warehouse, it is now the University's best performing office building. The project piloted Passive House design principles and features high levels of insulation, double glazed windows, an airtight building envelope to maintain stable indoor temperatures, and a heat recovery ventilation system that efficiently warms and circulates fresh air. Automated external shading on the building's north and east sides, as well as additional horizontal shades on northern windows are used to cool the interior in summer and maximise solar heat gain during winter. A 70 kW rooftop solar system supplies 65% of the building's electricity annually.

*This study was contributed by the Buildings and Property Division at Monash University.*

## POTENTIAL 2030 ENERGY TARGETS - Commercial buildings

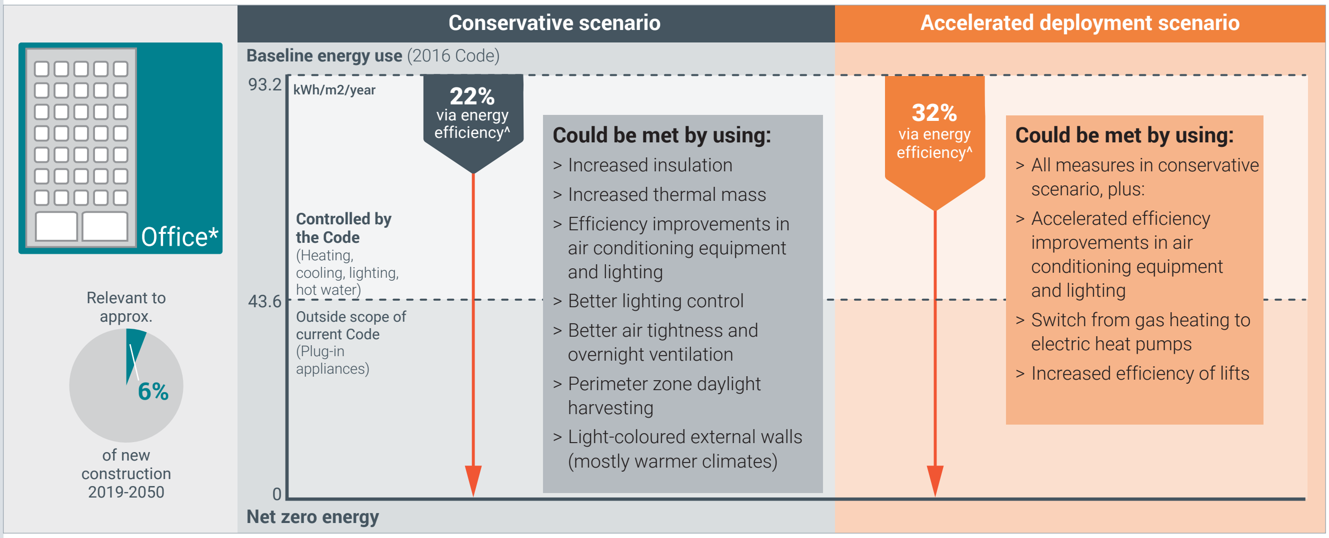


**Conservative scenario – Could be met by using:**

- > Increased insulation
- > Increased thermal mass
- > Adjustable outdoor shading
- > Efficiency improvements for air conditioning equipment
- > Light-coloured external walls (mostly warmer climates)

**Accelerated deployment scenario – Could be met by using:**

- > All measures in conservative scenario, plus:
- > Accelerated efficiency improvements in air conditioning equipment and lighting
- > Switch from gas heating to electric heat pumps
- > Increased efficiency of lifts

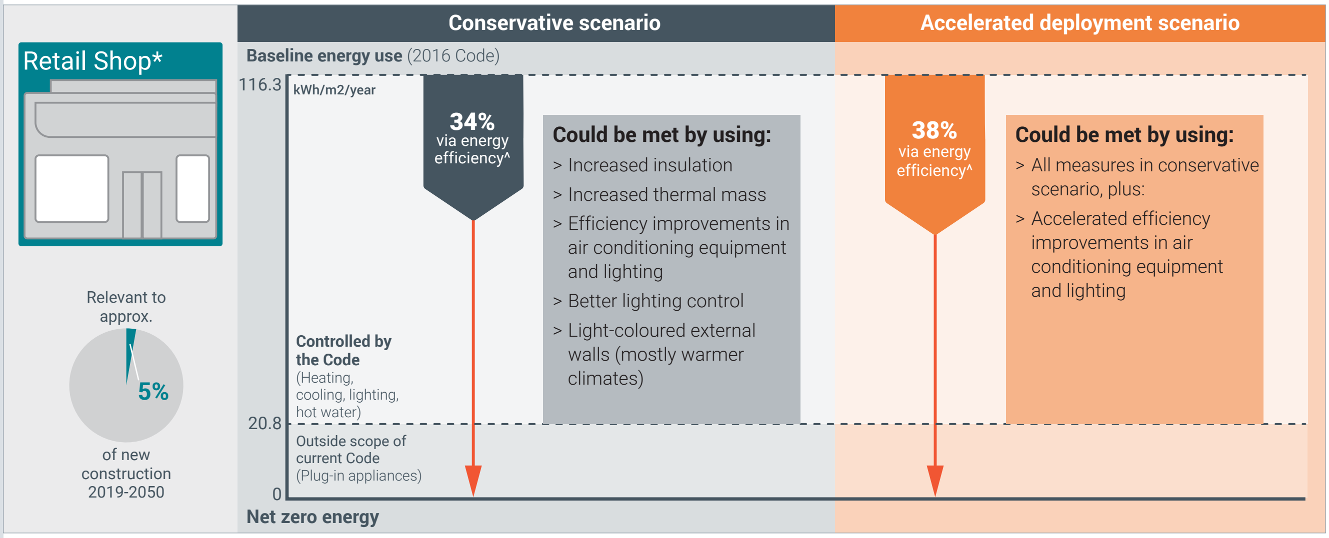


**Conservative scenario – Could be met by using:**

- > Increased insulation
- > Increased thermal mass
- > Efficiency improvements in air conditioning equipment and lighting
- > Better lighting control
- > Better air tightness and overnight ventilation
- > Perimeter zone daylight harvesting
- > Light-coloured external walls (mostly warmer climates)

**Accelerated deployment scenario – Could be met by using:**

- > All measures in conservative scenario, plus:
- > Accelerated efficiency improvements in air conditioning equipment and lighting
- > Switch from gas heating to electric heat pumps
- > Increased efficiency of lifts



**Conservative scenario – Could be met by using:**

- > Increased insulation
- > Increased thermal mass
- > Efficiency improvements in air conditioning equipment and lighting
- > Better lighting control
- > Light-coloured external walls (mostly warmer climates)

**Accelerated deployment scenario – Could be met by using:**

- > All measures in conservative scenario, plus:
- > Accelerated efficiency improvements in air conditioning equipment and lighting

**The gap to net zero energy can be met** by a combination of best practice design, on-site renewable energy, improved appliance efficiency and decarbonised grid electricity supply.

Analysis of on-site renewable energy potential shows it could meet approximately:
**23%** of the remaining energy use for a hotel
**28%** of the remaining energy use for an office
**67%** of the remaining energy use for retail

* Data presented here is an average for this building archetype across the modelled climate zones (2, 5, 6 and 7) for the 2028 Code

^ Percentage reduction is a proportion of whole building energy, including energy that is currently not in the scope of the Code and needs to be addressed by measures outside the Code

## Public buildings

Strengthening the energy requirements of the Code could deliver between 35 and 56 per cent of the energy savings required to achieve net zero energy in new hospital wards and school buildings by 2030, compared with a baseline that complies with the energy requirements proposed for the 2019 Code. This could be achieved through simple measures such as:

- Increasing insulation;
- Increasing thermal mass;
- Installing adjustable outdoor shading; and
- Increasing the efficiency of air conditioning and lighting.

Assuming minimal industry learning and conservative projections of technology cost and performance improvements, the upfront cost associated with these improvements would be approximately $57,000 for the modelled hospital ward archetype ($120 per square metre) and $39,000 for the school building archetype ($204 per square metre). These upfront costs would be more than offset by the energy bill savings, reduced spend on heating, cooling and ventilation equipment, and electricity network savings.

Under the accelerated deployment scenario, changes to the Code energy requirements could deliver 50-60 per cent of the required energy savings. This could be achieved through accelerated deployment of more efficient chillers, lighting and commercial-scale electric heat pumps.

The remaining task to reach net zero energy in public sector buildings would need to be addressed through a combination of best practice design, on-site renewable energy, voluntary measures to improve energy efficiency, strengthened standards for items outside the Code (such as plug-in appliances) and decarbonised electricity supply.

Analysis of on-site renewable energy potential shows that by 2030, when combined with strengthened Code energy requirements, there is potential for a single-storey hospital ward to generate approximately one-third of its annual energy use through rooftop solar PV, while a single-storey school building could generate over three-quarters of its energy use.

Determining the optimal balance between on-site renewables and other measures requires consideration of the issues outlined in Section 4.

