LOW CARBON LIVING CRC

Building Code Energy Performance Trajectory

Interim Technical Report

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1 Executive Summary

This report is the Interim Technical Report for the Building Code Energy Performance Trajectory Project. It accompanies the Interim Synthesis Report for the Building Code Energy Performance Trajectory Project, entitled *The Bottom Line – the household impacts of delaying improved energy requirements in the Building Code* and which was published on the 8th of February 2018, providing more detail on the assumptions behind and the preliminary results from the underlying modelling work.

The report provides the following key items:

1. Background, context and methodology for the study.
2. Review of parameters used in the economic assessment.
3. Preliminary baseline results for residential building energy modelling.
4. Preliminary benefit costs analyses for potential residential construction upgrades.
5. Preliminary modelling results for residential building energy modelling, incorporating improvements that are currently cost-beneficial.
6. Assumptions for the non-residential (commercial) building energy modelling.
7. Preliminary stock model projections of the impact of proposed residential upgrades at state, territory and national levels.

This study assessed a range of simple energy efficiency opportunities across three building types (detached, attached and apartment), and three climate zones covering Australia's largest population centres. It sought to identify improved energy efficiency measures for which the capital cost is outweighed by financial benefits ('cost-effective') from a societal perspective over the lifetime of the relevant building elements, in most cases a 10-15 year period.

It considered opportunities to improve efficiency of the building 'fabric' (walls, ceilings, windows etc.) and fixed equipment (hot water, lighting), but not plug-in appliances, which are regulated separately. Results presented in this report are preliminary, and a number of improvement opportunities remain under investigation.

The analysis used conservative assumptions and focused on simple lowest common denominator opportunities to improve energy efficiency.

Importantly, the analysis did not consider opportunities for accelerated adoption of best practice building design for energy efficiency, such as optimal building orientation and window sizing and placement.

Preliminary findings in relation to the residential study are as follows:

- Improved air tightness, ceiling fans and roof insulation were the most cost-effective measures identified, with variations across the different building types and climate zones. Of the cost- effective improvements, measures to reduce infiltration are the most significant building 'fabric' measure.
- Combined, these cost-effective measures could reduce energy consumption for heating and cooling by an estimated 28 to 51 per cent across a range of housing types and climates. This is equivalent to between 1 and 2.5 Stars on the NatHERS scheme.
- A high-level analysis of solar photovoltaics (PV) suggests that it is now highly economic. For buildings where solar access is available, PV is economic to the point that 60-70% of the generated energy is being exported under today's economics. However, it should be noted that PV does not of itself deliver a range of other co-benefits provided by the other energy efficiency measures modelled in this study, such as comfort, health and resilience, and faces a number of implementation challenges.
- Lighting and domestic hot water have potential for cost-effective upgrade in the mid-term, but is not immediately cost-effective on the economic analysis used for this study.

This research is funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative. The authors would also like to acknowledge the contributions of the Australian Sustainable Built Environment Council (ASBEC) and ClimateWorks Australia to this study.

2 Introduction

2.1 Project Context

The buildings sector is responsible for 23% of Australia's carbon emissions. The Australian Sustainable Built Environment Council (ASBEC), the peak body for sustainability in the built environment, has identified that improving the minimum standards for energy efficiency of new buildings can assist deliver carbon emissions reductions[1]. One of the key tools in delivering improved building efficiency is the National Construction Code (NCC), which sets the minimum standards for new building work in Australia. However, there have been no significant increases in the NCC's energy efficiency stringency since 2010.

Currently, there is work underway to update the provisions of Volume 1 of the code (covering commercial buildings) for release under NCC2019. However there is no stringency increase proposed for the provisions in Volume 2 (residential); instead, updates for 2019 are focussed on making Code requirements clearer and easier to comply with, and include separate heating and cooling caps to ensure buildings perform to a minimum standard in both winter and summer, clearer building sealing provisions and a new optional building sealing verification method based on post-construction testing of infiltration performance. An upgrade cycle of 3 years has been instituted for both volumes of the NCC.

As with any sector of the economy, the construction sector needs time to adapt and retool to changes in regulation, so a regular update cycle brings the benefit of some increased certainty about the timing of changes. However, without some clarity about the technical changes likely to occur, medium to long term planning is difficult. This is particularly relevant given that the construction cycle of large buildings can be of the order of three years, and sometimes longer. Thus there is a need to define the forward technical trajectory of the NCC beyond 2019. Greater certainty in this respect will reduce industry disruption and thereby potentially decrease resistance to each incremental change.

This project - the Building Code Energy Performance Trajectory project – is a partnership between ASBEC and ClimateWorks Australia. The project intends to bring together researchers, key industry stakeholders and government policy makers to develop an industry-led evidence base for the adoption of ambitious long-term targets and forward trajectories for progressive increases in energy performance for new building work under the Code.

In developing such targets and trajectories, it is necessary to consider many factors, including:

- The economics of energy efficiency measures that go beyond current NCC levels of stringency.
- The potential to expand the range of measures in the NCC to incorporate technologies or issues currently not covered.
- Projected reductions in technology cost and improvements in technology efficiency.
- Projected increases in energy costs.

In line with current government process, there has to be an economic justification for all measures included in the trajectory, hence the methodology for this study includes cost-benefit analysis. However, in considering the economics, barriers such as split incentives between builders and owners are ignored as it is these economic distortions that the NCC has to address to produce optimal societal outcomes. Economic analysis is only one of many factors to be considered when making decisions about changes in the NCC energy requirements.

The research as set out in this Interim Technical Report is funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative. The authors would also like to acknowledge the contributions of ASBEC and ClimateWorks Australia to this study.

2.2 Project Objectives

The key objectives of this project are as follows:

[1] Australian Sustainable Built Environment Council (ASBEC). 2016. Low Carbon, High Performance. ASBEC, Australia.

- Develop a baseline case of energy efficiency measures that are cost effective today.
- Develop a forward trajectory of energy efficiency measures that can be projected to be cost-beneficial in the future.
- Develop a timeline of decreasing energy intensity based on the projected forward trajectory.
- Develop estimates of the impacts of the proposed measures and timeline on the energy consumption of the national building stock, allowing for projected changes in the building stock due to new construction, demolition, and refurbishment.
- Develop an understanding of the technological and economic barriers that need to be addressed to bring critical technologies into economic feasibility.

2.3 Project Outline

This project consists of two distinct parallel streams, being residential and commercial (i.e. non-residential). These two streams have similar overall structure but differ in detail due to the fact that significant work has already been undertaken to determine current cost-effective opportunities to increase of energy requirements for commercial buildings as part of the update of the NCC2019 led by the Australian Building Codes Board (ABCB), while no such work has been undertaken for residential buildings.

2.4 Interim Report Context

This Interim Technical Report is intended to deliver the following key components of the project:

1. The basis of economic analysis to be used in the project.
2. The basis of technical analysis to be used in the project.
3. Preliminary results for proposed current cost-effective measures for residential buildings.
4. Recap of current cost-effective measures for commercial building, based on previous work by Energy Action for the ABCB.
5. Preliminary results for projection of the impact of current cost-effective energy efficiency measures (for residential buildings) on the national, state and territory building stock energy use.

Final results, and the development of the forward trajectories beyond what is currently cost-effective will be covered in the Final Technical Report, to be published in mid-2018.

3 Economic Assumptions

3.1 Energy Costs

The national electricity and gas prices are derived from previous work by CSIRO completed during the Electricity Network Transformation Roadmap – ENTR[2]. For the baseline scenario of the trajectory project, data outputs from the Roadmap scenario were used. A key feature of the Roadmap scenario was that the electricity sector does more than its proportional share of current national abatement targets (i.e. achieving 40% below 2005 levels by 2030) and accelerates that trajectory by 2050 to reach zero net emissions.

To calculate national average electricity prices for residential and commercial end-users the following procedure was used:

- Roadmap scenario modelling outputs providing estimates of electricity prices for residential and commercial end-users in c/kWh and c/MJ respectively by state and territory were sourced for the period 2017 to 2050.
- A scaling factor was applied to re-base prices from 2014/15 to 2015/16 real Australian dollars.
- Population projections by state and territory were sourced from Australian Bureau of Statistics (ABS) Catalogue No. 3222.0 - Population Projections, Australia, 2012 (base) to 2101.
- Individual state and territory time series were averaged on a population weighted basis to produce a national average time series.
- 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.

To calculate national average emission intensity of grid electricity the following procedure was used:

- Roadmap scenario modelling outputs providing estimates of the emission intensity of grid electricity (tCO_2-e/MWh) by state and territory were sourced for the period 2017 to 2050.
- Population projections by state and territory were sourced from Australian Bureau of Statistics (ABS) Catalogue No. 3222.0 - Population Projections, Australia, 2012 (base) to 2101.
- Individual state and territory time series were averaged on a population weighted basis to produce a national average time series.

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. The calculated price paths are shown in Figure 1.

[2] http://www.energynetworks.com.au/electricity-network-transformation-roadmap

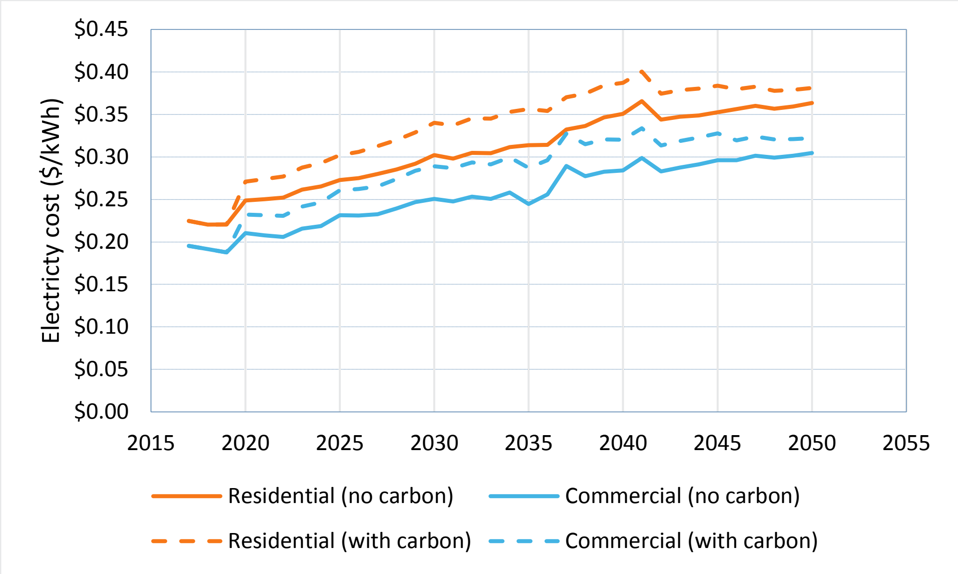

Figure 1. Calculated price paths for electricity

A significant component of retail electricity prices are network (transmission and distribution) costs that are passed through on a volumetric basis (c/kWh). It is likely that National Construction Code changes 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 $/kW augmentation costs were also 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.

3.1.1 Discussion – Energy Costs

We use retail prices to represent the value of avoided electricity costs. Some analysts, and indeed some states (at least NSW), prefer to use wholesale prices, or other constructs such as long run marginal cost, or avoidable cost, to represent the (net) value of energy savings. The apparent rationale is the view that the network component of electricity prices is not avoidable, therefore, if electricity savings are made, the revenue foregone by network businesses simply gets added to future network tariffs and distributed across future consumers.

However, network costs are 'sticky' rather than unavoidable. The Australian Energy Regular can reduce network charges, and indeed has been very actively doing so in recent years, as a delayed response to inflated demand growth and related cost growth projections by networks.[3,4] If network businesses imagined their revenues could not fall when their product is over-priced, then they are being reminded otherwise at present.[5] As with most businesses, when projected demand fails to materialise, revenues can indeed fall and fall sharply. At most, we could say that network costs are avoidable *with a lag*. The length of the lag would depend upon the sharpness of regulatory oversight, but would be unlikely to exceed 2 - 3 years, and such delays will rarely be material in the context of long-term social benefit cost analysis.[6]

[3] Australian Energy Regulator, 2016, AER finalises network charges in the ACT and NSW from 1 July 2016, Accessed Feb 2018, https://www.aer.gov.au/news-release/aer-finalises-network-charges-in-the-act-and-nsw-from-1-july-2016
[4] Australian Energy Regulator, 2015, Lower network charges for Victorian electricity customers in 2016, Accessed Feb 2018, https://www.aer.gov.au/news-release/lower-network-charges-for-victorian-electricity-customers-in-2016
[5] Han, E. 2014, 'Australian Energy Regulator clamps down on network charges', Sydney Morning Herald, 27 November.
[6] Houston Kemp, Residential Building Regulatory Impact Statement Methodology, April 2017, pp 14 – 15.

3.1.2 Discussion – Shadow Carbon Price

The production and consumption of electricity in Australia is, to varying degrees by state and territory, associated with the release of damaging greenhouse gas emissions. These emissions are not currently priced in markets, and therefore represent an external, or socialised, cost. In principle, benefit cost analysis should aim to reflect the avoided costs of future climate damage – however, there is significant uncertainty about the incidence and timing of damage costs associated with future climate change. Some research is being conducted into what is known as the 'social cost of carbon'. The Intergovernmental Panel on Climate Change has noted, for example[7]:

> *Aggregate economic losses accelerate with increasing temperature (limited evidence, high agreement), but global economic impacts from climate change are currently difficult to estimate. With recognized limitations, the existing incomplete estimates of global annual economic losses for warming of ~2.5°C above pre-industrial levels are 0.2 to 2.0% of income (medium evidence, medium agreement). Changes in population, age structure, income, technology, relative prices, lifestyle, regulation and governance are projected to have relatively larger impacts than climate change, for most economic sectors (medium evidence, high agreement). More severe and/or frequent weather hazards are projected to increase disaster-related losses and loss variability, posing challenges for affordable insurance, particularly in developing countries. International dimensions such as trade and relations among states are also important for understanding the risks of climate change at regional scales.*

Given the uncertainty over the expected economic cost of climate change itself, most analysts use observations of a 'shadow price' for carbon, based generally on countries with carbon trading schemes, as a proxy for climate change damage costs. Arguably, such shadow prices structurally undervalue avoided damage costs, as carbon market participants are responding primarily to short term market drivers. These will include the manner in which prevailing policy and regulatory frameworks influence the demand for and supply of carbon 'units'. These factors and resulting prices may carry very little if any real information about expected future damage costs.

Nevertheless, including shadow carbon prices is accepted practice in social benefit cost analysis. For example, shadow carbon prices (central, high and low) were developed by ACIL Allen in the context of the Climate Change Authority's 2013 *Targets and Progress Review* – see Figure 2. While these values date from 2013, the Australian Government has not updated these values since, and indeed they remain the consultant's assumptions, rather than officially-endorsed values. The 'central policy scenario' is taken as the default option for this project, but we note that this scenario suggests lower values than those used by Energy Networks Australia and CSIRO for their *Electricity Network Transformation Roadmap* – which uses values closer to the 'high carbon price' scenario.

[7] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, p. 16

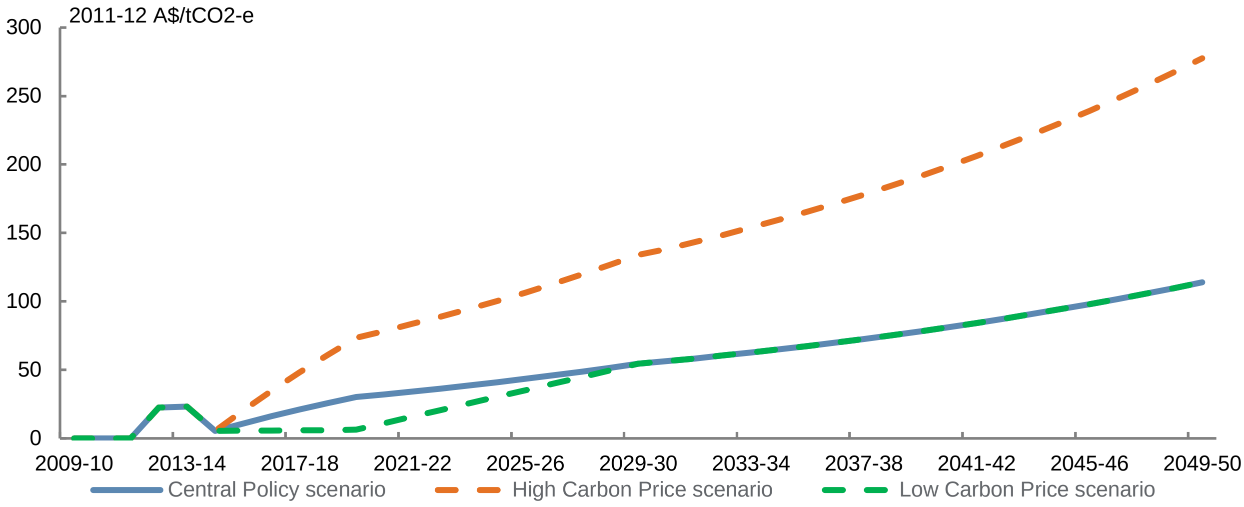

Figure 2. Shadow carbon price projections – ACIL Allen. The carbon price used for this study runs from $30/t in 2020 to $190/t in 2050, making it an intermediate case between the central and high price scenarios

3.2 Economic Methodology

The benefit cost methodology used for the baseline economic scenario is consistent with the Australian Government's Best Practice Regulation guidelines[8] and Guidance Note on Cost-Benefit Analysis[9]. That said, these guidance documents are not highly prescriptive, and the approach taken here is simplified when compared to that which would be used for a national regulation impact assessment.

3.2.1 Baseline Economic Scenario

The baseline economic methodology makes the following assumptions:

1. Baseline technology costs are as of 2017 as summarised in Section 3.3.
2. Electricity prices are as calculated in Section 3.1.
3. Discount rate is 7%, reflecting standard practice for government economic assessments.
4. Avoided network augmentation costs are priced at $963/kW, falling to around $905/kW by 2050 (see section 3.1).

A measure found to be economic under the baseline economic scenario is considered to be economic today and thus able to be used as a baseline measure. Note that in this interim report, this analysis is only conducted for the residential archetypes and measures.

3.2.1.1 Discussion – Discount Rates

The COAG Best Practice Regulation Guidelines, which apply to NCC energy performance stringency requirements *inter alia*, require that analyses use a reference real discount rate of 7%, and allows sensitivity analysis at 3% and 10%. This, therefore, is the common practice. The risk is that if the 'headline' results from this project were presented using a real discount rate lower than 7%, then they may be dismissed, particularly by those in government. Choosing a default discount rate of 7% will maximise the perceived credibility and impact of this project, and therefore we proceed on that basis. However, we note that using a discount rate of 7% results in a conservative assessment of the benefits of the proposed regulatory changes to future building owners and occupants, a material issue given the very long-lived nature of property assets. Further discussion of the issues surrounding discounting can be found in Appendix B.

[8] COAG, Best Practice Regulation: a guide for ministerial councils and national standard setting bodies, October 2007.
[9] Australian Government Department of the Prime Minister and Cabinet, Office of Best Practice Regulation, Cost-Benefit Analysis Guidance Note, February 2016.

3.2.2 Benefit Cost Analysis Criterion

In line with the criteria used by Energy Action for the NCC 2019 work for commercial buildings, a measure is deemed acceptable if:

a) It achieves the highest energy savings available for that measure; and

b) It has a benefit cost ratio in the region 1-1.5.

3.2.3 Future Economic Scenarios

For measures that are not economic under the baseline economic scenario, the following modified scenario is considered:

1. The base year is moved forward 5, 10 and 15 years
2. Baseline technology costs are adjusted, as relevant, to allow for learning rates
3. Electricity prices are as calculated in Section 3.1, with the technology introduction date becoming the first year of implementation
4. Discount rate is 7%, reflecting standard government practice
5. Avoided network augmentation costs are priced at the rate current for the year of implementation.
6. Learning rates are considered for both the cost of technology and the efficiency of technology, where evidence exists to do so.

The purpose of the future economic scenarios is to test whether it can be reasonably asserted that the technology will become economic at some point in the future, without further government support or intervention. This will in turn inform the timing of the introduction of the measure into the trajectory.

3.2.3.1 Discussion – Learning Rates

Learning rates, in this context, refer to the rate at which the incremental costs of compliance with building energy performance standards changes over time. One of the controversial elements of the previous (2009) regulation impact statements for NCC energy performance standards (residential and commercial) was that they assumed that the expected costs of compliance with the then proposed new standards (which took effect in 2010) would continue at the same level forever. That is, if it cost an additional $15/m^2$ to build to 6 Star rather than 5 Star in 2010, then it would cost an additional $15/m^2$ to do in 2020 or 2030. Intuitively, this is unrealistic, and the key reasons for this include:

- Technology performance tends to improve over time (e.g. more lumens per watt from lighting systems)
- Technology costs tend to decline over time (e.g. adjusted for lumens per watt, the $/W of installed lighting capacity has tended to fall over time), due to research and development (in Australia or overseas), competition, efficiency policies in Australia or in supplier markets (US, Japan, Korea) and reduced costs due to better designs or lower-cost installation/construction methods ('learning').
- As older technologies (e.g. those used to comply with pre-2010 standards in Australia) mature and, increasingly, are replaced by newer ones, they experience negative scale economies – due to shrinking production volumes and supply chain economics (lower returns to retailers and intermediaries, given them reasons to resupply with newer designs/technologies.

The principal difficulty in applying learning rates to anticipated future Code changes is a lack of hard data on the rate of past and anticipated future cost and performance trends for building components, construction techniques and designs. While it is possible to obtain quotes or other sources of information on building products and elements – like lighting components, windows and chillers – there is considerable uncertainty about the effect of volume discounts. Actual prices paid, particularly by larger or volume builders, are likely to be much lower than suppliers will provide quotes for – when they do not have the prospect of volume sales to justify lower margins.

Second, it is well understood in the building industry that costs estimated by quantity surveyors are highly conservative – that is, biased upwards. This is most likely to be because quantity surveyors may fear being sued for under-estimating costs on a major project, but they are most unlikely to be sued for over-estimating costs, leaving the construction firm with a higher-than-expected margin.

Third, even if elemental or input costs could be established with reasonable precision, the 'know-how' that is reflected in different designs and construction techniques will remain essentially impossible to capture. Construction firms will know to the last cent what the actual costs of construction were for a given project, but they are not required to report this information to anyone and would consider it commercially sensitive.

Fourth, incremental cost is an inherently counter-factual construct. If we want to know the additional cost of building a 6 Star house in Victoria in 2018, relative to the cost of building a 5 Star house, we have to deal with the fact that building 5 Star houses in Victoria has been illegal for 8 years. Therefore, this base case cost (at 5 Star) is not observable in reality. Not only the building product market, but the designs and the industry' know-how, have all moved on. So, not only do we need to estimate the cost of building at 6 Star, we also need to estimate the counterfactual of building at 5 Star. This problem looms much larger for commercial buildings, where there is much greater diversity of forms – with no two buildings being exactly alike.

Thus, while intuitively it is relatively straightforward to posit the existence of learning rates, and to build these into regulatory benefit cost analysis, finding hard evidence with which to quantify rates is extremely problematic. Houston Kemp in their Residential RIS Methodology report recommended applying a 'cost efficiency rate' of 2% per year, unless better information is available.[10] In this project, we have captured data from suppliers, quantity surveyors and other sources on the change in real prices for building elements where real prices are changing rapidly, such as LED lighting. For most building products, markets in Australia are more mature and real price changes are not significant. Research by *Strategy. Policy. Research.* found that a basket of 150 building products had declined in real terms by just 0.2% per year, on a sales-weighted average basis, over the 2004 – 2016 period. Given that this includes LED lighting, we have not applied learning rates to other products.

3.3 Cost Modelling

Cost modelling for all measures is built up from the following sources:

- Contractor pricing of systems
- Retail and trade pricing of components
- Quantity surveyor pricing
- Rawlinson's Australian Construction Handbook[11]

The methodology for cost estimation is described in more detail in the presentation of each measure.

For some technologies, learning rates have been asserted. Learning rates typically consist of a reduction in cost over time reflecting supply volume, production volume and industry familiarity discounts relative to what may currently be a specialist supply. The rationale for learning rates used is discussed in the presentation of each measure.

3.4 Other Costs and Benefits Included

3.4.1 Costs and Benefits Included

For this analysis, the only additional cost/benefit considered is the change in size of air-conditioning plant[12].

The incremental cost of air-conditioning has been modelled based on a brief study of the cost of split system air-conditioners. Retail purchase costs for 102 wall mounted reverse cycle split system air-conditioners were sourced from the websites of two major appliance retailers, covering a wide range of makes and models across the range of 2-10kW thermal capacity (kW_{th}). The cost to capacity relationship was as shown in Figure 3 below. For the purposes of this project retail cost versus thermal capacity were assumed similar for both heating and cooling.

[10] Houston Kemp, Residential Buildings Regulatory Impact Statement Methodology, April 2017, pp iv - v.
[11] Rawlinson's Australian Construction Handbook, Rawlinsons Publishing, Edition 35, 2017
[12] This is in addition to the avoided network augmentation costs discussed in Section 3.1

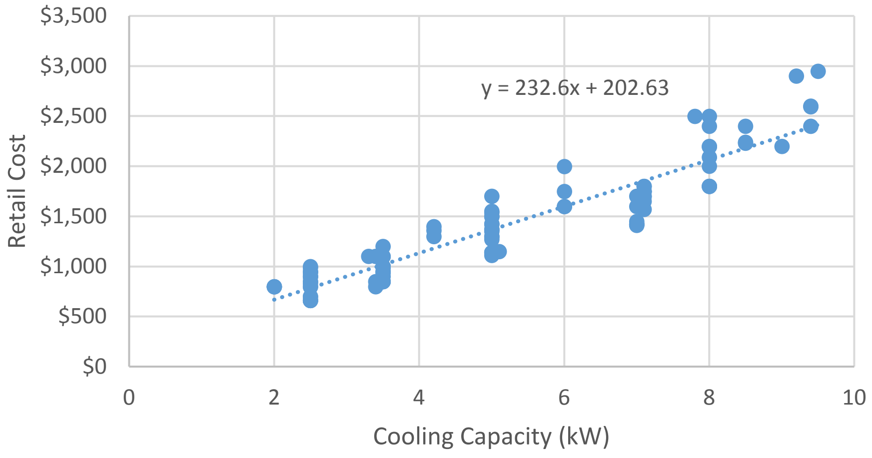

Figure 3. Cost of air-conditioning systems[13]

No allowance has been made for differences in installation costs, which are considered to be relatively insensitive to capacity. Bases on this we have allowed for an incremental air-conditioning cost of $230/kW_{th}$. Note that this has only been applied in situations where a large increment (>1kW) in capacity has been identified, recognizing the non-continuous nature of air-conditioner sizes in practice.

3.4.2 Other Costs and Benefits

Improved building energy performance can be associated with a range of benefits beyond those noted so far. Candidates include:

- Higher building values and rental yields
- Higher worker productivity/reduced lost time through illness
- For residential buildings, improved occupant health outcomes and reduced health system costs
- Increased climate resilience, including thermal resistance to heat- or cold-wave conditions, which may extend to reduced morbidity and in extreme cases reduced loss of life.

On the other hand, some would claim that higher energy performance regulation may also involve additional costs that may or may not be explicitly accounted for in benefit cost analysis. These could include:

- Costs of acquisition of new information (to become informed about and understand the consequences of new performance requirements)
- The costs associated with modifying designs and re-verifying compliance
- Costs associated with retraining personnel to acquire necessary knowledge/skills to comply with new standards
- Additional financing costs (where additional capital expenditure is required)
- Possible loss of 'amenity' associated with changed designs (for example, some have suggested that reducing glazing area in a building to comply with building energy performance regulation, regardless of the thermal performance or comfort of the initial design, must amount to a loss of amenity, as there is a diminution of choice)
- Potential negative implications for competition
- Incremental costs to government, e.g. associated with developing and applying a new standard.

The general guidance about the scope of both benefits and costs that should be included in benefit cost analysis, for regulatory impact assessment purposes, includes observations such as:[14]

- Costs and benefits should be valued in terms of the economy and society as a whole, and not from the perspective of individuals, firms, organisations or groups

[13] Cooling and heating capacities for air-conditioners are directly proportional

[14] COAG, Best Practice Regulation – A Guide for Ministerial Councils and National Standard Setting Bodies, October 2007, pp 21 – 26.

- 'Intangible' costs and benefits, that are hard to value in monetary terms, should be acknowledged, documented to the extent possible, and presented to decision-makers alongside those values that are monetised, so that they can be taken into account
- To identify costs or benefits attributable to a regulatory change, a clear chain of causation must be established
- Where they are relevant, productivity improvements should be included
- Non-marketed 'health, environmental or other social benefits' should be included
- The extent to which different costs or benefits should be quantified is dependent upon the expected returns – for example, if the costs of acquiring information on a class of benefits is high, but the expected impact on the analysis small, then it may not be worth collecting such information.

Essentially, there are no hard-and-fast rules on whether or not certain classes of (potential) social benefit or cost should be included or examined – the extent is context-dependent.

For some potential benefits – such as health or productivity improvements – the common problem with including these effects is a lack of objective evidence, particularly in Australia. A recent Harvard University study of public health benefits associated with energy efficiency buildings in many countries (but not Australia) found health benefits valued more than three times those of climate change abatement benefits. It also found that for every $1 saved on energy costs by green buildings, another $0.77 was saved in health and climate benefits.[15]

Second, the extent of benefits may be contingent on factors such as the starting point efficiency/energy performance, the quantum of performance improvement that is mooted, and the extent to which it is possible to establish a causal link between the effect and the building Code change. Practically, the limited extent of buildings research in Australia means that evidence on many of the above factors is limited and not able to be relied upon for regulatory assessment purposes.

The Australian Government's Office of Best Practice Regulation warns against risk of double counting benefits, such as the value of energy savings (associated with a lift in building energy performance standards, for example) and any attributable lift in property values. They argue that the latter '…is merely the capitalised equivalent of the benefits counted earlier'.[16] Whether this judgement is borne out by evidence is another matter.

Overall, we note that there is a paucity of buildings-related research in Australia and, as a result, it is likely that significant classes of benefits generated by energy efficient and green buildings are not being accounted for in Australia at present. If these benefits were able to be quantified and attributed to green buildings, higher minimum standards would be justified on economic grounds than are today.

[15] https://www.proudgreenbuilding.com/articles/study-green-buildings-provide-nearly-6-billion-in-benefits-to-health-climate/, viewed 26/2/2018.

[16] Australian Government, Department of the Prime Minister and Cabinet, Office of Best Practice Regulation, Cost Benefit Analysis Guidance Note, February 2016, p. 13.

4 Residential Modelling

4.1 Methodology

This section summarises the modelling approach for the residential building archetypes. Three baseline archetype models were developed in consultation with project stakeholders to represent a detached house, and attached house and a single mid-level apartment compliant with the current NCC energy requirements (further details are provided in Section 4.2 and 4.3).

For this project, the program of work has been broken into three stages:

- **One-Dimensional Analysis:** The sensitivity of the energy efficiency of each building archetype to changes in each of the identified building element/design factors was assessed on a one-dimensional basis, i.e. varying one design parameter while holding others constant. This approach was designed to provide an overall picture of the importance of key building components and parameters in improving the energy efficiency of the building. The one-dimensional analysis was completed in two steps: an energy analysis to determine the energy impacts of each element; and an economic analysis to estimate the cost-effectiveness of each measure based on the energy modelling results. The results from the one-dimensional energy analysis are summarised in Section 4.5, while the results from the one-dimensional economic analysis are summarised in Section 4.6.
- **Multi-Dimensional Analysis:** A range of scenario models will be completed, taking the most effective technologies identified for that building archetype from the one-dimensional analysis, and integrating them into a package of measures that cover existing technologies that are found to be cost-effective on current economic assumptions. The multi-dimensional analysis is still in progress, but preliminary results are provided in Section 4.7.
- **Trajectory Analysis:** Similar to the multi-dimensional analysis, but instead of limiting the analysis to what's currently cost effective, the project team will consider progressively stringent packages to be evaluated in respect of cost-effectiveness and likely future availability of technology. These packages can be characterised as: i) a conservative scenario employing existing technologies with extrapolations of current efficiency trends and economics, and ii) an ambitious scenario with relaxed economic criteria to assess the potential opportunity if costs or technologies improve faster. The trajectory analysis is outside the scope of this Interim Technical Report, but the results will be set out in the Final Report to be published in mid-2018. Section 7 provides a high-level summary of the approach to the trajectory analysis.

4.2 Archetypes

Archetypes were developed to represent simplified versions of typical buildings with a range of surface-area to volume ratio (bracketing the range of exposure to outdoor weather conditions), and were designed to characterise the energy performance of typical building types under typical operational conditions. There were three residential archetypes modelled (refer to Table 1) and used to benchmark the energy efficiency trajectory analysis within the Building Code Energy Performance Trajectory project.

Table 1. Residential Archetypes.

Building type	Description
Standalone detached house	Class 1A, Single Level, Gross floor area ≈ 190 m^2, 21.7 x 12.7 m, 2.4 m ceilings, Surface-to-Volume ratio ≈ 1.17
Attached townhouse	Class 1A, Two storey, Gross floor area ≈ 127 m^2, 10.1 x 7.3 m, 2.4 m ceilings, Surface-to-Volume ratio ≈ 0.51
Residential apartment	Class 2, Mid-level apartment, Gross floor area ≈ 75 m^2, 15.2 x 7.4 m, 2.7 m ceilings, Surface-to-Volume ratio ≈ 0.39

The archetype models and major inputs and assumptions (including form details, construction details and operation details) used for each archetype are presented in Appendix A. The archetypes were adjusted in response to feedback from the project's Technical Advisory Group (TAG). Refer to Appendix J for a sample of the TAG feedback provided..

Each archetype was developed to enable 'single-dimensional' energy efficiency performance measures to be applied at various levels of stringency using a baseline of NCC 2016 requirements. The archetypes were modelled using AccuRate Sustainability software, a building rating tool accredited under the Nationwide House Energy Rating Scheme (NatHERS).

For the apartment analysis, the project looked at only a single, mid-level apartment dwelling averaged across four different orientations in order to expand the applicability of the results to apartment blocks of different sizes. This approach is conservative (in keeping with virtually all the modelling undertaken in this study) as it does not allow for opportunities for whole-building design responses such as trade-offs in different orientations, or ceiling insulation on a top-floor, and insulation above a basement car park, for example. It also does not account for the variability in performance across different apartment dwellings in the one dwelling. The lower-rated apartments in a building are likely to have greater opportunities for improvement than the higher-rated apartments. The apartment archetype does not include shared services – these are covered in commercial parts of this analysis as they sit within Volume 1 of the NCC.

The analysis was specific to Climate Zones 2, 5 and 6 as defined by the ABCB.

- Zone 2: Warm humid summer, mild winter;
- Zone 5: Warm temperate; and
- Zone 6: Mild temperate.

4.3 Baselines

The baseline detached and attached archetypes were modified to comply with the National Construction Code 2016 Deemed-to-Satisfy (DtS) Elemental Provisions. As there are no DtS Elemental Provisions for Class 2 (apartment) buildings, the apartment archetype baseline was modelled at an Equivalent 6 Star rating under the National Home Energy Rating Scheme (NatHERS). For all archetypes the baseline simulations incorporated the air tightness benchmark of approximately 15 ACH at 50Pa (matching the blower door field test results of CSIRO[17]) so that the impact of the improvement in air tightness of the buildings could be modelled appropriately (further details provided in Section 4.3.1). Glazing types for baseline models were initially based on details of typical windows as provided by the Technical Advisory Group (TAG). This was later adjusted to ensure better alignment with the Code DtS requirements. DtS requirements for glazing were determined using the NCC Glazing Calculator Spreadsheet ensuring that glazing met DtS requirements for at least one orientation for each archetype, in each climate zone (Refer to Appendix M).

The Equivalent Star Ratings of the majority of the baseline archetype models used were approximately NatHERS 6 Stars, for each of the three climate zones considered (Climate Zones 2, 5, and 6).

4.3.1 Air Tightness and Infiltration

To ascertain the impact of air tightness improvements/changes the baseline archetype models were developed with air tightness values that approximately matched the average from blower door survey data made available by the CSIRO in their report "House Energy Efficiency Inspections Project" (Ambrose & Syme 2015, p10). This report stated that the average air change rate for the buildings tested *in situ* was 15.4 ACH (at 50 Pa). This figure included buildings up to 10 years old.

[17] Ambrose MD and Syme M (2015). House Energy Efficiency Inspections Project – Final Report. CSIRO, Australia.

To ensure that the ACH (at 50 Pa) data was as closely representative of buildings in the present Building Code Energy Performance Trajectory project as possible, only the city-by-city mean values provided by Ambrose and Syme for newly constructed buildings (up to 3 years old) were averaged. Thus, it could be inferred that the buildings in this dataset were built close to current NCC energy performance standards (noting that 6 Star NatHERS applied in most jurisdictions, with some less stringent requirements used in others). The resultant average air change rate was then calculated to be 14.7 ACH (at 50 Pa).

The UOW team developed a method to estimate the impact of improving the airtightness of the building envelope on the energy and thermal performance of a new dwelling; this method is outlined in some detail in Appendix G. The infiltration rates in the three archetype buildings were adjusted in Accurate by the addition of wall vents so as to implement a baseline air envelope air tightness of close to the target value of 15 ACH (at 50 Pa)[18]. However, it should be noted that it was not always possible to match this value exactly in the AccuRate Sustainability simulation tool, due to the nature of the in-built infiltration algorithms.

It should also be noted that the term Equivalent Star Ratings is sometimes used in this report as a reminder to readers of the fact that the many of the energy simulations have been undertaken with the 15 ACH@50Pa baseline air tightness indicator. While this approach has the benefit of setting a consistent air tightness benchmark across the different archetypes, it does mean that care needs to be taken with the interpretation of results, since they will differ somewhat from simulations using standard NatHERS-compliant software protocols. This is a result of the fact that when using the standard NatHERS software protocols air tightness and infiltration will vary significantly across multiple specific building designs according to the number and type of air leakage paths included (e.g. through downlight fittings, etc.). Whereas, in the present project it has been important to maintain consistent baseline and increased stringency air tightness values since this parameter has a very significant influence on building heating and cooling energy requirements.

4.3.2 Glazing

Two types of baseline glazing model were developed for the three building archetypes based on the following.

i) Baseline I ('Typical WWR'): Typical window sizes and window-to-wall ratios currently adopted by the industry. Baseline I was used for the one-dimensional analysis results presented in this Interim Technical Report.
ii) Baseline II ('Minimum WWR'): Minimum window sizes, where glazing provides close to the lowest cost in terms of construction, by being relatively small in area, but complies with the daylighting requirements in the NCC, i.e. windows which 'have an aggregate light transmitting area measured exclusive of framing members, glazing bars or other obstructions of not less than 10% of the floor area of the room' (NCC Vol. 2, 2016, clause 3.8.4.2). Baseline II was used for the multi-dimensional analysis presented in this Interim Technical Report (see Section 4.7 for further details).

The following list summarises the process by which the One-Dimensional and Multi-Dimensional Archetype glazing baselines were determined.

Baseline I

a) The archetype geometries, including windows sizes, were largely derived from archetypes published in the report by Isaacs[19]. In addition, the modelling team took advice from members of the Technical Advisory Group (TAG) and other stakeholders on a number of relatively minor layout and design modifications. The resultant glazing areas were larger than the minimum window to floor area ratio for daylighting requirements (i.e. >10% Window-to-Floor-Area-Ratio).

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[18] The baseline infiltration value is equivalent to approximately 12.8 m^3/m^2.hr for the detached house archetype, 15.2 m^3/m^2.hr for the attached house, and 11.1 m^3/m^2.hr for the single apartment, at 50Pa

[19] Isaacs, T. "Development of Housing Stock Model to predict heating and cooling energy use in Victoria", Tony Isaacs Consulting, 2007.

b) *The same glass type was used on all facades of a given dwelling, regardless of orientation*. This approach was taken to reduce the b) number of possible combinations of windows to be resized under different orientations, climates, etc. to a tractable cohort that could be processed with the resources available to the project. (To date the only time this constraint has been relaxed was for the Glazing Energy Analysis described below).

Baseline II

a) A number of representative glazing types, that were available to the modellers in the AccuRate Sustainability default glazing library, were chosen following relevant advice of the TAG and other stakeholders/practitioners. These glazing types are listed in Table 2 below.

b) The initial modelling glazing baseline was set using sizes representing the minimum window to floor area ratio for day lightingrequirements of the Code (i.e. this ratio must exceed 10% as detailed in NCC Vol. 2, 2016, clause 3.8.4.2). The lowest performance glazing option Glass 1 was first trialled in the NCC Glazing Calculator for the Detached and Attached archetypes, and substituted by higher performance glazing options if compliance was not achieved.

c) In the case of the Apartment archetype glazing was chosen to satisfy an Equivalent 6 Star rating (i.e. using the 15 ACH@50Pa air tightness baseline) since the NCC does not have a DtS pathway for Class 2 buildings.

d) *For each archetype, in a given climate zone, the glazing type and window sizes were held constant for all orientations of the building*. In other words, no attempt was made to 'optimise' the design of glazing for the building as a function of orientation. This was done to maintain consistency of designs, and to limit the number of glazing configurations. While this might be contrary to the approach taken by a good building designer, the key objective of setting the baselines for this analysis was to facilitate the evaluation of improved performance in individual building elements, not to develop the highest performance building possible.

e) For the purposes of the Multi-Dimensional energy analyses, the glazing of an archetype in a particular climate zone *was deemed to meet the requirements of the present study if the building complied with NCC glazing requirements in at least one cardinal orientation (N, S, E or W).* The Detached and Attached archetypes had to comply with NCC Glazing Calculator in at least one cardinal orientation, and the Apartment had to achieve at least an Equivalent 6 Stars with AccuRate (using the 15 ACH@50Pa air tightness baseline), in at least one orientation.

Table 2. Glazing types used in this study and taken from the default AccuRate Sustainability glazing library.

Type	U-value (W/m^{2}K)	SHGC	VT	Frame ratio (%)	Description
Glass 1	6.7	0.7	0.9	0.24	Single glazing (SG) clear glass
Glass 2	4.6	0.46	0.61	0.19	Composite frame, SG low solar gain and low-E
Glass 3	4.3	0.53	0.75	0.24	Al frame, double glazing (DG), air fill, glass: High solar gain low-E - Clear
Glass 4	2.3	0.25	0.45	0.2	uPVC frame, DG, air fill, glass: Low solar gain low-E - Clear
Glass 5	2.9	0.51	0.75	0.24	Al frame, DG, Argon fill, glass: High solar gain low-E - Clear
Glass 6	2.6	0.53	0.82	0.35	Timber frame, DG, Argon fill, glass: Clear - Clear

During the Multi-Dimensional energy analysis the Baseline I glazing was adjusted to more closely align with the more detailed process of determining Baseline II glazing, specifically to utilise only glass types from Table 2 as per a) from Baseline II approach above and to ensure compliance with Baseline II requirement e).

As stated above, Baseline II was developed for the Multi-Dimensional analysis. The following additional considerations were included in the development of Baseline II.

a) A decision by the NCC Trajectory Project team was also made that glass areas should be increased to compensate for the reduction in visual transmittance (VT) of light through higher performing glazing types. The baseline visual transmittance for a single-glazed window was taken to be 0.9.

b) Once the windows were sized for the lowest performing glass, a test was made to see if the energy consumption/equivalent star rating from AccuRate (with infiltration of approximately 15ACH at 50 Pa implemented) was better than the equivalent NatHERS Star bands value *for at least one orientation of the building*.

c) If this was *not* the case the glazing (on all windows) was changed to the next highest performing glass, all windows resized (if necessary for maintenance of overall visual light transmission) and the energy/star performance again tested against the equivalent NatHERS Star rating.

d) Item d) was repeated until at least one orientation had higher performance than the nominal 6 Star band (noting that this was with infiltration of approximately 15ACH at 50Pa implemented).

A summary of the window to wall ratios and glass types chosen for the Single Dimensional Analysis Glazing Baseline (Baseline I) and the two Multi-Dimensional Analyses Glazing Baseline (Baseline II) is shown in Table 3 below.

Table 3. Window-to-wall ratios and glazing types adopted for the Baseline I (one-dimensional analysis), and Baseline II (multi-dimensional analysis) archetypes as a function of climate zone.

Apartment Archetype												
Climate Zone	Baseline I Model						Baseline II Model					
	WWR	Glass Type	U Value (W/m²K)	SHGC	VT	Frame	WWR	Glass Type	U Value (W/m²K)	SHGC	VT	Frame
2	20%	-	4.8	0.51	0.82	0.41	23.4%	4	2.3	0.25	0.45	0.2
5	20%	-	4.8	0.51	0.82	0.41	23.4%	4	2.3	0.25	0.45	0.2
6	20%	-	4.8	0.51	0.82	0.41	14.9%	3	4.3	0.53	0.75	0.24

Attached Archetype												
Climate Zone	Baseline I Model						Baseline II Model					
	WWR	Glass Type	U Value (W/m²K)	SHGC	VT	Frame	WWR	Glass Type	U Value (W/m²K)	SHGC	VT	Frame
2	40%	-	6.7	0.57	0.9	0.41	20.0%	1	6.7	0.7	0.9	0.24
5	40%	-	6.7	0.57	0.9	0.41	20.0%	1	6.7	0.7	0.9	0.24
6	40%	-	6.7	0.57	0.9	0.41	20.0%	1	6.7	0.7	0.9	0.24

Detached Archetype												
Climate Zone	Baseline I Model						Baseline II Model					
	WWR	Glass Type	U Value (W/m²K)	SHGC	VT	Frame	WWR	Glass Type	U Value (W/m²K)	SHGC	VT	Frame
2	28%	-	6.7	0.57	0.9	0.41	30.9%	4	2.3	0.25	0.45	0.2
5	28%	-	6.7	0.57	0.9	0.41	16.3%	1	6.7	0.7	0.9	0.24
6	28%	-	6.7	0.57	0.9	0.41	19.5%	5	2.9	0.51	0.75	0.24

4.4 Overview of One-Dimensional Analysis Results

For each archetype and climate zone, analysis was undertaken to assess the energy impact and benefit-cost ratio of each building element. A summary of the results below are presented from analysis which involved graphing benefit cost ratio versus percentage energy saving to assist in the identification of measures that are both effective (>2% saving) and economic (BCR>1), as well as identification of measures that are variously ineffective but economic, effective but economic, or neither. Further details are provided in following sections.

The summary results for the three archetypes are presented in Table 4 to Table 6 below.

Table 4. Overview of measures for the Apartment Archetype, current day economics.

	Not Effective	Effective
Economic		Lighting Infiltration CZ6
Not Economic	Wall Ins CZ2,5 Wall colour CZ2,5,6 Roller Shutters CZ6	Wall insulation CZ6 Roller shutters CZ2,5 Infiltration CZ2,5 Thermal Mass CZ2,5,6

Table 5. Overview of measures for the Attached Archetype, current day economics.

	Not Effective	Effective
Economic	(Roof Type CZ2,5)	(Roof type CZ6)

	Not Effective	Effective
	(Roof colour CZ 2)	(Roof colour CZ5) Infiltration CZ6
Not Economic	Roof Insulation CZ2 Wall Insulation CZ2,5 Wall colour CZ2,5,6 Roof openness CZ 2,5,6 Slab insulation CZ2,5,6 Thermal Mass CZ2,5 Roller shutters CZ6 Eaves Extension CZ5,6 (Roof colour CZ6) Ventilation fan CZ6	Roof insulation CZ5,6 Infiltration CZ2,5 Eaves Extension CZ2 DHW Wall insulation CZ6 Thermal Mass CZ6 Ventilation fan CZ2,5 Roller Shutters CZ2,5

Table 6. Overview of measures for the Detached Archetype, current day economics.

	Not Effective	Effective
Economic		Roof Insulation CZ 5,6 Infiltration CZ 5,6 Eaves Extension CZ 5 Ventilation fan CZ 5
Not Economic	Wall Insulation CZ 5 Wall colour CZ 2,5,6 (Roof type CZ2,6) (Roof colour CZ 2,6) Slab insulation CZ 2,5,6 Ventilation fans CZ6	Wall Insulation CZ 2,6 Lighting CZ 2,5,6 Roller Shutters CZ 2,5,6 Ventilation fans CZ 2 Eaves Extension CZ2,6 DHW CZ2,5,6 Thermal Mass CZ2,5,6 (Roof Type CZ5)

The apartment savings show a consistent pattern of generally smaller with poor economics. The notable exceptions are lighting, which shows a negative costs for the apartment archetype and infiltration testing in climate zone 6 only.

4.5 Details of One-Dimensional Energy Analysis

The design and construction changes outlined in Section 4.2 were applied to each orientation of the one-dimensional baseline model to investigate the heating and cooling energy savings and the equivalent star rating changes. Similar to the approach of the Zero Carbon Australia Building Plan[20], the individual design and construction changes were tested for performance and potential economic opportunities and challenges, within the constraints and guidance provided by ClimateWorks in relation to objectives and targets. It is noted that this approach is perceived as being conservative, and more cost effective opportunities than those derived from the one-dimensional elemental approach could be determined using a whole of house equivalent Star rating approach. However, the elemental approach enables the many available design factors/improvement options to be rationalised with a consistent baseline.

[20] Beyond Zero Emissions. (2013). Zero Carbon Australia Buildings Plan. (The University of Melbourne & Melbourne Energy Institute, Eds.).

The simulated energy efficiency stringency scenarios included different magnitudes, or 'levels', for each design factor, which generally (though not always) resulted in increased energy efficiency performance. Up to four levels of change in each design parameter were chosen, resulting in up to a total of five levels: Baseline, Level 1 Change, Level 2 Change, Level 3 Change and Maximum Change. The Maximum Change level was considered to be the practical maximum change that could be made in the building parameter given current and near-term materials, construction and design practices. The levels of change for the different design factors were chosen on a case-by-case basis, and as a result of input from stakeholders such as the Technical Advisory Group, and domain experts. For example, the width of the eaves was increased linearly between each level, whereas the Level 1 Change in infiltration rates was chosen as being achievable with reasonable improvements to current construction industry practice.

Table 7. Matrix of building types and relevant technologies tested.

	Apartment	Attached Townhouse	Detached House
Insulation	Y	Y	Y
Surface Colour (ext. wall surface only)	Y	Y	Y
Infiltration	Y	Y	Y
Thermal Mass	Y	Y	Y
External Shading	Y	Y	Y
Appliances	Y	Y	Y
Lighting	Y	Y	Y
Efficient Domestic Hot Water	N	Y	Y
Ceiling Fans	N (present in the base case)	Y	Y
HVAC efficiency and controls	Y	Y	Y
PV	N	Y	Y

Each of the above stringencies was initially tested on a one-dimensional basis.

The AccuRate Sustainability software tool was employed for this energy analysis, in which it was assumed that natural ventilation is always utilised by the occupant whenever the outdoor temperature is suitable to maintain indoor thermal comfort conditions. However, it should be noted that in practice it is likely that many occupants may not adopt the schedules, control strategies, and other assumptions incorporated in NatHERS/Accurate.

4.5.1 Energy Efficiency Measures Tested

A range of energy efficiency design factors/measures were considered by the project team, which were informed by suggestions provided by the TAG following the meeting on 31st July 2017. The 'baseline' selected for each measure, with the exception of glazing in some cases (as discussed in Section 4.2.3), was in minimum compliance with the deemed-to-satisfy (DtS) elemental provisions of NCC 2016. These design factors are briefly described below and detailed in

Table 8 to Table 10. Glazing is currently being considered separately (see Section 4.8.2).

4.5.1.1 Insulation

In many residential archetypes, insulation is considered as one of the most practical and cost effective measures to maintain indoor thermal comfort and improve building energy performance. We assessed the likely benefits through increasing the insulation levels of ceiling, floor, and walls.

4.5.1.2 Surface Colour of Walls and Roof

The surface colour will impact solar absorption and therefore the amount of heat gains. We investigated the impact of the surface colours of external walls (for all archetypes) and roof (for attached and detached archetypes).

4.5.1.3 Glazing

Glazing is a very important element influencing building energy consumption. In order to limit unwanted heat gain in summer and heat loss in winter, window size should be minimised. However, the nature of a window is to allow the penetration of natural light and fresh air, and offer views that connect interior living spaces with outdoors. In addition, winter solar heat gains can aid in decreasing the heat load, while in summer cross ventilation can be used to diminish the cooling demand. In order to determine the appropriate values that should be used in the one-dimensional analysis, the impact of the type of window glazing in terms of thermal transmittance (U-value), solar heat gain coefficient (SHGC), and window-to-wall ratio (WWR) on the energy performance need to be considered.

The analysis of glazing is being undertaken separately from the other one-dimensional analysis summarised in this report due to the complexities of glazing performance (as per described above). The objective of the separate work was to determine the impact of the type of window glazing, in terms of thermal and solar transmittance (i.e. window U-value and Solar Heat Gain Coefficient, SHGC), and window-to-wall ratio (WWR) on the annual heating and cooling energy requirements of the three residential archetypes that represent apartments, attached terrace townhouses, and detached houses.

This glazing analysis is still ongoing. Energy analysis and cost benefit analysis results for glazing are not yet complete. Results of the glazing analysis will be included in the Final Technical Report for this project. Refer to Section 4.8.2 for further information on how the glazing analysis is being carried out.

4.5.1.4 Infiltration

Infiltration is the uncontrolled movement of air through windows, cracks or other openings in the building envelope principally due to natural buoyancy and wind effects. By contrast, ventilation is an intentional introduction of air from the outside into the building, either driven mechanically by fans, etc. or by the control of natural ventilation through openable windows.

The rate of air leakage through the building envelope, i.e. the volume flow rate of the air that passes through the building envelope, is dependent on the quantity, size and type of leakage paths which in turn determine the building envelope airtightness or permeability.

Different levels of airtightness were considered using the in-built algorithms in the AccuRate Sustainability software. The Level 1 stringency for air tightness was estimated to be approximately 6 ACH (at 50Pa)[21] from the Accurate simulations of archetypes, using the method described in Appendix G. The archetypes upgraded to Level 1 air tightness stringency were designed so that well sealed building components were used throughout, including 'sealed' exhaust fans (i.e. exhaust fans that incorporate a sealing device/damper).

[21] The Level 1 stringency infiltration is equivalent to approximately 5.1 m^3/m^2.hr for the detached house archetype, 6.1 m^3/m^2.hr for the attached house, and 4.4 m^3/m^2.hr for the single apartment, at 50Pa

4.5.1.5 Thermal Mass

The thermal mass of any building (e.g. thermal mass of the floor and external walls) has a potentially significant impact on the energy performance of the residential archetypes. We investigated the impact of using reverse brick veneer, increasing the thickness of the exposed concrete floor, and the combination of both these approaches on the energy performance of the building archetypes.

4.5.1.6 External Shading

External shading can have an important impact on house energy consumption, particularly in cooling dominated climates. In our analysis, the impact of two external shading options on the performance of the three residential archetypes has been assessed, i.e. i) extending the eaves of the building as a passive measure, and ii) inclusion of roller shutters as an active measure.

4.5.1.7 Energy Efficient Appliances and Lighting Controls

The default lighting technology for each archetype was initially chosen as compact fluorescent lights (CFL) for baseline energy consumption calculations. The transition to alternative lighting technologies, (e.g. LEDs), was then considered as a way to further reduce lighting-related energy consumption.

4.5.1.8 Roof Ventilation

While roof insulation slows the heat transfer from outdoors via roof materials and roof spaces reaching into living areas, it does not prevent heat entering over an extended period of time. Removal of a component of this heat from roof spaces can be achieved through implementation of additional roof ventilation. This can be via additional vents or ventilation systems. For the single dimensional analysis hurricane ventilators were considered as an addition to relevant roof areas to achieve two levels if increased roof ventilation.

4.5.1.9 Domestic Hot Water Upgrades

Domestic hot water energy consumption requirements based on typical usage rates were considered for each archetype in the overall energy consumption calculations.

Hot water heating with standard and high performance heat pumps and electrical boosted solar were considered.

4.5.1.10 Ceiling Fans

Ceiling fans were considered as a means to facilitate air movement to improve occupant summer thermal comfort and reduce demand for air conditioning. Ceiling fans are currently an option under the NCC deemed-to-satisfy provisions.

Ceiling fan installation data from the Australian Bureau of Statistics for pre- and post-regulations show that the installation of fans has been generally stable over previous decades and higher in locations that are warmer, i.e. Queensland and the Northern Territory.[22] Ceiling fans are included in the baseline model for the Apartment Archetype and as stringency increases for the Attached and Detached Archetypes.

4.5.1.11 Solar Photovoltaic Systems

Solar photovoltaic systems were considered at a high level as a measure to offset energy consumption in the residential archetypes. Photovoltaic systems sized to take up 40% and 50% of the available roof surfaces on north, west, and east facing roof areas were considered for the attached and detached archetypes respectively, with two export scenarios (full export and full on-site use). The apartment archetype was excluded from this analysis due to very limited roof area per dwelling available in the archetype model, but high-level estimates of the opportunity for apartments will be undertaken for the trajectory analysis. Grid integration issues have not been considered in the analysis.

4.5.2 One-Dimensional Simulation Scenarios

[22] Australian Bureau of Statistics, Environmental Issues: Energy Use and Conservation, 4602.0.55.001, March 2008.

Table 8 details the measures adopted for the one-dimensional simulation scenarios for the apartment archetype. The grey areas of the table indicate situations that are not suitable for the application of the corresponding technical option. The simulation results under the Climate Zones 2, 5, and 6 are summarised in Appendix C, respectively.

Table 9 summarises the one-dimensional simulation scenarios designed for the attached archetype. Similar to the apartment archetype, the grey areas mean that it is not applicable to use the corresponding technical option for the change scenario(s). The simulation results for Climate Zones 2, 5, and 6 are presented in Appendix C.

Table 10 summarises the one-dimensional simulation scenarios designed for the detached archetype. Similar to the apartment archetype, the grey areas mean that it is not applicable to use the corresponding technical option for the change scenario(s). The resulting simulation results under the Climate Zones 2, 5, and 6 are presented in Appendix C.

Table 8. Single-dimensional measures and design parameters studied for the Apartment Archetype.

Design parameters		Baseline case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
External wall	Insulation*	**Climate Zone 5 and 6:** South wall (R-value 2.4 Km²/W): 90mm of Glass fibre batts and 18mm Polystyrene extruded. Other walls (R-value 2.9 Km²/W): 90mm of Glass fibre batts and 27mm Polystyrene extruded	**Climate Zone 5 and 6**: South wall (R-value 2.9 W/m²K): 90mm of Glass fibre batts and 27mm Polystyrene extruded Other walls (R-value 3.5 m²K/W): 90mm of Glass fibre batts and 49mm Polystyrene extruded.	**Climate Zone 5 and 6:** South wall: (R-value 3.5 m²K/W): 90mm of Glass fibre batts and 49mm Polystyrene extruded. Other walls (R-value 4.2 m²K/W): 90mm of Glass fibre batts and 73mm Polystyrene extruded.	**Climate Zone 5 and 6:** South wall (R-value 4.0 m²K/W): 90mm of Glass fibre batts and 68mm Polystyrene extruded Other walls (R-value 4.9 m²K/W): 90mm of Glass fibre batts and 92mm Polystyrene extruded	**Climate Zone 5 and 6 :** South wall (R-value 4.8 m²K/W): 90mm of Glass fibre batts and 90mm Polystyrene extruded Other walls (R-value 5.8 m²K/W): 90mm of Glass fibre batts and 118mm Polystyrene extruded
		Climate Zone 2: South wall (R-value 2.9 m²K/W): 90mm of Glass fibre batts and 27mm Polystyrene extruded Other walls (R-value 3.4 m²K/W): 90mm of Glass fibre batts and 47mm Polystyrene extruded	**Climate Zone 2:** South wall (R-value 3.5 m²K/W): 90mm of Glass fibre batts and 49mm Polystyrene extruded. Other walls (R-value 4.2 m²K/W): 90mm of Glass fibre batts and 73mm Polystyrene extruded	**Climate Zone 2:** South wall (R-value 4.2 m²K/W): 90mm of Glass fibre batts and 73mm Polystyrene extruded. Other walls (R-value 5 m²K/W): 90mm of Glass fibre batts and 95mm Polystyrene extruded	**Climate Zone 2:** South wall (R-value 4.9 m²K/W): 90mm of Glass fibre batts and 92mm Polystyrene extruded Other walls (R-value 5.8 m²K/W): 90mm of Glass fibre batts and 118mm Polystyrene extruded	**Climate Zone 2:** South wall (R-value 5.8 m²K/W): 90 mm of glass fibre batt and 118mm of polystyrene extruded Other walls (R-value 6.8 m²K/W): 90mm of Glass fibre batts and 145mm Polystyrene extruded
	Surface colour (absorptance)	External render, 65%	50%, light green the external render	30%, light cream	23%, white	
Roof	Roof type	Roof tiles				
	Surface colour	Brick (red press clay), 79%				
	Openness (roof ventilation)	Standard				
Ceiling	Insulation*	R-value 1.5 (total R-value 2.5)				

Design parameters		Baseline case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
Floor	Slab Insulation (Edge)	None				
	Slab Insulation (Under)	None				
Window Glazing+	U-value (W/m²K) and SHGC	Double glazed, Clear glass. U-value=4.8 W/m²K; SHGC=0.51; WWR=20%				
Fans	Ceiling fan	900mm fan (bedrooms, kitchen); and 1200 mm fan (living room)				
Infiltration	Improve workmanship	Approximately 15 ACH at 50 Pa	Approximately 6 ACH at 50 Pa			
External shading	Eave extension	Balcony 0.8 m overhang and eave 0.45 m length	Extend eaves to 0.56 m	Extend eaves to 0.68 m	Extend eaves to 0.8 m	Extend eaves to 1.2 m
	Roller shutters	None	include roller shutters			
Thermal mass	Floor, External walls	200 mm concrete and carpet, Brick veneer	Reverse brick veneer	Increase concrete floor to 300mm and leave it expose	300 mm exposed concretes floors and reverse brick veneer	

* Impact of thermal bridging included in insulation R-value

+ Glazing analysis was subsequently superseded by comprehensive U_{total} vs. WWRxSHGC analysis (see Section 4.4.4)

Table 9. Single dimensional measures and design parameters studied for the Attached Archetype.

Design parameters		Baseline case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
External wall	**Insulation***	R-value 2.8 m^2K/W: 90 mm of glass fibre batt and 27mm of polystyrene extruded	R-value 3.5 m^2K/W: 90 mm of glass fibre batt and 50mm of polystyrene extruded	R-value 4.2 m^2K/W: 90 mm of glass fibre batt and 70mm of polystyrene extruded	R-value 4.9 m^2K/W: 90 mm of glass fibre batt and 90mm of polystyrene extruded	R-value 5.8 m^2K/W: 90 mm of glass fibre batt and 120mm of polystyrene extruded
	Surface colour (absorptance)	External render, 65%	50%, light green external render	30%, light cream	23%, white	
Roof	**Roof type**	Roof tiles	Metal Steel deck, medium colour (50%)	Metal Steel deck, light colour (30%)	Metal Steel deck, white (23%)	
	Surface colour	Brick (red press clay), 79%	50%, medium colour	30%, light colour	23%, white	
	Openness (roof ventilation)	Standard	Ventilated (Roof Ventilators)	Highly ventilated (Dual Dutch Gable or Roof Ventilators)		
Ceiling	**Insulation***	Total roof and ceiling R-value 5.1 m^2K/W: 255 mm of Glass fibre batt	Total R-value of roof and ceiling 6.4 m^2K/W: 310 mm of Glass fibre batt	Total R-value of roof and ceiling 7.7 m^2K/W: 370 mm of Glass fibre batt	Total R-value of roof and ceiling 9 m^2K/W: 480mm of Glass fibre batt	Total R-value of roof and ceiling 10.1 m^2K/W: 540mm of Glass fibre batt
Floor	**Slab Insulation (Edge)****	None	Polystyrene expanded R-value of 0.5 m^2K/W	Polystyrene expanded R-value of 1.5 m^2K/W		
	Slab Insulation (Under)	None	Polystyrene expanded R-value of 1 m^2K/W			Polystyrene expanded R-value of 2 m^2K/W
Window Glazing[+]	**U-value (W/m^2K) and SHGC**	U-value=6.7 W/m^2K; SHGC=0.57; WWR=40%				

Design parameters		Baseline case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
Fans	Ceiling fan	None	900mm fan (bedroom 2, studio), 1200mm fan (bedroom 1, kitchen), 1400mm fan (living)			
Infiltration	Improve workmanship	Approximately 15 ACH at 50 Pa	Approximately 6 ACH at 50 Pa			
External shading	Eave extension	Balcony 0.8 m overhang and eave 0.45 m length	Extend eaves to 0.56 m	Extend eaves to 0.68 m	Extend eaves to 0.8 m	Extend eaves to 1.2 m
	Roller shutters	None	Include roller shutters			
Thermal mass	Floor, External Walls	200 mm concrete and carpet, brick veneer	Reverse brick veneer	Increase concrete floor to 300mm and leave it expose	300 mm exposed concretes floors and reverse brick veneer	

* Impact of thermal bridging included in insulation R-value

** Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

+ Glazing analysis was subsequently superseded by comprehensive U_{total} vs. WWRxSHGC analysis (see Section 4.4.4)

Table 10. Single-dimensional measures and design parameters studied for the Detached Archetype.

Design parameters		Baseline case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
External wall	Insulation*	R-value 2.8 m^2K/W: 90 mm of glass fibre batt and 27mm of polystyrene extruded	R-value 3.5 m^2K/W: 90 mm of glass fibre batt and 50mm of polystyrene extruded	R-value 4.2 m^2K/W: 90 mm of glass fibre batt and 70mm of polystyrene extruded	R-value 4.9 m^2K/W: 90 mm of glass fibre batt and 90mm of polystyrene extruded	R-value 5.6 m^2K/W: 90 mm of glass fibre batt and 114mm of polystyrene extruded
	Surface colour (absorptance)	External render, 65%	50%, light green external render	30%, light cream	23%, white	
Roof	Roof type	Steel deck	Roof tiles			

Design parameters		Baseline case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
	Surface colour	50%, medium	49%, pink	30%, light	23%, white	
	Openness (roof ventilation)	Standard	Ventilated (Roof Ventilator)	Highly ventilated (Dual Dutch Gable or Roof Ventilators)		
Ceiling	**Insulation***	**Climate 2 and 5:** 175 mm of Glass fibre batts, R-value 2.93 (Total R-value of roof and ceiling 4.6 m²K/W)	**Climate 2 and 5:** 220mm of Glass fibre batts, R-value 3.7 m²K/W	**Climate 2 and 5:** 260 mm of Glass fibre batts, R-value 4.41 m²K/W	**Climate 2 and 5:** 305mm of Glass fibre batts, R-value 5.2 m²K/W	**Climate 2 and 5:** 340mm of Glass fibre batts, R-value 5.8 m²K/W
		Climate 6: 205 mm of Glass fibre batts, R-value 3.45 m²K/W (Total R-value of roof and ceiling 5.1 m²K/W)	**Climate 6:** 250mm of Glass fibre batts, R-value 4.24 m²K/W (Total R-value of roof and ceiling 5.7 m²K/W)	**Climate 6:** 305mm of Glass fibre batts, R-value 5.2 m²K/W (Total R-value of roof and ceiling 6.7 m²K/W)	**Climate 6:** 350 mm of Glass fibre batts, R-value 5.99 m²K/W (Total R-value of roof and ceiling 7.5 m²K/W)	**Climate 6:** 405mm of Glass fibre batts, R-value 6.95 m²K/W (Total R-value of roof and ceiling 8.5 m²K/W)
Floor	**Slab Insulation (Edge)****	None	Polystyrene expanded R-value of 0.5 m²K/W	Polystyrene expanded R-value of 1.5 m²K/W		
	Slab Insulation (Under)	None	Polystyrene expanded R-value of 1 m²K/W	Polystyrene expanded R-value of 2 m²K/W	Polystyrene expanded R-value of 3 m²K/W	Polystyrene expanded R-value of 4 m²K/W
Window Glazing⁺	**U-value (W/m²K) and SHGC**	U-value=6.7 W/m²K; SHGC =0.57; WWR=28%				

Design parameters		Baseline case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
Fans	**Ceiling fan**	None	900mm fan (bedrooms, study), 1200mm fan (living 2); 1400mm fan (living 1, kitchen)			
Infiltration	**Improve workmanship**	Approximately 15 ACH at 50 Pa	Approximately 6 ACH at 50 Pa			
External shading	**Eave extension**	0.450 m length	Eaves 0.563 m	Eaves 0.675 m	Eaves 0.788 m	Eaves 0.900 m
	Roller shutters	None	Include roller shutters			
Thermal mass	**Floor**	200 mm concrete and carpet	400 mm concrete and carpet	200 mm concrete and carpet	400 mm concrete and carpet	
	External walls	Brick veneer	Brick veneer	Reverse brick veneer	Reverse brick veneer	

* Impact of thermal bridging included in insulation R-value

** Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

+ Glazing analysis was subsequently superseded by comprehensive U_{total} vs. WWRxSHGC analysis (see Section 4.4.4)

4.5.3 Summary of Simulated Energy Performance Analysis

The significant results from the energy performance analysis for each archetype are summarised in Table 11, Table 12 and Table 13. The values indicated within the tables are the annual heating and cooling electrical energy savings per unit area (kWh/m²/year) in comparison to the baseline case. The results are based on an assumed heating and cooling coefficient of performance (COP) of 3.0. It is to be noted that while a majority of the values presented in these tables are from the Maximum Change in design factor, there are some instances where this was not the case.

Table 11. Significant results for Apartment Archetype (Unit - kWh/m²/year).

Impact	Climate Zone	Orientation			
		0˚	90˚	180˚	270˚
Highest 66%-100% of maximum impact	2	Thermal mass (1.26) Infiltration (1.14) Roller shutters (0.94)	Thermal mass (1.03)	Roller shutters (0.58) Thermal mass (0.55) infiltration (0.43)	Infiltration (0.93) Thermal mass (0.75)
	5	Infiltration (1.31)	Thermal mass (0.9) Infiltration (0.76)	Infiltration (0.79) Thermal mass (0.7)	Infiltration (1.35)
	6	Infiltration (4.67)	Infiltration (4.49)	Infiltration (4.61)	Infiltration (4.68)

Impact	Climate Zone	Orientation			
		0˚	90˚	180˚	270˚
Medium 33%- 66% of maximum impact	2	-	Infiltration (0.6) Roller shutters (0.55)	Ext. wall insulation (0.28)	Roller shutters (0.5) Ext. wall insulation (0.31)
	5	Thermal mass (0.68) Roller shutters (0.45)		Roller shutters (0.41) Ext. wall insulation (0.26)	Thermal mass (0.57)
	6				
Low <33% of maximum impact	2	Eaves (0.39) Ext. wall insulation (0.31) Ext. wall colour (0.06)	Ext. wall insulation (0.15) Eaves (0.13) Ext. wall colour (0.01)	Eaves (0.11) Ext. wall colour (0.06)	Eaves (0.22) Ext. wall colour (0.06)
	5	Ext. wall insulation (0.36) Eaves (0.1) Ext. wall colour (0.02)	Roller shutters (0.26) Ext. wall insulation (0.21) Eaves (0.02)	Eaves (0.02)	Ext. wall insulation (0.37) Roller shutters (0.36) Eaves (0.04)
	6	Ext. wall insulation (1.06) Thermal mass (0.9) Roller shutters (0.36)	Thermal mass (1.27) Ext. wall insulation (0.96) Roller shutters (0.33)	Ext. wall insulation (1.05) Thermal mass (0.95) Roller shutters (0.32)	Ext. wall insulation (1.09) Thermal mass (0.85) Roller shutters (0.25)
Negative Impact	2	-	Ext. wall colour (-0.02)	-	-
	5	Ext. wall colour (-0.06)	Ext. wall colour (-0.1) Eaves (-0.01)	Ext. wall colour (-0.11) Eaves (-0.06)	Ext. wall colour (-0.1) Eaves (-0.02)
	6	Eaves (-0.43) Ext. wall colour (-0.31)	Eaves (-0.56) Ext. wall colour (-0.36)	Eaves (-0.48) Ext. wall colour (-0.36)	Ext. wall colour (-0.29) Eaves (-0.23)

Table 12. Significant results for Attached Archetype (Unit - kWh/m^2/year).

Impact	Climate Zone	Orientation			
		0˚	90˚	180˚	270˚
Highest 66%- 100% of maximum impact	2	Ventilation (1.52)	Ventilation (2.06) Roller shutters (1.69)	Ventilation (1.42)	Ventilation (2.13)
	5	Infiltration (1.11)	Infiltration (1.16) Ventilation (1.10)	Ventilation (0.73) Infiltration (0.62)	
	6	Infiltration (4.06)	Infiltration (4.05)	Infiltration (3.94)	Infiltration (3.99)
Medium 33%- 66% of maximum impact	2	Infiltration (0.98)	Infiltration (1.47)	Infiltration (0.64)	Roller shutters (1.41) Infiltration (1.23)
	5	Ventilation (0.69)	Roller shutters (1.05)	-	Ventilation (1.08) Infiltration (0.96) Roller shutters (0.8)
	6	-	-	-	-

Impact	Climate Zone	Orientation			
		0˚	90˚	180˚	270˚
Low < 33% of maximum impact	2	Roller shutters (0.18) Ceiling insulation (0.14) Roof colour (0.1) Roof surface type (0.09) Thermal mass (0.09) Roof openness (0.07) Eaves (0.09) Ext. wall colour (0.06) Ext. wall insulation (0.06)	Eaves (0.53) Thermal mass (0.41) Ceiling insulation (0.19) Roof colour (0.16) Roof surface type (0.15) Ext. wall insulation (0.13) Ext. wall colour (0.13) Roof openness (0.07)	Roller shutters (0.13) Eaves (0.09) Roof surface type (0.08) Ceiling insulation (0.07) Roof colour (0.06) Ext. wall insulation (0.05) Ext. wall colour (0.02) Roof openness (0.01) Thermal mass (0.01)	Eaves (0.63) Thermal mass (0.3) Ceiling insulation (0.14) Ext. wall insulation (0.11) Ext. wall colour (0.07) Roof openness (0.03) Roof colour (0.03) Roof surface type (0.02)
	5	Thermal mass (0.11) Ext. wall insulation (0.12) Ceiling insulation (0.1) Roller shutters (0.1) Eaves (0.02) Roof openness (0.02)	Eaves (0.33) Ceiling insulation (0.21) Thermal mass (0.19) Ext. wall insulation (0.17) Roof type (0.08) Roof colour (0.07) Roof openness (0.06) Ext. wall colour (0.05)	Thermal mass (0.18) Ceiling insulation (0.14) Eaves (0.12) Roller shutters (0.1) Ext. wall insulation (0.09) Roof colour (0.07) Roof type (0.07) Roof openness (0.05) Ext. wall colour (0.03)	Eaves (0.36) Thermal mass (0.26) Ceiling insulation (0.20) Ext. wall insulation (0.12) Roof colour (0.02) Ext. wall colour (0.02) Roof openness (0.03) Roof type (0.03)
	6	Ceiling insulation (0.56) Under slab insulation (0.46) Ext. wall insulation (0.42) Thermal mass (0.31) Ventilation (0.2) Roller shutters (0.07)	Roller shutters (0.61) Ceiling insulation (0.56) Under slab insulation (0.53) Ext. wall insulation (0.46) Thermal mass (0.42) Ventilation (0.33)	Thermal mass (0.75) Under slab insulation (0.72) Ceiling insulation (0.7) Ext. wall insulation (0.42) Ventilation (0.21) Roller shutters (0.06)	Ceiling insulation (0.57) Roller shutters (0.5) Under slab insulation (0.48) Ext. wall insulation (0.44) Ventilation (0.38) Thermal mass (0.29)
Negative Impact	2	Underslab insulation (-0.51) Thermal mass (-0.21)	Underslab insulation (-0.21)	Underslab insulation (-0.33) Thermal mass (-0.16) Roof colour (-0.02) Roof surface type (-0.04) Roof openness (-0.01)	Underslab insulation (-0.41) Roof colour (-0.01) Roof surface type (-0.01)
	5	Underslab insulation (-0.44) Thermal mass (-0.25) Roof surface type (-0.08) Roof openness (-0.03) Roof colour (-0.02) Ext. wall colour (-0.02)	Underslab insulation (-0.29)	Underslab insulation (-0.22)	Underslab insulation (-0.33) Roof type (-0.01)

Impact	Climate Zone	Orientation			
		0˚	90˚	180˚	270˚
	6	Eaves (-0.9) Roof type (-0.21) Roof colour (-0.19) Ext. wall colour (-0.19) Roof openness (-0.06)	Eaves (-0.46) Roof surface type (-0.19) Roof colour (-0.18) Ext. wall colour (-0.09 Roof openness (-0.04)	Eaves (-0.48) Ext. wall colour (-0.15) Roof type (-0.14) Roof colour (-0.13)) Roof openness (-0.04)	Eaves (-0.41) Roof colour (-0.17) Ext. wall colour (-0.16) Roof type (-0.16) Roof openness (-0.09)

* Slab edge insulation results omitted, to be re-modelled in updated version of AccuRate Sustainability when available

Table 13. Significant results from Detached Archetype (Unit - kWh/m^2/year).

Impact	Climate Zone	Orientation			
		0˚	90˚	180˚	270˚
Highest 66%-100% of maximum impact	2		Ventilation (1.75) Infiltration (1.28)	Ventilation (2.03)	
	5				
	6	Infiltration (3.2)	Infiltration (3.28)	Infiltration (3.31)	Infiltration (3.29)
Medium 33%-66% of maximum impact	2	Ventilation (1.48) Roller shutters (1.4) Infiltration (1.18) Thermal mass (0.95)	Roller shutters (1.25) Thermal mass (0.81)	Roller shutters (1.43) Infiltration (1.3) Thermal mass (1.05)	Ventilation (1.98) Roller shutters (1.74) Infiltration (1.43)
	5	Infiltration (1.04) Ventilation (0.94) Roller shutters (0.82)	Ventilation (1.08) Infiltration (1.03) Roller shutters (0.79)	Infiltration (1.13) Ventilation (1.12) Roller shutters (0.81)	Infiltration (1.14) Ventilation (1.03) Roller shutters (0.93)
	6	-	-	-	-
Low < 33% of maximum impact	2	Eaves (0.62) Ext. wall insulation (0.42) Ceiling insulation (0.22) Roof colour (0.11) Ext. wall colour (0.09) Roof type (0.01)	Ext. wall insulation (0.44) Ceiling insulation (0.29) Eaves(0.19) Roof colour (0.15) Ext. wall colour (0.13) Roof type (0.06)	Eaves (0.63) Ext. wall insulation (0.49) Ceiling insulation (0.29) Roof colour (0.2) Ext. wall colour (0.09) Roof type (0.01)	Thermal mass (0.86) Eaves (0.67) Ext. wall insulation (0.54) Ceiling insulation (0.37) Roof colour (0.2) Ext. wall colour (0.13) Surface type (0.04) Roof openness (0)
	5	Thermal mass (0.67) Eaves (0.43) Ceiling insulation (0.39) Roof type (0.28) Ext. wall insulation (0.21) Roof colour (0.08)	Thermal mass (0.57) Eaves (0.45) Ceiling insulation (0.33) Ext. wall insulation (0.23) Roof surface type (0.22) Roof colour (0.13) Ext. wall colour (0.08)	Thermal mass (0.65) Eaves (0.4) Ceiling insulation (0.35) Roof type (0.23) Ext. wall insulation (0.18) Roof colour (0.11) Ext. wall colour (0.03)	Thermal mass (0.63) Eaves (0.5) Ceiling insulation (0.41) Ext. wall insulation (0.24) Roof type (0.23) Roof colour (0.09) Ext. wall colour (0.01)

	6	Ceiling insulation (1.05) Ext. wall insulation (0.68) Roller shutters (0.63) Thermal mass (0.26) Ventilation (0.26) Roof surface type (0)	Thermal mass (1.07) Ceiling insulation (1.06) Ext. wall insulation (0.7) Roller shutters (0.53) Ventilation (0.28) Roof surface type (0.01)	Ceiling insulation (1.10) Thermal mass (0.88) Ext. wall insulation (0.67) Roller shutters (0.48) Ventilation (0.24) Roof surface type (0)	Ceiling insulation (1.07) Thermal mass (0.98) Ext. wall insulation (0.68) Roller shutters (0.62) Ventilation (0.29) Roof surface type (0.01)
Negative impact	2	Underslab insulation (-3.56) Roof openness (-0.02)	Underslab insulation (-3.56) Large eaves (-0.38) Roof openness (-0.05)	Underslab insulation (-3.99) Roof openness (-0.04)	Underslab insulation (-3.76)
	5	Underslab insulation (-3.44) Roof openness (-0.02) Ext. wall colour (-0.01)	Underslab insulation (-3.27) Roof openness (-0.04) Thermal mass (-0.02) Roof colour (-0.02)	Underslab insulation (-3.33) Roof openness (-0.03) Roof colour (-0.01)	Underslab insulation (-3.26) Roof openness (-0.02) Ext. wall colour (-0.02)
	6	Underslab insulation (-1.73) Eaves (-0.39) Ext. wall colour (-0.33) Roof openness (-0.29) Roof colour (-0.09)	Underslab insulation (-1.58) Eaves (-0.39) Ext. wall colour (-0.25) Roof openness (-0.25) Roof colour (-0.06)	Underslab insulation (-1.43) Eaves (-0.56) Ext. wall colour (-0.39) Roof openness (-0.3) Roof colour (-0.11)	Underslab insulation (-1.46) Eaves (-0.38) Ext. wall colour (-0.31) Roof openness (-0.28) Roof colour (-0.08)

* Slab edge insulation results omitted, to be re-modelled in updated version of AccuRate Sustainability when available

4.5.4 Summary of Simulated Peak Load Analysis

Table 14. Apartment Archetype - Peak Load Improvement (Cooling) (Units - kW)

Impact	Climate Zone	Apartment Archetype Peak Load Improvement (Cooling)			
		0˚	90˚	180˚	270˚
Highest 66%- 100% of maximum impact	2			Thermal mass (0.41) Eaves (0.35)	
	5	Thermal mass (0.25)	Infiltration (0.9) Thermal mass (0.66)	Eaves (0.46) Thermal mass (0.4) Infiltration (0.33) Surface colour (0.31) Ext. wall ins. (0.3)	Thermal mass (0.51) Infiltration (0.48) Surface colour (0.48) Eaves (0.48) Ext. wall ins. (0.47)
	6		Roller shutters (0.25)	Ext. wall ins. (0.33) Thermal mass (0.31)	Thermal mass (0.31)
Medium 33%- 66% of maximum impact	2	Thermal mass (0.16)			Roller shutters (0.27) Thermal mass (0.2) Infiltration (0.19)
	5				Roller shutters (0.16)
	6		Eaves (0.13) Surface colour (0.13) Ext. wall ins. (0.13)	Infiltration (0.18)	
Low < 33% of maximum	2		Ext. wall ins. (0.04) Surface colour (0.04) Roller shutters (0)	Infiltration (0.15) Roller shutters (0.1) Ext. wall ins. (0.06) Surface colour (0.06)	Eaves (0.14) Surface colour (0.05) Ext. wall ins. (0.05)

impact	5	Ext. wall ins. (0.09) Infiltration (0.02)	Roller shutters (0.25) Surface colour (0.06) Ext. wall ins. (0.04) Eaves (0.04)		Roller shutters (0.07)
	6				Infiltration (0.06)
Negative Impact	2	Eaves (-0.26) Roller shutters (-0.19) Ext. wall ins. (-0.1) Surface colour (-0.09) Infiltration (-0.01)	Thermal mass (-0.39) Eaves (-0.28) Infiltration (-0.09)		
	5	Eaves (-0.39) Surface colour (-0.09) Roller shutters (-0.07)		Roller shutters (-0.11)	
	6	Thermal mass (-0.49) Eaves (-0.47) Ext. wall ins. (-0.39) Infiltration (-0.34) Roller shutters (-0.23) Surface colour (-0.09)	Thermal mass (-0.45) Infiltration (-0.11)	Eaves (-0.27) Roller shutters (-0.24) Surface colour (-0.14)	Surface colour (-0.39) Eaves (-0.39)

Table 15. Apartment Archetype - Peak Load Improvement (Heating) (Units - kW)

Impact	Climate Zone	Apartment Archetype Peak Load Improvement (Heating)			
		0˚	90˚	180˚	270˚
Highest 66%-100% of maximum impact	2	Infiltration (0.35) Thermal mass (0.23)	Infiltration (0.32)	Infiltration (0.37)	Infiltration (0.30)
	5	Infiltration (0.34)	Infiltration (0.35)	Infiltration (0.31)	Infiltration (0.30)
	6	Infiltration (0.44)	Infiltration (0.45)	Infiltration (0.43)	Infiltration (0.42)
Medium 33%-66% of maximum impact	2		Thermal mass (0.18)		Thermal mass (0.13)
	5	Thermal mass (0.18)	Thermal mass (0.17)	Thermal mass (0.13)	Thermal mass (0.13)
	6		Thermal mass (0.15)		Thermal mass (0.14)
Low < 33% of maximum impact	2	Ext. wall ins. (0.10) Ext. wall colour (0.00) Roller shutters (0.00)	Ext. wall ins. (0.09) Ext. wall colour (0.00) Roller shutters (0.00)	Ext. wall ins. (0.09) Thermal mass (0.10) Roller shutters (0.00)	Ext. wall ins. (0.09) Ext. wall colour (0.00) Roller shutters (0.00)
	5	Ext. wall ins. (0.07) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)	Ext. wall ins. (0.06) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)	Ext. wall ins. (0.06) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)	Ext. wall ins. (0.06) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)

	6	Thermal mass (0.14) Ext. wall ins. (0.07) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)	Ext. wall ins. (0.07) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)	Thermal mass (0.13) Ext. wall ins. (0.07) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)	Ext. wall ins. (0.07) Ext. wall colour (0.00) Eave extension (0.00) Roller shutters (0.00)
Negative Impact	2	Eave extension (-0.04) Ext. wall colour (-0.01)	Eave extension (-0.06) Ext. wall colour (-0.01)	Eave extension (-0.10) Ext. wall colour (-0.01)	Eave extension (-0.04) Ext. wall colour (-0.01)
	5	Eave extension (-0.02), Ext. wall colour (-0.01)	Eave extension (-0.01) Ext. wall colour (-0.01)	Eave extension (-0.01) Ext. wall colour (-0.01)	Eave extension (-0.01)
	6	Ext. wall colour (-0.01) Eave extension (-0.01)	Ext. wall colour (-0.01) Eave extension (-0.01)	Eave extension (-0.01)	Eave extension (-0.01)

Table 16. Attached Archetype – Peak Load Improvement (Cooling) (Units - kW)

Impact	Climate Zone	Attached Archetype Peak Load Improvement (Cooling)			
		0˚	90˚	180˚	270˚
Highest 66%-100% of maximum impact**	2				
	5				
	6				
Medium 33%-66% of maximum impact	2	Ventilation (0.32)	Roller shutters (1.15)	Infiltration (0.39)	
	5	Infiltration (0.23) Ventilation (0.23)			
	6	Thermal mass (0.5)	Roller shutters (0.95)	Ceiling ins. (0.45) Eaves (0.44)	
Low < 33% of maximum impact	2	Roller shutters (0.13) Roof type (0.07) Ceiling ins. (0.06) Roof colour (0.04) Roof openness (0.04) Ext. wall ins. (0.02) Ext. wall colour (0.02) Infiltration (0.01)	Eaves (0.27) Thermal mass (0.13) Ceiling ins. (0.1) Roof type (0.09) Roof colour (0.08) Roof openness (0.08) Ext. wall colour (0.03) Ext. wall ins. (0.03)	Ventilation (0.13) Ceiling ins. (0.1) Eaves (0.04) Ext. wall ins. (0.03) Ext. wall colour (0.03) Roof openness (0.03) Roller shutters (0.01)	Roller shutters (0.34) Eaves (0.2) Ceiling ins. (0.12) Roof colour (0.11) Roof type (0.11) Roof openness (0.07) Infiltration (0.05) Ext. wall colour (0.05) Ext. wall ins. (0.04)
	5	Roller shutters (0.03)	Ext. wall colour (0.17) Ext. wall ins. (0.15) Roller shutters (0.13)	Infiltration (0.11) Roof type (0.1) Roof colour (0.07) Roof openness (0.06) Eaves (0.04)	Roller shutters (0.4) Thermal mass (0.37) Eaves (0.12) Ventilation (0.04)

			Roof type (0.12) Roof colour (0.11) Ceiling ins. (0.08) Roof openness (0.07) Underslab ins. (0.03)	Roller shutter (0.01)	Roof colour (0.04) Roof type (0.03) Ceiling ins. (0.02) Ext. wall colour (0.01)
	6	Ventilation (0.46) Roof colour (0.45) Ceiling ins. (0.42) Infiltration (0.33) Eaves (0.05) Roof type (0.05) Roof openness (0.03) Ext. wall ins. (0.03) Ext. wall colour (0.01) Roller shutters (0.01)	Eaves (0.29) Roof colour (0.18) Roof openness (0.15) Ext. wall colour (0.03) Ext. wall ins. (0.03)	Roof openness (0.42) Ext. wall ins. (0.41) Ext. wall colour (0.41) Ventilation (0.39) Thermal mass (0.36) Infiltration (0.12) Roof colour (0.05) Roller shutters (0.04)	Ventilation (0.42) Infiltration (0.27) Eaves (0.27) Roller shutters (0.23) Ceiling ins. (0.22) Roof openness (0.21) Roof type (0.15) Roof colour (0.14) Ext. wall ins. (0.13) Ext. wall colour (0.12)
Negative Impact	2	Thermal mass (-0.36) Eaves (-0.1) Underslab ins. (-0.01)	Infiltration (-0.03) Underslab ins. (-0.1) Ventilation (-0.1)	Thermal mass (-0.27) Roof colour (-0.03) Roof type (-0.02) Underslab ins. (-0.1)	Thermal mass (-0.14) Underslab ins. (-0.14) Ventilation (-0.03)
	5	Thermal mass (-0.46) Underslab ins. (-0.45) Roof colour (-0.42) Roof type (-0.34) Ceiling ins. (-0.22) Eaves (-0.12) Ext. wall ins. (-0.12) Roof openness (-0.12) Ext. wall colour (-0.11)	Thermal mass (-0.36) Infiltration (-0.28) Ventilation (-0.12) Eaves (-0.1)	Underslab ins. (-0.41) Thermal mass (-0.27) Ventilation (-0.21) Ext. wall ins. (-0.12) Ext. wall colour (-0.12) Ceiling ins. (-0.05)	Underslab ins. (-0.12) Ext. wall ins. (-0.02) Infiltration (-0.01) Roof openness (-0.01)
	6	Underslab ins. (-0.62)	Underslab ins. (-0.51) Thermal mass (-0.48) Roof type (-0.35) Ceiling ins. (-0.22) Infiltration (-0.12) Ventilation (-0.01)	Underslab ins. (-0.7) Roof type (-0.05)	Underslab ins. (-0.47) Thermal mass (0.1)

* Slab edge insulation results omitted, to be re-modelled in updated version of AccuRate Sustainability when available

** Glazing was previously identified as having highest impact on peak cooling load. However, results have been removed as preliminary glazing analysis was subsequently superseded by more comprehensive approach (see Section 4.3.3).