### Case study:
### Towards a zero emissions future - ACT Public Schools

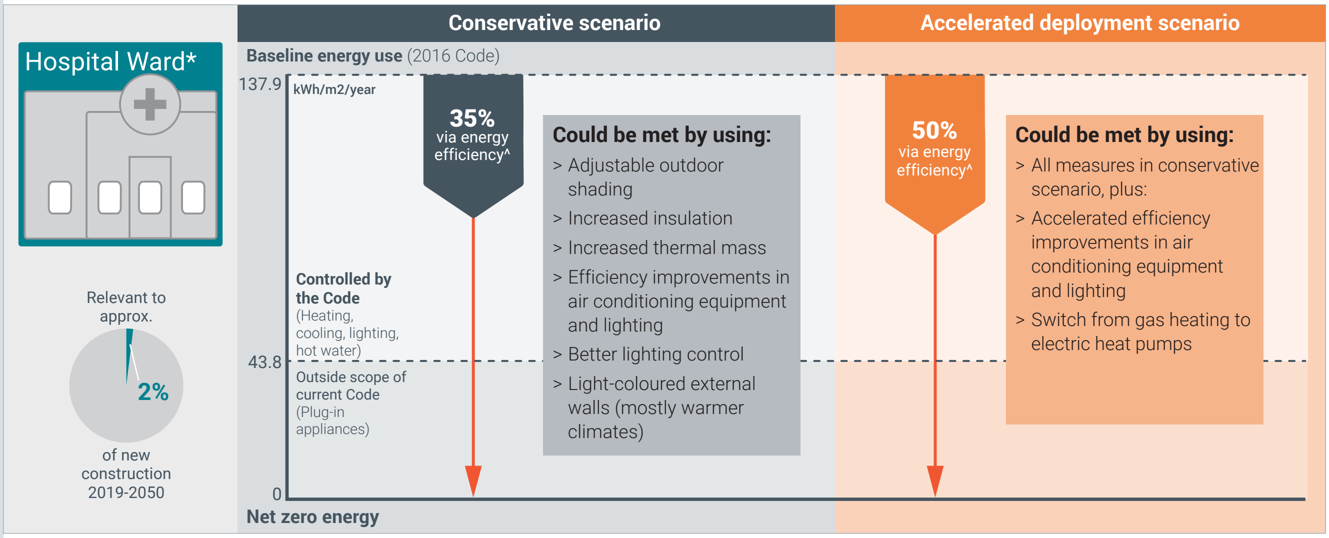
The ACT Education Directorate (the Directorate) has adopted a holistic approach to transitioning ACT public schools toward a zero-emission future. Since the commencement of the Carbon Neutral Government Framework in 2012, the Directorate has implemented a range of carbon emission reduction strategies including the installation of solar panels, lighting upgrades, implementation of sustainable transport options and capacity building within schools. These approaches explore the roles that technology, infrastructure and behaviour play in reducing carbon emissions across an aged building portfolio.

Across the schools and support offices, a total of 2.4MW in solar panel array systems have been installed. This includes 1.265MW of systems installed in partnership with the Australian Government National Solar Schools Program in 2012 and 2013, which send generated electricity to the local grid (gross fed) under an ACT feed-in-tariff arrangement. In addition to the systems mentioned above, a 600kW system is in place at Amaroo School (Preschool to Year 10 students) and is part of a unique leasing arrangement between the Directorate and a private company.

To support ongoing sustainability performance, the Directorate entered an agreement with schools to reinvest all feed-in-tariff income into sustainability initiatives. This is supported through access to sustainability advisors within the Directorate. Schools have also undertaken sustainability initiatives, such as lighting upgrades, using their own funds in addition to income from the feed-in-tariff.

*This case study was contributed by the ACT Education Directorate.*

## POTENTIAL 2030 ENERGY TARGETS - Public buildings

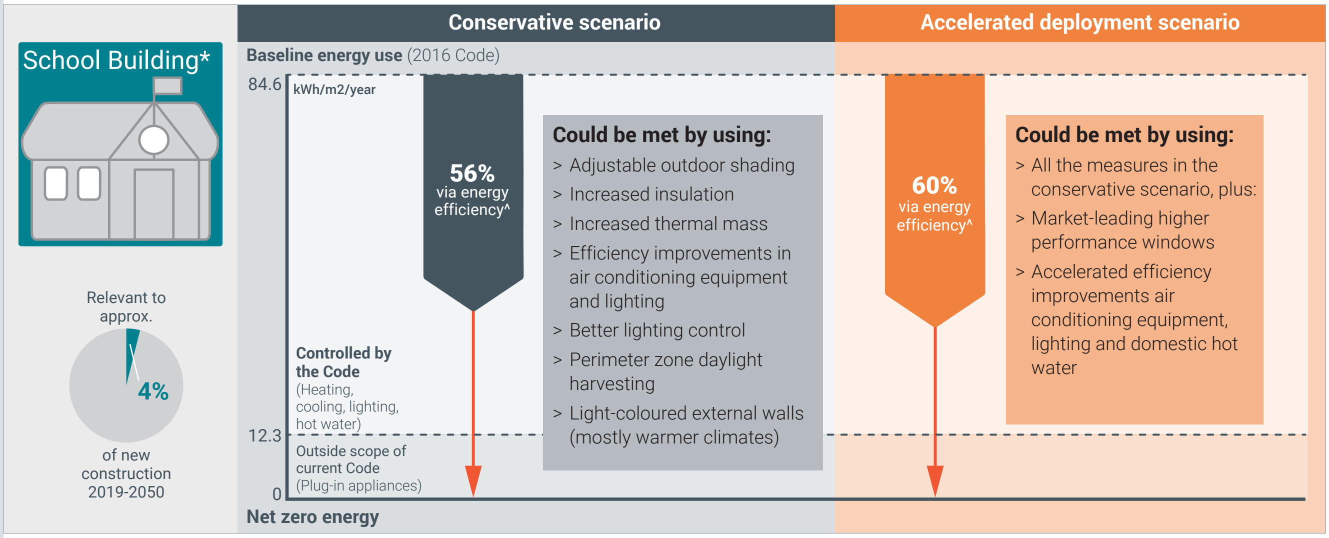


**Conservative scenario – Could be met by using:**

- Adjustable outdoor shading
- Increased insulation
- Increased thermal mass
- Efficiency improvements in air conditioning equipment and lighting
- Better lighting control
- Light-coloured external walls (mostly warmer climates)

**Accelerated deployment scenario – Could be met by using:**

- All measures in conservative scenario, plus:
- Accelerated efficiency improvements in air conditioning equipment and lighting
- Switch from gas heating to electric heat pumps



**Conservative scenario – Could be met by using:**

- Adjustable outdoor shading
- Increased insulation
- Increased thermal mass
- Efficiency improvements in air conditioning equipment and lighting
- Better lighting control
- Perimeter zone daylight harvesting
- Light-coloured external walls (mostly warmer climates)

**Accelerated deployment scenario – Could be met by using:**

- All the measures in the conservative scenario, plus:
- Market-leading higher performance windows
- Accelerated efficiency improvements air conditioning equipment, lighting and domestic hot water

**The gap to net zero energy can be met** by a combination of best practice design, on-site renewable energy, improved appliance efficiency and decarbonised grid electricity supply.

Analysis of on-site renewable energy potential shows it could meet approximately:
**33%** of the remaining energy use for a hospital ward
**86%** of the remaining energy use for a school building

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* Data presented here is an average for this building archetype across the modelled climate zones (2, 5, 6 and 7) for the 2028 Code

^ Percentage reduction is a proportion of whole building energy, including energy that is currently not in the scope of the Code and needs to be addressed by measures outside the Code

**Climate Zones**

🟨 2 🟩 5

# Warmer climates

The results above provide averages across all climate zones, however the modelling has been completed separately for each zone. This section highlights the specific results for the warmer Climate Zones 2 and 5. As defined by the ABCB[40], Climate Zone 2 is described as having warm humid summers and mild winters and covers a large proportion of coastal Queensland (including Brisbane), from just north of Mackay down to just south of Coffs Harbour. Climate Zone 5 is described as warm temperate and covers coastal areas on the west, south and east coasts of Australia. Perth, Adelaide and Sydney all fall within Climate Zone 5, as do Geraldton, Esperance, Ceduna, Newcastle and a hinterland strip west of Brisbane.

Although many of the energy efficiency measures were found to be cost effective for all the climate zones analysed, the measures that were found to be generally more effective for the warmer climates included:

- Ceiling fans for residential buildings;
- Larger eaves for some residential buildings; and
- Lighter outside wall colour for non-residential buildings.

## Case studies:
Housing in warmer climates

### Josh's House

Josh's House has achieved a 10 Star NatHERS rating using conventional building materials, demonstrating that high energy performance is possible at little or no extra cost. The Perth project was built in 2013, and is both oriented east-west with few windows on the eastern and western walls to minimise solar heat gain in the summer. Shading and eaves on the northern windows, well insulated walls and ceilings, and carefully selected internal materials help ensure indoor temperatures remain comfortable without air conditioning during Perth's hot summers and cool winters.  A 3kW rooftop solar system on each house provides more energy than the house needs on average over the year, saving the family over $1,500 in electricity bills every year compared to the Perth average.