Table 17. Attached Archetype – Peak Load Improvement (Heating) (Units - kW)

Impact	Climate Zone	Attached Archetype Peak Load Improvement (Heating)			
		0˚	90˚	180˚	270˚
Highest 66%-100% of maximum impact	2	Infiltration (0.3)	Infiltration (0.29)	Infiltration (0.28)	Infiltration (0.25)
	5	Infiltration (0.46)	Infiltration (0.44)	Infiltration (0.48)	Infiltration (0.44)
	6	Infiltration (0.52)	Infiltration (0.5)		
Medium 33%-66% of maximum impact	2				
	5				
	6			Infiltration (0.54)	Infiltration (0.49)
Low < 33% of maximum impact	2	Ceiling ins. (0.05) Ext. wall ins. (0.04) Roof openness (0.01) Ventilation (0.01) Roof type (0.01) Roof colour (0.01) Roller shutters (0)	Ceiling ins. (0.04) Ext. wall ins. (0.03) Roof openness (0.01) Ventilation (0) Roller shutters (0)	Ceiling ins. (0.06) Ext. wall ins. (0.03)	Thermal mass (0.07) Ceiling ins. (0.07) Ext. wall ins. (0.05) Underslab ins. (0.02) Roller shutters (0.01) Roof openness (0.01) Roof colour (0) Ventilation (0)
	5	Thermal mass (0.1) Ceiling ins. (0.05) Ext. wall ins. (0.04) Underslab ins. (0.01) Ventilation (0) Roller shutters (0)	Ceiling ins. (0.05) Ext. wall ins. (0.04) Ventilation (0) Roof openness (0) Roller shutters (0)	Ceiling ins. (0.07) Ext. wall ins. (0.05) Ventilation (0) Roof openness (0)	Thermal mass (0.06) Ceiling ins. (0.05) Ext. wall ins. (0.04) Underslab ins. (0.01) Ventilation (0) Roller shutters (0) Roof openness (0)
	6	Underslab ins. (0.07) Ceiling ins. (0.05) Ext. wall ins. (0.04) Roof colour (0.01) Roof type (0) Roof openness (0) Ventilation (0) Roller shutters (0)	Underslab ins. (0.06) Ceiling ins. (0.05) Ext. wall ins. (0.04) Roller shutters (0.01) Roof colour (0) Ext. wall colour (0) Roof openness (0) Ventilation (0) Roof type (0)	Underslab ins. (0.07) Ceiling ins. (0.05) Ext. wall ins. (0.04) Roof openness (0) Roof colour (0) Roller shutters (0) Ventilation (0) Ext. wall colour (0)	Underslab ins. (0.06) Ceiling ins. (0.05) Ext. wall ins. (0.04) Roof colour (0.01) Roller shutters (0) Roof openness (0) Ventilation (0) Ext. wall colour (0) Roof type (0)
Negative Impact	2	Thermal mass (-0.13) Eaves (-0.08) Underslab ins. (-0.03) Ext. wall colour (-0.01)	Thermal mass (-0.1) Eaves (-0.05) Underslab ins. (-0.05) Ext. wall colour (-0.01) Roof colour (-0.01) Roof type (-0.01)	Thermal mass (-0.11) Eaves (-0.03) Roof type (-0.02) Ventilation (-0.01) Roller shutters (-0.01)	Eaves (-0.03) Ext. wall colour (-0.01) Roof type (-0.01)

				Roof openness (-0.01) Ext. wall colour (-0.01) Roof colour (-0.01) Underslab ins. (-0.01)	
	5	Eaves (-0.04) Roof colour (-0.01) Ext. wall colour (-0.01) Roof openness (-0.01) Roof type (-0.01)	Thermal mass (-0.13) Eaves (-0.08) Ext. wall colour (-0.01) Roof type (-0.01) Roof colour (-0.01) Underslab ins. (-0.01)	Thermal mass (-0.11) Eaves (-0.03) Roof colour (-0.01) Underslab ins. (-0.01) Ext. wall colour (-0.01) Roof type (-0.01) Roller shutters (-0.01)	Eaves (-0.03) Roof type (-0.01) Roof colour (-0.01) Ext. wall colour (-0.01)
	6	Thermal mass (-0.08) Eaves (-0.02) Ext. wall colour (-0.01)	Thermal mass (-0.1) Eaves (-0.01)	Thermal mass (-0.07) Eaves (-0.01) Roof type (-0.01)	Thermal mass (-0.1) Eaves (-0.01)

* Slab edge insulation results omitted, to be re-modelled in updated version of AccuRate Sustainability when available

Table 18. Detached Archetype - Peak Load Improvement (Cooling) (Units - kW)

Impact	Climate Zone	Detached Archetype Peak Load Improvement (Cooling)			
		0˚	90˚	180˚	270˚
Highest 66%-100% of maximum impact	2		Thermal mass (0.92)		
	5				
	6				
Medium 33%-66% of maximum impact	2	Roller shutters (1.22)	Roller shutters (0.87) Infiltration (0.78)	Roller shutters (0.92)	Thermal mass (0.63)
	5		Roller shutters (1.06) Thermal mass (1.06) Infiltration (0.97)	Thermal mass (0.80)	Thermal mass (0.89)
	6				Infiltration (0.54) Roller shutters (0.47)
Low (< 33% of maximum impact)	2	Infiltration (0.64) Roof colour (0.52) Thermal mass (0.51) Ceiling insulation (0.48) Ext. wall colour (0.45) Eave extension (0.33) Roof type (0.21) Ceiling fan (0.12) Roof openness (0.08) Ext. wall ins. (0.05)	Eave extension (0.34) Roof colour (0.28) Ceiling fan (0.24) Ext. wall colour (0.21) Ext. wall ins. (0.20) Roof openness (0.20) Ceiling insulation (0.09) Roof type (0.06)	Thermal mass (0.35) Infiltration (0.27) Eave extension (0.24) Roof colour (0.11) Ext. wall colour (0.10) Roof type (0.09) Roof openness (0.09) Ceiling insulation (0.09) Ext. wall ins. (0.07) Ceiling fan (0.06)	Roller shutters (0.49) Ext. wall colour (0.19) Roof colour (0.15) Infiltration (0.15) Eave extension (0.15) Roof type (0.14) Ext. wall ins. (0.13) Roof openness (0.11) Ceiling insulation (0.11)
	5	Roller shutters (0.45) Thermal mass (0.43) Infiltration (0.36) Eave extension (0.15) Ceiling insulation (0.14) Ext. wall ins. (0.11) Ext. wall colour (0.10) Roof colour (0.09) Roof type (0.05)	Eave extension (0.26) Ceiling insulation (0.14) Ext. wall ins. (0.13) Ext. wall colour (0.13) Roof type (0.09) Roof colour (0.09) Roof openness (0.04)	Roller shutters (0.55) Infiltration (0.42) Eave extension (0.20) Ceiling insulation (0.14) Ext. wall ins. (0.12) Ext. wall colour (0.11) Roof type (0.10) Roof colour (0.09) Roof openness (0.04)	Roller shutters (0.37) Infiltration (0.39) Eave extension (0.18) Ext. wall colour (0.16) Ext. wall ins. (0.15) Ceiling insulation (0.14) Roof colour (0.09) Roof type (0.08) Roof openness (0.04)

		Roof openness (0.03)			
	6	Roller shutters (0.48) Thermal mass (0.43) Ceiling insulation (0.24) Eave extension (0.24) Ext. wall ins. (0.19) Infiltration (0.19) Roof colour (0.06) Ext. wall colour (0.05) Roof type (0.00) Roof openness (0.00)	Ceiling insulation (0.28) Ext. wall colour (0.24) Roller shutters (0.21) Ext. wall ins. (0.20) Roof colour (0.18) Ceiling fan (0.04) Roof type (0.00) Roof openness (0.00)	Ext. wall ins. (0.47) Roller shutters (0.45) Thermal mass (0.21) Ext. wall colour (0.12) infiltration (0.12) Ceiling insulation (0.02) Roof type (0.00) Roof openness (0.00)	Thermal mass (0.43) Ext. wall colour (0.25) Eave extension (0.13) Ceiling insulation (0.09) Ext. wall ins. (0.08) Roof colour (0.08) Roof openness (0.02) Roof type (0.01)
Negative Impact	2	Underslab ins. (-0.55)	Underslab ins. (-0.41)	Underslab ins. (-0.45)	Underslab ins. (-0.62) Ceiling fan (-0.37) Underslab ins. (-0.03) Thermal mass (-0.01)
	5	Underslab ins. (-0.70)	Underslab ins. (-0.63) Ceiling fan (-0.01) Thermal mass (-0.01)	Underslab ins. (-0.69) Ceiling fan (-0.03) Thermal mass (-0.03)	Underslab ins. (-0.69) Ceiling fan (-0.02) Thermal mass (-0.01)
	6	Underslab ins. (-1.12) Ceiling fan (-0.04) Thermal mass (-0.03) Roof openness (-0.01)	Underslab ins. (-1.43) Ext. wall colour (-0.33) Eave extension (-0.24) Infiltration (-0.20) Thermal mass (-0.18)	Underslab ins. (-1.28) Ceiling fan (-0.32) Ceiling ins. (-0.21) Eave extension (-0.14) Roof colour (-0.13) Ext. wall colour (-0.12) Thermal mass (-0.11)	Underslab ins. (-1.19) Thermal mass (-0.04) Ceiling fan (-0.03)

* Slab edge insulation results omitted, to be re-modelled in updated version of AccuRate Sustainability when available

Table 19. Detached Archetype - Peak Load Improvement (Heating) (Units - kW)

Impact	Climate Zone	Detached Archetype Peak Load Improvement (Heating)			
		0˚	90˚	180˚	270˚
Highest 66%-100% of maximum impact	2	Infiltration (0.58) Thermal mass (0.44)	Infiltration (0.58) Thermal mass (0.43)	Infiltration (0.58) Thermal mass (0.44)	Infiltration (0.57) Thermal mass (0.45)
	5	Infiltration (0.52)	Infiltration (0.52)	Infiltration (0.52)	Infiltration (0.52)
	6				
Medium 33%-66% of maximum impact	2		Ceiling insulation (0.21)	Ceiling insulation (0.21)	Ceiling insulation (0.21)
	5	Thermal mass (0.28)	Thermal mass (0.29)	Thermal mass (0.29)	Thermal mass (0.28)
	6	Infiltration (0.52)	Infiltration (0.52), Thermal mass (0.28)	Infiltration (0.53)	Infiltration (0.51)
Low < 33%	2	Ceiling insulation (0.21) Ext. wall ins. (0.12) Ceiling fan (0.00)	Ext. wall ins. (0.12) Roof colour (0.00) Ceiling fan (0.00)	Ext. wall ins. (0.11) Roof colour (0.00) Ceiling fan (0.00) Roller shutters (0.00)	Ext. wall ins. (0.12) Roof colour (0.00) Ceiling fan (0.00)

of maximum impact	5	Ceiling insulation (0.15) Ext. wall ins. (0.10) Roof colour (0.00) Ceiling fan (0.00) Roller shutters (0.00)	Ceiling insulation (0.15) Ext. wall ins. (0.09) Roof colour (0.00) Ceiling fan (0.00) Roller shutters (0.00)	Ceiling insulation (0.15), Ext. wall ins. (0.09), Roof colour (0.00), Ceiling fan (0.00), Roller shutters (0.00)	Ceiling insulation (0.15) Ext. wall ins. (0.10) Roof colour (0.00) Ceiling fan (0.00) Roller shutters (0.00)
	6	Thermal mass (0.27) Ceiling insulation (0.12) Ext. wall ins. (0.08) Ext. wall colour (0.00) Roof type (0.00) Roof colour (0.00) Ceiling fan (0.00) Eave extension (0.00) Roller shutters (0.00)	Ceiling insulation (0.12) Ext. wall ins. (0.08) Ext. wall colour (0.00) Roof type (0.00) Roof colour (0.00) Ceiling fan (0.00) Eave extension (0.00) Roller shutters (0.00)	Thermal mass (0.27) Ceiling insulation (0.12) Ext. wall ins. (0.07) Ext. wall colour (0.00) Roof type (0.00) Roof colour (0.00) Ceiling fan (0.00) Eave extension (0.00) Roller shutters (0.00)	Thermal mass (0.27) Ceiling insulation (0.11) Ext. wall ins. (0.07) Ext. wall colour (0.00) Roof type (0.00) Roof colour (0.00) Ceiling fan (0.00) Eave extension (0.00) Roller shutters (0.00)
Negative Impact	2	Underslab ins. (-1.39) Eave extension (-0.08) Roof openness (-0.06) Roof openness (-0.06) Ext. wall colour (-0.03) Roof type (-0.03) Roller shutters (-0.01)	Underslab ins. (1.39) Eave extension (-0.07) Roof openness (-0.06) Ext. wall colour (-0.03) Roof type (-0.03) Roof colour (-0.01) Roller shutters (-0.01)	Underslab ins. (-1.39) Eave extension (-0.07) Roof openness (-0.06) Ext. wall colour (-0.04) Roof type (-0.03) Roof colour (-0.01),	Underslab ins. (-1.36) Eave extension (-0.07) Roof openness (-0.06) Roof type (-0.04) Ext. wall colour (-0.03) Roof colour (-0.01) Roller shutters (-0.01)
	5	Underslab ins. (-1.03) Eave extension (-0.05) Roof openness (-0.04) Ext. wall colour (-0.02) Roof type (-0.02) Roof colour (-0.01)	Underslab ins. (-1.03) Eave extension (-0.05) Roof openness (-0.04) Ext. wall colour (-0.02) Roof type (-0.02) Roof colour (-0.01)	Underslab ins. (-1.02) Eave extension (-0.05) Roof openness (-0.04) Ext. wall colour (-0.03) Roof type (-0.02) Roof colour (-0.01)	Underslab ins. (-1.01) Eave extension (-0.05) Roof openness (-0.04) Ext. wall colour (-0.02) Roof type (-0.02) Roof colour (-0.01)
	6	Underslab ins. (-0.82) Roof openness (-0.03) Eave extension (-0.02) Ext. wall colour (-0.01)	Roof openness (-0.03) Ext. wall colour (-0.01) Eave extension (-0.01)	Underslab ins. (-0.82) Roof openness (-0.03) Eave extension (-0.02) Ext. wall colour (-0.01)	Underslab ins. (-0.82) Roof openness (-0.03) Eave extension (-0.02) Ext. wall colour (-0.01)

* Slab edge insulation results omitted, to be re-modelled in updated version of AccuRate Sustainability when available

4.6 Details of One-Dimensional Economic Analysis

The following sections provide a summary of the inputs and economic outcomes for each of the one dimensional scenarios analysed (from Section 4.5) including an outline of capital costs for implementation, benefit cost analysis results, and subsequent recommendations.

4.6.1 Infiltration

4.6.1.1 Capital Costs

Based on feedback from industry, the capital costs associated with improved infiltration control are nominal and are more associated with workmanship than capital works. As a result, capital costs are based on estimated costs for undertaking a blower door test only.

4.6.1.2 Benefit Cost Analysis

- **Attached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50	$ -		555	2.77				
Level 1	5.3 ACH at 50 Pa	$1,000	-$102	436	2.67	0.35	0.40	0.43	0.46

- **Attached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50	$ -		401	2.75				
Level 1	5.3 ACH at 50 Pa	$1,000	-$13	295	2.73	0.28	0.32	0.35	0.37

- **Attached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50	$ -		1,352	2.67				
Level 1	5.3 ACH at 50 Pa	$1,000	-$145	910	2.52	1.35	1.55	1.69	1.79

- **Detached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50 Pa	$ -		1,164	3.96				
Level 1	5.8 ACH at 50 Pa	$770	-$444	938	3.49	1.82	2.08	2.22	2.33

- **Detached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50 Pa	$ -		920	3.55				
Level 1	5.8 ACH at 50 Pa	$770	-$364	730	3.17	1.22	1.40	1.50	1.58

- **Detached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50 Pa	$ -		2,588	2.31				
Level 1	5.8 ACH at 50 Pa	$1,000	-$107	2,016	2.20	1.67	1.92	2.10	2.22

- **Apartment Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50 Pa	$ -		519	3.47				
Level 1	7 ACH at 50 Pa	$1,000	-$98	434	3.36	0.25	0.28	0.31	0.33

- **Apartment Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50 Pa	$ -		471	2.24				
Level 1	7 ACH at 50 Pa	$1,000	$9	355	2.25	0.30	0.34	0.38	0.40

- **Apartment Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	14.5 ACH at 50 Pa	$ -		1,466	2.08				
Level 1	7 ACH at 50 Pa	$1,000	-$20	958	2.06	1.35	1.55	1.70	1.80

4.6.1.3 Recommendations

Inclusion of infiltration improvements into additional stringency measures is recommended for all archetypes for CZ6 and for detached houses in CZ2 and CZ5.

It should also be noted that the scale of the savings from 15 ACH to 7 ACH is not sufficient to justify the $3,000+ cost of heat recovery ventilation associated with reducing the infiltration significantly below 7ACH. As a result we have not assessed infiltration rates below 7 ACH.

4.6.2 Wall Insulation

4.6.2.1 Capital Costs

The following underlying cost figures were used in the assessment of insulation, based on available retail costs for insulation.

- Expanded polystyrene batts used Foamex EPS Expanded Polystyrene Styroboard SL (price for coverage at required thicknesses estimated at $0.12/mm/m² based average costs of 4 products with differing thickness and batt coverage)

- Glass fibre batts used Bradford Gold Wall Batts (price for coverage at required thicknesses estimated at $0.04/mm/m² based average costs of 4 products with differing thickness and batt coverage)

- Polyurethane rigid foamed aged Knauf XPS Multi-Use Foam Board at (average price at $0.40/mm/m² based average costs of 4 products with differing thickness and batt coverage)

- Polyester batts used Bradford Polymax Wall Batts (price for coverage at required thicknesses estimated at $0.09/mm/m² based average costs of 8 products with differing thickness and batt coverage)

No learning rate has been applied to either performance or cost. The modelled costs for each insulation construction were as follows:

Detached		Attached	
R2.8	$14.18	R2.8	$14.18
R3.5	$23.38	R3.5	$23.38
R4.2	$31.38	R4.2	$31.38
R4.9	$39.38	R4.9	$39.38
R5.6	$48.98	R5.8	$51.38

Apartment							
CZ2				CZ5 & 6			
South walls		Other walls		South walls		Other walls	
R2.9	$14.18	R3.4	$22.18	R2.4	$10.58	R2.9	$14.18
R3.5	$22.98	R4.2	$32.58	R2.8	$14.18	R3.5	$22.98
R4.2	$32.58	R5	$41.38	R3.5	$22.98	R4.2	$32.58
R4.9	$40.18	R5.8	$50.58	R4.2	$30.58	R5	$40.18
R5.8	$50.58	R6.8	$61.38	R4.9	$39.38	R5.8	$50.58

4.6.2.2 Benefit Cost Analysis

Energy performance was calculated for each orientation. In order to obtain a suitable metric for assessment, the energy performance and peak demand are expressed as the average of the figures for each orientation. The benefit cost ratio is the then expressed in terms of this average, effectively expressing the average impact for the archetype across all orientations.

The performance of each scenario, averaged across the four orientations was as follows:

- **Attached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.8	$1,007		555	2.77				
Level 1	R3.5	$ 1,660	-$13	550	2.76	0.03	0.03	0.03	0.03
Level 2	R4.2	$ 2,228	-$19	548	2.75	0.02	0.02	0.03	0.03
Level 3	R4.9	$ 2,796	-$ 21	546	2.75	0.02	0.02	0.02	0.02
Level 4	R5.8	$3,648	-$ 28	546	2.74	0.01	0.02	0.02	0.02

- **Attached Archetype, Climate zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years

Base case	R2.8	$ 1,007		401	2.75				
Level 1	R3.5	$ 1,660	-$ 13	396	2.73	0.03	0.03	0.04	0.04
Level 2	R4.2	$ 2,228	-$6	393	2.74	0.03	0.03	0.03	0.03
Level 3	R4.9	$2,796	$20	390	2.77	0.02	0.03	0.03	0.03
Level 4	R5.8	$ 3,648	$ 22	387	2.77	0.02	0.02	0.02	0.03

- **Attached Archetype, Climate zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.8	$ 1,007		1,352	2.67				
Level 1	R3.5	$ 1,660	-$ 8	1,334	2.67	0.11	0.13	0.14	0.14
Level 2	R4.2	$ 2,228	-$ 139	1,321	2.53	0.12	0.13	0.14	0.14
Level 3	R4.9	$ 2,796	-$ 19	1,314	2.65	0.09	0.10	0.10	0.11
Level 4	R5.8	$ 3,648	-$ 127	1,304	2.54	0.08	0.09	0.09	0.09

- **Detached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.8	$ 2,192		1,164	3.96				
Level 1	R3.5	$ 3,613	-$303	1,101	3.64	0.23	0.26	0.27	0.28
Level 2	R4.2	$ 4,850	-$89	1,093	3.86	0.11	0.12	0.13	0.14
Level 3	R4.9	$ 6,086	-$70	1,091	3.88	0.08	0.09	0.09	0.10
Level 4	R5.6	$7,569	-$83	1,082	3.87	0.06	0.07	0.07	0.08

- **Detached Archetype, Climate zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.8	$2,192		920	3.55				
Level 1	R3.5	$3,613	-$47	904	3.50	0.05	0.05	0.05	0.06
Level 2	R4.2	$ 4,850	-$24	895	3.53	0.04	0.04	0.05	0.05
Level 3	R4.9	$6,086	-$65	890	3.48	0.03	0.03	0.04	0.04
Level 4	R5.6	$7,569	-$80	882	3.47	0.03	0.03	0.03	0.04

- **Detached Archetype, Climate zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.8	$ 2,192		2,588	2.31				
Level 1	R3.5	$ 3,613	-$40	2,539	2.27	0.14	0.16	0.17	0.18
Level 2	R4.2	$4,850	-$ 24	2,507	2.29	0.12	0.14	0.15	0.15
Level 3	R4.9	$5,856	-$ 379	2,486	1.92	0.13	0.14	0.15	0.15
Level 4	R5.6	$ 7,569	-$ 76	2,469	2.23	0.09	0.10	0.11	0.11

- **Apartment Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.9/R3.4	$1,637		342	3.47				
Level 1	R3.5/R4.2	$2,447	-$38	336	3.43	0.03	0.04	0.04	0.04
Level 2	R4.2/R5	$3,176	$ -	330	3.47	0.03	0.04	0.04	0.04
Level 3	R4.9/RR5.8	$3,889	-$85	327	3.38	0.03	0.03	0.03	0.04
Level 4	R5.8/RR6.8	$4,756	-$ 100	323	3.36	0.03	0.03	0.03	0.03

- **Apartment Archetype, Climate zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.9/R3.4	$1,077		311	2.24				
Level 1	R3.5/R4.2	$1,686	-$11	291	2.23	0.13	0.15	0.16	0.16
Level 2	R4.2/R5	$2,447	-$72	297	2.17	0.05	0.05	0.05	0.06
Level 3	R4.9/RR5.8	$3,063	-$134	289	2.10	0.05	0.05	0.06	0.06
Level 4	R5.8/RR6.8	$3,873	-$76	304	2.16	0.01	0.01	0.01	0.01

- **Apartment Archetype, Climate zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.9/R3.4	$1,077		968	2.08				
Level 1	R3.5/R4.2	$1,686	$ 9	942	2.09	0.17	0.19	0.20	0.21
Level 2	R4.2/R5	$2,447	-$72	939	2.01	0.09	0.10	0.11	0.11
Level 3	R4.9/RR5.8	$2,833	-$609	928	1.45	0.14	0.16	0.16	0.17
Level 4	R5.8/RR6.8	$3,873	-$47	948	2.03	0.03	0.03	0.03	0.04

The results indicate limited benefits for increased wall insulation.

4.6.2.3 Recommendations

No change in wall insulation stringency is recommended.

4.6.3 Wall Colour

4.6.3.1 Capital Costs

The following costs were used to determine the attached archetype cost benefit ratio:

Scenarios	Performance Value	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
Base Case	External render, 65%	$67.80	$50.16	$59.11
Level 1	50%, light green external render	$67.80	$50.16	$59.11

Level 2	30%, light cream	$67.80	$50.16	$59.11
Level 3	23%, white	$67.80	$50.16	$59.11
Number of units for construction cost:		72.42 m²		

No learning rate has been applied to either performance or cost.

4.6.3.2 Benefit Cost Analysis

Energy performance was calculated for each orientation. In order to obtain a suitable metric for assessment, the energy performance and peak demand are expressed as the average of the figures for each orientation. The benefit cost ratio is the then expressed in terms of this average, effectively expressing the average impact for the archetype across all orientations. Data for each individual orientation is provided in the Appendices.

The performance of each scenario, averaged across the four orientations was as follows:

- **Attached Archetype, Climate Zone 2**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		555	2.77				
Level 1	50%, light green external render	$ 4,910	-$11	553	2.76	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$4,910	-$19	551	2.75	0.00	0.00	0.00	0.00
Level 3	23%, white	$4,910	-$29	549	2.74	0.00	0.00	0.00	0.00

- **Attached Archetype, Climate zone 5**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		401	2.75				
Level 1	50%, light green external render	$3,633	-$ 11	401	2.74	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$3,633	-$ 4	399	2.74	0.00	0.00	0.00	0.00
Level 3	23%, white	$ 3,633	$17	401	2.77	0.00	0.00	0.00	0.00

- **Attached Archetype, Climate zone 6**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		1,352	2.67				
Level 1	50%, light green external render	$4,281	-$7	1,356	2.67	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$4,281	-$11	1,361	2.66	-0.01	-0.01	-0.01	-0.01
Level 3	23%, white	$4,281	-$132	1,366	2.54	-0.01	-0.01	-0.01	-0.01

- **Detached Archetype, Climate Zone 2**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		1,164	3.96				
Level 1	50%, light green external render	$10,740	-$31	1,160	3.92	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$10,740	-$194	1,156	3.76	0.00	0.00	0.00	0.00
Level 3	23%, white	$10,740	-$188	1,149	3.76	0.00	0.00	0.00	0.00

- **Detached Archetype, Climate zone 5**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		920	3.55				
Level 1	50%, light green external render	$ 7,945	-$ 42	919	3.51	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$7,945	$ -	919	3.55	0.00	0.00	0.00	0.00
Level 3	23%, white	$7,945	$85	913	3.64	0.00	0.00	0.00	0.00

- **Detached Archetype, Climate zone 6**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		2,588	2.31				
Level 1	50%, light green external render	$9,363	-$ 42	2,601	2.27	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$9,363	$ -	2,616	2.31	-0.01	-0.01	-0.01	-0.01
Level 3	23%, white	$9,363	$230	2,636	2.55	-0.01	-0.02	-0.02	-0.02

- **Apartment Archetype, Climate Zone 2**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		342	3.47				
Level 1	50%, light green external render	$10,740	-$47	341	3.42	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$10,740	$ -	340	3.47	0.00	0.00	0.00	0.00
Level 3	23%, white	$10,740	$78	340	3.55	0.00	0.00	0.00	0.00

- **Apartment Archetype, Climate zone 5**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		311	2.24				
Level 1	50%, light green the external render	$2,149	-$42	312	2.20	0.00	0.00	0.00	0.00
Level 2	30%, light cream	$2,149	$24	317	2.27	-0.01	-0.01	-0.01	-0.01
Level 3	23%, white	$2,149	$138	317	2.38	-0.01	-0.01	-0.01	-0.01

- **Apartment Archetype, Climate zone 6**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	External render, 65%	$ -		968	2.08				
Level 1	50%, light green the external render	$2,533	-$18	977	2.06	-0.01	-0.01	-0.01	-0.01
Level 2	30%, light cream	$2,533	$24	989	2.11	-0.02	-0.03	-0.03	-0.03
Level 3	23%, white	$2,763	$348	992	2.44	-0.02	-0.02	-0.03	-0.03

4.6.3.3 Recommendations

No wall colour measure is recommended.

4.6.4 Roof Insulation

4.6.4.1 Capital Costs

The following cost figures were used in the assessment of insulation, based on available retail costs for insulation.

- Expanded polystyrene batts used Foamex EPS Expanded Polystyrene Styroboard SL (price for coverage at required thicknesses estimated at $0.12/mm/m² based average costs of 4 products with differing thickness and batt coverage)
- Loose fill blown in cellulose (price for coverage estimated at $0.12/mm/m² based on $33 per bag that provides 6.5m² coverage at 100mm thickness plus $1,500 for machine blown in installation)
- Glass fibre batts used Bradford Polymax Ceiling Batts (price for coverage at required thicknesses estimated at $0.04/mm/m² based average costs of 8 products with differing thickness and batt coverage)

No learning rate has been applied to either performance or cost. The modelled costs for each insulation construction were as follows:

Table 20. Per m² insulation costs used for the analysis

Detached				Attached	
CZ2 & 5		CZ6		All zones	
R2.93	$14.98	R3.45	$16.00	R3.45	$16.00
R3.7	$16.50	R4.2	$17.52	R4.2	$17.52
R4.45	$18.03	R5.2	$19.55	R5.2	$19.55
R5.2	$19.55	R5.95	$21.07	R5.95	$21.07
R5.82	$20.82	R6.95	$23.10	R6.95	$23.10

4.6.4.2 Benefit Cost Analysis

Energy performance was calculated for each orientation. In order to obtain a suitable metric for assessment, the energy performance and peak demand are expressed as the average of the figures for each orientation. The benefit cost ratio is the then expressed in terms of this average, effectively expressing the average impact for the archetype across all orientations. Data for each individual orientation is provided in the Appendices.

The performance of each scenario, averaged across the four orientations was as follows:

- **Attached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.5	$2,840		555	2.77				
Level 1	R4.45	$3,294	-$35	547	2.74	0.07	0.08	0.09	0.09
Level 2	R5.3	$3,862	$ 0	542	2.77	0.05	0.06	0.06	0.06
Level 3	R6.6	$4,430	-$26	527	2.75	0.07	0.08	0.09	0.09
Level 4	R8.7	$ 5,140	-$52	543	2.72	0.02	0.02	0.03	0.03

- **Attached Archetype, Climate zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.5	$2,840		401	2.75				
Level 1	R4.45	$3,294	-$17	393	2.73	0.07	0.08	0.09	0.09
Level 2	R5.3	$3,862	$49	389	2.80	0.04	0.05	0.05	0.05
Level 3	R6.6	$4,430	$28	370	2.78	0.08	0.09	0.09	0.10
Level 4	R8.7	$5,140	$24	384	2.77	0.03	0.03	0.04	0.04

- **Attached Archetype, Climate zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.5	$2,840		1,352	2.67				
Level 1	R4.45	$3,294	-$210	1,322	2.46	0.49	0.54	0.57	0.59
Level 2	R5.3	$3,862	-$19	1,308	2.65	0.18	0.20	0.21	0.22
Level 3	R6.6	$4,430	-$ 95	1,291	2.58	0.17	0.18	0.20	0.20
Level 4	R8.7	$5,140	-$45	1,289	2.63	0.11	0.13	0.13	0.14

- **Detached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.93	$2,854		1,164	3.96				
Level 1	R3.7	$3,144	-$31	1,145	3.92	0.31	0.34	0.36	0.37
Level 2	R4.45	$3,434	-$62	1,132	3.89	0.25	0.28	0.30	0.31
Level 3	R5.2	$3,724	-$178	991	3.77	1.02	1.13	1.20	1.24
Level 4	R5.82	$3,966	-$172	955	3.78	0.91	1.01	1.07	1.11

- **Detached Archetype, Climate zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.93	$2,854		920	3.55				
Level 1	R3.7	$ 3,144	-$29	896	3.52	0.37	0.41	0.43	0.45
Level 2	R4.45	$3,434	-$48	879	3.50	0.31	0.34	0.37	0.38
Level 3	R5.2	$3,724	-$169	736	3.38	1.07	1.19	1.25	1.30
Level 4	R5.82	$3,736	-$415	698	3.12	1.94	2.15	2.25	2.32

- **Detached Archetype, Climate zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	R2.93	$2,854		2,588	2.31				
Level 1	R3.7	$3,144	-$31	2,516	2.28	1.13	1.25	1.32	1.37
Level 2	R4.45	$3,434	-$72	2,466	2.24	0.98	1.09	1.15	1.20
Level 3	R5.2	$3,494	-$616	2,323	1.67	43.54	48.15	34.87	31.36
Level 4	R5.82	$3,736	-$424	2,272	1.87	2.82	3.12	3.26	3.36

4.6.4.3 Recommendations

The results indicate that increased insulation has limited impact on energy use for the attached archetype, but a more significant impact for the detached archetype, supplemented by a significant demand impact. The implication is that detached houses would merit the highest level of insulation, while attached houses do not merit a change from the existing requirement. More work would be required to understand the reason for this difference. For the purposes of the trajectory analysis, Level 4 insulation is recommended for the detached archetype but no change is recommended for the attached archetype.

4.6.5 Roller Shutters

4.6.5.1 Capital Costs

Shutters used were manually powered aluminium/foam shutters. Prices were obtained for individual window sizes that ranged from $475 to $800 per window.

4.6.5.2 Benefit Cost Analysis

Energy performance was calculated for the building in each orientation, with shutters installed on specific windows only.

Attached Archetype, Climate Zone 2 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		555	2.77				
Level 1	Shutters installed	$2,338	-$291	508	2.47	0.06	0.07	0.08	0.08

Attached Archetype, Climate Zone 2 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		555	2.77				
Level 1	Shutters installed	$2,338	-$33	548	2.74	0.01	0.01	0.01	0.01

Attached Archetype, Climate Zone 2 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		555	2.77				
Level 1	Shutters installed	$2,338	-$29	519	2.74	0.04	0.05	0.05	0.05

Attached Archetype, Climate Zone 5 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		401	2.75				
Level 1	Shutters installed	$2,338	-$238	373	2.50	0.04	0.04	0.04	0.05

Attached Archetype, Climate Zone 5 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		401	2.75				
Level 1	Shutters installed	$2,338	$13	396	2.76	0.01	0.01	0.01	0.01

Attached Archetype, Climate Zone 5 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		401	2.75				
Level 1	Shutters installed	$2,338	-$181	379	2.56	0.03	0.03	0.03	0.04

Attached Archetype, Climate Zone 6 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		1,352	2.67				
Level 1	Shutters installed	$2,338	-$242	1,334	2.42	0.02	0.03	0.03	0.03

Attached Archetype, Climate Zone 6 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		1,352	2.67				
Level 1	Shutters installed	$2,338	$-	1,349	2.67	0.00	0.00	0.00	0.00

Attached Archetype, Climate Zone 6 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		1,352	2.67				
Level 1	Shutters installed	$2,338	-$62	1,339	2.61	0.01	0.02	0.02	0.02

Detached Archetype, Climate Zone 2 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		1,164	3.96				
Level 1	Shutters installed	$1,828	-$816	1,041	3.11	0.32	0.37	0.39	0.41

Detached Archetype, Climate Zone 2 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		1,164	3.96				
Level 1	Shutters installed	$2,288	$-	884	3.96	0.32	0.37	0.40	0.43

Detached Archetype, Climate Zone 2 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		1,164	3.96				
Level 1	Shutters installed	$2,288	-$205	852	3.74	0.39	0.45	0.49	0.52

Detached Archetype, Climate Zone 5 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		920	4.17				
Level 1	Shutters installed	$2,288	-$314	844	3.84	0.10	0.11	0.13	0.13

Detached Archetype, Climate Zone 5 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		920	4.17				
Level 1	Shutters installed	$2,288	-$58	898	4.11	0.03	0.03	0.03	0.03

Detached Archetype, Climate Zone 5 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		920	4.17				
Level 1	Shutters installed	$2,288	-$24	869	4.14	0.06	0.07	0.07	0.08

Detached Archetype, Climate Zone 6 West – Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		2,588	3.39				
Level 1	Shutters installed	$2,058	-$529	2,539	2.84	0.08	0.10	0.10	0.11

Detached Archetype, Climate Zone 6 North – Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		2,588	3.39				
Level 1	Shutters installed	$2,288	-$48	2,474	3.34	0.13	0.15	0.17	0.18

Detached Archetype, Climate Zone 6 East – Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		2,588	3.39				
Level 1	Shutters installed	$2,288	-$48	2,474	3.34	0.13	0.15	0.17	0.18

Apartment Archetype, Climate Zone 2 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		342	1.55				
Level 1	Shutters installed	$900	-$22	303	1.53	0.12	0.14	0.15	0.16

Apartment Archetype, Climate Zone 2 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		342	1.55				
Level 1	Shutters installed	$900	$18	326	1.57	0.05	0.05	0.06	0.06

Apartment Archetype, Climate Zone 2 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		342	1.55				
Level 1	Shutters installed	$900	$38	312	1.59	0.08	0.10	0.11	0.11

Apartment Archetype, Climate Zone 5 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		311	1.61				
Level 1	Shutters installed	$900	-$61	296	1.55	0.05	0.05	0.06	0.06

Apartment Archetype, Climate Zone 5 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		311	1.61				
Level 1	Shutters installed	$900	-$2	303	1.61	0.02	0.03	0.03	0.03

Apartment Archetype, Climate Zone 5 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		311	1.61				
Level 1	Shutters installed	$900	$60	300	1.67	0.03	0.03	0.04	0.04

Apartment Archetype, Climate Zone 6 West - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		968	1.13				
Level 1	Shutters installed	$900	$122	955	1.25	0.03	0.04	0.04	0.04

Apartment Archetype, Climate Zone 6 North - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$ -		968	1.13				
Level 1	Shutters installed	$ 900	$ 12	893	1.14	0.21	0.25	0.27	0.29

Apartment Archetype, Climate Zone 6 East - Cost Benefit Ratio

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No shutters	$-		968	1.13				
Level 1	Shutters installed	$900	$39	891	1.17	0.21	0.25	0.27	0.29

4.6.5.3 Recommendations

Based on the findings, roller shutters are not economic. We note however that this analysis is being reworked currently to assess roller shutters individually on each façade.

4.6.6 Roof Ventilation

4.6.6.1 Capital Costs

The capital costs for roof ventilation were as follows:

- Roof ventilators used are the 300mm CRS Edmonds Windmaster natural roof vents ($120 each).
- The eave vents are Haron 400mm x 200mm Aluminium vents ($21 – 2 pack).

- Installation labour of $160 for every 2 ventilators has been allowed for.

4.6.6.2 Benefit Cost Analysis

Energy performance was calculated for each orientation. In order to obtain a suitable metric for assessment, the energy performance and peak demand are expressed as the average of the figures for each orientation. The benefit cost ratio is the then expressed in terms of this average, effectively expressing the average impact for the archetype across all orientations. Data for each individual orientation is provided in the Appendices.