*This case study was contributed by Josh Byrne & Associates.*

### Wunya House

Wunya House is situated in Queensland's sub-tropical Mary Valley, which experiences large variations in seasonal temperatures. The house is well adapted to this variability, keeping indoor temperatures cool during the summer through features like its light coloured roof to reflect heat, and strategically placed insulation and ceiling fans. Wunya House has proved to be a highly affordable home to run, as its 3 kW rooftop solar system supplies what little electricity the household uses and exports the excess energy to the grid for a profit.

*This case study was contributed by Don Parry.*

**Climate Zones**

▨ 6 🟦 7

# Milder and cooler climates

The results above provide averages across all climate zones, however the modelling has been completed separately for each zone. This section highlights the specific for the milder and cooler Climate Zones 6 and 7. Climate Zone 6 is described by the ABCB as mild temperate, and spans coastal and inland regions in the south-west and south-east of Australia. Melbourne, the Adelaide Hills and western Sydney fall within Climate Zone 6, as do Albany and Ballarat. Climate Zone 7 is described as cool temperate and covers most of Tasmania, as well as the sub-alpine regions of Victoria and southern New South Wales. Canberra and Hobart are major cities located within Climate Zone 7.

Although many of the energy efficiency measures were found to be cost-effective for all the climate zones analysed, the measures that were found to be generally more effective for the warmer climates included:

- Higher levels of wall insulation for residential buildings;
- Under slab and slab edge insulation for residential buildings;
- Increased thermal mass for some residential buildings; and
- Stronger requirements for heat exchangers for some non-residential buildings.

## Case studies:

Housing in milder and cooler climates

### Stray Leaf House

Stray Leaf House is designed to be comfortable and cheap to run in Canberra's climate. The house makes the most of the sun's warmth in the winter, with living spaces oriented to the north and features like double glazing, concrete floors, thorough insulation and a well-sealed internal building envelope to retain heat. Appropriately sized eaves allow high levels of solar heat gain in the winter, and shade floors during Canberra's hot summers. The efficiency measures at Stray Leaf and its 1.5 kW rooftop solar system mean that in summer power bills can be as little as one third of that of typical one-person households in the area.

*This case study was contributed by Light House Architecture and Science.*

### Davison Street Collaborative

The Melbourne townhouses in the Davison Street Collaborative will be constructed to reach net zero energy usage annually. A 4 kW rooftop solar and battery storage system is predicted to meet 100% of each home's energy demand, which will be kept low through energy efficient design and equipment. An airtight building envelope along with double-glazed, timber-framed windows ensures that unwanted heat loss and gain is minimised. Inside, cross ventilation in living areas and energy recovery ventilation, as well as ceiling fans and a heat pump hydronic heating system will provide fresh air and keep temperatures comfortable for building occupants across all seasons.

*This case study was contributed by HIP V. HYPE.*

# 3. Recommendations

## RECOMMENDATION 1: Commit to a Zero Carbon Ready Building Code

The COAG Energy Council and Building Ministers Forum should commit to deliver a 'Zero Carbon Ready' Code.

### Why?

According to the World Green Building Council's Advancing Net Zero program, all new construction globally needs to be operating at net zero carbon from 2030 onwards to align with the Paris Climate Change Agreement[41], a target which the Green Building Council of Australia[42] has also proposed for Australia. This report demonstrates the potential for the National Construction Code to contribute to this transition. Committing to a Zero Carbon Ready Code would mean establishing targets and a process to progressively upgrade the Code energy requirements to maximise this potential contribution. This would provide the regulatory certainty needed to stimulate investment and innovation by industry to deliver higher performance buildings at lower cost.

### How?

By the end of 2018, the COAG Energy Council and Building Ministers Forum should commit to make the National Construction Code Zero Carbon Ready, and establish and fund a work program to develop a Zero Carbon Ready Code Implementation Plan.

Delivering a Zero Carbon Ready Code would mean:

1. Setting a trajectory for future energy efficiency targets in the Code at least as stringent as the conservative energy efficiency targets (excluding renewable energy potential) in this report;
2. Introducing net energy targets (including renewable energy potential) along with a trajectory for future net targets. This report sets out the potential for on-site renewable energy for different building types, which provides an indication of where net energy targets could be set. The specific net energy targets appropriate for the Code requires the investigation of a number of key issues as outlined in Section 4; and
3. Establishing a clear set of processes for implementation of the targets in the Code, and adjustment of targets over time to take advantage of future technology developments and design innovations (see further detail in Section 4.1).

The COAG Energy Council and Building Ministers Forum should establish and fund a work program to develop a Zero Carbon Ready Code Implementation Plan, due for completion by the end of 2019.

## RECOMMENDATION 2:
## Deliver a step change in 2022

The COAG Energy Council and Building Ministers Forum should jointly agree to task the Australian Building Codes Board (ABCB) to deliver a step change in the energy requirements in the 2022 Code, with a strong focus on residential standards and a further incremental increase in non-residential standards.

### Why?

Work is already in progress to increase the stringency of non-residential energy requirements in the 2019 Code update, along with improvements to the residential requirements (but no increase in stringency). The analysis in this report shows that a step change in energy performance is possible today for residential buildings. Further gains for non-residential buildings are also possible beyond the proposed 2019 changes. This indicates that the Code energy requirements for both residential and non-residential should be strengthened in 2022.

Delaying these upgrades would be costly. Just three years' delay from 2022 to 2025 could lock in $2 billion in residential energy bills, $620 million in non-residential energy bills and $930 million of additional network investments between now and 2030.

### How?

By the end of 2018, the COAG Energy Council and Building Ministers Forum should task and resource the ABCB to deliver a step change in Code energy requirements in 2022, to at least the level of energy performance for 2022 identified in the conservative energy efficiency targets in this report.

## RECOMMENDATION 3:
## Expand the scope of the Code and progress complementary measures

As part of an integrated package of building energy and emissions policy, the COAG Energy Council and Building Ministers Forum should jointly establish work programs that investigate expanding the scope of the Code to prepare for future sustainability challenges and opportunities, while also progressing measures to complement the Code that drive towards zero carbon new and existing buildings.

### Why?

There are a range of issues outside the scope of this report and currently outside the scope of the Code that have been identified by stakeholders as important issues to address moving forward. Consideration should be given to expanding the scope of the Code to address future energy and emissions challenges and opportunities.

In addition, the Code is important but can only deliver part of the solution. Effective compliance and enforcement is paramount, and a range of complementary measures are required to drive towards zero carbon new and existing buildings.

### How?

A Zero Carbon Ready Code needs to be complemented by a broader set of policies to enable the transition to a zero carbon built environment by 2050. This includes fixing compliance and enforcement (see Section 4.3) and a range of other complementary measures as recommended in Low Carbon, High Performance (see Section 4.7). These complementary policies could be progressed as part of the National Energy Productivity Plan.

As part of the development of a Zero Carbon Ready Code Implementation Plan, the COAG Energy Council and Building Ministers Forum should also establish work programs that investigate the expansion of the Code to cover future energy and emissions challenges and opportunities, including:

**Health and safety requirements:** Introduction of specific health and safety requirements in relevant sections of the Code to complement energy requirements. This would include mechanical ventilation requirements for airtight buildings and free-running indoor temperature limits during periods of extreme weather;

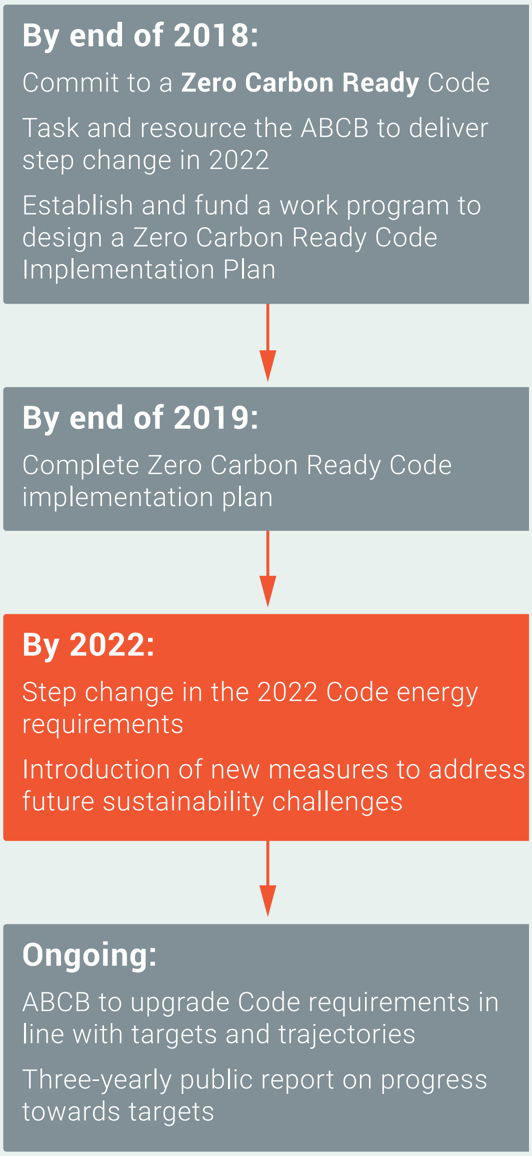
**Peak demand:** Introduction of Code requirements relating to peak demand reduction, including emerging demand management technologies such as batteries and 'smart' appliances integrated with smart metres and time-of-use electricity pricing;

**Maintainability:** Introduction of Code requirements that systems are designed and installed to enable commissioning and ongoing maintainability;

**Electric vehicles:** Potential to incorporate new requirements to prepare buildings for future electric vehicle uptake; and

**Embodied energy and emissions:** Potential to integrate embodied energy and emissions into the Code in the future.

FIGURE 5: Timeline for implementation of recommendations



# 4. Implementation considerations

This section sets out the key issues that need to be considered in pursuing the recommendations of this report. These include:

1. Processes for code updates and target adjustments over time
2. Issues relating to introducing renewables into the Code
3. Fixing compliance and enforcement
4. Appropriately managing air leakage and ventilation
5. Phase out of gas
6. Accelerating the trajectories through market transformation initiatives
7. Other complementary policies

## 4.1 Process for Code updates and target adjustments over time

**A clear, rules-based process for Code updates and target adjustments is essential to fully capture potential benefits and provide the policy stability required by industry.**

The Zero Carbon Ready Code Implementation Plan should include:

- An updated objective statement for the Code energy requirements to reference health and resilience outcomes and the contribution to broader zero carbon policy objectives;
- A clearly defined process for the ABCB to implement Code upgrades over time in line with the targets, including the potential to quantify the Performance Requirements in the Code and a requirement that all Verification Methods be shown to deliver broadly the same energy performance outcomes;
- A set process for monitoring and publicly reporting on progress towards the targets; and
- Scheduled reviews at least every six years to identify opportunities to strengthen targets to account for faster improvement in technology or design practices and effective implementation of complementary measures to accelerate trajectories by driving down technology costs or improving industry capability. Reviews should include an assessment of the gap between market leaders and minimum standards. Reviews should also be subject to independent third-party assurance and provide industry and other stakeholders with the opportunity to be consulted and provide input.

The Implementation Plan should also provide clear and public guidelines for Regulatory Impact Assessments of Code updates, which should include:

- Clarification that the objective of Code energy requirements includes contributing the maximum cost-effective level of energy performance in new construction in line with the economy-wide transition to net zero emissions in line with the Paris Climate Agreement;
- Valuation of key externalities and financial and non-financial costs and benefits, including costs and benefits for human health and comfort, productivity of building occupants, resilience in the face of extreme temperatures, and the electricity network;

- Projecting the future cost of achieving performance targets, anticipating the impact of industry learning including learning relating to passive solar design, market transformation initiatives, changing technology performance/cost and existing and anticipated barriers to compliance based on industry consultation and findings from 3 yearly reviews; and
- Assuming a future changed climate in line with the best available projections.

## 4.2 Renewables in the Code

### Pursuing the potential for on-site renewables through the Code presents significant opportunities but also challenges that will need to be resolved.

The capacity of installed small-scale solar photovoltaic (PV) systems has grown strongly since 2010, driven primarily by steadily reducing prices[43]. The pace of rooftop solar PV installations is also accelerating; recently published data from Green Energy Market showed that the rate of growth in solar PV installations increased by a record 60 per cent in the year to April 2018[44].

However, there is significant, cost-effective potential for additional on-site renewables as illustrated in this report. Incorporating net energy requirements into the Code that reflect this potential could remove market barriers (similar to those described in Section 1.3 for energy efficiency) which are currently preventing the accelerated uptake of distributed renewable energy systems, including rooftop solar PV. This could make a major additional contribution towards decarbonisation of the built environment and the economy more broadly.

An alternative approach to accelerate uptake of distributed renewables could be to rely on policy mechanisms outside the Code, such as national energy emissions policies or direct financial incentives. This report has not investigated the relative costs and benefits of these alternatives.

One significant advantage of introducing on-site renewable energy requirements into the Code is that it could provide greater certainty about the likely speed of distributed renewable energy uptake, which would support planning for future electricity network upgrades. In addition, distributed renewable energy paired with battery storage may help address grid stability issues, reduce transmission and distribution losses, increasing the resilience of the grid during power outages[45] and assist with the broader transition to a zero carbon electricity sector.

By contrast, inclusion of on-site renewable energy requirements in the Code may create challenges. These include:

- **Variability of solar potential:** This report presents the solar PV potential for eight different building types, with a limited assessment of the sensitivity to different building sizes. But the rooftop solar PV potential of new construction will vary significantly by building type. This may create challenges for setting specific targets that incorporate solar PV potential;
- **Need for exemptions:** The analysis assumes that roofs are unshaded with an average amount of rooftop equipment. Exemptions may be required where there is unavoidable shading or constraints on the roof space, though this would need to be combined with measures to combat individuals seeking to minimise their investment in on-site renewables;
- **Barriers to grid connection:** There is no regulatory oversight in Australia of rules and requirements that govern the connection of distributed energy to the grid – the requirements are set by individual electricity distributors, which has led to inconsistency in connection standards and requirements around the country[46]. Many distributors also set a 5 kW limit for solar PV systems on housing connected to the grid[47], meaning that the PV system sizes assessed as cost-effective in this report could not be installed in practice;
- **Grid integration:** Accelerated growth in distributed renewable energy can increase the complexity of managing the electricity grid by increasing the amount of variable generation in the system; and
- **High upfront costs:** Installation of renewable energy systems requires significant upfront capital. Even smaller systems require a considerable upfront investment. While this cost will be more than offset by financial benefits over time, greater availability of financing instruments and leasing arrangements are needed for building owners who may be capital-constrained.

These issues are likely to be solvable, and other jurisdictions such as the State of California have already begun to introduce specific on-site renewable energy requirements into building codes[48]. Accelerating and facilitating the uptake of battery storage systems is likely to be an important contributor to solving a number of these issues, as grid-connected storage systems can help reduce solar variability and grid integration issues, and potentially improve the economics for building owners. Batteries are already on a rapid cost-reduction trajectory, driven by technological advances in smartphones and electric vehicles as well as the growth of the renewable energy industry globally. Analysis by the Alternative Technology Association estimates that batteries will become cost-effective for many households by 2020, well before the 2022 Code update[49].

Australian governments can help accelerate and facilitate uptake of battery storage systems. A report by the Clean Energy Council outlines four key reforms that are required. These are levelling the playing field for batteries to participate in the energy market, removing regulatory barriers to storage by making grid connection easier for battery-equipped renewable energy systems, recognising and rewarding the full value of storage systems, and supporting the introduction of appropriate product standards and consumer protection measures[50].

The issues outlined above would require further consideration before net energy requirements incorporating on-site renewable energy potential are introduced.

# 4.3 Compliance and enforcement

## Fixing compliance and enforcement regimes is paramount.

This project has focused on developing a feasible set of energy targets for the Code, and has not focused on how to improve compliance, monitoring or enforcement.

However, it is widely acknowledged that non-compliance with the Code is an ongoing issue[51]. 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 be addressed as a matter of urgency if a zero carbon built environment is to be achieved by 2050.

While compliance and enforcement issues affect the building sector beyond just energy efficiency, there is a need for a specific focus on energy efficiency compliance. This requires cooperation between the ABCB, Building Ministers Forum, COAG Energy Council, the relevant state and territory building agencies, and local government, as well as appropriate resourcing of the agencies responsible for oversight of construction standards and compliance.

A number of the issues relating to compliance and enforcement could be addressed through the recommendations of the Shergold and Weir building and construction industry compliance and enforcement systems review. The review focused primarily on safety issues but the following recommendations have particular relevance to energy efficiency[52]:

- A nationally consistent approach to registration and training of building practitioners, including compulsory continual professional development;
- Improvements and expansion of regulatory oversight, including a proactive audit strategy;
- Enhanced statutory and reporting requirements with a legislated code of conduct for building surveyors;
- A central database or platform for sharing building information;
- Measures to improve design documentation including enhancements to third party reviews of documentation and approval processes for performance solutions;
- Expanded inspection regimes;
- Requirements for more comprehensive post-construction documentation management, including a digital building manual;
- Establishment or expansion of product certification schemes; and
- A plan for implementation of the recommendations with regular review and reporting.

The National Energy Efficient Buildings Project (NEEBP) has focused more specifically on compliance and enforcement of building energy efficiency regulation. The project is a joint initiative of the Council of Australian Governments under the National Energy Productivity Plan. Its latest report focused on the residential sector has recommended a range of measures to improve compliance, including improvements to:

- **Planning and building approvals processes:** Requiring energy efficiency measures to be explicitly outlined on the plans and building contract and a compliance review checklist to be undertaken prior to handover from the builder to the owner;
- **Associated systems and tools:** Requiring an appropriate level of energy efficiency education, knowledge and training for building professionals; development of a national product verification system to ensure the energy efficiency of products supplied to builders meet Australian or appropriate standards and that those products are installed correctly; and development of a national audit/inspection system that can be applied across all states, territories and climate zones; and

- **Consumer awareness:** Increase consumer awareness of the value of energy efficiency compliance in reducing heating and cooling costs, improving comfort and quality of life, and reducing power bills.