The performance of each scenario, averaged across the four orientations was as follows:

Attached Archetype, Climate Zone 2

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Standard	$ -		555	2.77				
Level 1	Ventilated	$442	-$35	552	2.74	0.03	0.03	0.03	0.03
Level 2	Highly Ventilated	$884	-$49	549	2.72	0.02	0.03	0.03	0.03

Attached Archetype, Climate Zone 5

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Standard	$ -		401	2.75				
Level 1	Ventilated	$442	$14	399	2.76	0.02	0.02	0.02	0.03
Level 2	Highly Ventilated	$884	-$3	399	2.74	0.01	0.01	0.01	0.01

Attached Archetype, Climate Zone 6

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Standard	$ -		1,352	2.67				
Level 1	Ventilated	$442	-$43	1,356	2.63	-0.05	-0.05	-0.06	-0.06
Level 2	Highly Ventilated	$884	-$191	1,357	2.48	-0.03	-0.04	-0.04	-0.04

Detached Archetype, Climate Zone 2

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Standard	$ -		1,164	3.96				
Level 1	Ventilated	$884	-$104	1,170	3.85	-0.03	-0.03	-0.03	-0.04
Level 2	Highly Ventilated	$1,768	-$ 87	1,169	3.87	-0.01	-0.01	-0.01	-0.01

Detached Archetype, Climate zone 5

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Standard	$ -		920	3.55				
Level 1	Ventilated	$884	-$76	923	3.47	-0.01	-0.02	-0.02	-0.02
Level 2	Highly Ventilated	$1,768	$48	924	3.60	-0.01	-0.01	-0.01	-0.01

Detached Archetype, Climate zone 6

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Standard	$ -		2,588	2.31				
Level 1	Ventilated	$884	$7	2,630	2.32	-0.20	-0.22	-0.23	-0.24
Level 2	Highly Ventilated	$1,768	$72	2,636	2.39	-0.11	-0.12	-0.13	-0.13

4.6.6.3 Recommendations

No stringency is recommended in this area as the impacts were variously trivial or negative.

4.6.7 Eaves Extension

4.6.7.1 Capital Costs

The capital costs for the attached architype eaves extension were as follows:

Scenarios	Performance Value	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
Base Case	Balcony 0.8 m overhang and eave 0.45 m length	$44.20	$37.60	$37.99
Level 1	Extend eaves to 0.56 m	$44.68	$36.10	$34.92
Level 2	Extend eaves to 0.68 m	$59.58	$48.14	$46.56
Level 3	Extend eaves to 0.8 m	$70.75	$57.17	$55.30
Level 4	Extend eaves to 1.2 m	$104.26	$84.24	$81.49
Number of units for construction cost:		19.4 m (attached), 69.4 m (detached)		

The capital costs for the detached architype eaves extension were as follows:

Scenarios	Performance Value	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
Base Case	Balcony 0.8 m overhang and eave 0.45 m length	$37.24	$30.09	$29.10
Level 1	Extend eaves to 0.56 m	$53.04	$45.12	$45.58
Level 2	Extend eaves to 0.68 m	$70.72	$60.16	$60.78
Level 3	Extend eaves to 0.8 m	$83.98	$71.44	$72.17
Level 4	Extend eaves to 1.2 m	$97.23	$82.72	$83.57
Number of units for construction cost:		19.4 m (attached) 69.4 m (detached)		

Costs are based on linear metres of eaves, no soffits, painted timber extensions, no barge board or gutters, no wall plates

4.6.7.2 Benefit Cost Analysis

Energy performance was calculated for each orientation.

The performance of each scenario was as follows:

- **Attached Archetype – Climate Zone 2 West**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		555	2.77				
Level 1	Eaves 1.2m length	$381	-$76	539	2.69	0.13	0.15	0.16	0.17

- **Attached Archetype – Climate Zone 2 North**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		555	2.77				
Level 1	Eaves 1.2m length	$381	$1	560	2.77	-0.04	-0.04	-0.05	-0.05

- **Attached Archetype – Climate Zone 2 East**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		555	2.77				
Level 1	Eaves 1.2m length	$381	-$26	533	2.74	0.16	0.18	0.20	0.21

- **Attached Archetype – Climate Zone 5 West**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		401	2.75				
Level 1	Eaves 1.2m length	$307	-$125	390	2.62	0.15	0.18	0.19	0.20

- **Attached Archetype – Climate Zone 5 North**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		401	2.75				
Level 1	Eaves 1.2m length	$307	$24	406	2.77	-0.04	-0.04	-0.05	-0.05

- **Attached Archetype – Climate Zone 5 East**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		401	2.75				
Level 1	Eaves 1.2m length	$307	-$72	382	2.67	0.22	0.25	0.27	0.29

- **Attached Archetype – Climate Zone 6 West**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		1,352	2.67				
Level 1	Eaves 1.2m length	$297	$159	1,349	2.84	0.02	0.02	0.02	0.02

- **Attached Archetype – Climate Zone 6 North**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		1,352	2.67				
Level 1	Eaves 1.2m length	$297	$131	1,365	2.81	-0.08	-0.09	-0.10	-0.11

- **Attached Archetype – Climate Zone 6 East**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		1,352	2.67				
Level 1	Eaves 1.2m length	$297	$88	1,343	2.77	0.06	0.07	0.07	0.08

- **Detached Archetype – Climate Zone 2 West**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		1,164	3.96				
Level 1	Eaves 1.2m length	$1,672	-$250	1,135	3.70	0.05	0.06	0.07	0.07

- **Detached Archetype – Climate Zone 2 North**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		1,164	3.96				
Level 1	Eaves 1.2m length	$1,672	-$104	1,155	3.85	0.01	0.02	0.02	0.02

- **Detached Archetype – Climate Zone 2 East**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		1,164	3.96				
Level 1	Eaves 1.2m length	$1,672	-$69	1,094	3.88	0.11	0.13	0.14	0.15

- **Detached Archetype – Climate Zone 5 West**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		920	4.17				
Level 1	Eaves 1.2m length	$1,423	-$57	893	4.11	0.05	0.06	0.06	0.07

- **Detached Archetype – Climate Zone 5 North**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		920	4.17				
Level 1	Eaves 1.2m length	$1,423	-$37	874	4.13	0.09	0.10	0.11	0.11

- **Detached Archetype – Climate Zone 5 East**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		2,588	3.39				
Level 1	Eaves 1.2m length	$1,437	-$79	2,553	3.30	0.07	0.08	0.08	0.09

- **Detached Archetype – Climate Zone 6 West**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		920	4.17				
Level 1	Eaves 1.2m length	$1,423	-$71	908	4.09	0.02	0.03	0.03	0.03

- **Detached Archetype – Climate Zone 6 North**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		2,588	3.39				
Level 1	Eaves 1.2m length	$1,437	-$10	2,577	3.38	0.02	0.02	0.03	0.03

- **Detached Archetype – Climate Zone 6 East**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	Eaves 0.45m length	$-		2,588	3.39				
Level 1	Eaves 1.2m length	$1,437	-$10	2,577	3.38	0.02	0.02	0.03	0.03

4.6.7.3 Recommendations

None of the scenarios appears cost effective. However it is noted that the analysis is being reworked to examine the effect of increasing the width of eaves in individual orientations; this may yield some cost-effective scenarios.

4.6.8 Slab Edge Insulation

4.6.8.1 Capital Costs

Insulation materials were represented as expanded polystyrene board, with costs of $2.32/m² for R0.5 and $4.53/m² for R1.0. The slab perimeter was 33m for the attached house and 64m for the detached house; insulation depth was 0.5m.

4.6.8.2 Benefit Cost Analysis

The results for slab edge insulation have been withdrawn owing to errors in the AccuRate package representation of slab performance. Results will be made available once updates to the simulation package have been received and models rerun.

4.6.8.3 Recommendations

Recommendations will be made available once updates to the simulation package have been received and models rerun.

4.6.9 Thermal Mass

4.6.9.1 Capital Costs

The capital costs for the attached architype thermal mass were as follows:

Scenarios	Performance Value	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
Base Case	200 mm concrete and carpet, brick veneer	$385.20	$416.54	$443.91
Level 1	200 mm concrete and carpet, brick veneer, Reverse brick veneer	$455.66	$484.77	$517.10
Level 2	Increase concrete floor to 300mm and leave it expose	$347.83	$368.31	$380.31
Level 3	300 mm exposed concretes floors and reverse brick veneer	$381.66	$397.62	$421.75
Number of units for construction cost:		122.34 m^2 (attached)		

The capital costs for the detached architype thermal mass were as follows:

Scenarios	Performance Value	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
Base Case	200 mm concrete and carpet & brick veneer	$270.63	$296.06	$313.79
Level 1	400 mm concrete and carpet & brick veneer	$333.16	$362.72	$391.89
Level 2	200 mm concrete and carpet & reverse brick veneer	$315.44	$334.87	$368.68
Level 3	400 mm concrete and carpet & reverse brick veneer	$377.98	$401.54	$446.78
Number of units for construction cost:		202.04 m^2 (detached)		

The capital costs for the apartment architype thermal mass were as follows:

Scenarios	Performance Value	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
Base Case	200 mm concrete and carpet, Brick veneer	$403.68	$431.51	$450.27
Level 1	200 mm concrete and carpet, Reverse brick veneer	$435.46	$459.04	$489.19
Level 2	Increase concrete floor to 300mm and leave it expose	$366.69	$386.03	$403.03
Level 3	300 mm exposed concretes floors and reverse brick veneer	$398.47	$413.56	$441.96
Number of units for construction cost:		77.06 m^2 (apartment)		

4.6.9.2 Benefit Cost Analysis

Energy performance was calculated for each orientation. In order to obtain a suitable metric for assessment, the energy performance and peak demand are expressed as the average of the figures for each orientation. The benefit cost ratio is the then expressed in terms of this average, effectively expressing the average impact for the archetype across all orientations.

The performance of each scenario, averaged across the four orientations was as follows:

- **Attached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet, brick veneer	$47,125		555	2.77				

Level 1	200 mm concrete and carpet, reverse brick veneer	$55,745	$14	543	2.79	0.01	0.01	0.01	0.01
Level 2	Increase concrete floor to 300mm and leave it expose	$50,506	$ 181	555	2.96	0.00	0.00	0.00	0.00
Level 3	300 mm exposed concretes floors and reverse brick veneer	$54,644	$123	538	2.90	0.01	0.01	0.01	0.01

- **Attached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet, brick veneer	$50,960		401	2.75				
Level 1	200 mm concrete and carpet, reverse brick veneer	$59,307	$68	398	2.82	0.00	0.00	0.00	0.00
Level 2	Increase concrete floor to 300mm and leave it expose	$53,011	$208	387	2.96	0.03	0.03	0.03	0.03
Level 3	300 mm exposed concretes floors and reverse brick veneer	$56,597	$150	387	2.90	0.01	0.01	0.01	0.01

- **Attached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet, brick veneer	$54,308		1,352	2.67				
Level 1	200 mm concrete and carpet, reverse brick veneer	$63,262	-$298	1,344	2.36	0.00	0.00	0.00	0.00
Level 2	Increase concrete floor to 300mm and leave it expose	$54,479	$153	1,315	2.83	0.46	0.51	0.55	0.57
Level 3	300 mm exposed concretes floors and reverse brick veneer	$59,549	-$131	1,310	2.54	0.03	0.04	0.04	0.04

- **Detached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet & brick veneer	$54,678		1,164	3.96				
Level 1	400 mm concrete and carpet & brick veneer	$67,312	-$56	1,166	3.90	0.00	0.00	0.00	0.00
Level 2	200 mm concrete and carpet & reverse brick veneer	$63,501	-$ 581	1,004	3.35	0.08	0.09	0.09	0.10
Level 3	400 mm concrete and carpet & reverse brick veneer	$76,137	-$574	1,008	3.36	0.03	0.03	0.04	0.04

- **Detached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet & brick veneer	$59,816		920	3.55				
Level 1	400 mm concrete and carpet & brick veneer	$73,284	$ 42	919	3.59	0.00	0.00	0.00	0.00
Level 2	200 mm concrete and carpet & reverse brick veneer	$67,657	$ -	810	3.55	0.06	0.06	0.07	0.07
Level 3	400 mm concrete and carpet & reverse brick veneer	$ 81,127	-$281	810	3.26	0.02	0.02	0.03	0.03

- **Detached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet & brick veneer	$63,398		2,588	2.31				
Level 1	400 mm concrete and carpet & brick veneer	$79,177	$49	2,537	2.36	0.01	0.01	0.02	0.02
Level 2	200 mm concrete and carpet & reverse brick veneer	$74,488	-$24	2,501	2.29	0.03	0.04	0.04	0.04
Level 3	400 mm concrete and carpet & reverse brick veneer	$90,267	-$129	2,459	2.18	0.02	0.02	0.02	0.02

- **Apartment Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet, Brick veneer	$31,108		342	4.06				
Level 1	200 mm concrete and carpet, reverse Brick veneer	$33,557	$98	291	4.16	0.08	0.09	0.10	0.10
Level 2	Increase concrete floor to 300mm and leave it expose	$33,266	-$149	313	3.90	0.06	0.07	0.07	0.07
Level 3	300 mm exposed concretes floors and reverse brick veneer	$35,715	-$136	277	3.92	0.06	0.07	0.07	0.07

- **Apartment Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet, Brick veneer	$33,252		311	1.00				
Level 1	200 mm concrete and carpet, reverse Brick veneer	$35,374	-$96	271	0.90	0.08	0.09	0.09	0.10
Level 2	Increase concrete floor to 300mm and leave it expose	$34,756	-$74	287	0.93	0.07	0.08	0.08	0.08

Level 3	300 mm exposed concretes floors and reverse brick veneer	$36,878	-$145	259	0.85	0.06	0.07	0.07	0.07

- **Apartment Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	200 mm concrete and carpet, Brick veneer	$34,698		968	1.46				
Level 1	200 mm concrete and carpet, reverse Brick veneer	$37,697	-$100	918	1.35	0.07	0.08	0.08	0.09
Level 2	Increase concrete floor to 300mm and leave it expose	$36,066	-$50	928	1.41	0.12	0.14	0.15	0.15
Level 3	300 mm exposed concretes floors and reverse brick veneer	$39,066	-$134	896	1.32	0.07	0.08	0.08	0.09

4.6.9.3 Recommendations

The thermal mass scenarios do not show an energy saving and do not provide a substantive peak demand benefit. As a result, no modification to stringency is recommended.

4.6.10 Lighting

4.6.10.1 Capital Costs

Lighting design for each of the archetypes assumed that CFL technology was used in the base case line scenarios, and that LED technologies were used in the improved design factors. Since the same luminaire was used throughout all models with just the lamp being replaced, luminaire pricing remained consistent throughout all models at $70.

Lamp pricing was referenced from Bunnings website as of October 2017.

Osram and Philips lamps tend to cost the same so we assumed the 11W and 13W Osram lamps used in the original model would cost the same as the 15W Philips lamps on the Bunnings website- $6.49 including GST.

https://www.bunnings.com.au/philips-15w-cool-white-bc-tornado-spiral-globe-cfl_p4320539

LED case – pricing and lumen output referenced from Bunnings website - $7.95 + GST

Osram 10W 1050lm B22d Warm White 114mm long LED Value stick

https://www.bunnings.com.au/osram-10w-1050lm-warm-white-led-value-stick-b22d-globe_p4320899

Osram 7W 700lm B22d Warm White 114mm long LED Value stick

https://www.bunnings.com.au/osram-7w-700lm-warm-white-led-value-stick-b22d-globe_p4320892

The cost benefit analysis compares a base case of compact fluorescent lamps (CFL) which are in common use in 2017, to an LED case which is in increasing use in 2017 and is on track to become the dominant lighting technology used in residential buildings.

Simulations were conducted to find the energy consumption and lighting power density (LPD) of each archetype for the base case and the LED case. To calculate kWh the NatHERS protocol for individual room type's hours of use were applied.

4.6.10.2 Learning Rates

Pricing learning rates for the residential lighting benefit cost analysis were based on analysis done previous by Energy Action for the purposes of Section J Lighting measures development, based on a survey of 13 luminaire manufacturers comparing 394 LED luminaires. The luminaire types included and compared in the survey were:

- Diffused battens
- Recessed troffers
- Down lights
- High bays

Pricing, lumen output and power consumption data was surveyed for all luminaires using archived and current price lists, IES files and data sheets and tables filled in by suppliers, covering the years 1999 – 2017. Some predictions were provided by 2 suppliers for the years 2018 and 2019.

The data from this survey was graphed and the percentage figure for the learning rates were calculated based on the trend line created from the historical data for each of the following technology groups:

- Linear battens and troffers
- Down lights
- High bays

This report uses the results produced for down lights as down lights are the most commonly used luminaire type in residential lighting. The graphs and description of the analysis from the report are provided below.

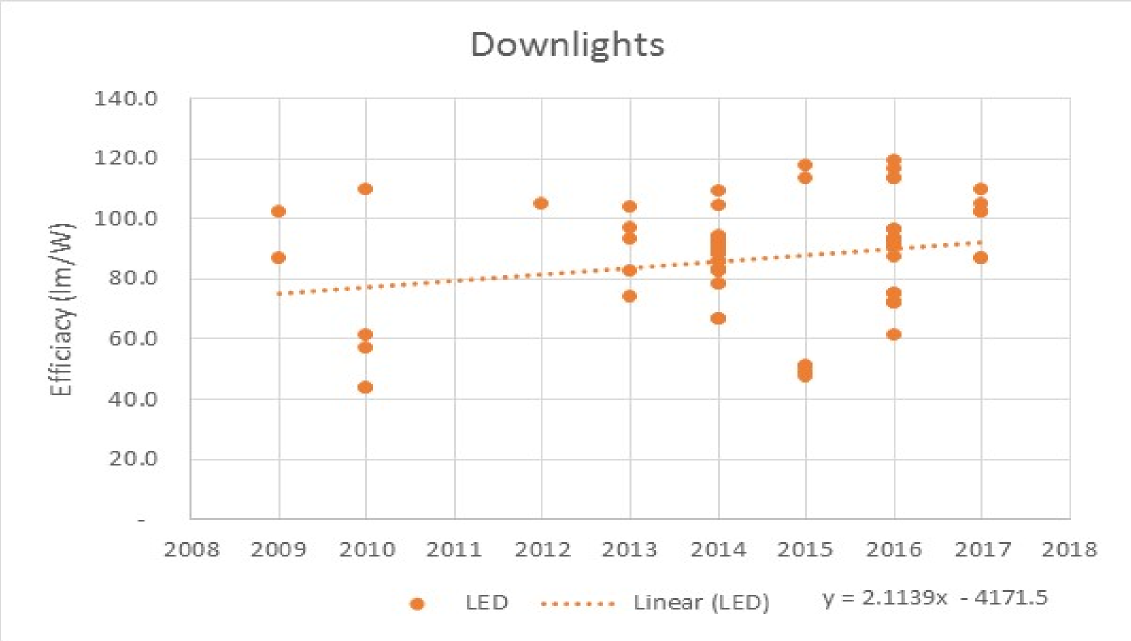


Figure 4: Pricing learning rate for LED down lights over time

According to the graph in Figure 4 the price of LED down lights is dropping at a rate of $0.075 per lumen, per year equivalent to 11% p.a. Based on this the projected price reduction by 2021 would be 37%. We have conservatized this to 30%.

The 30% decrease in the cost has been applied to the residential lighting analysis for the first 5 years, with the expectation that the cost would plateau after that.

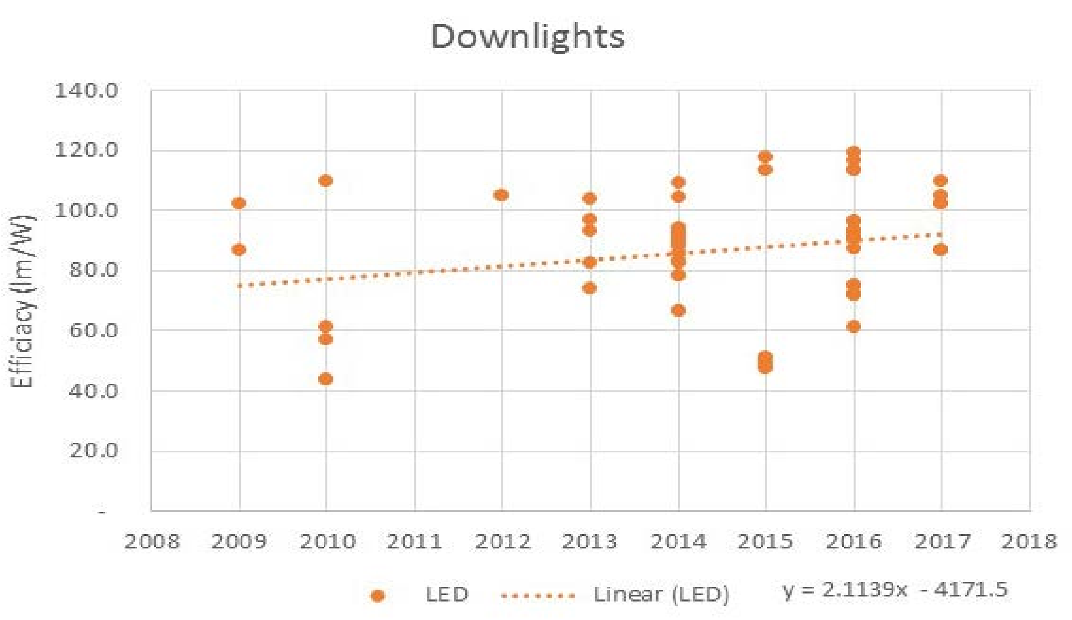


Figure 5: Efficacy learning rate for LED down lights over time

According to the graph in Figure 5, the efficacy of LED down lights is improving at a rate of 2 lumens per Watt, per year. This is equivalent to a 2021 learning rate of 9% relative to 2017.

4.6.10.3 Energy Consumption and Savings

As the NatHERS protocol specifies a set lighting schedule for individual room types, it was adopted for the purposes of this study. Lighting was assumed to remain unchanged through different orientations and climate zones. Table 21 summarises the annual lighting electrical energy consumption for CFL and LED technologies.

Table 21. Lighting annual energy demand for CFL and LED technologies for each archetype.

	Design Technology	Details	Lighting Power Density (W/m^2)	Annual Energy (kWh/year)	Annual Energy Density ($kWh/m^2/year$)
Apartment	CFL (MF 0.8)	21 x 13W oysters on ceiling, 6 x 11W wall lights	4.25	270	3.48
	LED (MF 0.7)	LED: 21 x 10W oysters on ceiling, 6 x 7W wall lights	3.22	203	2.61
	Savings ($kWh/m^2/year$)				0.87
Attached	CFL (MF 0.8)	Ground: 15 x 20W oysters on ceiling, 5 x 12W oysters on walls. 1st floor: 10 x 20W oysters on ceiling, 7 x 12W oysters on walls	4.4	429	3.1
	LED (MF 0.7)	Ground: 15 x 16W oysters on ceiling, 5 x 7W oysters on walls. 1st floor: 10 x 16W oysters on ceiling, 7 x 7W oysters on walls	3.3	322	2.3
	Savings ($kWh/m^2/year$)				0.77
Detached	CFL (MF 0.8)	37 x 20W oysters on ceiling, 8 x 12W oysters on walls	4.4	351	1.9
	LED (MF 0.7)	37 x 16W oysters on ceiling, 8 x 7W oysters on walls	3.4	266	1.4
	Savings ($kWh/m^2/year$)				0.46

4.6.10.4 Benefit Cost Analysis

The results of the simulation and cost benefit analysis are shown in Table 22.

Table 22. Results of lighting benefit cost analysis. Note that the results do not include allowance for the 9% projected efficiency improvement in LEDs; inclusion of this, however, has no significant impact to the overall outcome.

	Apartment	Detached House	Attached House
Today	negative cost	0.53	0.74
5 years	negative cost	negative cost	negative cost
10 years	negative cost	negative cost	negative cost
15 years	negative cost	negative cost	negative cost

The results indicate that it is not cost effective to install LED in a residential building instead of CFL today, but that it will become cost effective within the next 5 years. The negative cost for apartments today is driven by a reduction in network demand; actual upfront capital costs are very marginally higher for the LED option than the CFL option.

4.6.10.5 Recommendations

It is recommended that the current stringency for lighting (5W/m²) is maintained for the next code upgrade, but that this should be dropped by 25% (3.75W/m²) from 5 years onwards. Further increases in stringency will need to reflect the availability of improved LED sources 10 to 15 years into the future. Predictions prepared for the US DOE[23] indicate that LED downlight luminaires are predicted to reduce in energy consumption by 75% over the period 2015-2035, with prices reducing by 50-60% over the same period. For the purpose of future trajectory work we have simplified this to a 20% reduction in energy per lumen in 5 years, 40% in 10 years and 60% in 15 years, with a 30% reduction in cost per lumen in 5 years, 40% in 10 years and 50% in 15 years.

4.6.11 Domestic Hot Water

Domestic hot water is a significant energy use within Australian homes, and indeed is dominant in mild climates where heating and cooling needs are limited. Australian homes currently use a mix of technologies for domestic hot water, including:

- Electric storage
- Instantaneous electric
- Gas storage
- Instantaneous gas
- Electric heat pump
- Solar – electric boosted
- Solar – gas boosted

For the purposes of this study, only electric options are being considered as this enables many building types to become net zero emission buildings through the use of PV. This however is only a reflection of the scenario development process and is not a recommendation against gas DHW *per se*. A full Code development process would need to properly address the complex issues of the electricity/gas question.

4.6.11.1 Scenario Formulation

The available electric DHW technologies have been characterised as listed in Table 23.

Table 23. Electric DHW technologies considered. Efficiency COP is the number of units of hot water produced per unit of energy put in, not including standing losses. It is noted that the actual efficiency of solar varies widely based on the installation and climate zone, and the efficiency of heat pump units is temperature dependent.

Technology	Description	Effective Efficiency (COP)
Electric storage	Direct electric heating elements in a storage tank.	1.0
Standard Heat Pump	HCFC refrigerant heat pump with storage tank. Examples: Rheem MPi series	3.0
High Performance Heat Pump	CO2 refrigerant heat pump with storage tank. Examples: Sanden EcoPlus	4.5
Solar with electric boost	Roof mounted solar panel/storage tank unit. Examples: Rheem Hiline series	4.0

[23] Energy Savings Forecast of Solid State Lighting in General Illumination Applications Prepared by Navigant Consulting Inc for US Department of Energy, September 2016. https://energy.gov/sites/prod/files/2016/10/f33/energysavingsforecast16_0.pdf

For the townhouse and detached house archetypes, all of the nominated technologies are viable. For apartments, however, only direct electric heating is viable as a technology for DHW on an individual apartment basis; other technologies require a centralised system (which is common practice, albeit typically gas fired, in larger apartment buildings). As it is beyond the scope of this study to assess centralised DHW versus individual unit DHW, and as it is possible for heat pump and solar technologies to be used with centralised systems, we have elected not to analyse DHW for apartments, and instead extrapolate the results for the other archetypes to the apartment case.

Assuming a townhouse occupancy of 3 persons and a detached house occupancy of 5 persons, both can be served adequately using a system of any technology with approximately 300-325 litre storage. Costs vary but based on a survey of prices available on the web it is possible to characterise costs as follows:

Technology	Sample System	Capital Cost
Electric storage	3.6kW direct electric heating elements in a 315 litre storage tank.	$1,200
Standard Heat Pump	R134a heat pump plus 3.6kW booster elements in a 325 litre storage	$3,000
High Performance Heat Pump	CO_2 pump with 315 litre storage tank	$4,800
Solar with electric boost	300 litre roof mounted solar panel/storage tank unit with 3.6kW boost.	$4,500

Based on work by Whaley et al, annual standing losses from storage systems have been estimated at around 1.8kWh/day. The same reference identifies average hot water use as 39 litre per person per day; for the purposes of the current calculation, a 40°C temperature rise has been assumed. In practice this varies with inlet temperature and thus with climate zone; however this is a second order factor and has been disregarded for the purpose of the current calculation.

Based on these assumptions the calculated energy use figures are as shown in Table 24 and Table 25.

Table 24. DHW energy use calculations for the townhouse

Technology	Annual water use (litres)	Water use energy (kWh_e)	Standing losses (kWh_{th})	Standing losses (kWh_e)	Annual energy use (kWh_e)
Direct Elec	42705	1993	664	664	2657
Standard HP	42705	664	664	221	886
Hi Perf HP	42705	443	664	148	590
Solar DHW	42705	498	664	166	664

Table 25. DHW calculations for the detached house.

Technology	Annual water use (litres)	Water use energy (kWh_e)	Standing losses (kWh_{th})	Standing losses (kWh_e)	Annual energy use (kWh_e)
Direct Elec	71175	3322	664	664	3986
Standard HP	71175	1107	664	221	1329
Hi Perf HP	71175	738	664	148	886
Solar DHW	71175	830	664	166	996

It is noted that there is a significant difference in the peak demand from each of these systems. However, as all are typically connected to ripple or off-peak control, no allowance has been included in the economic analysis for the impacts on network infrastructure.

A 15 year lifespan has been assumed for all systems.

4.6.11.2 Results – Baseline Analysis

All three upgraded technologies are cost effective relative to direct electric heating, as shown in Figure 6.

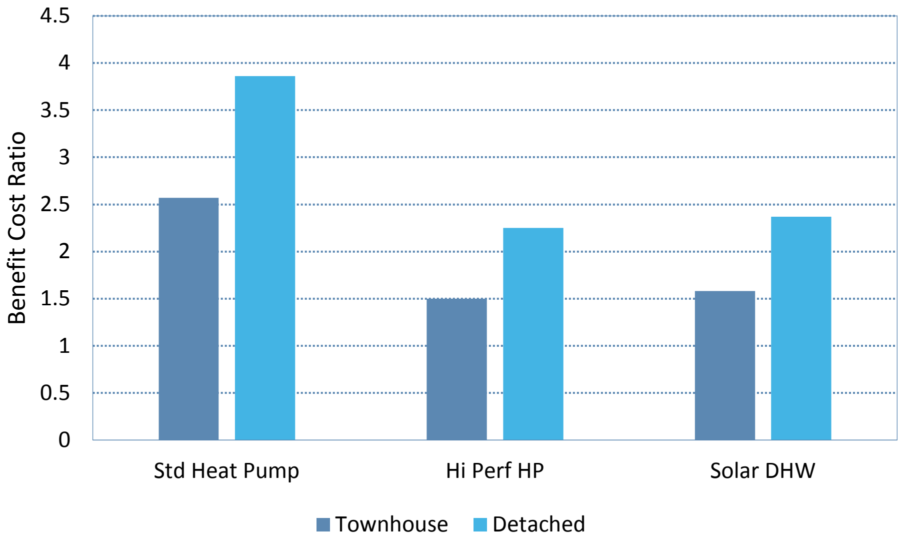


Figure 6. Benefit cost results for DHW technologies relative to direct electric.

However, the cost benefit for high performance heat pumps and solar DHW relative to standard heat pump is not attractive, at 0.43/0.39 (HP/solar respectively) for townhouses and 0.64/0.58 for the detached house. As NCC 2016 DTS largely (but not totally) proscribes the use of direct electric heating for hot water[24], the standard heat pump is a more suitable baseline for economic assessment.

Based on these results, the appropriate level of stringency for DHW based on current economics is taken to be that of standard heat pump technology. Under today's economic conditions, the unit cost for the high efficiency heat pump would have to drop from $4,800 to $3,750 to become economic relative to a standard heat pump.

4.6.11.3 Future Economic Scenarios

The high performance heat pump currently carries a significant (60%) price premium relative to the standard heat pump, and yet comprises essentially the same technological components while using a different refrigerant (albeit at higher pressure).

[24] Section BP2.8(b) of the Plumbing Code rules out the use of direct electricity for domestic hot water heating unless there are no alternatives, but only for Class 1 and 10 buildings. Class 2 buildings (apartments) do not have this limitation and thus can use direct electric heating

However, it is reasonable to expect that the real cost of the high performance heat pump will reduce significantly as production volumes and market competition increase. Given the 85% phase down of R134a over the next 20 years, it is reasonable to project that the current R134a technology will be phased out of the market and gradually replaced with the higher performance CO_2 units. As there are few technical differences between the R134a and CO_2 systems, it is expected that the vast majority of the current rice difference is due to supply and scale issues rather than inherent technical cost. As a result, it is projected that the cost of the high performance units will reduce to approximately 110% of the standard heat pump over the next 10 years. Based on this assertion, a price path has been derived and the forward economic scenarios developed, as shown in Figure 7.

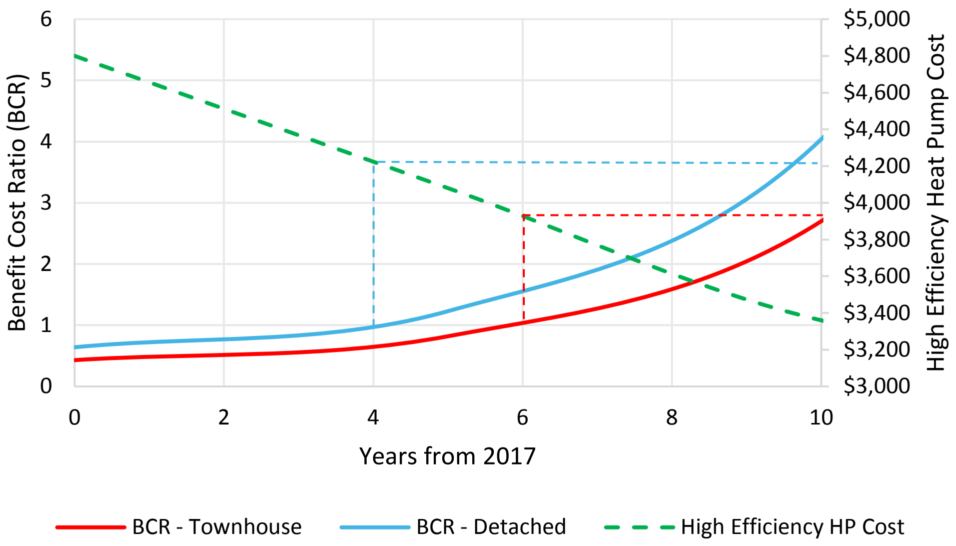


Figure 7. Projected future economics of high efficiency heat pumps (relative to standard heat pumps) based on an assumed learning curve for capital cost. It can be seen that the technology is expected to become cost effective relative to standard heat pumps win 4-6 years at a capital cost of $3900-$4200.

4.6.12 Photovoltaics (PV) Analysis

4.6.12.1 Analysis

The benefit of using PV systems for the attached and detached residential archetypes was analysed using online PVWatts calculator[25] developed by US National Renewable Energy Laboratory (NREL). This calculator estimates the electricity production and energy value of a grid-connected roof or ground-mounted photovoltaic system based on default inputs or user-defined inputs about the system's location, basic design parameters, and system economics.

In this analysis, the PV system was assumed to be installed on the north, east and west roofs of the detached and attached archetypes. The analysis was carried out for three Climate Zones 2, 5 and 6, and four different orientations. The hip type roof was considered for both archetypes. The specifications of the PV systems used are summarised in Table 26. Table 27 summarises the roof areas and roof pitch of both the detached and attached archetypes and the DC system size installed when the orientation of the house was 0^o. In order to simplify the PV analysis, the North and South facing roof sections were assumed to be the average of the two areas (80 m^2 for the detached archetype, 14.5 m^2 for the attached archetype), as were the East and West facing sections (37 m^2 for the detached archetype and 29 m^2 for the attached archetype). A usable roof space factor of 0.5 (for detached) and 0.4 (for attached) was used to determine the DC system size (in increments of panel size).

[25] http://pvwatts.nrel.gov/pvwatts.php

Table 26. Specifications of the PV systems used.

Module type	Standard (Efficiency: ~15%)
Array type	Fixed (roof mount)
System losses (%)	14
Invert efficiency (%)	96
DC to AC size ratio	1.1

Table 27. Roof areas of the Attached and Detached houses (0 degree orientation).

Orientation	Detached house			Attached house		
	Roof area (m^2)	Roof pitch (º)	DC system size* (kW)	Roof area (m^2)	Roof pitch (º)	DC system size (kW)
North	77	23	6.0	14.5	23	0.75
East	40	23	2.75	29.1	23	1.75
South	84	23	-	14.5	23	-
West	34	23	2.75	29.1	23	1.75

* Size (kW) = Array Area (m^2) × 1 kW/m^2 × Module Efficiency (%), based on average roof sizes of 80m^2 and 37m^2 for North/South and East/West facing roof sections for detached archetype.

For PV analysis Climate Zones 2, 5 and 6 were represented by weather data from Brisbane, Sydney, and Melbourne coordinates to establish nominal solar irradiance levels. It was assumed that there was no shading from nearby buildings/objects, roof sections, or other roof mounted equipment.

Table 28 to Table 30 summarises the AC output of the PV system when the detached archetype was oriented at 0°, 90°, 180°, and 270°, respectively. As expected, for the same climate zone, the monthly AC output of the PV system was quite different. A higher PV output can be achieved when the baseline house was oriented at 90° or 270°, in comparison to that was oriented at 0° or 180°, due to the capacity of roof area to install a larger system. The AC output of the PV system also varied greatly with the variation in climate zones. The annual AC output of the PV system in this detached archetype for Climate Zones 2, 5 and 6 were 20,010 kWh, 18,036 kWh and 17,745 kWh respectively, when the house was oriented at 90° or 270° and with a DC system size of 14.75 kW.

Table 28. The electricity generation of the Detached Archetype – Climate Zone 2.

Month	**Detached Climate Zone 2**					
	0° and 180°			**90° and 270°**		
	North	**East + West**	**Total**	**North**	**East + West**	**Total**
January	875	807	1682	401	1761	2162
February	721	634	1355	331	1384	1715
March	788	636	1424	361	1388	1749
April	675	504	1179	309	1101	1410
May	568	398	966	260	869	1129
June	570	371	941	261	809	1070
July	664	436	1100	304	950	1254
August	771	542	1313	353	1182	1535
September	849	656	1505	389	1431	1820
October	827	702	1529	379	1532	1911
November	838	762	1600	384	1662	2046
December	890	826	1716	408	1801	2209
Annual (kWh)	**9036**	**7274**	**16310**	**4140**	**15870**	**20010**
DC System Size (kW)	**6**	**5.5**	**11.5**	**2.75**	**12**	**14.75**

Table 29. The electricity generation of the Detached Archetype – Climate Zone 5.

Month	Detached Climate Zone 5					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	846	762	1608	388	1662	2050
February	739	627	1366	339	1369	1708
March	669	530	1199	306	1157	1463
April	617	436	1053	283	951	1234
May	482	316	798	221	691	912
June	496	299	795	227	653	880
July	530	326	856	243	712	955
August	636	426	1062	291	931	1222
September	762	570	1332	349	1242	1591
October	856	704	1560	392	1537	1929
November	827	732	1559	379	1596	1975
December	866	788	1654	397	1720	2117
Annual (kWh)	**8326**	**6516**	**14842**	**3815**	**14221**	**18036**
DC System Size (kW)	**6**	**5.5**	**11.5**	**2.75**	**12**	**14.75**

Table 30. The electricity generation of the Detached Archetype – Climate Zone 6.

Month	Detached Climate Zone 6					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	959	847	1806	439	1848	2287
February	829	690	1519	380	1504	1884
March	810	620	1430	371	1354	1725
April	623	429	1052	286	935	1221
May	418	268	686	192	586	778
June	400	234	634	183	510	693
July	427	266	693	196	581	777
August	550	371	921	252	811	1063
September	632	476	1108	289	1038	1327
October	849	693	1542	389	1513	1902
November	831	724	1555	381	1580	1961
December	882	790	1672	404	1723	2127
Annual (kWh)	**8210**	**6408**	**14618**	**3762**	**13983**	**17745**
DC System Size (kW)	**6**	**5.5**	**11.5**	**2.75**	**12**	**14.75**

Table 31 to Table 33 summarise the AC output of the PV system when the attached house was oriented at 0°, 90°, 180°, and 270°, respectively. Similar variation as that observed in the detached house was also observed. A higher PV output can be achieved when the baseline house was oriented at 0° or 180°, in comparison to that was oriented at 90° or 270°. The annual AC output of the PV system in this attached house under Climate Zones 2, 5 and 6 were 5,756 kWh, 5,187 kWh and 5,106 kWh respectively, when the house was oriented at 0° or 180° with a DC system size of 4.25 kW.

Table 31. The electricity generation for the Attached archetype – Climate Zone 2.

Month	Attached Climate Zone 2					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	109	514	623	255	220	475
February	90	404	494	210	173	383
March	98	405	503	230	174	404
April	84	321	405	197	138	335
May	71	253	324	166	108	274
June	71	237	308	166	101	267
July	83	276	359	194	118	312
August	96	345	441	225	148	373
September	106	417	523	248	178	426
October	103	447	550	241	192	433
November	105	485	590	244	208	452
December	111	525	636	260	225	485
Annual (kWh)	**1127**	**4629**	**5756**	**2636**	**1983**	**4619**
DC System Size (kW)	**0.75**	**3.50**	**4.25**	**1.75**	**1.50**	**3.25**

Table 32. The electricity generation for the Attached Archetype – Climate Zone 5.

Month	Attached Climate Zone 5					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	106	485	591	247	208	455
February	92	400	492	216	171	387
March	84	337	421	195	145	340
April	77	278	355	180	119	299
May	60	201	261	141	86	227
June	62	190	252	145	82	227
July	66	208	274	155	89	244
August	79	271	350	185	116	301
September	95	363	458	222	155	377
October	107	448	555	250	192	442
November	103	465	568	241	199	440
December	108	502	610	253	215	468
Annual (kWh)	**1039**	**4148**	**5187**	**2430**	**1777**	**4207**
DC System Size (kW)	**0.75**	**3.50**	**4.25**	**1.75**	**1.50**	**3.25**

Table 33. The electricity generation for the Attached archetype – Climate Zone 6.

Month	Attached Climate Zone 6					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	120	539	659	280	231	511
February	104	439	543	242	188	430
March	101	395	496	236	169	405
April	78	273	351	182	117	299
May	52	171	223	122	73	195
June	50	149	199	117	64	181
July	53	170	223	125	73	198
August	69	237	306	161	101	262
September	79	303	382	184	130	314
October	106	442	548	248	189	437
November	104	460	564	242	198	440
December	110	502	612	257	216	473
Annual (kWh)	**1026**	**4080**	**5106**	**2396**	**1749**	**4145**
DC System Size (kW)	**0.75**	**3.50**	**4.25**	**1.75**	**1.50**	**3.25**

4.6.12.2 Capital Costs

Capital costs were modelled as being $2.30/W for current pricing. A wide range of figures are touted as to future cost of PV, with costs generally predicted to drop significantly over the next 10 years. We have interpreted this as a cost reduction from $2.30/W today, $1.85/W in 5 years and $1.40/kW from 10 years onwards.

4.6.12.3 Benefit Cost Analysis

- **Attached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No PV	$ -		0	0.00				
Level 1	PV - full export	$8,625	$ -	-1,651	0.00	0.60	0.85	1.22	1.29
Level 2	PV - full internal use	$8,625	$ -	-5,188	0.00	1.88	2.67	3.85	4.04

- **Attached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No PV	$ -		0	0.00				
Level 1	PV - full export	$8,625	$ -	-1,495	0.00	0.54	0.77	1.11	1.16
Level 2	PV - full internal use	$8,625	$ -	-4,697	0.00	1.70	2.42	3.48	3.66

- **Attached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No PV	$ -		0	0.00				

Level 1	PV - full export	$8,625	$ -	-1,472	0.00	0.53	0.76	1.09	1.15
Level 2	PV - full internal use	$8,625	$ -	-4,626	0.00	1.68	2.38	3.43	3.60

- **Detached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No PV	$ -		0	0.00				
Level 1	PV - full export	$30,188	$ -	-5,778	0.00	0.60	0.85	1.22	1.29
Level 2	PV - full internal use	$30,188	$ -	-18,160	0.00	1.88	2.67	3.85	4.04

- **Detached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No PV	$ -		0	0.00				
Level 1	PV - full export	$30,188	$ -	-5,231	0.00	0.54	0.77	1.11	1.16
Level 2	PV - full internal use	$30,188	$ -	-16,439	0.00	1.70	2.42	3.48	3.66

- **Detached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	No PV	$ -		0	0.00				
Level 1	PV - full export	$30,188	$ -	-5,149	0.00	0.53	0.76	1.09	1.15
Level 2	PV - full internal use	$30,188	$ -	-16,182	0.00	1.68	2.38	3.43	3.60

The results indicate that under current economics, the installation of PV panels is economic to the point where approximately 60% (CZ2) – 70% (CZ5, CZ6) of the power is being exported. For an actual house, the extent of export is determined by the relative size of the household electricity use and its timing relative to the scale of the PV generated load and its timing, in a manner that is likely to vary significantly based on occupancy patterns. Future work will use empirical data to develop an export percentage model.

4.6.13 Ceiling fans

4.6.13.1 Capital Costs

Fans used were electrical ceiling fans of 900mm, 1200mm and 1400mm diameter. Prices obtained for the various sizes include:

- HPM 900mm 55W celling fan: $66 each
- HPM 1200mm 65W celling fan: $85 each
- HPM 1400mm 65W celling fan: $95 each

4.6.13.2 Cost Benefit Analysis

- **Attached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	0	$ -		555	2.77				
Level 1	2 x 1200mm 3 x 900mm	$ 656	-$76	358	2.69	0.88	1.01	1.11	1.17

- **Attached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	0	$ -		401	2.75				
Level 1	2 x 1200mm 3 x 900mm	$640	$14	302	2.76	0.40	0.45	0.50	0.53

- **Attached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	0	$ -		1,352	2.67				
Level 1	2 x 1200mm 3 x 900mm	$580	-$303	1,321	2.36	0.29	0.34	0.36	0.38

- **Detached Archetype, Climate Zone 2 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	0	$ -		1,164	3.96				
Level 1	2 x 1400 mm 2 x 1200mm 5 x 900mm	$1,122	-$12	850	3.94	0.74	0.85	0.93	0.98

- **Detached Archetype, Climate Zone 5 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	0	$ -		920	3.55				
Level 1	2 x 1400 mm 2 x 1200mm 5 x 900mm	$408	-$1,001	738	2.51	negative cost	negative cost	negative cost	negative cost

- **Detached Archetype, Climate Zone 6 - Cost Benefit Ratio**

	Performance value (e.g. R value)	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
Base case	0	$ -		2,588	2.31				
Level 1	2 x 1400 mm 2 x 1200mm 5 x 900mm	$ 1,008	-$256	2,541	2.05	0.16	0.19	0.20	0.21

4.6.13.3 Recommendation

Based on the results, it is recommended that ceiling fans are mandatory in CZ 2 for the attached archetype and in CZ2 & 5 for the detached archetype.

4.7 Preliminary Multi-Dimensional Analysis Results

4.7.1 Archetype Modification and Modelling Approach

From the one-dimensional analysis described in Section 4.3 the cost and energy benefit of each element or design improvement factor was established, with results presented in Sections 4.4 and 4.5. These results was used to identify an 'economic stringencies' package, i.e. those stringencies which provided a benefit cost ratio (BCR) greater than 1, and an 'ambitious stringencies' package, i.e. those stringencies which provided an energy savings impact greater than 2% of baseline. These two sets of multi-dimensional stringencies packages were identified for each archetype, in each climate zone.

As glazing was not included in the initial one-dimensional analysis, the impact of glazing on the multi-dimensional results was attempted to be minimised by using the minimum window area required for each archetype (as detailed in Section 4.3.4). This required a determination of a new baseline for the multi-dimensional analysis.

4.7.2 Economic Stringency Scenarios

The results from Sections 4.4 and 4.5 indicate that there are many technologies capable of making significant impact on energy use, but far fewer that are cost effective on current economic assumptions. However, it is also apparent that PV is cost effective in essentially all cases, which undermines the general case for pushing for effective but uneconomic technologies.

Based on the benefit cost analysis results, it is possible to project forward stringencies for each technology. The resulting scenarios representing the measures that fit the strict economic criteria from Section 4.5 are summarised in Table 34 to Table 36 below for the apartment, attached and detached archetypes.

Table 34. Economic stringencies for apartment archetype (other factors remain as per NCC 2016)

Technology	NCC 2016	Currently Cost effective
Infiltration	Not required	Blower door test and seal, CZ6 only
PV	No requirement	N,E & W facing up to 60% export

Table 35. Economic stringencies for attached archetype (other factors remain as NCC2016)

Technology	NCC 2016	Currently Cost effective
Infiltration	Not required	Blower door test and seal, CZ6
Ceiling Fan	Optional	Required CZ2
PV	No requirement	N,E & W facing up to 60% export

Table 36. Economic stringencies for detached archetype (other factors remain as per NCC2016)

Technology	NCC 2016	Currently Cost effective
Infiltration	Not required	Blower door test and seal, CZ2, 5, 6
Ceiling Fan	Optional	Required CZ2, CZ5
PV	No requirement	N,E & W facing up to 60% export
Roof Insulation	R2.9	R5.2 CZ2 R5.82 CZ5,6

4.7.3 Ambitious Stringency Scenarios

The following scenarios represent the measures that achieve the highest impact on performance while working with relaxed economic criteria.

Table 37. Ambitious stringencies for apartment archetype (other factors remain as per NCC 2016)

Technology	NCC 2016	Currently Desirable
Infiltration	Not required	Blower door test and seal, CZ2,5,6 only
PV	No requirement	N,E & W facing up to 60% export
Lighting	$5W/m^2$	$4W/m^2$
Roller shutters	Not required	North façade CZ 2 East Façade CZ 6
DHW	COP3	COP4.5

Table 38. Ambitious stringencies for attached archetype (other factors remain as NCC2016)

Technology	NCC 2016	Currently Desirable
Infiltration	Not required	Blower door test and seal, CZ2,5, 6
Lighting	$5W/m^2$	$4W/m^2$
PV	No requirement	N,E & W facing up to 60% export
Ventilation Fan	Optional	Add ventilations fans CZ2, 5
DHW	COP3.0	COP 4.5

Table 39. Ambitious stringencies for detached archetype (other factors remain as per NCC2016)

Technology	NCC 2016	Currently Desirable
Infiltration	Not required	Blower door test and seal, CZ2, 5, 6
Roller shutters	Not required	CZ2: W, N, E CZ5: W, E CZ6: N, E
Ventilation Fan	Optional	Required CZ2, CZ5
PV	No requirement	N,E & W facing up to 60% export
Roof Insulation	R2.9	R5.2 CZ2 R5.7 CZ5,6
DHW	COP 3.0	COP 4.5

4.7.4 Preliminary Multi-Dimensional Modelling Results

Table 40 presents the baseline cases heating and cooling energy and equivalent star rating baseline used for the multi-dimensional analysis. Note that the results presented in this section are to be treated as preliminary and will be updated in the Final Technical Report.

The most important heating and cooling energy performance results developed to date in this study are summarised in Table 41 and Table 42. These tables present the economic and ambitious stringencies package heating and cooling energy and equivalent star rating for each archetype, in each orientation, and for each of the three climate zones. The following notes apply:

- Glazing and window-to-wall ratio (WWR) chosen for both 6-Star and 10% of floor area minimum daylighting compliance (described as Baseline II in Section 4.3.2).
- Besides glazing, all other building elements are as for the Baseline I.
- The Baseline II case is not necessarily DtS compliant for glazing.
- The glazing type is the same for all windows of the house for a given climate zone/archetype.
- PV not included in energy results.
- Equivalent Star ratings were determined using an infiltration rate of approximately 15 ACH at 50Pa. These equivalent star ratings are potentially approximately 0.5-1.5 stars less than a NatHERS Star rating obtained with the building model assumed to be very well sealed (anecdotally evidence suggests that this is generally the assumption applied during determination of a NatHERS Star rating).The peak power results for the multi-dimensional stringencies packages, and the Economic and Ambitious stringencies packages applied to Baseline III (Increased WWR) are included in Appendix I.

We deduce that the overall conclusion from the key results of the Economic Stringency Energy Analysis (i.e. the two most far right columns of Table 41) is as follows:

- Combined, cost-effective measures could reduce energy consumption for heating and cooling by an estimated 28 to 51 per cent across a range of housing types and climates.
- This is equivalent to between 1 and 2.5 stars on the NatHERS scheme.

Table 40. Energy Results and Equivalent Star Rating of Baseline II for the Multi-Dimensional Analysis

Archetype	Climate Zone	Orientation	Baseline II (Minimum WWR) Energy Results (15ACH at 50Pa)**		
			Thermal Energy (MJ/m^2/y)	Electrical Energy (kWh/m^2/y)	Equivalent Star rating
Apartment	CZ 2	0	45.9	4.3	6.1
		90	35.8	3.3	6.8
		180	38.7	3.6	6.8
		270	47.8	4.4	5.9
	CZ 5	0	45.9	4.3	5.6
		90	35.4	3.3	6.7
		180	37.9	3.5	6.4
		270	50.8	4.7	5.2
	CZ 6	0	127.5	11.8	5.9
		90	109.9	10.2	6.4
		180	116.1	10.8	6.2
		270	135.5	12.5	5.7
Attached	CZ 2	0	43.7	4.0	6.4
		90	57.2	5.3	5.3
		180	32.9	3.0	7.6
		270	57	5.3	5.3
	CZ 5	0	37.2	3.4	6.7
		90	39.9	3.7	6.4
		180	22.8	2.1	8.2
		270	39.8	3.7	6.4
	CZ 6	0	122.5	11.3	6.2
		90	122.7	11.4	6.2
		180	103.1	9.5	6.8
		270	123.9	11.5	6.2
Detached	CZ 2	0	38.6	3.6	6.5
		90	43.7	4.0	6.0
		180	44.4	4.1	5.9
		270	44.6	4.1	5.9
	CZ 5	0	39.7	3.7	6.1
		90	41	3.8	5.9
		180	42.6	3.9	5.8
		270	42.8	4.0	5.8
	CZ 6	0	112.5	10.4	6.2
		90	109.6	10.1	6.3
		180	110.9	10.3	6.2
		270	114	10.6	6.1

Notes:

** Baseline II glazing/WWR chosen for both 6-Star and 10% of floor area minimum daylighting compliance. All other building elements as for the Baseline I. Not necessarily DtS compliant for glazing. The glazing type is the same for all windows of the house for a given climate zone/archetype.

Table 41. Economic Stringency Energy and Equivalent Star Rating

Archetype	Climate Zone	Orientation	Economic Stringency Case*			Economic - change relative to baseline			
			Thermal Energy (MJ/m^2/y)	Electrical Energy (kWh/m^2/y)	Equivalent Star rating	Electrical Energy	Equivalent Star improv't	Average energy improv't	Average Star improv't
Apartment	CZ 2	0							
		90							
		180							
		270							
	CZ 5	0							
		90							
		180							
		270							
	CZ 6	0	90.9	8.4	6.9	-29%	1.0	-35%	1.3
		90	64.9	6.0	7.8	-41%	1.4		
		180	73	6.8	7.5	-37%	1.3		
		270	89.3	8.3	7	-34%	1.3		
Attached	CZ 2	0	27.2	2.5	8.1	-38%	1.7	-40%	1.9
		90	34.2	3.2	7.4	-40%	2.1		
		180	18.7	1.7	9.1	-43%	1.5		
		270	34.6	3.2	7.4	-39%	2.1		
	CZ 5	0	28	2.6	7.7	-25%	1.0	-28%	1.0
		90	29.5	2.7	7.4	-26%	1.0		
		180	15	1.4	8.9	-34%	0.7		
		270	28.6	2.6	7.6	-28%	1.2		
	CZ 6	0	79	7.3	7.4	-36%	1.2	-37%	1.2
		90	79.8	7.4	7.4	-35%	1.2		
		180	59.6	5.5	8.1	-42%	1.3		
		270	80.8	7.5	7.4	-35%	1.2		
Detached	CZ 2	0	19.3	1.8	8.8	-50%	2.3	-51%	2.5
		90	22.1	2.0	8.4	-49%	2.4		
		180	21.4	2.0	8.5	-52%	2.6		
		270	21.2	2.0	8.5	-52%	2.6		
	CZ 5	0	19.3	1.8	8.3	-51%	2.2	-51%	2.3
		90	20.3	1.9	8.2	-50%	2.3		
		180	21.1	2.0	8.2	-50%	2.4		
		270	21.5	2.0	8.1	-50%	2.3		
	CZ 6	0	66.2	6.1	7.6	-41%	1.4	-42%	1.5
		90	62.8	5.8	7.8	-43%	1.5		
		180	63.8	5.9	7.7	-42%	1.5		
		270	68.3	6.3	7.6	-40%	1.5		

* Economic Stringencies applied to Baseline II. Economic stringencies for apartment archetype included infiltration for Climate Zone 6 only (no other stringencies were economic). PV not included in energy results.

Table 42. Ambitious Stringency Energy and Equivalent Star Rating

Archetype	Climate Zone	Orientation	High Impact Stringency Case****			Ambitious - change relative to baseline			
			Thermal Energy (MJ/m^2/y)	Electrical Energy (kWh/m^2/y)	Equivalent Star rating	Electrical Energy	Equivalent Star improv't	Average energy improv't	Average Equivalent Star improv't
Apartment	CZ 2	0	36.1	3.3	7.1	-21%	1.0	-11%	0.6
		90	35.7	3.3	7.1	0%	0.3		
		180	36.3	3.4	7.1	-6%	0.3		
		270	40.2	3.7	6.6	-16%	0.7		
	CZ 5	0	33.3	3.1	6.9	-27%	1.3	-20%	0.9
		90	32.4	3.0	6.9	-8%	0.2		
		180	30.2	2.8	7.2	-20%	0.8		
		270	38.1	3.5	6.4	-25%	1.2		
	CZ 6	0	80.4	7.4	7.3	-37%	1.4	-38%	1.4
		90	64.3	6.0	7.8	-41%	1.4		
		180	72.0	6.7	7.5	-38%	1.3		
		270	88.7	8.2	7.0	-35%	1.3		
Attached	CZ 2	0	17.9	1.7	9.2	-59%	2.8	-57%	2.7
		90	24.9	2.3	8.4	-56%	3.1		
		180	13.8	1.3	9.6	-58%	2.0		
		270	26.1	2.4	8.3	-54%	3.0		
	CZ 5	0	16.2	1.5	8.8	-56%	2.1	-56%	2.0
		90	17.6	1.6	8.7	-56%	2.3		
		180	9.1	0.8	9.7	-60%	1.5		
		270	18.6	1.7	8.6	-53%	2.2		
	CZ 6	0							
		90							
		180							
		270							
Detached	CZ 2	0	16.0	1.5	9.2	-59%	2.7	-60%	2.9
		90	17.7	1.6	8.9	-59%	2.9		
		180	17.9	1.7	8.9	-60%	3.0		
		270	17.2	1.6	9.0	-61%	3.1		
	CZ 5	0	16.4	1.5	8.6	-59%	2.5	-58%	2.6
		90	17.3	1.6	8.5	-58%	2.6		
		180	17.7	1.6	8.4	-58%	2.6		
		270	19.2	1.8	8.3	-55%	2.5		
	CZ 6	0	65.6	6.1	7.7	-42%	1.5	-42%	1.5
		90	62.2	5.8	7.8	-43%	1.5		
		180	63	5.8	7.8	-43%	1.6		
		270	67.4	6.2	7.6	-41%	1.5		

****Ambitious Stringencies applied to Baseline II.

Figure 8 provides a column graph of equivalent star ratings across each archetype for the baseline, the Economic Stringency Case, and the Ambitious Stringency Case (both applied to Baseline II). It can be seen that both of the multi-dimensional ('economic' and 'ambitious') stringency packages significantly increase the equivalent star ratings (1.0-2.5 stars and 0.6-2.9 stars respectively).

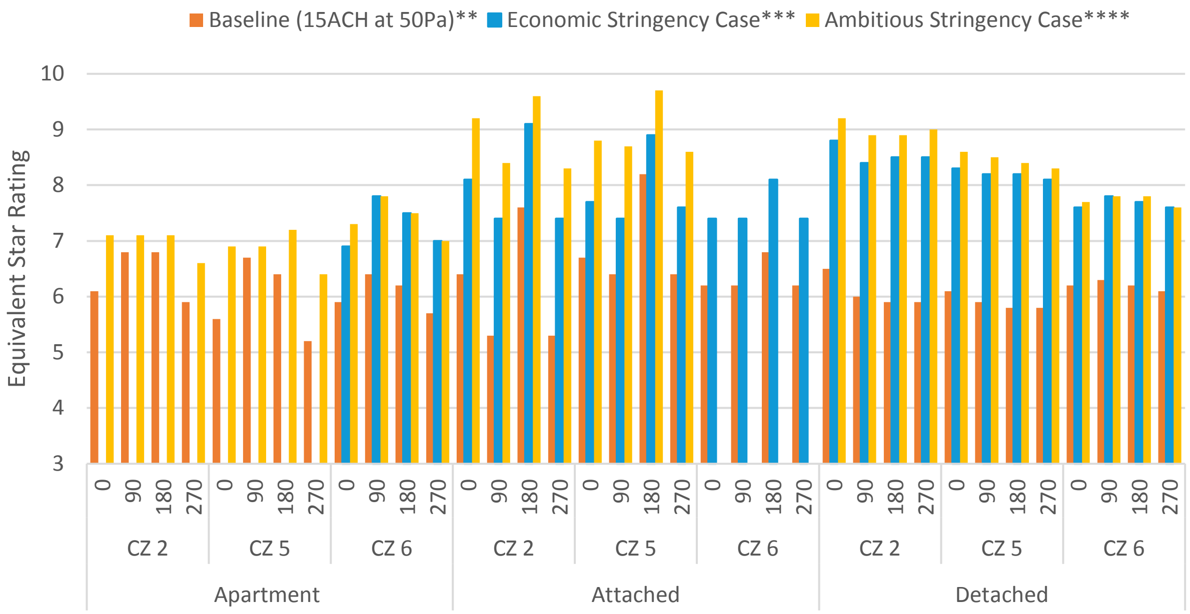


Figure 8. Equivalent star ratings across each archetype for Baseline II, Economic Stringency Case and Ambitious Stringency Case

In Figure 9 a column graph of the total heating and cooling energy requirement across each archetype for the baseline, the Economic Stringency Case, and the Ambitious Stringency Case is provided. By combining the heating and cooling energy demand with the estimated PV output, domestic hot water and an assumption of an additional 30% of plug appliance load, the allocated PV system provides an energy offset for the detached archetype significant enough to reach approximately net zero energy for the Ambitious scenarios package across all climate zones. The 'economic stringencies' scenario package provides similar performance reaching approximately net zero energy for all orientations and climate zones other than two orientations in Climate Zone 6.

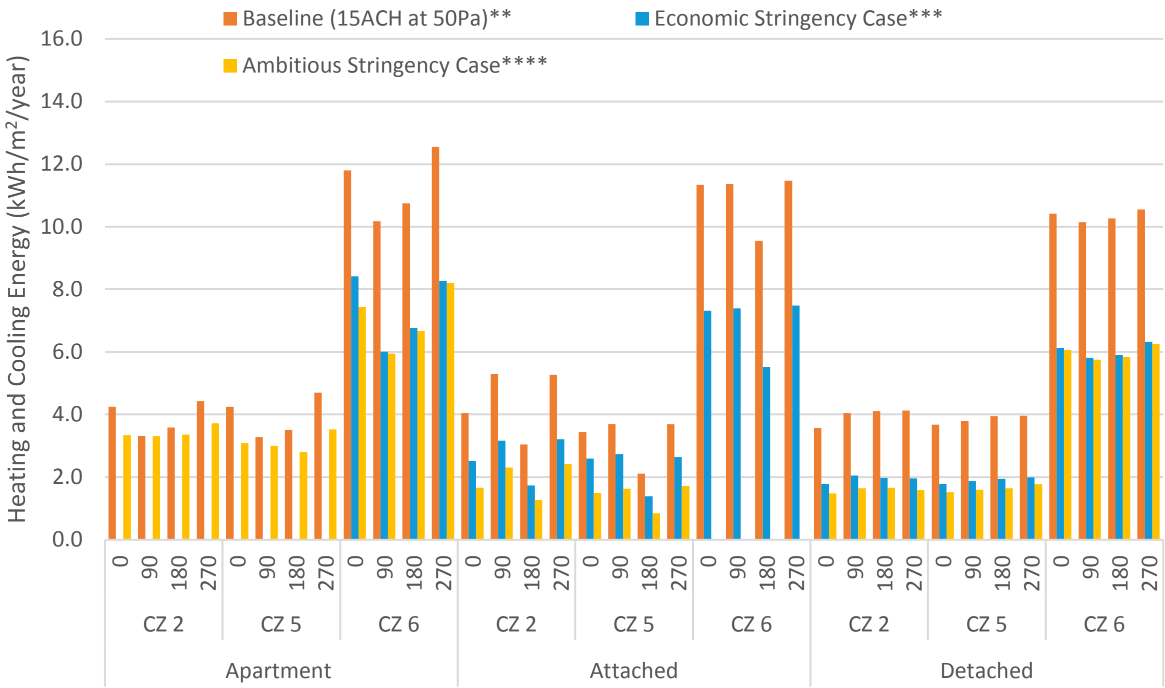


Figure 9. Heating and cooling electrical energy (total) for each archetype for the Baseline II, the Economic Stringency and Ambitious Stringency Cases

Figure 11 and Figure 12 illustrate the separated heating and cooling energy from the multi-dimensional analysis scenarios for the apartment archetype and detached archetype respectively. The dominance of heating or cooling for each climate zone is clearly illustrated. Figure 13 illustrates the peak heating and cooling load from the multidimensional analysis for the attached archetype in each climate zone.

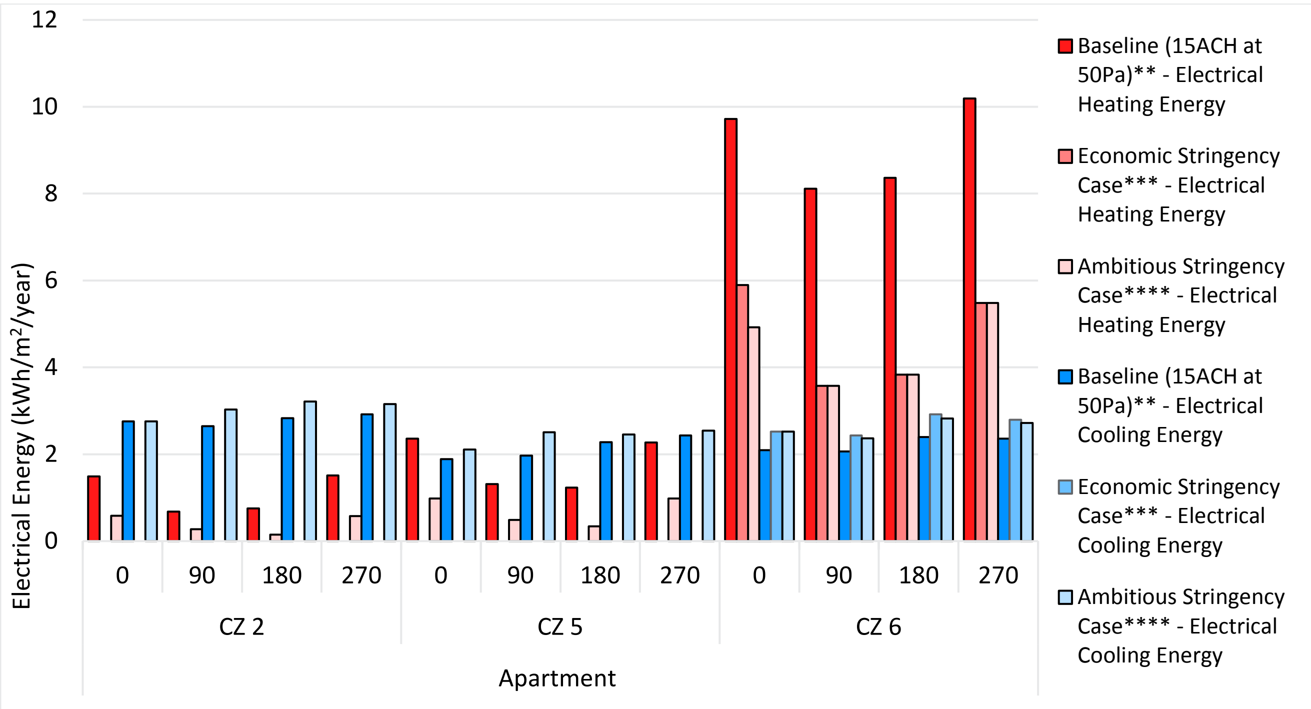
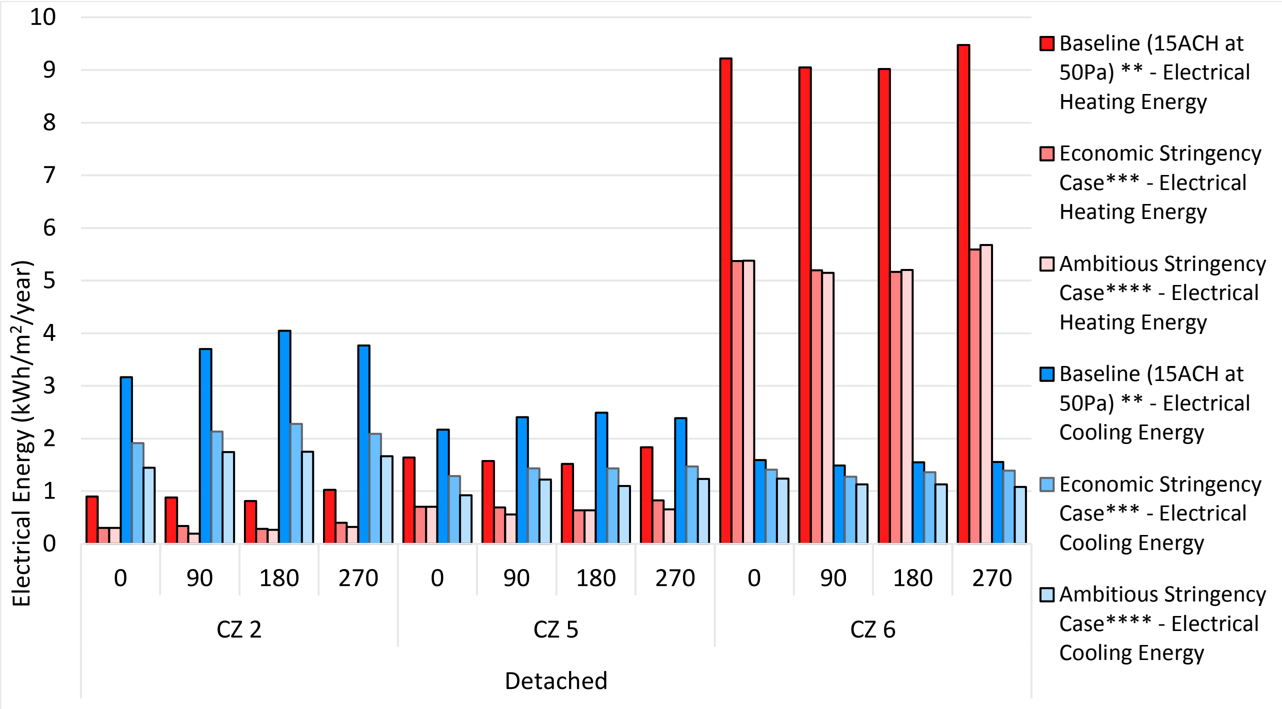


Figure 10. Heating and Cooling Electrical Energy (separate) for Apartment Archetype for Baseline II, the Economic Stringency Case and the Ambitious Stringency Case



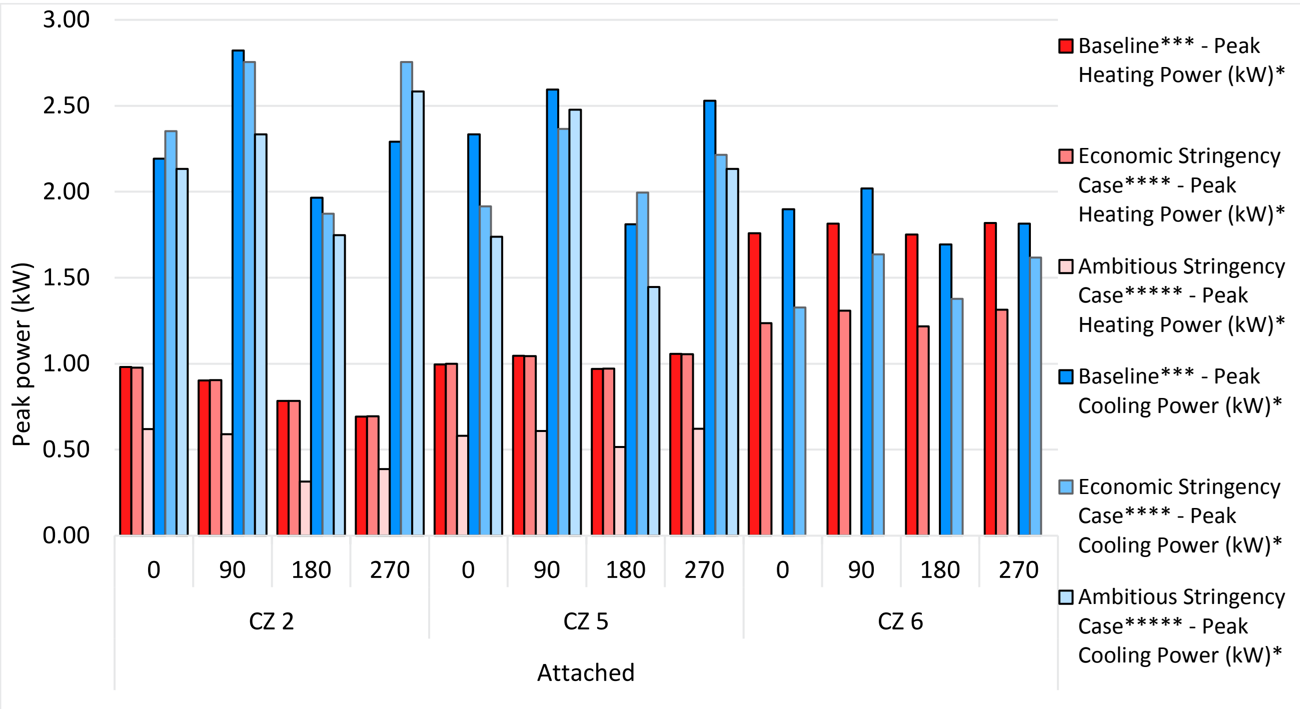


Figure 11. Heating and Cooling Peak Power (separate) for Attached Archetype for Baseline II, the Economic Stringency Case and the Ambitious Stringency Case

Further details of the results from the Multi-dimensional analysis of the package of building element upgrades are provided in Appendix I.

4.8 Remaining work

4.8.1 Additional One-Dimensional Analysis

Table 43 outlines a number of additional/emerging technologies and design changes identified through written and verbal feedback from the Technical Advisory Group (where not already included above). The identified items will be considered for potential inclusion in the next stage of the analysis.

Table 43. Summary of technologies and design changes to be considered for the Final Report.

Technology/Design Change	Comment
HVAC equipment efficiency	Opportunities to improve the efficiency of HVAC equipment are currently being explored, and will be reported in the Final Report. The AccuRate Sustainability software determines the thermal heating and cooling loads that need to be offset by the use of heating and cooling systems to meet the required indoor temperature conditions and occupancy schedules. The annual HVAC energy consumption was therefore determined through application of a suitable coefficient of performance (COP) for the HVAC system. The impact of HVAC efficiency on the energy performance of the residential archetypes will be investigated in our trajectory analysis.
PassivHaus Standards	PasssivHaus is not being investigated as the assessments of insulation and ultra-low infiltration do not indicate the likelihood of a cost-effective outcome[26].
Heat Recovery Ventilation	Our investigation of infiltration (Section 4.6.1) indicates that HRV is highly unlikely to be economic. As a result, it is not going to analysed further in this study
Slab Edge Insulation	An issue with the residential modelling software was identified in regards to establishing the impact of slab edge insulation in cooler climates. Subsequent to the modelling undertaken in this report an update of the software was provided to correct this issue. Modelling of slab-edge insulation will thus be re-run.
Building Integrated PV	This will not be assessed be assessed in the next stage of the project due to the presence of eaves on all the archetypes.

4.8.2 Glazing Analysis

Development of a rational way to assess the change in energy performance and the consequent Benefit Cost Ratio for an upgrade to the glazing of a building is not a trivial task, particularly given that there is a multitude of factors that influence this issue. Unlike the case of a simple building element such as insulation, which behaves thermally in a relatively straightforward way, windows have many functions, many types, and many external influences on their performance, such as: the degree of shading that the window is subject to, its orientation relative to north, the local climate, etc.

The approach being taken for this work reflects that used in the recent NCC Trajectory project concerning commercial buildings, in that it seeks to reduce the specification of glazing stringency to maximum figures for solar admittance (solar heat gain coefficient, adjusted for shading, times window wall ratio) and façade U value (the total U value of window and wall together). This approach results in a radical simplification from a largely opaque “glazing calculator” to a simple table of maximum solar admittance and U value figures.

Work to create and test this approach is incomplete at the time of writing and will be integrated into the final results.

[26] The lack of a cost beneficial outcome is not to be confused with a lack of benefit. Passivhaus design provides other benefits both demonstrable and intangible that are valued by those involved which lie outside the scope of this study, with the result that houses are built to this standard to the benefit of occupants.

4.8.3 Finalisation of Multi-Dimensional Analysis

The results presented in this report have focused on the short-term opportunities to improve energy performance for residential buildings. Some work has been completed to determine the costs and benefits when individual measures are combined, however further work is required to optimise these ‘multi-dimensional scenarios’ to achieve a benefit-cost ratio closer to the 1-1.5 range. This work is required to account for the complex interactions between individual measures when applied at the same time.

The immediate next steps to finalise the residential analysis are:

- Complete the glazing analysis to determine an appropriate glazing performance level for the first step of the residential forward trajectory; and
- Re-run the multi-dimensional analysis and add, or remove, measures where appropriate to achieve a total benefit-cost ratio closer to 1-1.5.

The results of the above will then form the first step for the residential forward trajectories.

5 Commercial Modelling

This section presents the investigation of commercial buildings with respect to the assessment of the forward trajectory for energy performance measures in the National Construction Code (NCC) as part of the Building Code Energy Performance Trajectory project. In this section, 'commercial building' refers to non-residential building types. As the analysis is currently in progress, this section presents only the input assumptions and methodology, and not the results.

This investigation builds on work already undertaken by Energy Action for the Australian Building Codes Board (ABCB) on the stringency of Section J in the NCC. The ABCB work is used as a baseline, and this investigation focuses on opportunities to go further, either through extension of measures incorporated in the ABCB analysis, or introduction of new measures. Based on a gap analysis of the ABCB work, technical areas for potential increased stringency have been selected as follows:

Table 44. The technical areas to be tested

Area	Notes
Glazing and Shading	Higher performance glass; improved shading; active shading;
Daylighting	Daylight control and the use of light shelves
Insulation	To be investigated in conjunction with overnight ventilation (see below)
Fabric colour	Light coloured walls to be investigated
Lighting	Extrapolation of trends in LED efficiency
Fan Systems	Higher minimum fan efficiencies; increases in duct/AHU size beyond NCC 2019 proposed
Pumps	Higher minimum pump efficiencies; increases in pipe size beyond NCC2019 proposed
Chillers and PAC units	Increased minimum efficiencies; some projection of future efficiency trends for equipment
Outside air treatment	Increased requirement for heat recovery on ventilation air
Lifts	Increased minimum efficiencies
Infiltration	Identification of building characteristics giving higher infiltration impacts; also has interactions with overnight ventilation and insulation
Overnight ventilation	Investigation of impacts of controlled overnight ventilation; cross-linked with insulation and infiltration
Economy cycle	Investigation of increased stringency for application of economy cycle
Commissioning	Investigation of sensitivity to poor commissioning (and, by proxy, poor maintenance and control)
Roof top PV	Evaluation of rooftop PV generation potential
Building integrated PV (BIPV)	Evaluation of BIPV (vertical face) generation potential
Thermal Mass	Investigation of thermal mass impacts, using building mass either as a passive element or activated via overnight ventilation
Direct/indirect evaporative cooling	Evaluation of potential as supplement/replacement for base case HVAC

For each of these factors, a preliminary single dimensional analysis will be undertaken to establish the potential impact on energy performance. Where feasible, costs and benefits will be evaluated including projections of changes in technology performance and cost in the future. Where the work extends beyond current boundaries of benefit-cost acceptability, an estimate of the change of capital cost required to achieve an acceptable economic outcomes will be made. This is intended to provide guidance as to the scope and magnitude of market transformation initiatives (e.g. policies to help reduce the cost of key technologies) required to achieve the full technological potential of buildings to improve energy performance and reduce emissions. Based on the results of these analyses, a subset of more important factors will be selected to produce multi-dimensional increased efficiency scenarios. These will be separately tested for aggregate economic performance.

5.1 Archetypes

The building typologies that will be used as the basis of the investigations will be as follows:

Table 45. The archetypes to be used in the analysis. Area figures are gross floor areas

Building	Description
Office	10,000m^2 office, 10 levels, 31.6m x 31.6m floor plate, 3.6m floor-floor, VAV system with central plant
School	200m^2, 1 level, 20m x 10m floor plate, 3.3m floor-ceiling, packaged AC with opening windows
Hotel	2000m^2, 3 level, 36.5m x 18.3m floor plate, 3.6m floor-floor, Fan coils with central plant
Shop	1000m^2, 1 level, 31.6m x 31.6m floor plate, 6 m floor-ceiling, packaged AC with economy cycle
Ward	500m^2, 1 level, 50m x 10m, 3.3m floor-ceiling, VAV system with central plant

These building archetype models were selected and designed based on:

- Selecting common building uses with a wide range of occupant hours and occupant intensity (i.e. internal loads); and
- Selecting a set of physical building forms that ranges from designs where external fabric loads have a relatively low impact on HVAC energy consumption through to designs where external loads have a relatively high impact.

5.2 Baseline Modelling

The modelling for the above archetypes were developed as the baseline to be used to test the technical areas for potential increased stringency. These baseline models were created to comply with the Deemed-to-Satisfy provisions that Energy Action proposed for Section J of NCC 2019.

5.2.1 Office

5.2.1.1 Geometry

The following figure shows the geometry (building form A) created for office building simulation.

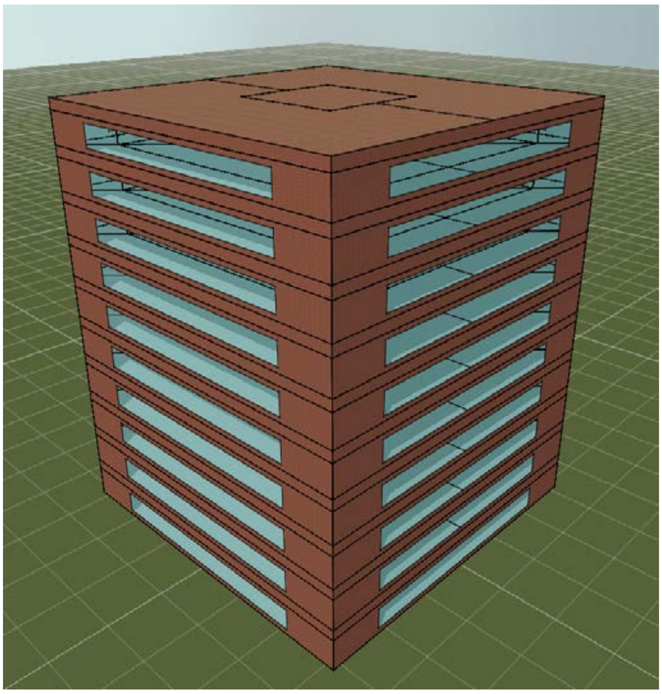


Figure 12. Building form A geometry as viewed in the IES <VE> software.

This model represents an office building that has 10,000m^2, 10 storeys, 31.6m x 31.6m floor plate and 3.6m floor-floor height.

5.2.1.2 Weather File

IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation.

5.2.1.3 Constructions

The constructions were modelled based on the NCC 2019 Section J deemed-to-satisfy provisions. The absorptance of the external wall and roof to be set to 0.7 and 0.4 respectively.

5.2.1.4 Internal Loads and Profiles

The internal load densities and the associated operating schedules are listed below.

Table 46. Internal loads for class 5 (office) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	11W/m^2
Occupants	75W sensible heat gain 55W latent heat gain per person Number of occupants: 14 m^2/person
Artificial lighting	4.5 W/m^2

Table 47. Occupancy, lighting, equipment and HVAC schedules for class 5 buildings.

Time Period	Occupancy (M-F)	Artificial Lighting (M-F)	Appliances and Equipment (M-F)	HVAC (M-F)
0:00 to 1:00	0%	10%	25%	OFF
1:00 to 2:00	0%	10%	25%	OFF
2:00 to 3:00	0%	10%	25%	OFF
3:00 to 4:00	0%	10%	25%	OFF
4:00 to 5:00	0%	10%	25%	OFF
5:00 to 6:00	0%	10%	25%	OFF
6:00 to 7:00	0%	10%	25%	OFF
7:00 to 8:00	15%	40%	25%	ON
8:00 to 9:00	60%	80%	70%	ON
9:00 to 10:00	100%	100%	100%	ON
10:00 to 11:00	100%	100%	100%	ON
11:00 to 12:00	100%	100%	100%	ON
12:00 to 13:00	100%	100%	100%	ON
13:00 to 14:00	100%	100%	100%	ON
14:00 to 15:00	100%	100%	100%	ON
15:00 to 16:00	100%	100%	100%	ON
16:00 to 17:00	100%	100%	100%	ON
17:00 to 18:00	50%	80%	60%	ON
18:00 to 19:00	15%	60%	25%	OFF
19:00 to 20:00	5%	40%	25%	OFF
20:00 to 21:00	5%	20%	25%	OFF
21:00 to 22:00	0%	10%	25%	OFF
22:00 to 23:00	0%	10%	25%	OFF
23:00 to 24:00	0%	10%	25%	OFF

Saturday and Sunday Profiles are 25% continuous artificial lighting and 25% continuous equipment. There is no occupancy and HVAC is "off".

5.2.1.5 HVAC

The HVAC model was created based on the NCC 2019 Section J deemed-to-satisfy (DTS) provisions. The zones are served by VAV system with VSD centrifugal chiller and condensing boiler. The zone control has 22.5°C zone setpoint with 1°C deadband and 1°C proportional band either side. 30% minimum VAV turndown was used for perimeter zones and 50% for centre zones. Drybulb economy cycle with dewpoint lockout at 14°C and drybulb lockout at 24°C was modelled when required by the NCC2019 Section J DTS provisions. The AHU heating supply air temperature decreases from 30°C to 22.5°C as the zone temperature increases from 21°C to 22°C. The AHU cooling supply air temperature decreases from 22.5°C to 12°C as the zone temperature increases from 23°C to 24°C. An $X^{2.7}$ turndown was used for supply air fan and the minimum turndown was set to 30%. An X^2 turndown was used for relief air fan and the minimum turndown was set to be 30% as well. Chilled water temperature was modelled to be reset from 6°C to 10°C when outside air drybulb drops from 25°C to 16°C. The heating hot water temperature was modelled to be reset from 80°C to 60°C when the outside air drybulb increases from the heating design temperature plus 4°C to the heating design temperature plus 14°C.

5.2.1.6 Baseline Results

The results that will be used as the baseline for this archetype are presented in Table 48, Table 49, and Table 50 below for Climate Zones 2, 5 and 6 respectively. The annual energy consumption for systems in particular are summed to give the total annual energy consumption for each model.