In addition to these, there are a number of structural issues with the Code that have been highlighted during the course of this project and should be investigated to support Code enforcement, including:

- Funding to update the NatHERS framework and relevant tools, or establishment of a new tool (for example, one which considers whole-of-house energy performance) to address shortcomings in the current NatHERS regime for residential buildings. For example, the NatHERS scheme currently does not provide an incentive for building more airtight buildings[53], and does not currently address comfort or resilience outcomes impacted by energy efficiency measures[54]; and
- Investigating the potential of mandatory post-construction verification of energy performance rather than allowing compliance to be verified based on modelling of the predicted outcomes based on the design. This should include investigation of options to remove or limit the availability of deemed-to-satisfy (DtS) elemental requirements in favour of a performance pathway[55]. For example, DtS elemental requirements could be made available for small projects or extensions only. The DtS elemental requirements are unlikely to provide sufficient flexibility to support higher levels of energy performance required under a Zero Carbon Ready Code.

Improvements to the energy efficiency requirements of the Code must be matched by improvements in compliance and enforcement. 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.

## 4.4 Air leakage and ventilation

**Code requirements for infiltration and ventilation must ensure that occupant health outcomes are maintained or improved when pursuing increased energy efficiency.**

Making buildings more airtight can significantly improve energy performance by reducing draughts, and decreasing the energy required to maintain comfortable indoor temperatures. This must go hand-in-hand with improved ventilation, which will both deliver improved indoor air quality and avoid unintended consequences of more airtight buildings such as condensation and mould issues or trapping of harmful airborne pollutants inside.

Steps to improve air leakage and ventilation include:

1. Establish a plan for introduction of quantified mandatory air tightness requirements in the DtS requirements;
2. Introduce education and training programs for designers and builders, including introduction into the tertiary curriculum;
3. Determine appropriate quantified air tightness standards with corresponding ventilation standards to ensure flushing of indoor air pollutants;
4. Provide a voluntary incentive to encourage the development of more airtight buildings;
5. Build the evidence base for appropriate air tightness and associated ventilation requirements for Australian climates, and refine the proposed standards; and
6. Introduce mandatory quantified standards in the DtS requirements.

## 4.5 Phase out of gas use in buildings

### Gas use in buildings needs to be phased out to meet long-term emissions targets, but further work is required to assess the best approach to this transition.

Phasing out gas in buildings is likely to be needed over the long term to meet Australia's commitments under the Paris Climate Change Agreement. All buildings built today will still be operating in 2050 when Australia will need to be at or near net zero emissions. In a zero net emission environment, gas use in buildings will need to be offset. This is unlikely to be a sensible strategy for buildings, as demand for offsets from industries where emissions are unable to be completely eliminated is likely to push offset prices higher in the future. In the short term, as electricity generation transitions towards low carbon energy sources and becomes less emissions-intensive than gas[56], all-electric buildings may become a less emissions intensive choice as a matter of course. In addition, retail gas prices have significantly increased in most states since 2006[57], making gas increasingly unaffordable for households and businesses.

This report assumes no new gas connections for residential buildings, and no new gas connections for commercial buildings in the accelerated deployment scenarios. Research has already shown that this is currently more cost-effective than installing gas connections in new residential buildings[58]. Installing gas equipment such as boilers in new buildings also risks locking in gas consumption and the associated emissions over the life of the equipment, and potentially increasing the cost of replacement during the end-of-life stage if equivalent electric equipment needs to be retrofitted into the building. Avoiding new building gas connections can also help relieve pressure on Australia's east coast gas supply market, which in turn will reduce energy costs for existing gas users[59].

The recommendations of this report do not specifically preclude gas use in new buildings, for example, a number of the non-residential archetypes modelled assume gas use for heating under the conservative scenario. But the recommended energy targets could be expected to facilitate the phase out of gas in buildings over the long term.

This report recommends an energy metric for the Code which is agnostic in respect to the fuel used. This means that different emissions outcomes could be seen for different developments that meet the same energy target, depending on whether gas appliances are installed or not, and on the emissions intensity of the grid at that location. Progressively strengthening energy requirements using a specific energy metric may in itself eventually lead to a gas phase out, as electric appliances such as heat pumps are generally more energy efficient options to deliver the same services, although the timeline over which this might occur is uncertain.

Further work is required to assess the best approach to transitioning away from gas, particularly in areas where gas is the dominant fuel for heating and cooking, and in specific applications such as commercial kitchens where gas may continue to be demanded. Further work is also needed to explore the role of zero carbon gas sources such as biogas in a future zero carbon built environment.

## 4.6 Accelerating trajectories with market transformation policies

**Research, development and deployment policies targeting key technologies, and design practices can help accelerate energy performance trajectories, while generating significant benefits.**

The analysis in this report highlights technologies that could have the greatest impact on building energy performance, and their relative costs and benefits. These conservative scenarios illustrate feasible energy performance targets based on current and projected economics. However, with research, development and deployment policies, these targets could be accelerated or increased over time.

The accelerated deployment scenarios highlight that additional energy savings could be achieved if cost reductions can be delivered for a range of technologies that are not currently cost-effective, or not projected to be cost-effective until later years. These include market-leading higher performance windows, large-scale electric heat pumps, and accelerated improvements in the efficiency of air conditioning, lighting and domestic hot water systems.

In addition, market transformation support should be considered for:

- Integrated solar PV and battery storage as discussed above; and
- To support industry learning and improvement in building design and construction for energy efficiency, for example, through training and accreditation programs.

## 4.7 Other complementary policies

**The Code is one part of the solution to transitioning buildings to zero carbon - other complementary policies targeting building energy performance are required.**

The Code energy requirements set minimum standards for heating and cooling performance of the building envelope, lighting energy efficiency, and energy efficiency of large fixed equipment such as air conditioning and lifts; however, they do not cover smaller appliances such as refrigerators or computers, nor do they cover the procurement of energy from off-site sources (for example, through renewable power purchasing agreements). The Code also only applies to new construction, and does not include rules for existing buildings unless they are undergoing major renovations. Finally, the Code does not target the embodied energy or emissions in building products and materials.

Because of this, a Zero Carbon Ready Code needs to be complemented by a broader set of policies to enable the transition to a zero carbon built environment by 2050.

The *Low Carbon, High Performance* report recommended a broad suite of policy measures to support the transition to a zero carbon built environment, including:

- Strengthening energy standards for equipment and appliances and establishing long-term targets and processes to support ongoing improvements as technology improves;
- Investigating the introduction of minimum standards for existing buildings and rental properties;
- Financial incentives to accelerate investment in high performance buildings, such as green depreciation and stamp duty concessions;
- Government leadership through its own procurement;

- Energy market reforms to provide appropriate financial incentives for distributed energy and energy efficiency, including cost-reflective network tariffs that are passed on to individuals; and
- Expanding mandatory disclosure of energy performance to sectors beyond large commercial buildings, including housing.

The National Energy Productivity Plan provides a vehicle for implementation of nationally harmonised or coordinated energy productivity measures, but may require additional resourcing. State, Territory and local-level energy efficiency and climate mitigation strategies provide another avenue for implementation of regional policies.

# Endnotes

[1] Adapted from ASBEC (2011), *Defining zero emission buildings-review and recommendations*, p.48.

[2] Harrington, P. and Toller, V. (2017). *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, p.19.

[3] Australian Sustainable Built Environment Council (ASBEC) (2016). *Low Carbon, High Performance*, p.27.

[4] Based on floor area across all building sectors, given currently expected growth rates (primarily from the Australian Bureau of Statistics) and allowing for a refurbishment/rebuild rate of 1 per cent of the stock each year, in addition to net stock growth.

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

[6] Australian Competition and Consumer Commission (ACCC) (2017). *Retail Electricity Pricing Inquiry - Preliminary Report*, pp.12-20.

[7] ACCC (2017), p.14.

[8] ACCC (2017), p.20.

[9] ACCC (2017), p.29.

[10] ASBEC (2016). *Low Carbon, High Performance*, Appendix 1 p.10.

[11] According to estimates by CSIRO from the Energy Network Transformation Roadmap.

[12] More information is available on the AEMC website: https://www.aemc.gov.au/our-work/our-current-major-projects/power-choice [Accessed 19-06-2018]

[13] A selection of studies is summarised in ASBEC and ClimateWorks Australia (2018). *The Bottom Line - The household impacts of delaying improved energy requirements in the Building Code*, p.18.

[14] World Green Building Council (2018). *Doing Right by Planet and People: The Business Case for Health and Wellbeing in Green Building*.

[15] Green Building Council of Australia (2012). *Green Schools*, pp.4-5.

[16] The analysis determined an average cost premium of \$58 per m$^2$ for the modelled detached house and \$44 per m$^2$ for the modelled office building. Estimates are based on what is cost-effective for the 2022 Code. Average construction costs are difficult to determine, but industry consultation suggests that for detached housing this ranges between \$1,500 per m$^2$ for volume built homes and upwards of \$4,000 per m$^2$ for custom architect-designed homes. Data from the Rawlinson's Australia Construction Handbook suggests that typical construction costs for commercial office buildings (finished floor, 7-20 storeys) range between approximately \$2,400 and \$3,300 per m$^2$.