Table 48. Baseline results for Climate Zone 2 - model 5A (office).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0003	20.9665	6.3588	0.4985	3.4602	14.2087
Feb 01-28	0.003	18.625	6.015	0.41	3.2855	13.1213
Mar 01-31	0.011	18.8354	6.7166	0.3955	3.6795	14.7659
Apr 01-30	0.0757	13.8977	5.9605	0.2025	2.8311	14.2177
May 01-31	0.5157	10.099	5.1494	0.1343	1.8314	14.2087
Jun 01-30	1.4571	7.5396	4.6217	0.1192	1.3411	14.2177
Jul 01-31	2.2823	7.4079	4.7965	0.1235	1.1369	14.4873
Aug 01-31	1.828	8.164	5.0602	0.1214	1.2229	14.4873
Sep 01-30	0.5235	10.7715	5.5753	0.1589	2.0111	14.2177
Oct 01-31	0.0286	13.611	5.8555	0.2101	2.5028	14.2087
Nov 01-30	0.0043	16.4831	6.3661	0.3159	2.9859	14.2177
Dec 01-31	0.0036	20.2548	6.8715	0.4354	3.7451	14.7659
Summed total	6.7331	166.6556	69.3472	3.125	30.0334	171.125
					Total (MWh)	447.02

Table 49. Baseline results for Climate Zone 5 - model 5A (office).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0188	15.0937	6.0902	0.366	2.6026	14.2087
Feb 01-28	0.0373	15.2636	5.9421	0.3879	2.4935	13.1213
Mar 01-31	0.0701	15.5163	6.3257	0.3566	2.7491	14.7659
Apr 01-30	0.3299	10.3456	5.5299	0.1562	1.6485	14.2177
May 01-31	1.6906	4.4265	3.7347	0.1921	0.6787	14.2087
Jun 01-30	4.8762	1.4912	3.1985	0.2225	0.2113	14.2177
Jul 01-31	7.5926	0.8314	3.1983	0.2655	0.1102	14.4873
Aug 01-31	3.9652	3.6208	4.0245	0.1803	0.4348	14.4873
Sep 01-30	1.3842	5.4804	4.7084	0.1929	0.7312	14.2177
Oct 01-31	0.6406	8.4938	5.5347	0.1875	1.1673	14.2087
Nov 01-30	0.1632	11.2922	6.2382	0.2016	1.7032	14.2177
Dec 01-31	0.0385	15.2362	6.4071	0.3766	2.4693	14.7659
Summed total	20.8072	107.0916	60.9324	3.0857	16.9998	171.125
					Total (MWh)	380.04

Table 50. Baseline results for Climate Zone 6 - model 5A (office).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.3619	9.4699	5.0005	0.1726	1.1795	14.2087
Feb 01-28	0.3975	10.7923	4.7599	0.2126	1.3897	13.1213
Mar 01-31	0.9451	9.2296	4.9374	0.1678	1.0666	14.7659
Apr 01-30	3.5734	2.7741	3.4434	0.108	0.2672	14.2177
May 01-31	9.7762	0.6067	2.8111	0.2562	0.0643	14.2087
Jun 01-30	20.953	0	3.1667	0.4435	0	14.2177
Jul 01-31	22.6649	0	3.3285	0.4671	0	14.4873
Aug 01-31	14.5908	0	2.9379	0.3084	0	14.4873
Sep 01-30	7.9668	0.6345	2.9452	0.1982	0.0671	14.2177
Oct 01-31	3.7811	2.5751	3.2753	0.1122	0.2515	14.2087
Nov 01-30	1.7705	5.698	4.3285	0.1278	0.5552	14.2177
Dec 01-31	0.7624	7.1708	4.9116	0.1298	0.8009	14.7659
Summed total	87.5436	48.951	45.8461	2.7043	5.642	171.125
					Total (MWh)	361.81

5.2.2 School

5.2.2.1 Geometry

The following figure shows the geometry (building form E) created for school building simulation.

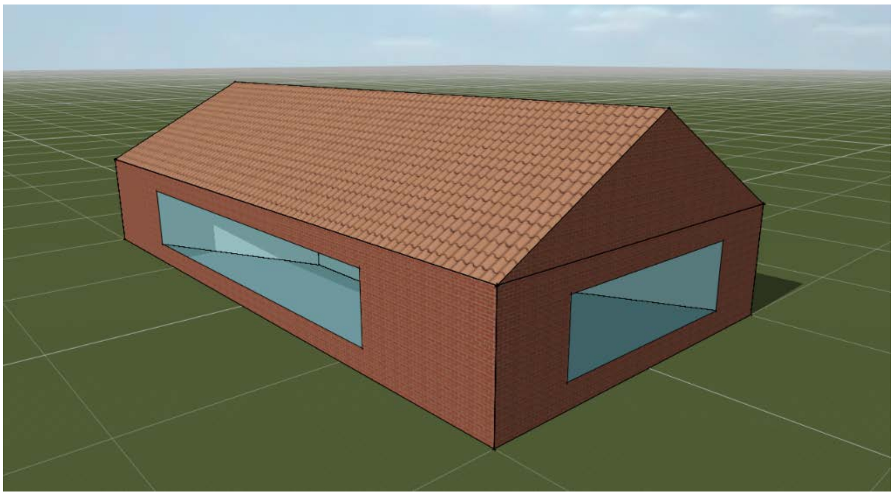


Figure 13. Building form E geometry as viewed in the IES <VE> software.

This model represents a school building that has 200m2, 1 storey, 20m x 10m floor plate and 3.3m floor-ceiling height.

5.2.2.2 Weather File

IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation.

5.2.2.3 Constructions

The constructions were modelled based on the NCC 2019 Section J deemed-to-satisfy provisions. The absorptance of the external wall and roof to be set to 0.7 and 0.4 respectively.

5.2.2.4 Internal Loads and Profiles

The internal load densities and the associated operating schedules are listed below.

Table 51. Internal loads for Class 9b (school) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	5W/m^2
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 2 m^2/person (School – general classroom)
Artificial lighting1	4.5 W/m^2 (School – general purpose learning areas and tutorial rooms)

Table 52. Occupancy, lighting, equipment and HVAC schedules for class 9b buildings.

Time Period	Occupancy (M-F)	Artificial Lighting (M-F)	Appliances and Equipment (M-F)	HVAC (M-F)
0:00 to 1:00	0%	5%	5%	OFF
1:00 to 2:00	0%	5%	5%	OFF
2:00 to 3:00	0%	5%	5%	OFF
3:00 to 4:00	0%	5%	5%	OFF
4:00 to 5:00	0%	5%	5%	OFF
5:00 to 6:00	0%	5%	5%	OFF
6:00 to 7:00	0%	5%	5%	OFF
7:00 to 8:00	5%	30%	30%	ON
8:00 to 9:00	75%	85%	85%	ON
9:00 to 10:00	90%	95%	95%	ON

10:00 to 11:00	90%	95%	95%	ON
11:00 to 12:00	90%	95%	95%	ON
12:00 to 13:00	50%	80%	70%	ON
13:00 to 14:00	50%	80%	70%	ON
14:00 to 15:00	90%	95%	95%	ON
15:00 to 16:00	70%	90%	80%	ON
16:00 to 17:00	50%	70%	60%	ON
17:00 to 18:00	20%	20%	20%	OFF
18:00 to 19:00	20%	20%	20%	OFF
19:00 to 20:00	20%	20%	20%	OFF
20:00 to 21:00	10%	10%	10%	OFF
21:00 to 22:00	5%	5%	5%	OFF
22:00 to 23:00	5%	5%	5%	OFF
23:00 to 24:00	5%	5%	5%	OFF

Saturday and Sunday Profiles are 5% continuous artificial lighting and 5% continuous equipment. There is no occupancy and HVAC is “off”.

5.2.2.5 HVAC

The HVAC model was created based on the NCC 2019 Section J deemed-to-satisfy (DTS) provisions. The zones are served by VAV system with air-cooled reverse cycle PACs. The zone control has 22.5°C zone setpoint with 1°C deadband and 1°C proportional band either side. 30% minimum VAV turndown was used for perimeter zones and 50% for centre zones. No economy cycle was modelled for this building. The PAC heating supply air temperature decreases from 30°C to 22.5°C as the zone temperature increases from 21°C to 22°C. The PAC cooling supply air temperature decreases from 22.5°C to 12°C as the zone temperature increases from 23°C to 24°C. An $X^{2.7}$ turndown was used for the PAC supply air fan and the minimum turndown was set to 30%. The natural ventilation was modelled by opening the window when the zone is in cooling mode and outside air drybulb is between 16°C to 24°C.

5.2.2.6 Baseline Results

The baseline results for the school models in climate zones 2, 5 and 6 are presented in the following tables. The systems of interest include the air-to-air heat pump heating energy, PAC unit cooling energy and lights.

Table 53. Baseline results for Climate Zone 2 - model 9bE (school).

Date	PAC Heating Energy (MWh)	PAC Cooling Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0001	1.669	0.0938
Feb 01-28	0.0003	1.4956	0.0885
Mar 01-31	0.0028	1.293	0.1011
Apr 01-30	0.0608	0.8183	0.0969
May 01-31	0.1433	0.3672	0.0938
Jun 01-30	0.2796	0.151	0.0969
Jul 01-31	0.2909	0.1215	0.0974
Aug 01-31	0.3006	0.1966	0.0974
Sep 01-30	0.1567	0.3792	0.0969
Oct 01-31	0.0495	0.7804	0.0938
Nov 01-30	0.023	1.0662	0.0969
Dec 01-31	0.001	1.4961	0.1011
Summed total	1.3087	9.834	1.1546
		Total (MWh)	12.30

Table 54. Baseline results for climate zone 5 - model 9bE (school).

Date	PAC Heating Energy (MWh)	PAC Cooling Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0482	0.9144	0.0938
Feb 01-28	0.0282	0.9211	0.0885
Mar 01-31	0.1319	0.8636	0.1011
Apr 01-30	0.2011	0.5154	0.0969
May 01-31	0.3722	0.144	0.0938
Jun 01-30	0.5069	0.0464	0.0969
Jul 01-31	0.5251	0.039	0.0974
Aug 01-31	0.3747	0.1411	0.0974
Sep 01-30	0.3868	0.1764	0.0969
Oct 01-31	0.2808	0.4141	0.0938
Nov 01-30	0.2405	0.5109	0.0969
Dec 01-31	0.2031	0.8496	0.1011
Summed total	3.2995	5.536	1.1546
		Total (MWh)	9.99

Table 55. Baseline results for climate zone 6 - model 9bE (school).

Date	PAC Heating Energy (MWh)	PAC Cooling Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.3115	0.4743	0.0938
Feb 01-28	0.2301	0.6953	0.0885
Mar 01-31	0.328	0.541	0.1011
Apr 01-30	0.4437	0.1724	0.0969
May 01-31	0.6099	0.0317	0.0938
Jun 01-30	0.7766	0.0001	0.0969
Jul 01-31	0.7922	0	0.0974
Aug 01-31	0.6668	0.0023	0.0974
Sep 01-30	0.5968	0.0378	0.0969
Oct 01-31	0.4263	0.1612	0.0938
Nov 01-30	0.3664	0.3656	0.0969
Dec 01-31	0.3272	0.3729	0.1011
Summed total	5.8755	2.8545	1.1546
		Total (MWh)	9.88

5.2.3 Hotel

5.2.3.1 Geometry

The following figure shows the geometry (building form B) created for hotel building simulation. This model represents a hotel building that has 2000m^2, 3 storeys, 36.5m x 18.3m floor plate and 3.6m floor-floor height.

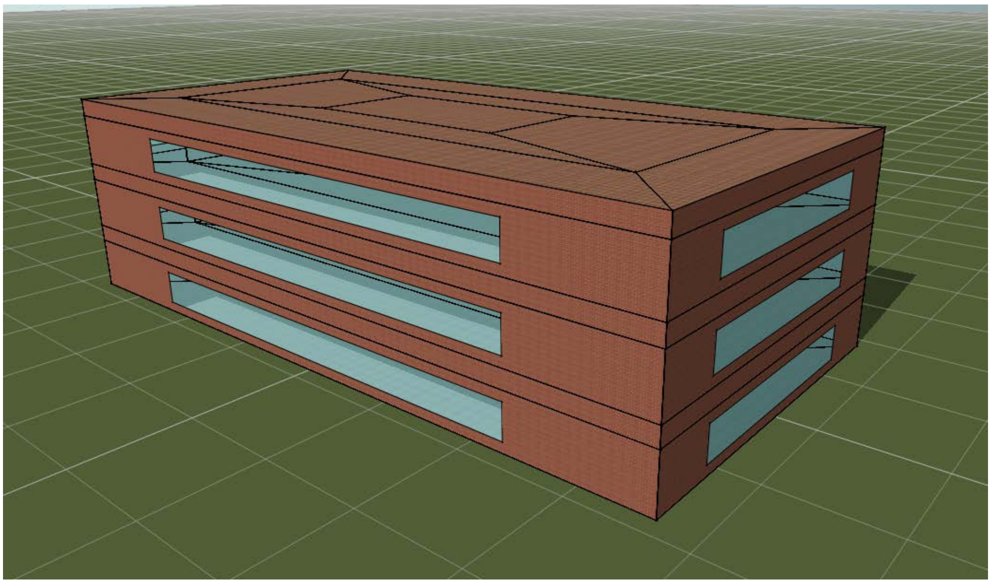


Figure 14. Building form B geometry as viewed in the IES <VE> software.

5.2.3.2 Weather File

IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation.

5.2.3.3 Constructions

The constructions were modelled based on the NCC 2019 Section J deemed-to-satisfy provisions. The absorptance of the external wall and roof to be set to 0.7 and 0.4 respectively.

5.2.3.4 Internal Loads and Profiles

The internal load densities and the associated operating schedules are listed below.

Table 56. Internal loads for class 3 (hotel) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	Using 270 W per room with a room size of 4m x 7m = 9.64W/m^2
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 17.5 m^2/person
Artificial lighting	2.5 W/m^2 (Sole-occupancy unit of a Class 3 building)

Table 57. Occupancy, lighting, equipment and HVAC schedules for class 3 buildings.

Time Period	Occupancy (M-F)	Occupancy (Weekend)	Artificial Lighting	HVAC (M-F)	HVAC (Weekend)	Equipment
0:00 to 1:00	85%	85%	5%	ON	ON	20%
1:00 to 2:00	85%	85%	5%	ON	ON	20%
2:00 to 3:00	85%	85%	5%	ON	ON	20%
3:00 to 4:00	85%	85%	5%	ON	ON	20%
4:00 to 5:00	85%	85%	5%	ON	ON	20%
5:00 to 6:00	85%	85%	25%	ON	ON	20%
6:00 to 7:00	85%	85%	80%	ON	ON	30%
7:00 to 8:00	80%	85%	80%	ON	ON	30%
8:00 to 9:00	50%	50%	50%	ON	ON	30%
9:00 to 10:00	10%	50%	20%	OFF	ON	30%
10:00 to 11:00	10%	20%	20%	OFF	OFF	30%
11:00 to 12:00	10%	20%	20%	OFF	OFF	20%
12:00 to 13:00	10%	20%	20%	OFF	OFF	20%
13:00 to 14:00	10%	20%	20%	OFF	OFF	20%
14:00 to 15:00	10%	20%	20%	OFF	OFF	20%
15:00 to 16:00	10%	30%	20%	OFF	OFF	20%
16:00 to 17:00	50%	50%	20%	ON	ON	20%
17:00 to 18:00	50%	50%	50%	ON	ON	45%
18:00 to 19:00	70%	50%	50%	ON	ON	45%
19:00 to 20:00	70%	70%	50%	ON	ON	45%
20:00 to 21:00	80%	80%	50%	ON	ON	45%
21:00 to 22:00	85%	80%	50%	ON	ON	45%
22:00 to 23:00	85%	85%	50%	ON	ON	40%
23:00 to 24:00	85%	85%	5%	ON	ON	25%

5.2.3.5 HVAC

The HVAC model was created based on the NCC 2019 Section J deemed-to-satisfy (DtS) provisions. The zones are served by FCU system with VSD centrifugal chiller and condensing boiler. No economy cycle was modelled for this building. The FCU heating supply air temperature decreases from 30°C to 22.5°C as the zone temperature increases from 21°C to 22°C. The FCU cooling supply air temperature decreases from 22.5°C to 12°C as the zone temperature increases from 23°C to 24°C. No heating or cooling was supplied when the zone temperature is between 22°C and 23°C. The FCU fans were modelled as constant speed configuration. Chilled water temperature was modelled to be reset from 6°C to 10°C when outside air drybulb drops from 25°C to 16°C. The heating hot water temperature was modelled to be reset from 80°C to 60°C when the outside air drybulb increases from the heating design temperature plus 4°C to the heating design temperature plus 14°C.

5.2.3.6 Baseline Results

The baseline results for the hotel models are given in the following tables. The format is the standard tabular output from the IES <VE> software.

Table 58. Baseline results for Climate Zone 2 - model 3B (hotel).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0	6.7471	4.9284	0.0622	1.4685	0.6203
Feb 01-28	0	5.4874	4.4419	0.0477	1.2948	0.5603

Mar 01-31	0	5.5329	4.91	0.0435	1.2625	0.6203
Apr 01-30	0.0865	4.3858	4.754	0.0367	0.7403	0.6003
May 01-31	0.7935	3.4577	4.9284	0.069	0.5259	0.6203
Jun 01-30	1.9476	1.8102	4.754	0.1019	0.2438	0.6003
Jul 01-31	2.4181	1.6461	4.9192	0.0899	0.2177	0.6203
Aug 01-31	2.0776	1.9853	4.9192	0.0955	0.2604	0.6203
Sep 01-30	0.7213	3.3173	4.754	0.0587	0.4742	0.6003
Oct 01-31	0.1692	4.5044	4.9284	0.0423	0.7861	0.6203
Nov 01-30	0.0064	5.0599	4.754	0.0376	0.9634	0.6003
Dec 01-31	0	5.8855	4.91	0.0488	1.3105	0.6203
Summed total	8.2202	49.8195	57.9013	0.7338	9.5481	7.3037
					Total (MWh)	133.53

Table 59. Baseline results for Climate Zone 5 - model 3B (hotel).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0077	5.7276	4.9335	0.0502	0.9013	0.6203
Feb 01-28	0.003	5.5123	4.4466	0.0492	1.031	0.5603
Mar 01-31	0.026	5.5916	4.9152	0.0499	0.9139	0.6203
Apr 01-30	0.516	3.7189	4.759	0.0688	0.4859	0.6003
May 01-31	1.7919	1.9618	4.9335	0.0849	0.2347	0.6203
Jun 01-30	3.1376	0.3917	4.759	0.076	0.0469	0.6003
Jul 01-31	3.3749	0.3656	4.9243	0.0702	0.0431	0.6203
Aug 01-31	2.9052	1.0857	4.9243	0.0792	0.125	0.6203
Sep 01-30	1.928	1.8725	4.759	0.0896	0.2219	0.6003
Oct 01-31	0.8296	3.6423	4.9335	0.0818	0.4536	0.6203
Nov 01-30	0.1645	4.5208	4.759	0.052	0.6104	0.6003
Dec 01-31	0.0518	5.3252	4.9152	0.0544	0.9317	0.6203
Summed total	14.7361	39.7162	57.9621	0.8061	5.9994	7.3037
					Total (MWh)	126.52

Table 60. Baseline results for Climate Zone 6 - model 3B (hotel).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0371	2.8826	4.935	0.0712	0.5846	0.6203
Feb 01-28	0.0412	2.9266	4.4479	0.0837	0.6468	0.5603
Mar 01-31	0.1467	2.5835	4.9166	0.0812	0.5101	0.6203
Apr 01-30	0.5221	1.295	4.7604	0.0728	0.2545	0.6003
May 01-31	1.1413	0.2432	4.935	0.0398	0.0494	0.6203
Jun 01-30	1.3405	0	4.7604	0.0196	0	0.6003
Jul 01-31	1.456	0.0005	4.9258	0.0205	0.0001	0.6203
Aug 01-31	1.3846	0.0201	4.9258	0.022	0.0041	0.6203
Sep 01-30	1.0615	0.3994	4.7604	0.0449	0.0806	0.6003
Oct 01-31	0.6115	1.3771	4.935	0.0619	0.2692	0.6203
Nov 01-30	0.328	1.8566	4.7604	0.0804	0.3608	0.6003
Dec 01-31	0.1185	2.4067	4.9166	0.0765	0.4831	0.6203
Summed total	8.189	15.9912	57.9793	0.6744	3.2432	7.3037
					Total (MWh)	93.38

5.2.4 Shop

5.2.4.1 Geometry

The following figure shows the geometry (building form C) created for shop building simulation.

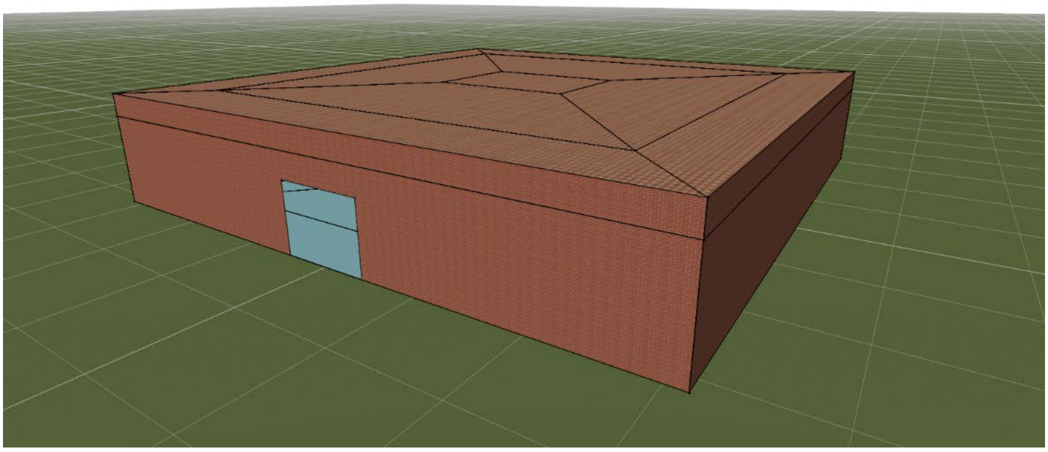


Figure 15. Building form C geometry as viewed in the IES <VE> software.

This model represents a small shop building that has 1000m^2, 1 storey, 31.6m x 31.6m floor plate and 6 m floor-ceiling height.

5.2.4.2 Weather File

IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation.

5.2.4.3 Constructions

The constructions were modelled based on the NCC 2019 Section J deemed-to-satisfy provisions. The absorptance of the external wall and roof to be set to 0.7 and 0.4 respectively.

5.2.4.4 Internal Loads and Profiles

The internal load densities and the associated operating schedules are listed below.

Table 61. Internal loads for class 6 (retail) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	5W/m^2
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 3 m^2/person (at a level entered direct from the open air or any lower level)
Artificial lighting	14 W/m^2 (Retail space including a museum and gallery whose purpose is the sale of objects)

Table 62. Occupancy, lighting, equipment and HVAC schedules for class 6 buildings.

Time Period	Occupancy (Daily)	Artificial Lighting (Daily)	Appliances and Equipment (Daily)	HVAC (Daily)
0:00 to 1:00	0%	10%	25%	OFF
1:00 to 2:00	0%	10%	25%	OFF
2:00 to 3:00	0%	10%	25%	OFF
3:00 to 4:00	0%	10%	25%	OFF
4:00 to 5:00	0%	10%	25%	OFF
5:00 to 6:00	0%	10%	25%	OFF
6:00 to 7:00	0%	10%	25%	OFF
7:00 to 8:00	10%	100%	70%	ON
8:00 to 9:00	20%	100%	70%	ON
9:00 to 10:00	20%	100%	70%	ON
10:00 to 11:00	15%	100%	70%	ON
11:00 to 12:00	25%	100%	70%	ON
12:00 to 13:00	25%	100%	70%	ON
13:00 to 14:00	15%	100%	70%	ON
14:00 to 15:00	15%	100%	70%	ON
15:00 to 16:00	15%	100%	70%	ON
16:00 to 17:00	15%	100%	70%	ON
17:00 to 18:00	5%	100%	70%	ON
18:00 to 19:00	5%	100%	70%	OFF
19:00 to 20:00	0%	10%	25%	OFF
20:00 to 21:00	0%	10%	25%	OFF
21:00 to 22:00	0%	10%	25%	OFF
22:00 to 23:00	0%	10%	25%	OFF
23:00 to 24:00	0%	10%	25%	OFF

5.2.4.5 HVAC

The HVAC model was created based on the NCC 2019 Section J deemed-to-satisfy (DTS) provisions. The zones are served by VAV system with air-cooled reverse cycle PACs. The zone control has 22.5°C zone setpoint with 1°C deadband and 1°C proportional band either side. 30% minimum VAV turndown was used for perimeter zones and 50% for centre zones. Drybulb economy cycle with dewpoint lockout at 14°C and drybulb lockout at 24°C was modelled when required by the NCC2019 Section J DTS provisions. The PAC heating supply air temperature decreases from 30°C to 22.5°C as the zone temperature increases from 21°C to 22°C. The PAC cooling supply air temperature decreases from 22.5°C to 12°C as the zone temperature increases from 23°C to 24°C. An $X^{2.7}$ turndown was used for the PAC supply air fan and the minimum turndown was set to 30%.

5.2.4.6 Baseline Results

The baseline results for the retail model are presented in the following tables below for climate zones 2, 5 and 6. PAC units heat and cool the retail space for this archetype.

Table 63. Baseline results for Climate Zone 2 - model 6C (retail).

Date	PAC Heating Energy (MWh)	PAC Cooling Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0	3.4135	2.9994
Feb 01-28	0	2.9441	2.7091

Date	PAC Heating Energy (MWh)	PAC Cooling Energy (MWh)	Total Lights Energy (MWh)
Mar 01-31	0	2.7211	2.9994
Apr 01-30	0.0043	1.772	2.9026
May 01-31	0.0474	1.2032	2.9994
Jun 01-30	0.1275	0.5901	2.9026
Jul 01-31	0.1606	0.4978	2.9994
Aug 01-31	0.1438	0.6261	2.9994
Sep 01-30	0.0734	1.0529	2.9026
Oct 01-31	0.0164	1.7165	2.9994
Nov 01-30	0	2.2391	2.9026
Dec 01-31	0	2.9319	2.9994
Summed total	0.5735	21.7083	35.3151
		Total (MWh)	57.60

Table 64. Baseline results for Climate Zone 5 - model 6C (retail).

Date	PAC Heating Energy (MWh)	PAC Cooling Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0009	2.0412	2.9994
Feb 01-28	0.0002	2.1077	2.7091
Mar 01-31	0.0013	1.8888	2.9994
Apr 01-30	0.0334	1.1824	2.9026
May 01-31	0.1145	0.5831	2.9994
Jun 01-30	0.2606	0.1585	2.9026
Jul 01-31	0.4132	0.1103	2.9994
Aug 01-31	0.3119	0.2318	2.9994
Sep 01-30	0.1861	0.3983	2.9026
Oct 01-31	0.0914	1.1045	2.9994
Nov 01-30	0.0276	1.2389	2.9026
Dec 01-31	0.0099	1.8096	2.9994
Summed total	1.451	12.8552	35.3151
		Total (MWh)	49.62

Table 65. Baseline results for Climate Zone 6 - model 6C (retail).

Date	PAC Heating Energy (MWh)	PAC Cooling Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0662	1.0992	2.9994
Feb 01-28	0.0479	1.2663	2.7091
Mar 01-31	0.1071	0.9826	2.9994
Apr 01-30	0.2368	0.3295	2.9026
May 01-31	0.6689	0.0276	2.9994
Jun 01-30	1.034	0	2.9026
Jul 01-31	1.247	0	2.9994
Aug 01-31	1.0574	0	2.9994
Sep 01-30	0.7142	0.0216	2.9026
Oct 01-31	0.3918	0.3002	2.9994
Nov 01-30	0.194	0.5669	2.9026
Dec 01-31	0.1272	0.838	2.9994
Summed total	5.8924	5.4317	35.3151
		Total (MWh)	46.64

5.2.5 Ward

5.2.5.1 Geometry

The following figure shows the geometry (building form D) created for a small part of a ward building.

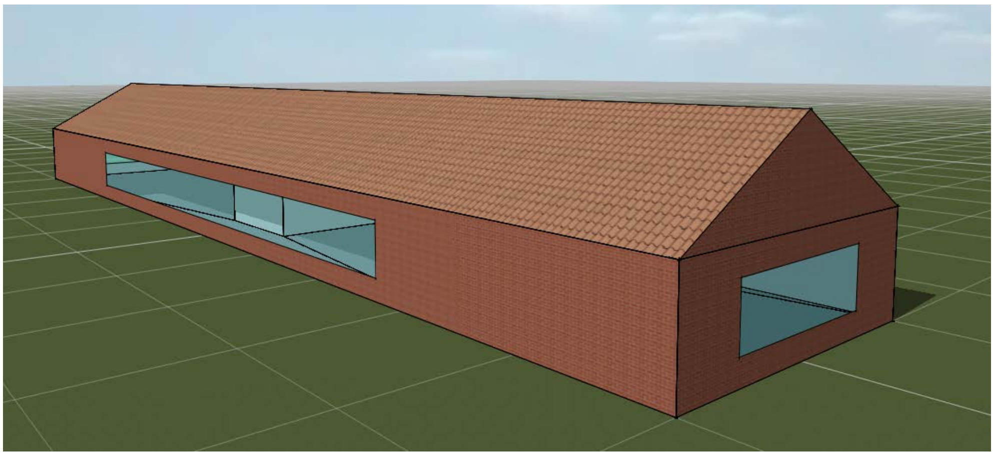


Figure 16. Building form D geometry as viewed in the IES <VE> software.

This model represents a small part of a ward building that has 500m^2, 1 storey, 50m x 10m floor plate and 3.3m floor-ceiling height.

5.2.5.2 Weather File

IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation.

5.2.5.3 Constructions

The constructions were modelled based on the NCC 2019 Section J deemed-to-satisfy provisions. The absorptance of the external wall and roof to be set to 0.7 and 0.4 respectively.

5.2.5.4 Internal Loads and Profiles

The internal load densities and the associated operating schedules are listed below.

Table 66. Internal loads for class 9a (ward area) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	5W/m^2
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 14 m^2/person
Artificial lighting	2.5 W/m^2 (Health care – patient ward)

Table 67. Occupancy, lighting, equipment and HVAC schedules for class 9a (ward area) buildings.

Time Period	Occupancy (M-F)	Occupancy (Weekend)	Artificial Lighting	HVAC (M-F)	HVAC (Weekend)
0:00 to 1:00	85%	85%	5%	ON	ON
1:00 to 2:00	85%	85%	5%	ON	ON
2:00 to 3:00	85%	85%	5%	ON	ON
3:00 to 4:00	85%	85%	5%	ON	ON
4:00 to 5:00	85%	85%	5%	ON	ON

Time Period	Occupancy (M-F)	Occupancy (Weekend)	Artificial Lighting	HVAC (M-F)	HVAC (Weekend)
5:00 to 6:00	85%	85%	25%	ON	ON
6:00 to 7:00	85%	85%	80%	ON	ON
7:00 to 8:00	85%	85%	80%	ON	ON
8:00 to 9:00	85%	85%	50%	ON	ON
9:00 to 10:00	85%	85%	20%	ON	ON
10:00 to 11:00	85%	85%	20%	ON	ON
11:00 to 12:00	85%	85%	20%	ON	ON
12:00 to 13:00	85%	85%	20%	ON	ON
13:00 to 14:00	85%	85%	20%	ON	ON
14:00 to 15:00	85%	85%	20%	ON	ON
15:00 to 16:00	85%	85%	20%	ON	ON
16:00 to 17:00	85%	85%	20%	ON	ON
17:00 to 18:00	85%	85%	50%	ON	ON
18:00 to 19:00	85%	85%	50%	ON	ON
19:00 to 20:00	85%	85%	50%	ON	ON
20:00 to 21:00	85%	85%	50%	ON	ON
21:00 to 22:00	85%	85%	50%	ON	ON
22:00 to 23:00	85%	85%	50%	ON	ON
23:00 to 24:00	85%	85%	5%	ON	ON

Equipment is on 24/7 with an averaged consumption of 5 W/m^2.

5.2.5.5 HVAC

The HVAC model was created based on the NCC 2019 Section J deemed-to-satisfy (DTS) provisions. The zones are served by VAV system with VSD centrifugal chiller and condensing boiler. The zone control has 22.5°C zone setpoint with 1°C deadband and 1°C proportional band either side. 30% minimum VAV turndown was used for perimeter zones and 50% for centre zones. Drybulb economy cycle with dewpoint lockout at 14°C and drybulb lockout at 24°C was modelled when required by the NCC2019 Section J DTS provisions. The AHU heating supply air temperature decreases from 30°C to 22.5°C as the zone temperature increases from 21°C to 22°C. The AHU cooling supply air temperature decreases from 22.5°C to 12°C as the zone temperature increases from 23°C to 24°C. An $X^{2.7}$ turndown was used for supply air fan and the minimum turndown was set to 30%. An X^2 turndown was used for relief air fan and the minimum turndown was set to be 30% as well. Chilled water temperature was modelled to be reset from 6°C to 10°C when outside air drybulb drops from 25°C to 16°C. The heating hot water temperature was modelled to be reset from 80°C to 60°C when the outside air drybulb increases from the heating design temperature plus 4°C to the heating design temperature plus 14°C.

5.2.5.6 Baseline Results

The baseline results for the 24/7 operating ward model are provided in the following tables.

Table 68. Baseline results for Climate Zone 2 - model 9aD (ward).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0	2.5593	0.9947	0.0787	0.4067	0.1404
Feb 01-28	0	2.0778	0.8122	0.0629	0.3623	0.1269
Mar 01-31	0	1.969	0.8492	0.0591	0.3506	0.1404
Apr 01-30	0.1083	1.196	0.8475	0.0392	0.2004	0.1359
May 01-31	0.8313	0.7752	0.935	0.0365	0.1248	0.1404

Jun 01-30	2.1065	0.3953	0.9445	0.0426	0.0596	0.1359
Jul 01-31	2.9784	0.4276	1.0153	0.0481	0.0617	0.1404
Aug 01-31	2.7127	0.4972	0.995	0.0493	0.0686	0.1404
Sep 01-30	1.0803	0.7089	0.8815	0.0392	0.1074	0.1359
Oct 01-31	0.312	1.139	0.8345	0.0387	0.1901	0.1404
Nov 01-30	0.0167	1.5102	0.8007	0.0438	0.2571	0.1359
Dec 01-31	0	2.1126	0.8767	0.0632	0.3709	0.1404
Summed total	10.146	15.3681	10.7867	0.6013	2.5603	1.6536
					Total (MWh)	41.12

Table 69. Baseline results for Climate Zone 5 - model 9aD (ward).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.0149	1.5086	0.7966	0.051	0.2291	0.1404
Feb 01-28	0.0034	1.6209	0.7352	0.0543	0.2543	0.1269
Mar 01-31	0.023	1.4118	0.7701	0.05	0.2216	0.1404
Apr 01-30	0.4593	0.7987	0.8295	0.0368	0.118	0.1359
May 01-31	1.6517	0.3614	0.8712	0.0378	0.0543	0.1404
Jun 01-30	3.5211	0.1467	0.904	0.0551	0.0226	0.1359
Jul 01-31	4.6763	0.1737	0.9548	0.0657	0.0263	0.1404
Aug 01-31	3.6607	0.2955	0.9279	0.0558	0.041	0.1404
Sep 01-30	2.3675	0.3686	0.7988	0.0446	0.0531	0.1359
Oct 01-31	1.1569	0.7474	0.8077	0.0434	0.1004	0.1404
Nov 01-30	0.2751	0.8753	0.715	0.0325	0.1289	0.1359
Dec 01-31	0.0964	1.292	0.7518	0.0432	0.2059	0.1404
Summed total	17.9063	9.6006	9.8625	0.5702	1.4554	1.6536
					Total (MWh)	41.05

Table 70. Baseline results for Climate Zone 6 - model 9aD (ward).

Date	Boilers Energy (MWh)	Chillers Energy (MWh)	Fans Energy (MWh)	CHW/HHW Pumps Energy (MWh)	Heat Rejection Fans/Pumps Energy (MWh)	Total Lights Energy (MWh)
Jan 01-31	0.2173	0.6252	0.8178	0.0355	0.1261	0.1404
Feb 01-28	0.151	0.7869	0.8127	0.0421	0.1445	0.1269
Mar 01-31	0.414	0.5923	0.8105	0.0375	0.1133	0.1404
Apr 01-30	1.1935	0.2507	0.7157	0.0336	0.0569	0.1359
May 01-31	2.7331	0.0568	0.6958	0.0585	0.015	0.1404
Jun 01-30	4.2273	0	0.6864	0.085	0	0.1359
Jul 01-31	5.095	0.0006	0.7518	0.0932	0.0002	0.1404
Aug 01-31	4.2121	0.0212	0.7032	0.0792	0.0062	0.1404
Sep 01-30	3.0623	0.0811	0.63	0.0608	0.0214	0.1359
Oct 01-31	1.8663	0.2394	0.6668	0.0445	0.0524	0.1404
Nov 01-30	1.1471	0.3854	0.7275	0.0359	0.0814	0.1359
Dec 01-31	0.4992	0.4789	0.7624	0.0304	0.0992	0.1404
Summed total	24.818	3.5186	8.7805	0.636	0.7166	1.6536
					Total (MWh)	40.12

6 National Estimation

6.1 Methodology

6.1.1 Introduction

The extent to which GHG emissions can be avoided in new building work is a function of the following major factors:

7. The energy intensity of the new buildings that would have been built under 'business as usual' conditions (in which we assume no new policy)
8. The energy intensity of the new building work that is expected to take place in the 'with measures' or higher stringency case(s)
9. The number of new square meters of buildings (by type) built (or refurbished) each year
10. The fuel mix of those buildings, including the (delivered) emissions intensity of the fuels used.

Broadly, emissions savings will be higher to the extent that:

- The degree to which the 'with measures' stringency is higher than the BAU case
- When more floor area is constructed (although, the proportionate savings may remain unchanged with the level of building activity – if the mix of new building types remains the same – whereas the total energy/emissions savings will rise/fall with construction volumes)
- The lower the (delivered) emissions intensity of the energy consumed by the new stock.

Lesser but not insignificant factors will include:

- the rate of demolition/replacement of existing buildings (as the replacement floor area will need to comply with the Code)
- the rate of refurbishment of existing buildings (at least to the extent that the refurbished area in fact complies with current Code requirements)
- the rate of repurposing of buildings from one Code class to another (which, in principle, triggers the application of the Code's performance requirements).

Occupant behaviours, contextual changes (such as operating hours or functional changes in buildings), and also the emissions embodied in building materials and in the construction process, will also impact on the emissions performance of the new buildings. However, these factors are a) generally not regulated by the National Construction Code (with limited exceptions), and b) are not likely to systematically vary with the stringency of energy performance requirements in the Code: that is they are, for the most part, independent variables.

6.1.1.1 A Note on Compliance

Much is made of the extent of compliance with the Code's energy performance requirements. As detailed in the *National Energy Efficient Buildings Project*, inter alia, there is an almost universal view in the building industry that many, perhaps most, buildings do not fully comply with the Code's energy performance requirements.[27] However, given the ongoing absence of any (visible) audit activity by building regulators, it remains difficult to quantify the extent and validity of this issue.

[27] pitt&sherry and Swinburne University of Technology,

That said, it is important to place the compliance issue into context. While under-compliance with the Code will generate worse social outcomes than would full compliance – virtually by definition, since current Code provisions have passed rigorous benefit cost and regulatory impact assessment processes – there is no reason to believe that the degree of compliance with the Code varies when Code stringency varies. Indeed, the NEEBP report cited above found that non-compliance issues appear to be systemic in nature, Australia-wide, and long-standing, while energy performance standards in practice vary significantly across Australia due to state variations. In other words, if there is x% non-compliance now, and x% non-compliance in future, then the proportionate (eg, per average building) energy and emissions savings from a stringency increase will be the same as if there were 100% compliance before and after. As above, compliance is an independent variable from Code stringency. Further, it would be ludicrous to argue in effect that the remedy for under-compliance with the Code is to refuse to upgrade stringency, even when it is cost-effective to do so, thereby ensuring that we have sub-optimally weak standards which are then also not complied with. Clearly, the remedy is to enforce the Code at any-and-all levels of stringency, to ensure that the expected net social benefits are in fact delivered.

Second, if there is systematic under-compliance with the Code, then those under-complying are also avoiding at least the majority of the costs associated with compliance, as well as foregoing the benefits. The non-compliers leave the national benefit cost ratio associated with the Code unchanged, no matter the non-compliance rate, since there are proportionate reductions in both benefits and costs. Since we know that, on average, benefits comfortably exceed costs under at least current Code settings, it is true that under-compliance does mean a net loss of social welfare for the nation, and a lower net present value of social benefits than would otherwise be the case. This leaves the economic case for energy performance standards unchanged, while demonstrating that maximising the social benefits associated with building energy performance requirements demands that the Code is enforced.

6.1.2 Overview

The general approach to estimating the national consequences of achieving the modelling improvements in building-level energy performance involves:

1. Applying a stock turnover model to estimate the area of new building work (including refurbishments) that could potentially be affected by higher Code performance standards
2. Applying 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. Estimating equivalent savings for those building forms not modelled as part of this project
4. Estimating expected savings from building forms in climate zones not modelled as part of this project
5. Aggregating costs and benefits to generate an estimates of the overall cost effectiveness of the scenarios modelled.

These steps are discussed in further detail below.

6.2 Building Stock Estimates

The building and construction industry is Australia's third largest industry, behind only mining and finance, comprising at least 330,000 businesses that produce 8% of Australia's GDP and directly employ over 1 million people. Despite this, the physical stock of buildings in Australia – that is, their number, size, location, age and other characteristics – along with the annual turnover of that stock, and the energy use and greenhouse gas emissions attributable to it, are all highly uncertain.

This means that the answers to key national policy questions – such as the expected contribution of this very large economic sector to the national emissions abatement task, or the contribution that different policies (including changes to the National Construction Code's energy performance requirements) could have on emissions, or the extent of Code compliance, or the social and economic impact on building energy performance, or many others – are equally uncertain.

These uncertainties represent the long-term outcome of decades of inadequate attention to and investment in statistics in Australia, particularly statistics that relate to matters other than the national accounts. Increasingly, there appears to be greater concern about the potential reporting burden on companies than there is for ensuring that robust evidence is available to underpin national policy development.

Excellent statistics are maintained on the financial value of construction work done in Australia, on investment and employment in the sector, and on its contribution to GDP. However, the physical legacy of this all this work and expenditure – for example in terms of the number or floor area or character of new buildings, energy performance and resulting greenhouse gas emissions, or the extent of change that this represents in our built environment – is largely unknown.

That said, the picture for residential buildings is reasonably clear. This is primarily because the Australian Bureau of Statistics maintains important statistical collections that reveal at least elements of the turnover of the residential building stock, and this has been available for many decades. Also, information about the total housing stock can be inferred from the Census and from GeoScience Australia's NEXIS database. Uncertainties exist, such as volume of demolition, major refurbishment, and addition/extension activity, as compared to new builds, and the average size of new builds is only available for detached housing. Overall, however, confidence is reasonably high.

For non-residential buildings, the picture is much less clear. ABS Building Activity statistics only track the *value* of work done in the non-residential building sector, and provide no information at all on the volume of work done or the type of work done. Further, the NEXIS database provides a static observation of the total floor area of commercial and industrial buildings, undifferentiated by type or class, but no data on institutional buildings, which include at least hospitals and healthcare; schools, universities and the like; museums and galleries; aged care; and all government buildings. Further, it appears that the floor area estimates for commercial and industrial buildings from this source are over-stated, and cannot be reconciled with other data sources. A Commercial Building Baseline Study was undertaken in 2013 (using data up to 2011), but this represented a largely bottom-up analysis of specified building types rather than the entire stock. Many building types including motels, hostels/other accommodation, industrial buildings, churches, some government buildings, car parks, healthcare other than hospitals, and certain retail buildings (eg, big box retail), are missing from this study.[28]

6.2.1 Residential Stock Model

Drawing on the above sources, *Strategy. Policy. Research.* produced a stock turnover model by dwelling type, state and territory and climate zone. In the absence of better data, we assume that 1% of the stock is either demolished and rebuilt, or undergoes major refurbishment, each year. The key results are shown in Figure 17 below. The distribution of the stock by state and territory in 2017 is shown in below.

[28] pitt&sherry, Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia Part 1 – Report, November 2012.

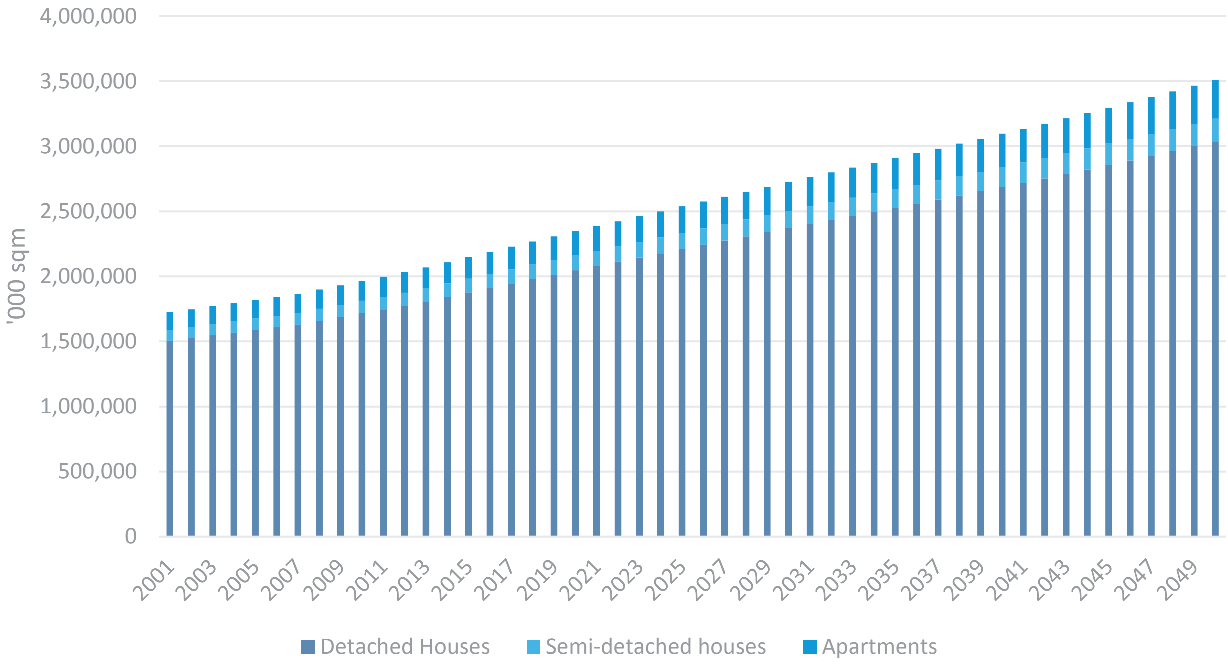


Figure 17. Residential Building Stock Totals by Type, 2001 – 2050, Australia
[Source: Strategy. Policy. Research.]

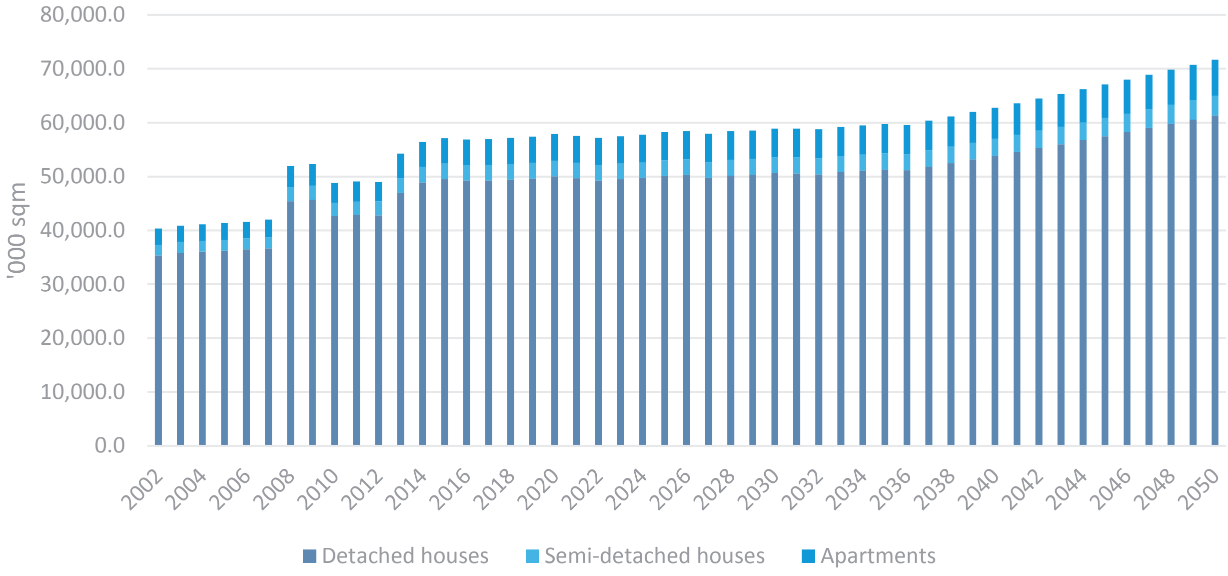


Figure 18. Annual Floor Area Built to Code, Residential Buildings by Type, 2002 – 2050, Australia
[Source: Strategy. Policy. Research.]

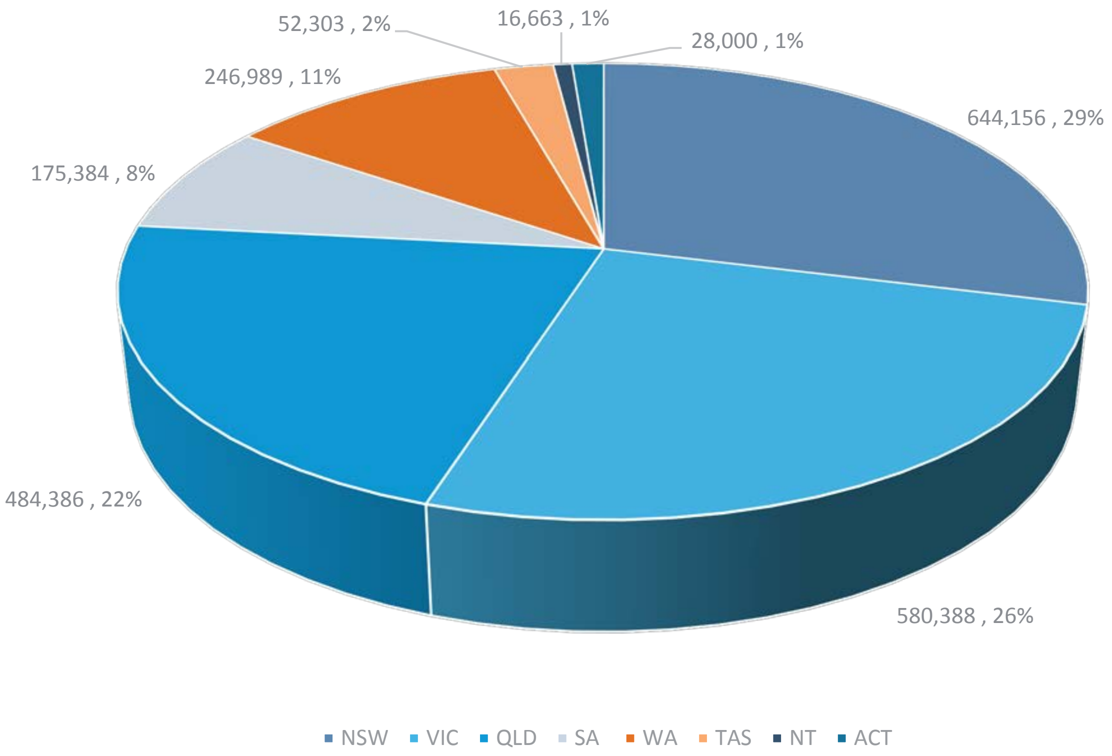


Figure 19. Distribution of Total Residential Stock by State and Territory, 2017 (‘000 sqm, %)
[Source: Strategy. Policy. Research.]

6.2.2 Non-Residential Stock Model

Figure 20 below summarises the historical and expected future growth of the sub-set of total non-residential buildings for which is reasonable confidence. This observation draws primarily on the Commercial Building Baseline Study and Beyond Zero Emissions’ Buildings Plan.[29] It is certain that this underestimates the total non-residential building stock in Australia, but as noted, without significant additional research, it is not possible to say by how much. The stock turnover model, as with residential, makes an allowance of 1% per year for major refurbishments and demolition/rebuild, in line with the Commercial Building Baseline Study. The apparent slower growth in new building work in the 2018 – 2020 period (see Figure 21) reflects assumptions in the Baseline Study for that period, most likely related to projections reflecting the post-GFC slow-down in construction activity that was apparent at the time that study was undertaken. The post-2020 growth rates are simply based on an extrapolation of expected growth over the 2015 – 2020 period.

[29] Beyond Zero Emissions et al, Zero Carbon Australia Buildings Plan, August 2013.

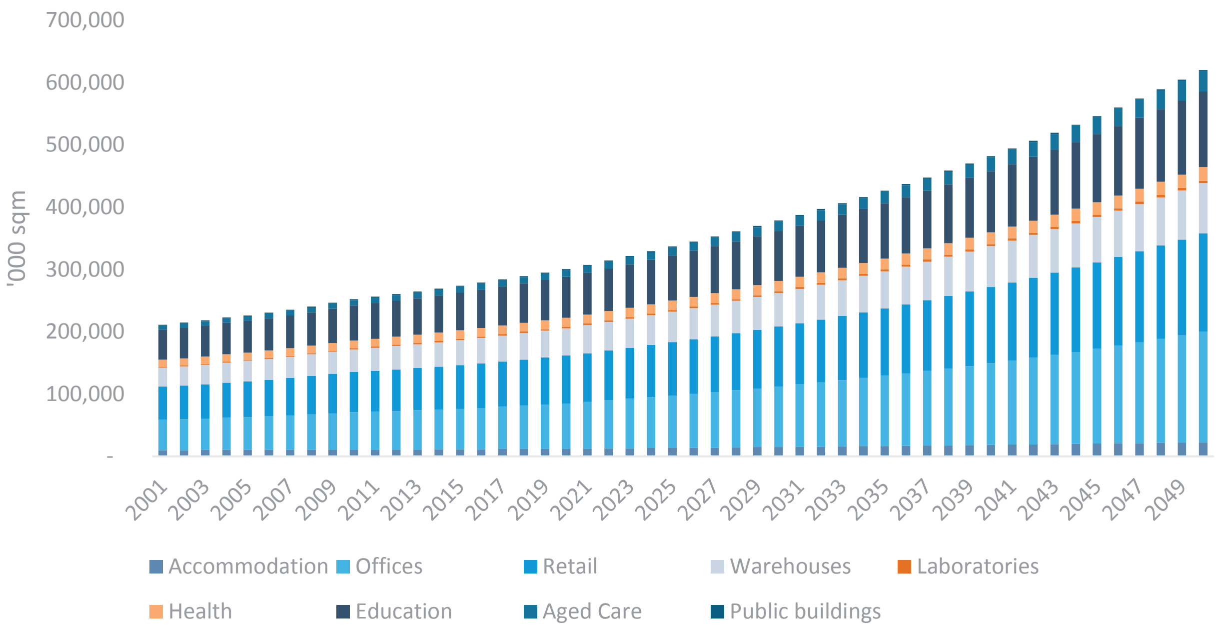


Figure 20. Non-Residential (Identified) Stock Projection ('000 sqm)
[Source: Strategy. Policy. Research.]

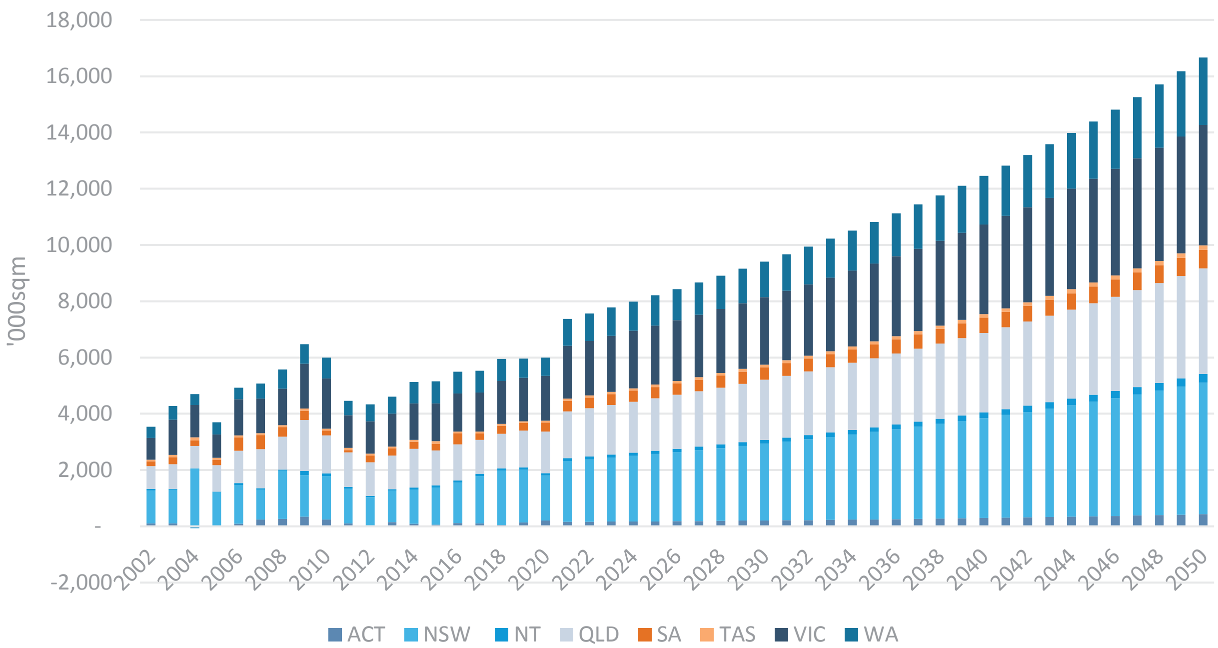


Figure 21: Annual Build to Code, Identified Non-Residential Buildings ('000 sqm)
[Source: Strategy. Policy. Research.]

The distribution of the identified non-residential stock by state/territory in 2017 is shown in Figure 22 below, while the distribution of the stock by building type is shown in Figure 23.

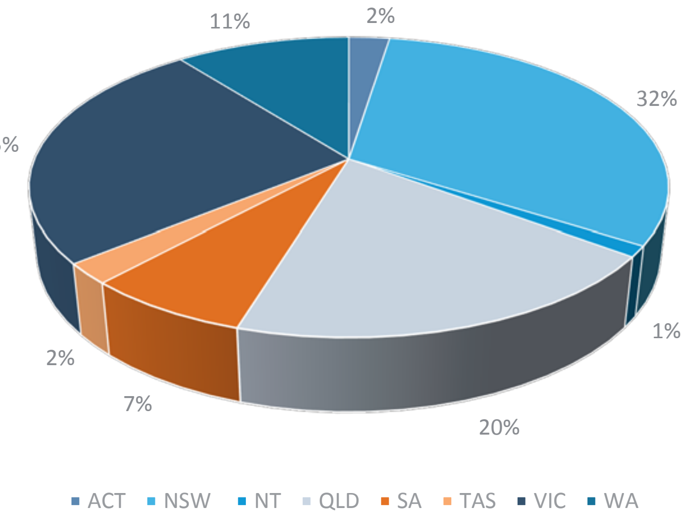


Figure 22. Non-Residential (Identified) Building Stock by State/Territory, 2017
[Source: Strategy. Policy. Research]

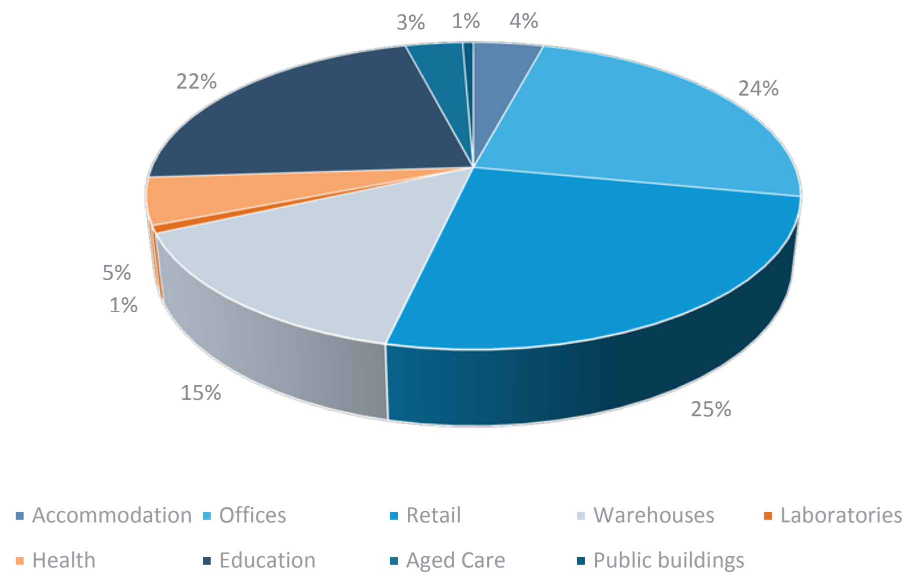


Figure 23. Distribution of Identified Non-Residential Stock by Building Type, 2017
[Source: Strategy. Policy. Research]

6.2.3 Mapping Modelled Building Forms to NCC Classes

The set of archetypes being modelled correspond with certain NCC classes, but not all of them, as set out in Table 71 below. In the majority of cases, the building form being modelled is likely to be a reasonable basis to represent the average energy intensity of new builds of that type. Exceptions include Class 2, where we need to make an allowance for the additional common area energy, which we assume is equivalent to 30% of the dwelling energy use on average, based on work undertaken by pitt&sherry for the NSW Office of Environment & Heritage. Class 4 is too small to be significant. In Class 5, the building form modelled is likely to be above the average size of new builds in this class, and therefore could (slightly) under-estimate their average energy intensity. Based on Energy Action's *Baseline Modelling Methodology and Results: Section J revision*, March 2017, however, the variation in energy intensity by size is modest, and most pronounced in Climate Zone 2 (of the climate zones modelled here). Therefore we propose small loadings on the modelled energy intensity, differentiated by climate zone.

For Class 7 (carparks, warehouses), Class 8 (laboratories), and Class 9C (aged care), these are not covered in this modelling work, but were included in the Energy Action report cited above. While these are not major building classes, nor are they insignificant. We propose that they be included by proxy/estimation, as a preferable choice to leaving them out altogether. We suggest that the BAU energy intensity for the classes be taken from the relevant form or forms as modelled by Energy Action for Section J 2019, with the proportionate 'with measures' savings (and costs) represented as the simple average of the savings modelled for all non-residential forms (for Class 7 and 8), or by all Class 9 forms modelled (for aged care).

Table 71. Coverage of NCC Classes by Modelled Archetypes

NCC Class	Represented Directly by Archetype?	Representation in National Model	Implicit Assumptions/Comments	Loading on Modelled Energy Intensity?
Class 1a)i) Detached	✓	1:1 Mapping (form to Class)	That the energy intensity of archetype is representative of average new build energy intensity	100%
Class 1a)ii) Semi-detached	✓	1:1 Mapping	"	
Class 1b Boarding house, etc, <300sqm	×	Not represented	Minor class, not separately resolved in most stock models. Likely to be reasonably represented by Class 2	100%
Class 2 Apartment	✓	1:1 Mapping of dwelling, with allowance for common area energy use	Change in common area energy use is proportionate to change in dwelling energy use	130%[30]
Class 3 Hotels, etc	✓	1:1 Mapping	That the energy intensity of archetype is representative of average new build energy intensity	100%
Class 4 Residential within a non-residential building	×	Not represented	Very minor type	-
Class 5 Offices	✓	Make allowance for higher intensity of smaller offices	Derive size-weighted average energy intensity for each climate, based on EA Section J Revision (variation between 5A and 5C)	CZ2: 105% CZ5: 102% CZ6: 102%

[30] Based on pitt&sherry, Apartment Building Common Area Energy and Water Use in Australia, July 2016, prepared for the NSW Office of Environment & Heritage.

NCC Class	Represented Directly by Archetype?	Representation in National Model	Implicit Assumptions/Comments	Loading on Modelled Energy Intensity?
Class 6 Retail	✓	1:1 Mapping	1000sqm form modelled appears to adequately represent energy intensity variability (being intermediate between larger and smaller forms)	100%
Class 7 Carparks, warehouses	×	Include by proxy	BAU values from EA Section J analysis, and average % savings of non-residential stock for 'with measures' case	100% of Class 7C in Section J analysis for base case
Class 8 Laboratory	×	Include by proxy	BAU values from EA Section J analysis, and average % savings of non-residential stock for 'with measures' case	100% of average of 8B and 8C in Section J analysis for base case
Class 9a) Healthcare	✓	1:1 Mapping	Ward archetype appears to have lower energy intensity than small clinics, but higher than larger hospitals – may represent reasonable average for the sector	100%
Class 9b) Assembly, education	✓	1:1 Mapping (school archetype)	Diverse class which ideally would be represented by more forms…but Section J work shows climate is dominate over form…and distribution of new builds over sub-types not well understood	100%
Class 9c) Aged care	×	Include by proxy	Section J work indicates energy intensities could be represented as an average of Class 9 forms – lower than 9a but higher than 9b	100% of average of Class 9 forms

The modelled energy intensities are applied to net new building work annually, from FY2020, using a stock turnover model, as described below, which makes allowances for net growth in floor area, demolition and major refurbishment. However, as the energy performance of the building forms noted is only being modelled for three climate zones (2, 5 & 6), we also need to estimate the additional energy/emissions savings available in the other NCC climate zones.

6.2.4 Estimation of Energy Performance in Non-Modelled Climate Zones

6.2.4.1 Non-Residential Forms

Energy intensities in non-modelled climate zones are estimated using past observations of the extent of observed variability of the different modelled forms in NCC climates zones; specifically Energy Action's *Baseline Modelling Methodology and Results* from March 2017, along with EA's *NCC2019 DTS Final Report*, May 2017.

Table 72 below selects from Baseline Methodology and Results the simulated energy intensities of those building forms that most closely correspond to those to be modelled for current the ASBEC/ClimateWorks project, along with those additional forms noted in Table 71 above to be 'included by proxy'. We note that the match between the 'ward' in this project and the form 9bB in the Baseline Methodology and Results report is relatively poor, in that the former has a floor area of 500sqm while the latter is 2,000sqm. Generally, however, the degree of variability in energy performance modelled by climate zone and form in this project – at least for those climate zones modelled – can be used as a further check on the estimates below, and adjustments made if necessary.

The methodology calculates the variation in energy intensity between climate zones in the base case in Baseline Methodology and Results, and proposes that these same variations are applied to the new modelled values for Climate Zones 2, 5 and 6. The results for each non-modelled climate zone are calculated relative to each modelled climate zone and then averaged, to minimise anomalies.

For the non-modelled forms – warehouses, laboratories and aged care – we have taken the NCC2016 baseline from *Baseline Methodology and Results* and applied a simple average energy intensity improvement for each climate zone, based on the results in Energy Action's *NCC2019 DTS Final Report*, May 2017 (Table 1, p. 1).

6.2.4.2 Residential Forms

For residential forms, we have sourced the maximum thermal loads allowed for 6 star dwellings from the 69 NatHERS star bands. These were first aggregated to weighted state/territory average results, using population weightings, as per the *Residential Baseline Study*. [31] As a second step, the resulting values were converted to NCC climate zone averages, again using population-based weightings as per the methodology from the *Residential Baseline Study.* Unfortunately, this source did not resolve climate zone 8, which is confined to a few alpine areas of Australia, and thus no results are available for this climate zone.

Table 72 shows, in the first row, the resulting weighted average maximum energy intensities allowed under 6 star for NCC climate zones 1 – 7. The choice of 6 star is arbitrary, as it is the variation in energy intensity by climate zone that we are interested in, rather than the absolute values. Of these climate zones, this current project will model new values for climate zones 2, 5 and 6. To estimate the values for the other climate zones, and as with the non-residential forms, we propose that relative energy intensity of each non-modelled climate zone is estimated from all three observations available and then averaged, as shown in the Table.

[31] DEWHA, Energy Use in the Australian Residential Sector 1986 – 2020, 2008, prepared by Energy Efficient Solutions, p. 130-131.

Table 72. Estimation Factors for Energy Intensity of Non-Modelled Building Forms by Climate Zone – Non-Residential

Building Forms	Energy Intensity (NCC2016)	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
3B (Hotel)	MJ/m2.a	290	209	245	197	177	183	199	212
	Factors:	(CZ2 * 290/209+ CZ5*290/177+ CZ6*290/183)/3	As modelled	(CZ2 * 245/209+ CZ5*245/177+ CZ6*245/183)/3	(CZ2 * 290/209+ CZ5*290/177+ CZ6*290/183)/3	As modelled	As modelled	(CZ2 * 199/209+ CZ5*199/177+ CZ6*199/183)/3	(CZ2 * 212/209+ CZ5*212/177+ CZ6*212/183)/3
5A (Office)	MJ/m2.a	468	386	424	355	356	325	343	324
	Factors:	(CZ2 * 468/386+ CZ5*468/356+ CZ6*468/325)/3	As modelled	(CZ2 * 424/386+ CZ5*424/356+ CZ6*424/325)/3	(CZ2 * 355/386+ CZ5*355/356+ CZ6*355/325)/3	As modelled	As modelled	(CZ2 * 343/386+ CZ5*343/356+ CZ6*343/325)/3	(CZ2 * 324/386+ CZ5*324/356+ CZ6*324/325)/3
6C (Retail)	MJ/m2.a	856	659	779	606	578	554	572	665
	Factors:	(CZ2 * 856/659+ CZ5*856/578+ CZ6*856/554)/3	As modelled	(CZ2 * 779/659+ CZ5*779/578+ CZ6*779/554)/3	(CZ2 * 606/659+ CZ5*606/578+ CZ6*606/554)/3	As modelled	As modelled	(CZ2 * 572/659+ CZ5*572/578+ CZ6*572/554)/3	(CZ2 * 665/659+ CZ5*665/578+ CZ6*665/554)/3
7C (Warehouses)	MJ/m2.a	292	217	265	192	184	174	176	188
	Factors:	292*(1-30%)	217*(1-41.5%)	265*(1-39.3%)	192*(1-35.8%)	184*(1-41.3%)	174*(1-37.3%)	176*(1-33.8%)	188*(1-8.3%)
8B/C (Laboratories)[32]	MJ/m2.a	574	519	525	479	475	436	432	418
	Factors:	574*(1-30%)	519*(1-41.5%)	525*(1-39.3%)	479*(1-35.8%)	475*(1-41.3%)	436*(1-37.3%)	432*(1-33.8%)	418*(1-8.3%)
9aD (School)	MJ/m2.a	549	442	503	398	387	363	358	369
	Factors:	(CZ2 * 549/442+ CZ5*549/387+ CZ6*549/363)/3	As modelled	(CZ2 * 503/442+ CZ5*503/387+ CZ6*503/363)/3	(CZ2 * 398/442+ CZ5*398/387+ CZ6*398/363)/3	As modelled	As modelled	(CZ2 * 358/442+ CZ5*358/387+ CZ6*358/363)/3	(CZ2 * 369/442+ CZ5*369/387+ CZ6*369/363)/3
9bB (Ward)	MJ/m2.a	416	268	366	239	209	198	213	305
	Factors:	(CZ2 * 416/268+ CZ5*416/209+ CZ6*416/198)/3	As modelled	(CZ2 * 366/268+ CZ5*366/209+ CZ6*366/198)/3	(CZ2 * 239/268+ CZ5*239/209+ CZ6*239/198)/3	As modelled	As modelled	(CZ2 * 213/268+ CZ5*213/209+ CZ6*213/198)/3	(CZ2 * 305/268+ CZ5*305/209+ CZ6*305/198)/3

[32] Simple average of the two data points.

Building Forms	Energy Intensity (NCC2016)	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
9cD/H (Aged Care)[6]	MJ/m2.a	464	326	398	316	299	316	315	372
	Factors:	464*(1-30%)	326*(1-41.5%)	398*(1-39.3%)	316*(1-35.8%)	299*(1-41.3%)	316*(1-37.3%)	315*(1-33.8%)	372*(1-8.3%)

Table 73. Estimation Factors for Energy Intensity of Non-Modelled Building Forms by Climate Zone – Residential

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
MJ/m2.a @ 6 star	277	66	133	81	88	116	165	-
Factor	(CZ2*277/66+ CZ5*277/88+ CZ6*277/116)/3	Modelled value	(CZ2*133/66+ CZ5*133/88+ CZ6*133/116)/3	(CZ2*81/66+ CZ5*81/88+ CZ6*81/116)/3	Modelled value	Modelled value	(CZ2*165/66+ CZ5*165/88+ CZ6*165/116)/3	-

As these maximum thermal loads apply to all dwelling types, the estimates are applicable (via the formulae shown) to detached, semi-detached and apartment dwellings. We note that Class 2 buildings involve common area energy use, in addition to dwelling energy use. This energy use is regulated under Section J of the NCC, but was not modelled in Energy Action's *Baseline Modelling Methodology and Results.* Therefore, we propose that an allowance of 30% of the modelled dwelling energy consumption of Class 2 forms is added to the base case for these forms, based on research conducted by pitt&sherry for the Office of Environment & Heritage in NSW.[33] For the 'with measures' scenarios, we propose that the BAU common area energy use allowances are reduced by the average savings modelled for NCC2019 in Energy Action's *NCC2019 DTS Final Report*, May 2017 (Table 1, p. 1).

6.3 Energy savings – Residential Sector

The energy savings are categorised according to the classes of residential buildings outlined in Section 7.2. The energy savings of residential buildings are calculated based on the differential between the 2016 NCC energy intensity and the estimated 2019 NCC energy intensity multiplied by the cumulative annual additions to the building stock of each class. It is assumed that the 2019 NCC is applied to all new builds from 2019/20 onwards.

6.3.1 National Results

Figure 24 shows the energy savings of the three classes of residential building: Detached, Attached, and Units/Apartments. It should be noted here energy savings specifically refer to electricity savings, given the assumption that all new builds are not using natural gas in this study. As it can be observed from this figure, Detached occupies the largest energy savings, followed by Units/Apartments and Attached. The energy savings for residential buildings increases from around 110 GWh in 2020 to 3215 GWh in 2050. Although the energy savings from Detached dominate the total, the relative share of Units/Apartments increases over the projection period due to the higher growth rate in new builds, from 4.9% in 2020 to 5.7% in 2050. By 2050, the NCC 2019 code change results in around 2875 GWh, 155 GWh and 185 GWh of energy savings in Detached, Attached and Units/Apartments respectively.

[33] pitt&sherry, Apartment Building Common Area Energy and Water Use in Australia, July 2016.

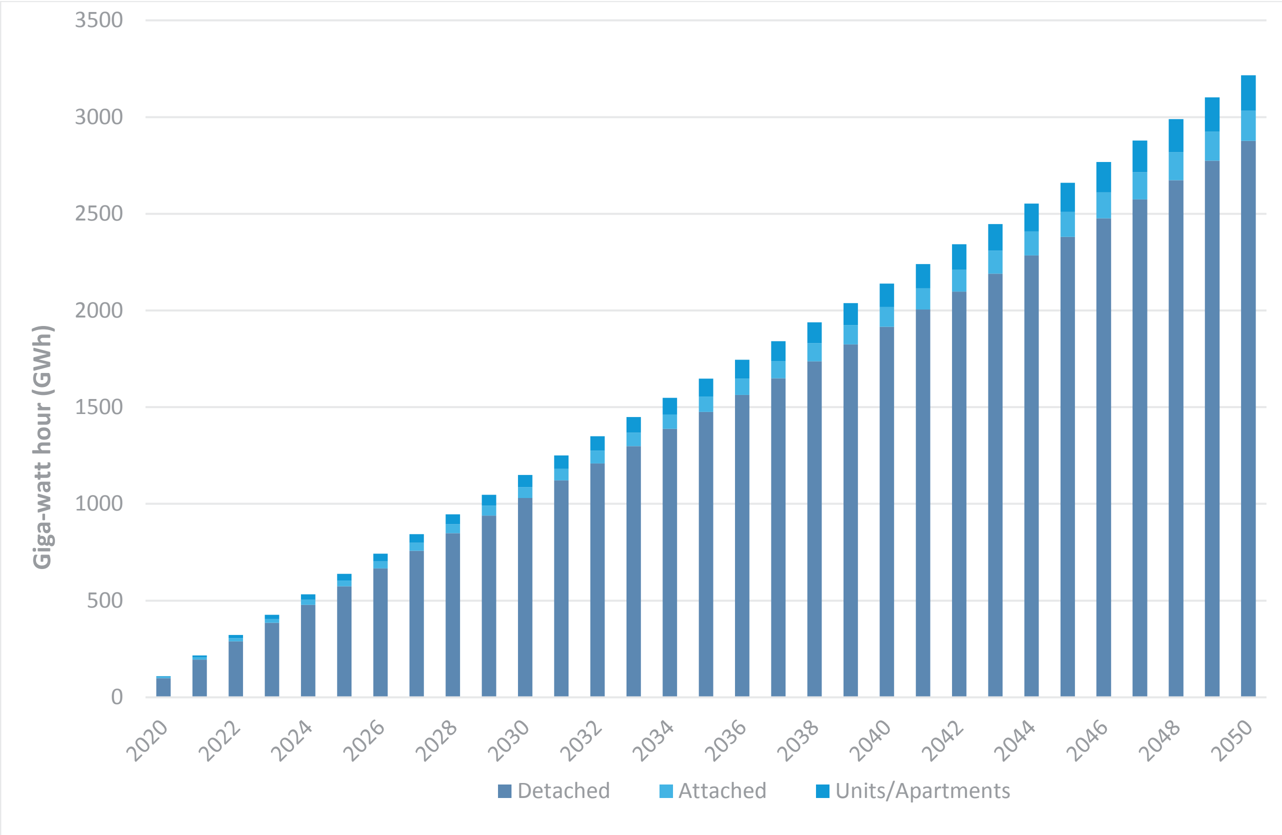


Figure 24. Residential Building Energy Savings by Type, Australia (GWh), 2020-2050
[Source: CSIRO]

6.3.2 State Results

In this section, the state levels are analysed to demonstrate the energy savings variation in different states/territories over the projection period. Decadal snapshot years starting from 2020 and ending in 2050 are chosen to reflect the change. Energy savings by residential building type by state and territory for these selected years are shown in Figure 25.

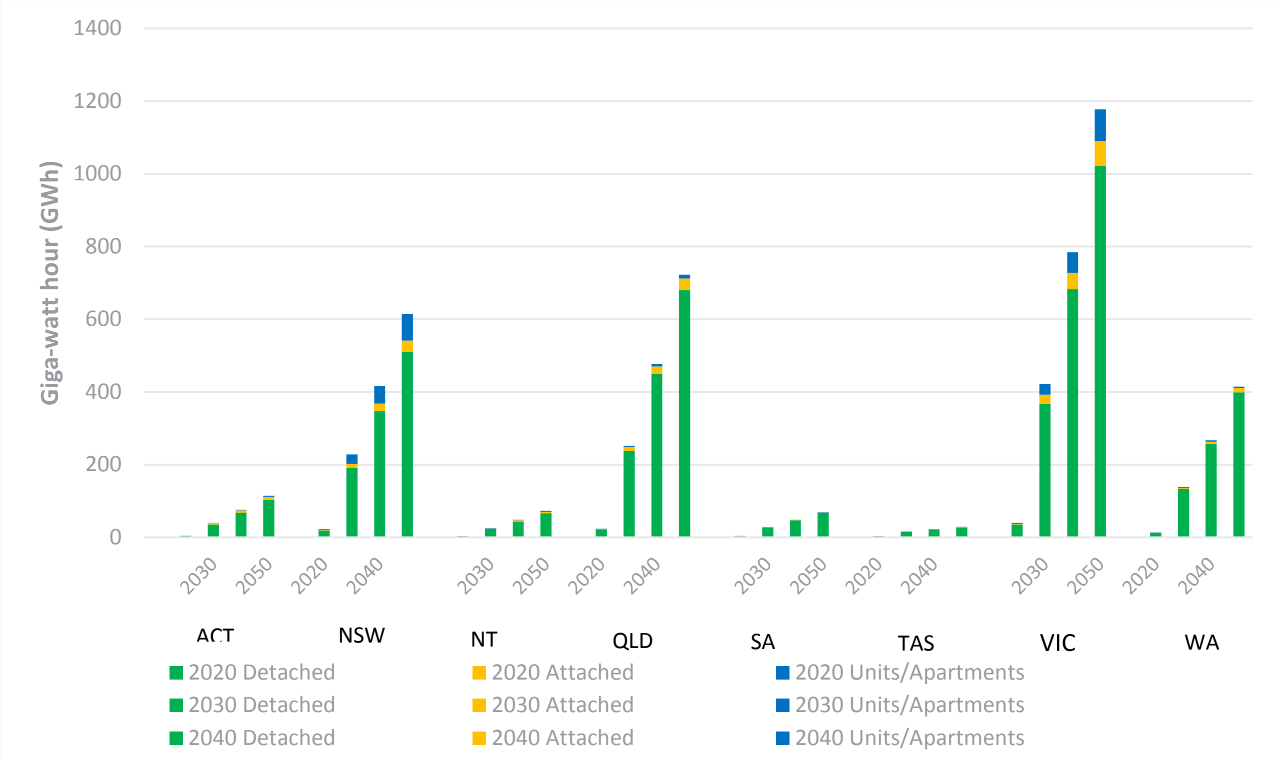


Figure 25. Residential Building Energy Savings by Type, State/Territory (GWh), 2020, 2030, 2040 and 2050
[Source: CSIRO]]

The greatest energy savings are in VIC, QLD and NSW reflecting percentage growth in new builds off a large base. By the end of 2050, VIC has around 1175 GWh energy savings, QLD has 720 GWh energy savings, and NSW has 615 GWh energy savings, respectively.

Over the projection period, QLD, VIC and WA increase their relative share of national energy savings due to higher assumed growth rates compared to the other states and territories. Similar to the national results, Detached dominate the energy savings in all the states/territories. The Attached energy savings share is less than the Units/Apartments energy savings share in NSW and VIC, which complies with the national results. While in QLD and SA, the Attached energy savings share is larger than Units/Apartments energy savings share.

6.4 Emission Reductions – Residential Sector

Greenhouse gas (GHG) emission savings are categorised according to the classes of residential buildings outlined in Section 7.2. The GHG emissions savings of residential buildings are calculated based on the energy savings discussed in Section 6.3 multiplied by the emission intensity of grid electricity.

6.4.1 National Level

National GHG emissions savings by residential building type for the projection period 2020-2050 are shown in Figure 26.

Over the first half of the projection period, GHG emissions reduction increased steadily in line with the energy savings discussed in Section 6.3. From the mid-2030s, the rate of decline in the GHG emissions intensity of grid electricity accelerates, initially stabilising the annual emission savings before declining towards the end of the projection period.

Similar to the energy saving results, Detached ranks first in emission reductions, followed by Units/Apartments and Attached. The peak emission reduction over the projection period occurs in 2033, with the total value being 565 thousand tonnes. Detached contributes around 505 thousand tonnes, Units/Apartments contribute around 35 thousand tonnes, and Attached contributes around 25 thousand tonnes.

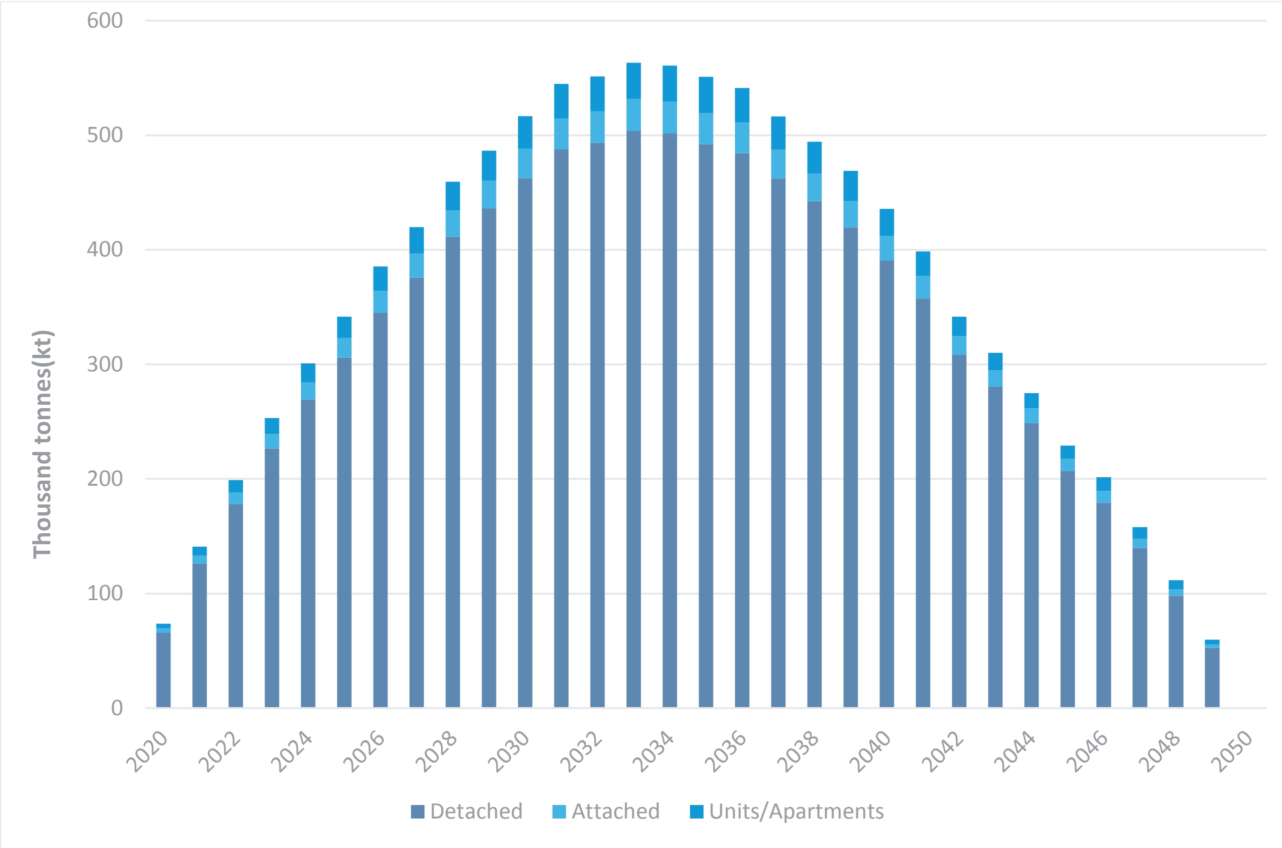


Figure 26. Residential Building GHG Emission Reductions by Type, Australia ('000 tonnes), 2020-2050
[Source: CSIRO]

The annual GHG emission savings from new buildings based on NCC 2019 code change at national level is denoted in Figure 27. It can be seen that the highest GHG emission savings from new builds occur in 2033 at around 0.9 million tonnes. In 2050, the emission savings become zero due to the decarbonisation of grid electricity by 2050.