[17] Global Real Estate Sustainability Benchmark (GRESB). *Press Release: 2017 Results Show Australia and New Zealand Real Estate Sector Leading the World in Sustainability Performance*. 13 September 2017, available at: https://gresb.com/australia-and-new-zealand-real-estate-sector-leading-the-world-in-sustainability-performance/ [Accessed 19-06-2018]

[18] More information available at: https://www.cefc.com.au/case-studies/amp-capital-wholesale-office-fund-aims-for-net-zero-emissions-by-2030.aspx [Accessed 19-06-2018]

[19] More information available at: https://www.investa.com.au/news-and-media/news/2016/investa-%E2%80%93-the-first-australian-property-company-to [Accessed 19-06-2018]

[20] More information at: https://www.thefifthestate.com.au/innovation/dexus-commits-to-net-zero-2030-target [Accessed 20-06-2018]

[21] More information available at: http://sustainability.mirvac.com/our-strategy/ [Accessed 20-06-2018]

[22] More information available at: https://www.gpt.com.au/sustainability/environment/climate-change-energy [Accessed 20-06-18]

[23] More information available at: https://www.thefifthestate.com.au/innovation/commercial/lendlease-fund-sets-2025-net-zero-carbon-target [Accessed 20-06-2018]

[24] More information available at: https://www.monash.edu/net-zero-initiative [Accessed 19-06-2018]

[25] Based on data for 220,000 class 1 dwellings (detached and attached housing) from the CSIRO University Certificate Database, including FirstRate5 data from Sustainability Victoria, since May 2016. Not all of the projects that have submitted certificates have necessarily been built, and although efforts are made to ensure only one certificate is submitted per property there may be cases there may be more than one rating corresponding to a particular project.

[26] ClimateWorks Australia (2013). *Tracking Progress Towards a Low Carbon Economy: Buildings*. P.19. 'Emissions intensity' is defined as the annual greenhouse gas emissions (in $kgCO2_2$-e) divided by the building floor area.

[27] Adapted from ASBEC (2016). *Low Carbon, High Performance*, Appendix 2 p.12.

[28] *Low Carbon, High Performance* (ASBEC, 2016) sets out a holistic package of five broad policy areas required to save energy and rapidly decarbonise Australia's built environment: a national plan with strong governance and action; mandatory minimum standards with a forward trajectory to provide a regulatory signal; targeted programs and incentives to stimulate the market; energy market reform to provide a level playing field; and data, research, information, education and training to enable effective action.

[29] Although there are early leaders already bringing higher performing products, such as windows, to the market, feedback from stakeholders suggests that a lead time of three to four years is typically required to re-tool manufacturing to produce new products.

[30] For a summary, see ASBEC and ClimateWorks Australia (2017). *Building Code Energy Performance Trajectory Project: Issues Paper*, pp.10-11.

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

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

[33] ASBEC (2016). Low Carbon, High Performance, p.78. This target refers only to 2030 annual emissions. Once the international rules for setting national targets under the Paris Agreement are negotiated and agreed, the 2030 target will be translated into a cumulative emissions limit to 2030 in line with the existing government commitment. The current estimates from government projections is that the 26-28 per cent target translates to a cumulative emissions reduction of 868-934 million tonnes of carbon dioxide equivalents between 2021-2030. If a cumulative emissions limit is set, taking early action to begin reducing emissions becomes more important.

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

[35] ASBEC (2016). *Low Carbon, High Performance*, pp.77-78.

[36] ASBEC and ClimateWorks Australia (2018). *The Bottom Line - The household impacts of delaying improved energy requirements in the Building Code.*

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

[38] Department of the Environment and Energy (2017). *Changes Associated with Efficient Dwellings - Final Report*, p.43.

[39] As no increase in stringency is proposed for residential Code energy requirements for the 2019 Code, it is assumed here that housing that complies with the 2016 Code energy requirements will also comply with the 2019 Code.

[40] For more information on the climate zones as defined by the ABCB, refer to: http://www.yourhome.gov.au/introduction/australian-climate-zones [Accessed 19-06-2018]

[41] World Green Building Council (2017). Doing Right by Planet and People: The Business Case for Health and Wellbeing in Green Building, p.7.

[42] Green Building Council of Australia (2018). A Carbon Positive Roadmap for Buildings – Summary Report.

[43] Australian Energy Market Operator (2017). Projections of uptake of small-scale systems, Section 2 'Historical Trends'.

[44] As reported by The Fifth Estate (2018), Australia breaks another rooftop solar record, 24 May 2018. Available at: https://www.thefifthestate.com.au/energy-lead/business-energy-lead/australia-breaks-another-rooftop-solar-record/99069?mc_cid=3505518555&mc_eid=597b61fbdd [Accessed 28 May 2018]

[45] Institute for Sustainable Futures (2014), *Issues Paper: A Level Playing Field for Local Energy*, prepared for the City of Sydney, p.9.

[46] ClimateWorks Australia and Seed Advisory (2018). *Plug & Play 2: Enabling distributed generation through effective grid connection standards*, pp.9-10.

[47] Based on stakeholder feedback provided for this project.

[48] California Energy Commission (2015). *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings Title 24 Part 6.*

[49] Alternative Technology Association (2016). *Household Battery Analysis*.

[50] Clean Energy Council (2017). Charging Forward: Policy and Regulatory Reforms to Unlock the Potential of Energy Storage in Australia.

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

[52] Adapted from Shergold, P. and Weir, B. (2018). *Building Confidence - Improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia.*

[53] More details on the modelling of air tightness under the current NatHERS scheme are provided in ASBEC and ClimateWorks Australia (2018). *The Bottom Line - The household impacts of delaying improved energy requirements in the Building Code*, p.35.

[54] The CRC for Low Carbon Living has undertaken work to investigate inclusion of comfort metrics in the NatHERS framework through its 'Advanced Comfort Index for Residential Homes' project. More information available at: http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/rp1019-advanced-comfort-index-residential-homes [Accessed 19-06-2018]

[55] More details on the issues relating to DtS elemental requirements are provided in ASBEC and ClimateWorks Australia (2018). *The Bottom Line - The household impacts of delaying improved energy requirements in the Building Code*, pp.35-36.

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

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

[58] Alternative Technology Association (2018). *Household Fuel Choice in the National Electricity Market*. This report found that "owners will be between $9,000 – $16,000 better off over 10 years if they establish their new home as all-electric with a 5-kilowatt solar system rather than gas-electric with no solar"; Alternative Technology Association (2014). *Are we still cooking with gas? Report for the Consumer Advocacy Panel.* The 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 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.

[59] ClimateWorks Australia (2017). *Solving the Gas Crisis*, p.3.

# Appendix A: 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 Technical Report, published by the CRC for Low Carbon Living and available on the ASBEC and ClimateWorks websites.

## Overview of the building energy modelling methodology

The Trajectory Project analysed eight building 'archetypes' across four climate zones. The eight building archetypes were developed to cover typical attributes of some of the most common types of buildings in Australia. Overall, the set of models cover a range of geometric properties from low to high external 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 were:

- For residential buildings:
  - Detached, single-storey house (190 m$^2$ floor area);
  - Attached, two-storey towwnhouse or terrace house (128 m$^2$); and
  - Apartment (76 m$^2$).
- For commercial and other non-residential buildings:
  - Office tower (9,000 m$^2$ floor area);
  - Hotel tower (1,800 m$^2$);
  - Medium retail shop (950 m$^2$);
  - Hospital ward (475 m$^2$); and
  - School building (190 m$^2$).

The four climate zones were 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).

The Trajectory Project modelling methodology can be summarised in the following key steps:

1. Project forwards electricity prices and technology costs (where these change over time);
2. Establish baseline consumption of each building archetype in each climate zone, based on the minimum energy requirements of the 2016 National Construction Code (for residential buildings) or the proposed energy requirements for the 2019 Code (for non-residential buildings);
3. Estimate the energy and cost savings associated with individual measures where each measure is varied independently;
4. Assess the costs and benefits of each measure from a societal perspective;
5. Prioritise the 'cost-effective' measures for further analysis, where the benefit-cost ratio is greater than one;

6. Estimate the combined impact of the set of cost-effective measures, and calculate the benefit-cost ratio for each time step (i.e. based on today's economics, then based on the economic scenarios in 5, 10 and 15 years' time);
7. If the overall benefit-cost ratio of the combined measures is outside the range of 1-1.5[iv], iterate Steps 5 and 6 by adding or removing measures (including measures which on their own may have a benefit cost ratio of less than 1) until a benefit cost ratio of 1-1.5 for the combined package of measures is achieved for every time step. This provides the **conservative energy efficiency targets;**
8. Take the conservative energy efficiency targets from Step 7 and apply a cost-effective level of rooftop solar PV (in most cases this is simply the maximum sized solar PV system that can fit on the roof). This provides the **net energy performance targets;** and
9. Take the conservative energy efficiency targets from Step 7 and apply additional measures that have a material energy benefit but are not cost-effective. This provides the **accelerated deployment energy efficiency targets**.

The three-yearly targets for each upgrade of the Code are determined by linear interpolation of the five-yearly results.

## Overview of the national estimation methodology

The impact of Code changes on state, territory and nation emissions was undertaken using the following steps:

1. Develop a 'stock turnover model' to estimate the area of new building work (including refurbishments) that could potentially be affected by higher Code performance standards. The stock turnover model was built using inputs from Australian Bureau of Statistics Census data, GeoScience Australia's NEXIS database and the Commercial Buildings Baseline Study[v];
2. Apply the modelled energy savings per-unit floor area to the stock model, to generate estimates of national energy and related greenhouse gas emissions savings over time;
3. Estimate equivalent savings for those building forms not modelled as part of this project;
4. Estimate expected savings from building forms in climate zones not modelled as part of this project; and
5. Aggregate costs and benefits to generate an estimates of the overall cost effectiveness of the scenarios modelled.

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[iv] Limiting opportunities to those with benefit-cost ratio greater than one aligns with the Best Practice Regulation approach of ensuring regulations deliver benefits that outweigh costs, while capping the benefit-cost ratio at less than 1.5 enables the cost-effective opportunities to be maximised.

[v] Department of Climate Change and Energy Efficiency (2012), *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia*

## Economic assumptions

The economic analysis is based on a benefit cost methodology that is informed by the Best Practice Regulation guidelines[vi] and Guidance Note on Cost-Benefit Analysis[vii].

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, in alignment with the Best Practice Regulation guidelines.

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 per cent 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 $\$30/tCO_2$-e to around $\$190/tCO_2$-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. A study on the incremental cost of split system air-conditioners was undertaken and based on this; an incremental air-conditioning cost saving of $230 per kW of thermal capacity was included.

A measure is deemed 'cost-effective', i.e. it delivers a net societal benefit, if it has a benefit cost ratio to society of at least 1.0 over a 15-year period.

## Limitations

The scope of the analysis is subject to the following limitations:

- Limited number of building archetypes modelled;
- Limited number of climate zones modelled;
- Future climate change has not been considered;
- There has been no quantification of co-benefits such as health and comfort relating to energy efficiency;
- Learning rates in reducing costs have not been considered for all technologies and measures;
- There has been no consideration of redesigning the buildings for energy efficiency; and
- The analysis has not dealt with major renovations separately.

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[vi] Council of Australian Governments (2017), *Best Practice Regulation: A guide for ministerial councils and national standard setting bodies*.

[vii] Australian Government Department of the Prime Minister and Cabinet, Office of Best Practice Regulation (2016), *Cost-Benefit Analysis Guidance Note*.

# Key results

The forward energy efficiency targets and net energy potential for each archetype, averaged across climate zones 2, 5, 6 and 7, are summarised in Figure A1.

**FIGURE A1: Summary of energy efficiency targets and net energy potential, averaged across the four modelled climate zones**

FIGURE A1: Summary of energy efficiency targets and net energy potential, averaged across the four modelled climate zones ... continued

Table A1 summarises the results for different climate zones for the conservative and accelerated deployment scenarios, relevant to the 2022 Code. Table A2 present the results relevant to the 2028 Code. Complete results relevant to each three-yearly Code upgrade from 2022 to 2034 inclusive are published in the Technical Report.

### TABLE A1: Results for each building archetype in each climate zone, relevant to the 2022 Code

| | | Base Case | 2022 Code | | | | |
|---|---|---|---|---|---|---|---|
| Climate Zone | Archetype | Energy use (kWh/m$^2$/year) | Energy efficiency target (kWh/m$^2$/year) | Up-front additional capital cost – Energy efficiency ($/m$^2$) | Annual energy bill savings, averaged over 15 years ($/year) | Net energy potential (kWh/m$^2$/year) | On-site solar PV system size (kWh)– includes rooftop and BIPV |
| **Conservative scenario** | | | | | | | |
| **CZ 2** | **Apartment** | 63.4 | 56.0 | $48 | $198 | 50.6 | 0.3 |
| | **Attached** | 41.3 | 35.2 | $46 | $270 | -3.5 | 3.6 |
| | **Detached** | 37.4 | 31.8 | $42 | $397 | -17.0 | 6.6 |
| | **Hotel** | 130.3 | 89.7 | $132 | $10,990 | 72.5 | 28.2 |
| | **Office** | 99.6 | 83.2 | $59 | $50,342 | 78.3 | 26.2 |
| | **Retail** | 129.1 | 99.8 | $98 | $11,430 | 54.4 | 26.2 |
| | **Hospital ward** | 138.5 | 85.9 | $144 | $6,519 | 50.7 | 31.0 |
| | **School building** | 93.5 | 57.8 | $149 | $2,529 | 13.6 | 12.0 |
| **CZ 5** | **Apartment** | 63.1 | 55.7 | $61 | $207 | 50.7 | 0.3 |
| | **Attached** | 40.3 | 34.9 | $37 | $245 | 1.2 | 3.4 |
| | **Detached** | 37.2 | 31.5 | $38 | $405 | -3.7 | 5.4 |
| | **Hotel** | 127.2 | 84.9 | $99 | $18,546 | 79.2 | 28.2 |
| | **Office** | 91.4 | 77.8 | $48 | $40,111 | 73.0 | 26.2 |
| | **Retail** | 116.9 | 92.4 | $79 | $9,456 | 49.6 | 26.2 |
| | **Hospital ward** | 140.3 | 89.2 | $122 | $5,201 | 59.6 | 29.7 |
| | **School building** | 76.7 | 41.6 | $158 | $2,324 | 7.8 | 12.0 |
| **CZ 6** | **Apartment** | 73.3 | 58.6 | $56 | $385 | 53.8 | 0.3 |
| | **Attached** | 47.3 | 36.9 | $62 | $451 | 3.3 | 3.5 |
| | **Detached** | 45.6 | 34.7 | $66 | $690 | -1.7 | 6.3 |
| | **Hotel** | 99.2 | 79.0 | $71 | $11,461 | 60.1 | 28.2 |
| | **Office** | 88.5 | 72.3 | $36 | $33,141 | 67.7 | 26.2 |
| | **Retail** | 109.0 | 86.5 | $75 | $8,438 | 46.0 | 26.2 |
| | **Hospital ward** | 128.9 | 103.1 | $60 | $3,273 | 76.0 | 28.1 |
| | **School building** | 77.9 | 40.0 | $149 | $2,424 | 11.1 | 11.9 |
| **CZ 7** | **Apartment** | 77.0 | 59.0 | $124 | $460 | 53.5 | 0.3 |
| | **Attached** | 50.3 | 38.2 | $67 | $454 | -1.9 | 3.7 |
| | **Detached** | 50.5 | 35.6 | $84 | $919 | -16.2 | 7.1 |
| | **Hotel** | 102.0 | 83.8 | $74 | $11,238 | 67.8 | 28.2 |
| | **Office** | 93.1 | 76.6 | $34 | $36,231 | 71.2 | 26.2 |
| | **Retail** | 110.0 | 85.4 | $94 | $8,824 | 41.6 | 26.2 |
| | **Hospital ward** | 144.1 | 106.3 | $77 | $3,329 | 78.1 | 29.7 |
| | **School building** | 90.2 | 50.8 | $167 | $2,528 | 13.3 | 12.0 |

### TABLE A1: Results for each building archetype in each climate zone, relevant to the 2022 Code... continued

| | | Base Case | 2022 Code | | | | |
|---|---|---|---|---|---|---|---|
| Climate Zone | Archetype | Energy use (kWh/$m^2$/year) | Energy efficiency target (kWh/$m^2$/year) | Up-front additional capital cost – Energy efficiency ($/$m^2$) | Annual energy bill savings, averaged over 15 years ($/year) | Net energy potential (kWh/$m^2$/year) | On-site solar PV system size (kWh) – includes rooftop and BIPV |
| **Accelerated deployment scenario** | | | | | | | |
| CZ 2 | **Apartment** | Same as the conservative scenario | 54.8 | $278 | $205 | 49.4 | 0.3 |
| | **Attached** | | 33.7 | $234 | $266 | -10.7 | 4.1 |
| | **Detached** | | 30.1 | $296 | $436 | -75.0 | 14.4 |
| | **Hotel** | | 81.4 | $139 | $22,343 | 69.1 | 28.2 |
| | **Office** | | 72.4 | $308 | $70,752 | 65.6 | 26.2 |
| | **Retail** | | 89.0 | $109 | $12,961 | 45.7 | 26.2 |
| | **Hospital ward** | | 70.2 | $165 | $7,242 | 38.1 | 31.0 |
| | **School building** | | 42.0 | $943 | $2,777 | 5.9 | 12.0 |
| CZ 5 | **Apartment** | Same as the conservative scenario | 54.4 | $210 | $206 | 49.4 | 0.3 |
| | **Attached** | | 33.4 | $225 | $236 | -6.9 | 4.1 |
| | **Detached** | | 29.9 | $306 | $437 | -65.2 | 14.4 |
| | **Hotel** | | 77.2 | $106 | $18,996 | 65.8 | 28.2 |
| | **Office** | | 67.9 | $510 | $57,445 | 61.1 | 26.2 |
| | **Retail** | | 81.6 | $142 | $11,495 | 41.8 | 26.2 |
| | **Hospital ward** | | 66.6 | $140 | $6,145 | 39.0 | 31.0 |
| | **School building** | | 33.4 | $597 | $2,334 | 5.0 | 12.0 |
| CZ 6 | **Apartment** | Same as the conservative scenario | 54.8 | $255 | $450 | 50.0 | 0.3 |
| | **Attached** | | 34.5 | $216 | $452 | -5.1 | 4.1 |
| | **Detached** | | 31.3 | $367 | $836 | -62.3 | 14.4 |
| | **Hotel** | | 72.6 | $76 | $12,159 | 61.3 | 28.2 |
| | **Office** | | 61.2 | $515 | $57,378 | 54.7 | 26.2 |
| | **Retail** | | 78.7 | $487 | $9,988 | 40.7 | 26.2 |
| | **Hospital ward** | | 76.8 | $301 | $2,936 | 48.3 | 31.0 |
| | **School building** | | 27.7 | $565 | $2,704 | 5.0 | 12.0 |
| CZ 7 | **Apartment** | Same as the conservative scenario | 55.4 | $283 | $530 | 49.9 | 0.3 |
| | **Attached** | | 35.3 | $209 | $522 | -9.6 | 4.1 |
| | **Detached** | | 31.5 | $290 | $1,154 | -74.6 | 16.2 |
| | **Hotel** | | 73.1 | $80 | $12,378 | 61.1 | 28.2 |
| | **Office** | | 60.1 | $480 | $62,204 | 52.8 | 26.2 |
| | **Retail** | | 79.0 | $394 | $10,163 | 37.4 | 26.2 |
| | **Hospital ward** | | 74.9 | $95 | $3,730 | 47.2 | 31.0 |
| | **School building** | | 40.0 | $578 | $2,734 | 7.4 | 12.0 |

## TABLE A2: Results for each building archetype in each climate zone, relevant to the 2028 Code

| | | Base Case | 2028 Code | | | | |
|---|---|---|---|---|---|---|---|
| Climate Zone | Archetype | Energy use (kWh/m$^2$/year) | Energy efficiency target (kWh/m$^2$/year) | Up-front additional capital cost – Energy efficiency ($/m$^2$) | Annual energy bill savings, averaged over 15 years ($/year) | Net energy potential (kWh/m$^2$/year) | On-site solar PV system size (kWh)– includes rooftop and BIPV |
| **Conservative scenario** | | | | | | | |
| CZ 2 | Apartment | 63.4 | 54.9 | $72 | $287 | 48.6 | 0.3 |
| | Attached | 41.3 | 34.1 | $51 | $385 | -18.1 | 4.8 |
| | Detached | 37.4 | 30.7 | $50 | $597 | -83.6 | 15.7 |
| | Hotel | 130.3 | 82.4 | $170 | $26,408 | 61.2 | 89.9 |
| | Office | 99.6 | 78.0 | $94 | $72,033 | 57.2 | 307.5 |
| | Retail | 129.1 | 82.5 | $207 | $18,401 | 26.1 | 103.2 |
| | Hospital ward | 138.5 | 80.7 | $168 | $7,992 | 46.6 | 53.0 |
| | School building | 93.5 | 44.1 | $202 | $3,164 | 4.1 | 22.8 |
| CZ 5 | Apartment | 63.1 | 54.6 | $68 | $295 | 48.8 | 0.3 |
| | Attached | 40.3 | 34.0 | $44 | $354 | -13.3 | 4.8 |
| | Detached | 37.2 | 30.3 | $53 | $601 | -70.7 | 15.3 |
| | Hotel | 127.2 | 78.6 | $148 | $23,023 | 70.7 | 89.9 |
| | Office | 91.4 | 73.2 | $64 | $58,086 | 53.3 | 307.5 |
| | Retail | 116.9 | 78.3 | $167 | $15,762 | 26.7 | 103.2 |
| | Hospital ward | 140.3 | 85.5 | $140 | $6,264 | 56.2 | 53.0 |
| | School building | 76.7 | 31.6 | $205 | $2,829 | 3.6 | 22.8 |
| CZ 6 | Apartment | 73.3 | 57.0 | $75 | $543 | 51.3 | 0.3 |
| | Attached | 47.3 | 35.5 | $75 | $647 | -11.0 | 4.8 |
| | Detached | 45.6 | 33.2 | $89 | $994 | -66.6 | 15.5 |
| | Hotel | 99.2 | 74.7 | $96 | $14,712 | 51.8 | 89.9 |
| | Office | 88.5 | 69.0 | $64 | $49,144 | 49.7 | 307.5 |
| | Retail | 109.0 | 74.4 | $154 | $13,942 | 25.6 | 103.2 |
| | Hospital ward | 128.9 | 91.0 | $85 | $4,065 | 63.8 | 53.0 |
| | School building | 77.9 | 30.9 | $209 | $3,014 | 5.9 | 22.8 |
| CZ 7 | Apartment | 77.0 | 57.4 | $139 | $641 | 50.9 | 0.3 |
| | Attached | 50.3 | 36.7 | $82 | $657 | -16.0 | 4.8 |
| | Detached | 50.5 | 33.6 | $105 | $1,284 | -82.4 | 17.5 |
| | Hotel | 102.0 | 79.3 | $98 | $14,364 | 59.1 | 89.9 |
| | Office | 93.1 | 69.4 | $64 | $51,618 | 47.0 | 307.5 |
| | Retail | 110.0 | 74.0 | $157 | $14,300 | 23.2 | 103.2 |
| | Hospital ward | 144.1 | 104.1 | $85 | $4,020 | 75.9 | 53.0 |
| | School building | 90.2 | 41.0 | $202 | $3,105 | 6.9 | 22.8 |

**TABLE A2: Results for each building archetype in each climate zone, relevant to the 2028 Code**... continued

| | | Base Case | 2028 Code | | | | |
|---|---|---|---|---|---|---|---|
| Climate Zone | Archetype | Energy use (kWh/m²/year) | Energy efficiency target (kWh/m²/year) | Up-front additional capital cost – Energy efficiency ($/m²) | Annual energy bill savings, averaged over 15 years ($/year) | Net energy potential kWh/m²/year | Rooftop solar PV system size (kW) |
| **Accelerated deployment scenario** | | | | | | | |
| CZ 2 | **Apartment** | Same as the conservative scenario | 53.9 | $282 | $262 | 47.6 | 0.3 |
| | **Attached** | | 33.1 | $236 | $334 | -19.1 | 4.8 |
| | **Detached** | | 29.4 | $297 | $550 | -94.1 | 16.9 |
| | **Hotel** | | 78.1 | $176 | $27,516 | 60.4 | 89.9 |
| | **Office** | | 70.2 | $315 | $90,086 | 46.5 | 307.5 |
| | **Retail** | | 77.6 | $219 | $18,635 | 23.7 | 103.2 |
| | **Hospital ward** | | 67.8 | $189 | $8,657 | 35.2 | 53.0 |
| | **School building** | | 39.7 | $941 | $3,383 | 3.5 | 22.8 |
| CZ 5 | **Apartment** | Same as the conservative scenario | 53.5 | $214 | $263 | 47.7 | 0.3 |
| | **Attached** | | 32.9 | $227 | $296 | -14.4 | 4.8 |
| | **Detached** | | 29.3 | $309 | $548 | -82.5 | 16.9 |
| | **Hotel** | | 74.1 | $156 | $24,485 | 58.6 | 89.9 |
| | **Office** | | 66.6 | $522 | $73,517 | 43.7 | 307.5 |
| | **Retail** | | 71.3 | $229 | $16,502 | 23.6 | 103.2 |
| | **Hospital ward** | | 64.4 | $156 | $7,210 | 36.3 | 53.0 |
| | **School building** | | 31.7 | $649 | $2,843 | 3.5 | 22.8 |
| CZ 6 | **Apartment** | Same as the conservative scenario | 53.9 | $258 | $555 | 48.2 | 0.3 |
| | **Attached** | | 33.8 | $217 | $562 | -12.8 | 4.8 |
| | **Detached** | | 30.5 | $368 | $1,042 | -79.5 | 16.9 |
| | **Hotel** | | 70.7 | $101 | $15,189 | 55.3 | 89.9 |
| | **Office** | | 59.3 | $514 | $72,282 | 37.9 | 307.5 |
| | **Retail** | | 69.2 | $641 | $14,390 | 23.7 | 103.2 |
| | **Hospital ward** | | 72.8 | $322 | $3,518 | 43.7 | 53.0 |
| | **School building** | | 25.6 | $633 | $3,239 | 3.5 | 22.8 |
| CZ 7 | **Apartment** | Same as the conservative scenario | 54.4 | $286 | $653 | 47.9 | 0.3 |
| | **Attached** | | 34.5 | $211 | $653 | -18.3 | 4.8 |
| | **Detached** | | 30.7 | $291 | $1,417 | -94.0 | 19.0 |
| | **Hotel** | | 70.6 | $105 | $15,372 | 53.8 | 89.9 |
| | **Office** | | 57.7 | $488 | $77,205 | 33.8 | 307.5 |
| | **Retail** | | 69.6 | $532 | $14,598 | 21.3 | 103.2 |
| | **Hospital ward** | | 71.7 | $103 | $4,349 | 43.2 | 53.0 |
| | **School building** | | 37.3 | $612 | $3,298 | 4.8 | 22.8 |

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