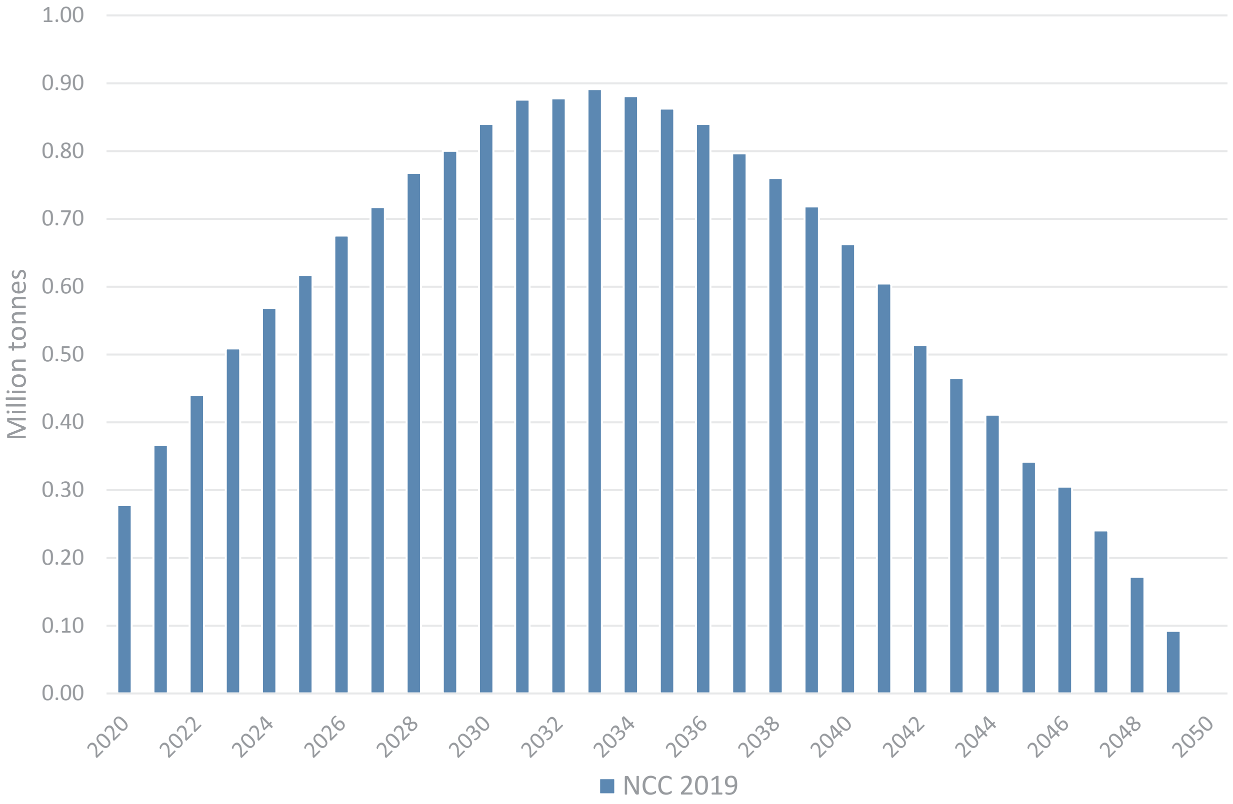


Figure 27. Annual GHG Emissions from New Builds (Million tonnes) at National Level, 2020-2050
[Source: CSIRO]

The cumulative emissions reduction by 2050 for residential buildings are denoted in Table 74. Note that the cumulative value is derived from the summation of each year over the projection period. As observed, the national residential building cumulative GHG emissions reduction is almost 11 million tonnes by 2050, with Detached constituting over 9 million tonnes, the Attached and Units/Apartments over half a million tonnes each.

Table 74. Cumulative GHG emission reductions: 2020-2050 by State/Territory and National (Million tonnes), Residential

State/Territory	Detached	Attached	Units/Apartments	Total
ACT	0.343	0.029	0.011	0.383
NSW	1.796	0.106	0.244	2.146
NT	0.334	0.022	0.013	0.369
QLD	2.428	0.113	0.035	2.576
SA	0.148	0.003	0.001	0.152
TAS	0.018	0.0005	0.001	0.020
VIC	3.525	0.232	0.281	3.979
WA	1.159	0.033	0.013	1.206
AUS	9.752	0.537	0.600	10.830

Source: CSIRO

Among all the states/territories, VIC contributes the most GHG emission reductions, i.e. nearly 4 million tonnes, followed by NSW contributing over 2 million tonnes and QLD contributing almost 3 million tonnes. In NT, QLD, SA, WA and SA, Attached has larger emission reductions than Units/Apartments. However, owing to the large building base in NSW and VIC, the national Units/Apartments emission reductions are larger than Attached.

In the event of slower, 'business-as-usual' grid decarbonisation, the cumulative tonnes of GHG emission savings to 2050 would be lower as shown in Table 75. The 'business-as-usual' grid decarbonisation trajectory assumes a 26 percent emissions reduction from the grid by 2030 on 2005 levels, then emissions continue to decline after 2030 at a comparable rate. According to the table, the national value is close to 20 million tonnes based on this lower emissions reduction trajectory.

Table 75. Cumulative Tonnes of GHG Emission Savings using the Alternative, Lower Ambition Emissions Trajectory (Million tonnes), 2020-2050

State/Territory	GHG emission savings
ACT	0.704
NSW	3.913
NT	0.803
QLD	4.540
SA	0.302
TAS	0.042
VIC	6.944
WA	2.090
AUS	19.337

6.4.2 State Level

This part denotes the residential building GHG emissions reduction amount by state/territory at 2020, 2030, 2040 and 2050.

As shown in Figure 28, all the states have zero emission reductions in 2050 owing to the emission intensity of grid electricity in 2050 being zero. Except NT, TAS, WA and SA, all the other states get to fairly low intensity by 2040 with different decline rates. VIC and NSW have larger decline rates, while QLD and ACT have relatively smaller decline rates.

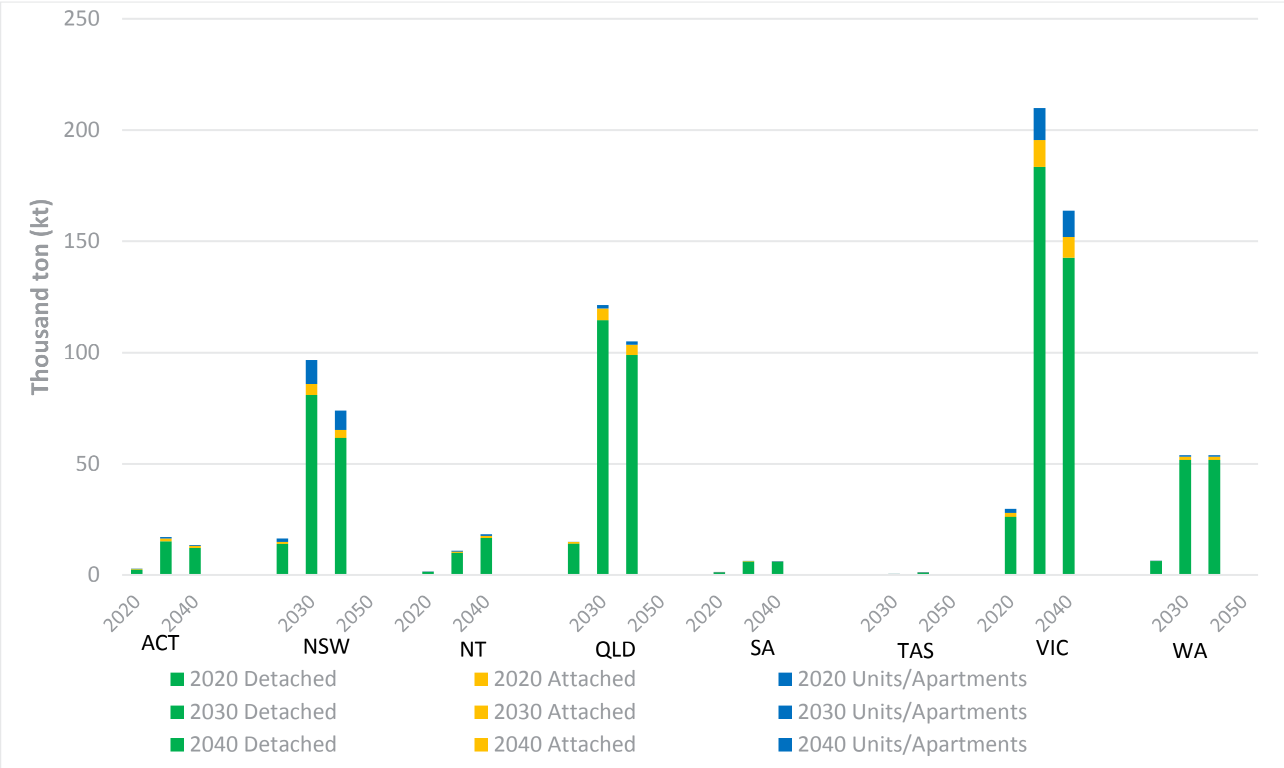


Figure 28. Residential Building GHG Emission Reductions by Type, State/Territory ('000 tonnes), 2020, 2030, 2040 and 2050 [Source: CSIRO]

6.5 Energy cost savings – Residential Sector

This section discusses the energy cost savings from new residential builds over the projection period. The savings are categorised according to the types of residential buildings as well. The energy cost savings are calculated based on the energy savings discussed in Section 7.3 multiplied by estimates of future retail electricity prices.

6.5.1 National Level

Figure 29 shows the national residential building electricity cost savings by different types over the projection periods. As we can see, the cost savings have increased steadily from 2020 to 2050. It can be observed from Figure 29 that Detached ranks the first in cost savings, followed by Units/Apartments and Attached. By 2050, the total residential buildings cost savings are heading towards $1.2 billion, with Detached being around $1045 million, Attached being around $55 million, and Units/Apartments being over $65 million respectively.

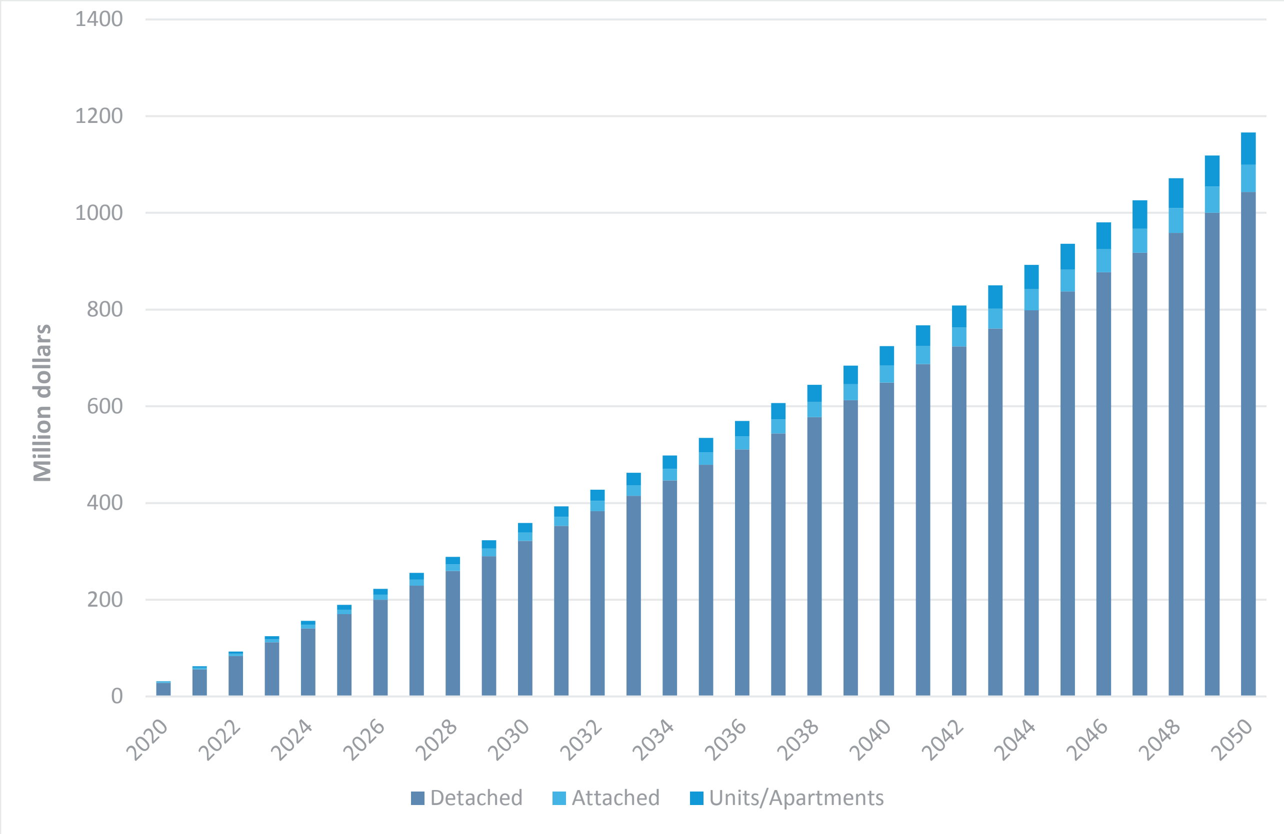


Figure 29. Residential Building Electricity Cost Savings by Type, Australia (Million dollars), 2020-2050
[Source: CSIRO]

The cumulative energy cost savings are derived based on the sum of energy cost savings in each year over the projection period. To 2050, the national cumulative energy cost savings are around $17.3 billion. Assuming a discount rate of 7% per annum, the discounted cumulative energy cost savings to 2050 are around $ 4.1 billion.

6.5.2 State Level

In this part, the state/territory level electricity cost savings are given in Figure 30 in terms of different types of residential buildings, at 2020, 2030, 2040, and 2050 respectively.

For all the states/territories, the electricity cost savings are growing from 2020 to 2050 and Detached dominates the cost savings among three categories. VIC continues to lead the trend, contributing almost 430 million dollars by 2050. QLD is ranked second, totalling more than 260 million dollars by 2050. Units/Apartments have larger share of electricity cost savings than Attached in NSW, VIC and TAS. In contrast, the electricity cost savings in Attached are larger than Units/Apartments in ACT, NT, QLD, SA and WA.

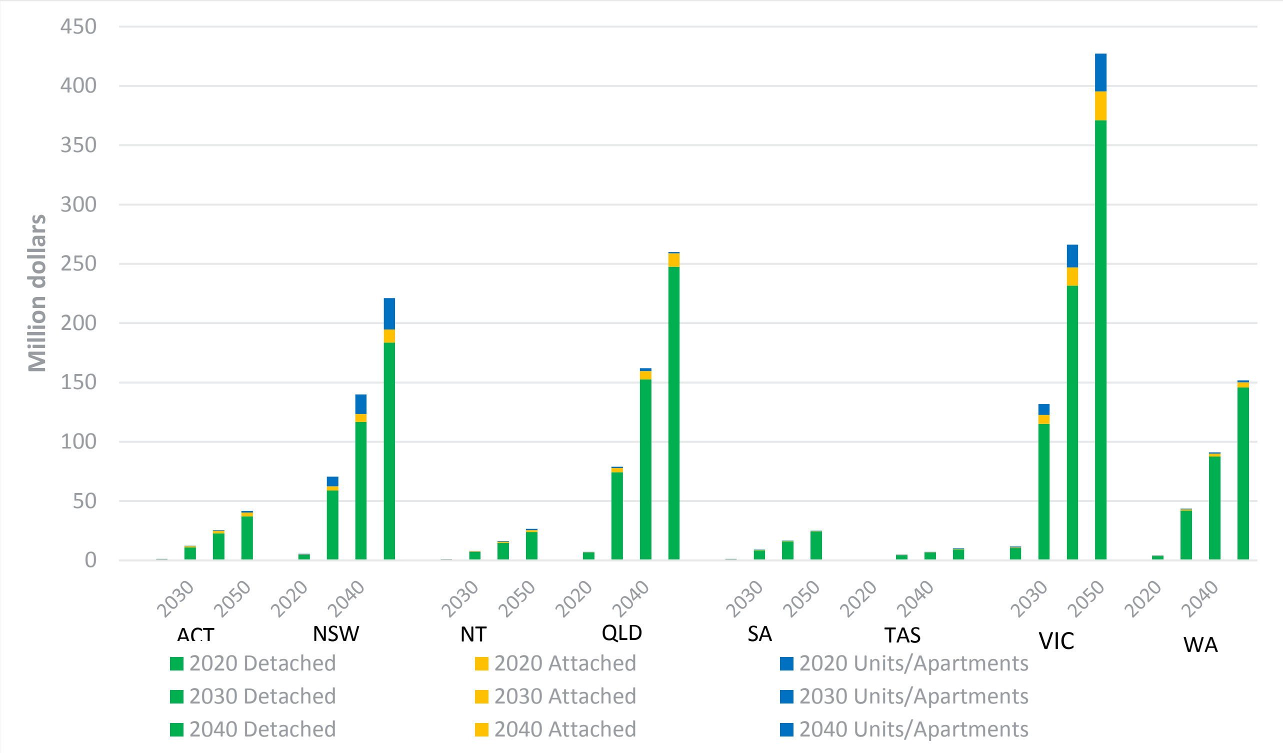


Figure 30. Residential Building Electricity Cost Savings by Type, State/Territory (Million dollars), 2020, 2030, 2040, 2050

The cumulative energy cost savings in terms of undiscounted and discounted values (i.e. discount rate is 7% per year) at state/territory level are denoted in Table 76. As observed, VIC leads the trend with undiscounted cumulative energy cost savings being more than $6.3 billion and discounted value being $1.5 billion. This is followed by QLD, whose undiscounted value is close to $3.8 billion dollars and discounted value at $0.9 billion. The least cumulative energy cost savings can be found in TAS, whose undiscounted savings are around $0.2 billion and discounted savings are close to $0.05 billion.

Table 76 Cumulative residential electricity cost savings (Billion dollars) at state/territory level to 2050

	Undiscounted	Discounted
ACT	0.61	0.14
NSW	3.33	0.79
NT	0.39	0.09
QLD	3.85	0.90
SA	0.40	0.10
TAS	0.18	0.05
VIC	6.34	1.49
WA	2.18	0.50

6.6 Cost of Delay Until 2022 – Residential Sector

In this section, we will focus on the energy savings lost, electricity cost savings lost, and GHG emission reduction savings lost owing to NCC change delay until 2022 over the projection period. The lost electricity savings from delaying the code change to 2022 are the energy savings that do not occur in the years 2020, 2021, and 2022. Once the code changes in 2023, the electricity savings are zero from that year onwards as the electricity savings are now identical. For cost of delay in electricity cost savings and GHG emission reductions, the values are calculated based on the cumulative energy savings in each year multiplying the electricity price/emission intensity in each year.

Table 77 shows the residential building energy savings lost due to NCC change delay until 2022 by state/territory level and national level. From Table 77, it can be clearly seen VIC has the largest energy savings, closely followed by QLD and NSW. TAS and NT have the least energy savings among all the states. The overall energy savings for Australia from NCC change delay until 2020 are over 320 GWh, comprised of almost 290 GWh in Detached, over 15 GWh in Attached, and almost 20 GWh in Units/Apartments.

Table 77. Energy Savings Lost from Delay until 2022 by State/Territory and National (GWh), Residential

State/Territory	Detached	Attached	Units/apartments	Total
ACT	10.028	0.849	0.319	11.196
NSW	54.707	3.229	6.849	64.786
NT	6.366	0.412	0.256	7.035
QLD	65.789	3.051	0.887	69.727
SA	8.097	0.148	0.066	8.312
TAS	5.243	0.136	0.178	5.556
VIC	103.470	6.800	7.603	117.872
WA	36.239	1.042	0.379	37.660
AUS	289.940	15.667	16.537	322.144

Source: CSIRO

Table 78 shows the residential buildings electricity cost savings lost from NCC change delay until 2022 by state/territory level and national level. The total electricity cost savings lost in Australia is approximately 3.5 billion dollars due to the delayed NCC change until 2022. Detached contributes over 3 billion dollars.

Table 78. Electricity Cost Savings Lost from Delay until 2022 by State/Territory and National (Billion dollars), Residential

State/Territory	Detached	Attached	Units/Apartments	Total
ACT	0.110	0.009	0.003	0.123
NSW	0.599	0.035	0.075	0.710
NT	0.070	0.005	0.003	0.077
QLD	0.721	0.033	0.010	0.764
SA	0.089	0.002	0.001	0.091
TAS	0.058	0.001	0.002	0.061
VIC	1.133	0.074	0.083	1.291
WA	0.397	0.011	0.004	0.412
AUS	3.176	0.172	0.181	3.529

Source: CSIRO

Assuming an annual real discount rate of 7%, the cost of delay for lost energy bill savings at national and state/territory level from 2020-2050 is summarized in Table 79, which includes undiscounted values and discounted values. As observed, the discounted electricity cost savings lost is around 1 billion dollars over the projection period.

Table 79. Cost of Delay in Lost Energy Bill Savings (Billion dollars) at National and State/Territory Level, 2020-2050

State/Territory	Undiscounted	Discounted
ACT	0.123	0.039
NSW	0.710	0.225
NT	0.077	0.024
QLD	0.764	0.242
SA	0.091	0.029
TAS	0.061	0.019

State/Territory	Undiscounted	Discounted
VIC	1.291	0.409
WA	0.412	0.131
AUS	3.529	1.117

Source: CSIRO

Table 80. Net Cost of Delay, Cost of Delay (Network Costs), and Cumulative Network Investment Savings (Billion dollars) at National Level, 2020-2050

	Undiscounted	Discounted
Net cost of delay	2.204	0.104
Cost of delay in network costs	0.707	0.528
Cumulative network investment savings	3.417	1.218

Source: CSIRO

As observed from Table 80, the net cost of delay is derived based on the cost of delay on lost energy bill savings minus the benefit of delay in avoided capital costs from building to a more stringent building code. Considering the discount rate is 7%, the undiscounted national net cost of delay value from 2020 to 2050 is around 2.2 billion dollars, with discounted value being 104 million dollars.

The undiscounted cost of delay in network costs for Australia over the projection period is around 700 million dollars, and the discounted value is more than 500 million dollars.

Network costs and benefits were estimated based on the conservation load factor (CLF) method. The CLF is defined as the average reduction in load divided by its peak reduction in load (annual energy savings in MWh) divided by number of hours per year divided by system co-incident peak reduction (in MW)". For this analysis a CLF of 0.1 was utilised for residential buildings, estimated based on typical energy use profiles. The undiscounted cumulative network investment savings for Australia are close to 3.5 billion dollars, with discounted value being over 1.2 billion dollars.

Table 81 indicates the cumulative residential building GHG emissions reduction savings lost from NCC change delay until 2022 by state/territory level and national level. The national cumulative residential building emissions reduction savings lost is over 3 million tonnes, with Detached being more than 2.5 million tonnes, Attached and Units/Apartments being over 0.15 million tonnes.

Table 81. Cumulative GHG Emission Reduction Savings Lost from Delay until 2022 by State/Territory and National (Million tonnes), Residential

State/Territory	Detached	Attached	Units/Apartments	Total
ACT	0.096	0.008	0.003	0.107
NSW	0.524	0.031	0.065	0.621
NT	0.073	0.005	0.003	0.081
QLD	0.653	0.030	0.009	0.692
SA	0.040	0.001	0.000	0.042
TAS	0.006	0.000	0.000	0.006
VIC	1.025	0.067	0.075	1.168
WA	0.300	0.009	0.003	0.312
AUS	2.717	0.151	0.159	3.027

Source: CSIRO

7 Next Steps: The Forward Trajectory

Phase two of this project will investigate pathways to improve energy requirements over future Code upgrades towards a long-term target of net zero buildings.

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

- Clear policy objectives for the Code energy requirements;
- A set long-term target;
- Indicative interim targets; and
- A clear process with established principles for Code upgrades over time.

As shown in Figure 31 below, a trajectory can take the form of energy performance targets that incrementally reduce along a pathway towards an end goal. A trajectory that sets out the allowable levels of energy consumption for new construction over subsequent upgrades to the Code – well in advance of each Code cycle – provides a regulatory signal to consumers and industry that encourages innovation and investment in new technology, design and construction practices. This is particularly important for innovations that require a long lead-time, such as the development of new products by manufacturers, as it allows the industry to plan ahead for future regulatory requirements

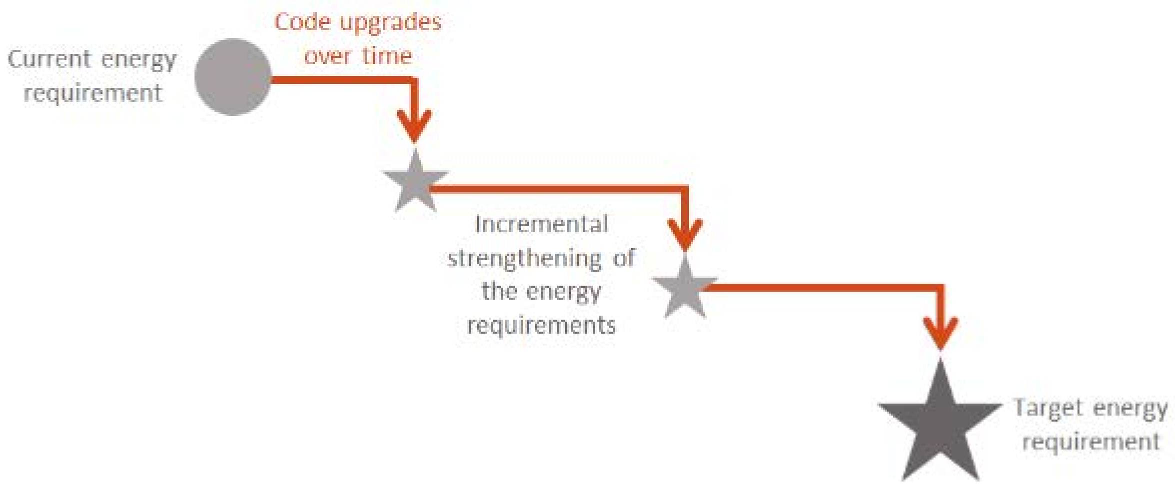


Figure 31. Building Code Energy Requirement Pathway

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

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

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

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

- Climate Zone 2 - Warm humid summer, mild winter (e.g. Brisbane);
- Climate Zone 5 - Warm temperate (e.g. Sydney, Adelaide, Perth);
- Climate Zone 6 - Mild temperate (e.g. Greater Western Sydney, Melbourne); and
- Climate Zone 7 - Cool temperate (e.g. Canberra, Hobart).

Modelling results will be included in the Final Report.

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

The development of the forward trajectories beyond what is currently cost-effective will be covered in the Final Technical Report, to be published in mid-2018.

Appendix A: Residential Archetype Details and Models

A.1 Apartment Archetype

7.1.1.1 A.1.1 Form Details

The apartment building modelled was based on the details provided by Isaacs[34] (2007, pp. 17-18). The apartment on the corner of the first floor was selected as the representative archetype, refer to Figure 32. The first floor was selected as it is representative of most midrise apartments, having a shared floor, roof and walls. Common areas have not been included. The floor plan of this apartment is illustrated in Figure 33, with 73 m^2 of total net conditioned floor area[35]. A 3D model of the apartment building showing approximate room layout is presented in Figure 34.

Figure 32. Schematic of the Apartment building (Isaacs 2007, p. 17)

Figure 33. Floor plan of the Apartment building (Isaacs 2007, p.17)

[34] Isaacs, T (2007), Development of housing stock model to predict heating and cooling energy use in Victoria.
[35] Total net conditioned floor area reduced compared to Isaacs' (2007, p. 17) model based on TAG feedback.

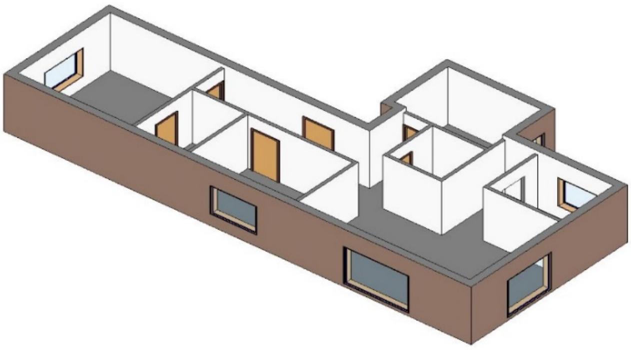


Figure 34. 3D model of the apartment building showing approximate room layout.

7.1.1.2 A.1.2 Construction Details

The main construction details used for the apartment are summarised in Table 82.

Table 82. Construction specifications for the apartment, for reference orientation of 0°.

Archetype Parameter		Construction details	References
External wall	All façades	Compressed fibre cement (6mm), brick (110mm), air gap + insulation thickness = 150mm, plasterboard (10mm)	
Internal partitions		Plasterboard, air gap and plasterboard	
Internal floor	All other areas	Concrete slab plus carpet with underlay	TAG provided drawings
	Wet areas and kitchen	Concrete slab plus tiles	
Ceiling		Concrete to next apartment, air gap, insulation and plasterboard	TAG provided drawings
Roof		Refer to the internal floor. As the apartment is on the first floor, the roof was modelled as the internal floor and boundary condition adjacent to the top apartment*	
Windows		The window types varied across the different stringency scenarios	
External shading	Eaves	The eaves length varied across the different stringency scenarios	(Wong 2013, p. 19)
Airtightness		As close as possible to 15ACH at 50P**, in some cases, stringency scenarios reduced airtightness to 7ACH at 50Pa	(Ambrose & Syme 2015, p. 10)

* Roof construction is not applicable for the first floor apartment. Roof and floor of neighbouring units to be modelled as an adiabatic layer within the limitations of existing software.

** Air change rate is the average sourced from Ambrose & Syme (2015, p10) and deemed to be a suitable figure for newly constructed homes. It was not possible to match this value exactly in AccuRate Sustainability due to infiltration calculation methodology.

7.1.1.3 A.1.3 Operational Details

Occupancy and operational details for internal load modelling followed the existing NatHERS protocol based on the discussion during TAG meeting. Details on the NatHERS Protocol may be found at (http://www.nathers.gov.au/files/publications/NatHERS Software Accreditation Protocol-June 2012.pdf). The occupancy schedule assumption provided by AccuRate Sustainability, with 9:00 to 17:00 being unoccupied, was employed in the modelling. It was derived from the Australian Bureau of Statistics[36]. Internal loads (such as lighting) and HVAC were included in the NatHERS protocol and AccuRate Sustainability schedules. Domestic hot water was considered separately.

The HVAC system modelled was a reverse cycle air-conditioner, and its operation schedule was dictated by the occupancy profile and weather conditions. This means that when the conditioned spaces were occupied, a minimum thermal comfort level was required. This comfort level in summer is described as having an indoor temperature equal to or lower than the neutral temperature. In other words, the cooling temperature setpoint equals the neutral temperature (Note: AccuRate Sustainability software uses the January neutral temperature for the cooling months) plus +2.5◦C, by following the 90% acceptability of thermal comfort limits[37]. The details are provided in Delsante[38]. AccuRate Sustainability default heating temperature setpoint values were employed for the heating conditions.

A.2 Attached House

7.1.1.4 A.2.1 Form Details

The attached house modelled was also selected from the Isaacs's (p. 16) report[39]. The house selected is shown in Figure 36. The gross floor area of the house was 125 m^2, which falls within the size distribution of the most frequent floor areas, i.e. 100-150 m^2 for a double-storey attached house. Refer to Figure 36 for more details. A 3D model of the attached house showing room layout is presented in Figure 37.

Figure 35. Façade of the attached house (Isaacs 2007, p.16)

36 Ren, Z., Foliente, G., Chan, W., Chen, D., & Syme, M. (2011). AUSZEH DESIGN : Software for Low-Emission and Zero-Emission House Design in Australia. In Proceedings of Building Simulation (pp. 14–16). Sydney, NSW.

37 de Dear, R.J. and Schiller Brager, G. (1998). "Developing an Adaptive Model of Thermal Comfort and Preference". ASHRAE Trans., Vol .104(1A), 145-167.

38 Delsante, A. (2005). Is the new Generation of Building Energy Rating Software up to the Task? - A Review of AccuRate, (September), 11–15.

39 Isaacs, T (2007), Development of housing stock model to predict heating and cooling energy use in Victoria.

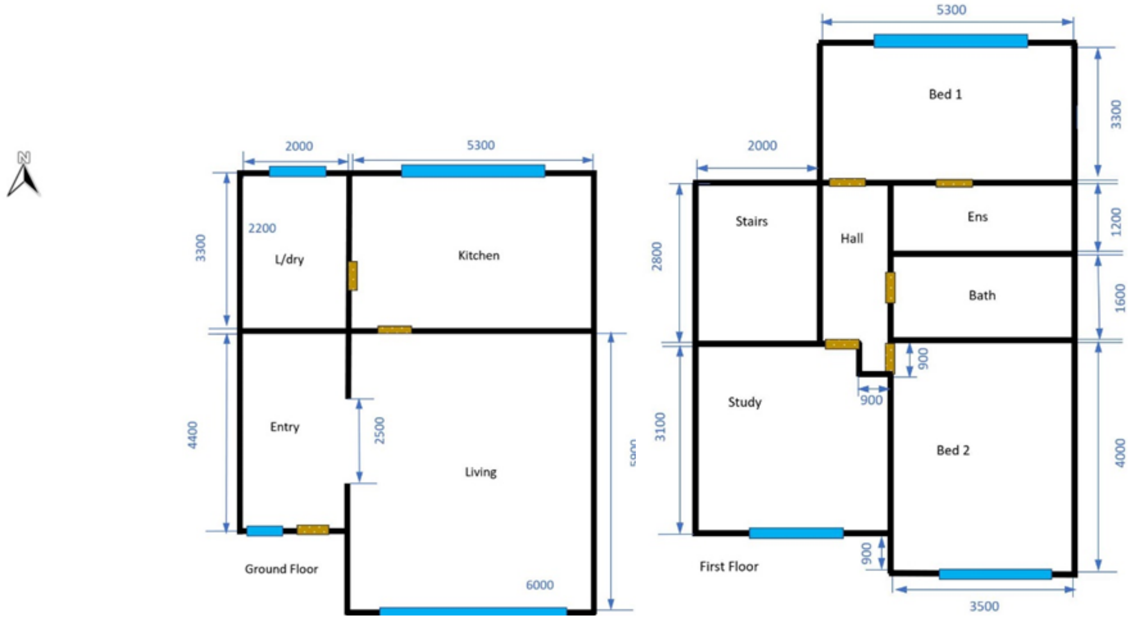


Figure 36. Floor plan of the ground and first floor of the attached house.

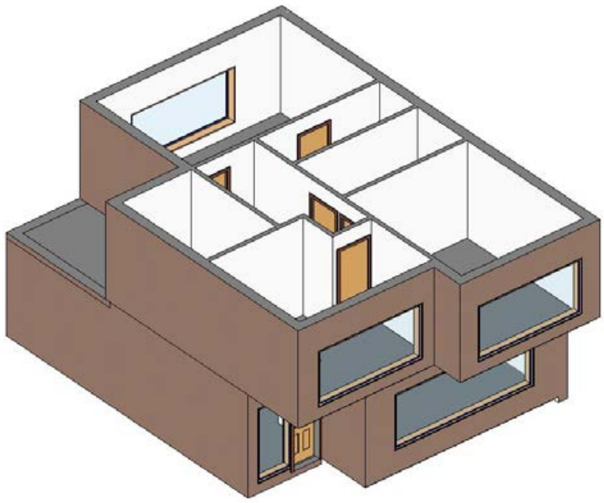


Figure 37. 3D model of the attached house showing room layout.

7.1.1.5 A.2.2 Construction Details

The construction details of the attached house are specified in

Table 83. They were determined based on expert suggestions from the Residential TAG members and the existing data from the Australian Bureau of Statistics reported by the Wong (2013) report.

Table 83. Construction specifications for the attached house.

Archetype Parameter		Construction	References
External Wall	Party wall with adjacent house	Plasterboard 12mm, Brick=110 mm, airspace =40mm, Brick=110 mm plasterboard 12mm	
	Eastern façade	Brick veneer: 110 mm external brick, airspace + insulation=150mm, 12 mm plasterboard	
Internal partitions		Plasterboard, air gap and plasterboard	
Floor	Ground floor	Concrete slab plus carpet with underlay	
	Internal floor	Concrete slab plus tiles for wet areas	
Ceiling		Ceiling insulation varied across the different stringency scenarios	
Roof		Typically clay tiles	(Wong, 2013)
Windows		The window types varied across the different stringency scenarios	(YourHome, 2017)
External Shading		The eaves length varied across the different stringency scenarios	(Wong, 2013)
Airtightness**		As close as possible to 15ACH at 50Pa**, in some cases, stringency scenarios had reduced airtightness to 7ACH at 50Pa	(Ambrose & Syme, 2015)

** Air change rate is the average sourced from Ambrose & Syme (2015, p10) and deemed to be a suitable figure for newly constructed homes. It was not possible to match this value exactly in AccuRate Sustainability due to infiltration calculation methodology.

7.1.1.6 A.2.3 Operational Details

As per the apartment, occupancy and operational details for internal load modelling followed the NatHERS protocol. Further details on the NatHERS Protocol may be found at (http://www.nathers.gov.au/files/publications/NatHERS Software Accreditation Protocol-June 2012.pdf). The occupancy schedule provided by AccuRate Sustainability from 9:00 to 17:00 unoccupied was employed. It was derived from the Australian Bureau of Statistics[40]. Internal loads (such as lighting) and HVAC were included in the NatHERS protocol and AuccRate schedules. Domestic hot water was considered separately. The HVAC system modelled and its operation were similar to those for apartment buildings.

A.3 Detached house

7.1.1.7 A.3.1 Form Details

The detached house selected was based on the archetype developed by Isaacs (2007, p. 12) report as shown in Figure 38. The model has been slightly revised, as shown in Figure 39, with a total floor area of 188 m^2, as per medium detached dwelling analysed in the Pitt & Sherry[41] report, and the dimensions are specified in Figure 40.

[40] Ren, Z., Foliente, G., Chan, W., Chen, D., & Syme, M. (2011). AUSZEH DESIGN : SOFTWARE FOR LOW-EMISSION AND ZERO-EMISSION HOUSE DESIGN IN AUSTRALIA. In Proceedings of Building Simulation (pp. 14–16). Sydney, NSW.

[41] Pitt&Sherry, Pathway to 2020 for Increased Stringency in New Building Efficiency Standards Benefit Cost Analysis. 2012. Department of Climate Change and Energy Efficiency: Published by the Department of Climate Change and Energy Efficiency.

Figure 38. 3D sketch of the detached house (Isaacs 2007, p. 12).

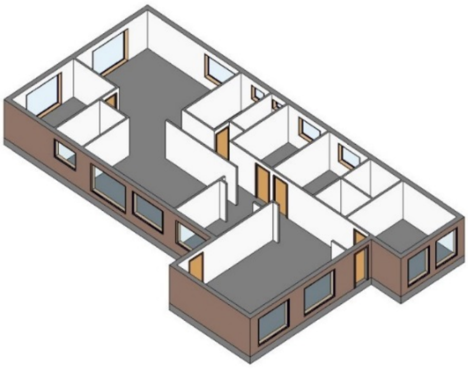


Figure 39. 3D model of the detached house showing room layout.

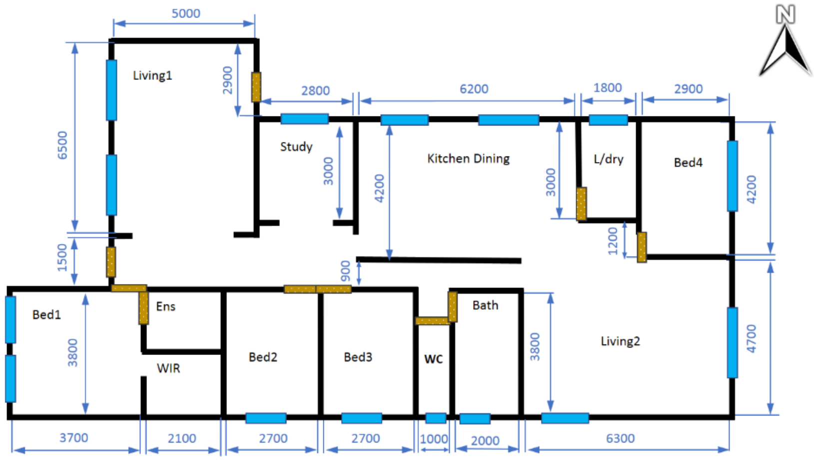


Figure 40. Dimensions of the detached house (Isaacs 2007, p. 12).

7.1.1.8 A.3.2 Construction Details

The construction details are specified in Table 84. They were determined based on specifications from the “YourHome” website (2017), suggestions from experts within the Residential TAG membership, and the existing data from the Australian Bureau of Statistics in Wong’s (2013) report.

Table 84. Construction specifications for the detached house.

Archetype Parameter		Construction	References
External Wall	All façades	Brick-veneer – 110 mm external brick, airspace/insulation, internal 12 mm plasterboard	(Wong, 2013)[42]
Internal partitions		Plasterboard, air gap and plasterboard	
Ground Floor	Other areas	Concrete slab plus carpet with underlay	
	Wet areas	Concrete slab plus tiles	
Ceiling		Ceiling insulation varied across different stringency scenarios	(NCC Deemed to Satisfy)
Roof		Steel deck with R1.5 Polyester blanket.	(YourHome, 2017)
Windows		The window types varied across the different stringency scenarios	
External Shading		The eaves length varied across the different stringency scenarios	(Wong, 2013)
Airtightness		As close as possible to 15ACH at50Pa**, in some cases, stringency scenarios had reduced airtightness to 7ACH at 50Pa	(Ambrose & Syme, 2015)

** Air change rate is the average sourced from Ambrose & Syme (2015, p10)[43] and deemed to be a suitable figure for newly constructed homes. It was not possible to match this value exactly in AccuRate Sustainability due to infiltration calculation methodology

7.1.1.9 A.3.3 Operational Details

As per the apartment, occupancy and operational details for internal load modelling followed the NatHERS protocol. Further details on the NatHERS Protocol may be found at (http://www.nathers.gov.au/files/publications/NatHERS Software Accreditation Protocol-June 2012.pdf).

The occupancy schedule assumption provided by AccuRate Sustainability, with 9:00 to 17:00 being unoccupied, was employed. It was derived from the Australian Bureau of Statistics. Internal loads (such as lighting) and HVAC were included in the NatHERS protocol and AccuRate Sustainability schedules. Domestic hot water was considered separately. The HVAC system modelled and its operation were similar to those for apartment buildings.

[42] Wong, J. P. (2013). Development of Representative Dwelling Designs for Technical and Policy Purposes. RMIT University, Melbourne, Victoria.

[43] Ambrose, M., & Syme, M. (2015). House Energy Efficiency Inspections Project Final Report.

Appendix B: Discount Rates

Discounting is a device intended to enable streams of value that occur over time (often over many years) to be compared with each other. This can be a controversial area, since the effect of discounting is to place a lower weighting on values or consequences that occur in the distant future as compared to those that occur today or in the near future. Arguably, this can contribute to problems of inter-generational equity.

For example, it is very likely that decisions made today, that have consequences for the degree and severity of the damage caused by future climate change, are failing to adequately take that damage into account. Using a high discount real discount rate will tend to favour projects (or policies) that generate net benefits in the short term, regardless of potentially large costs that may occur in future.

It is worth distinguishing between the issues affecting the choice of discount rate and the uncertainty associated with potential future impacts or consequences of decisions. It is often the case that some values can be readily monetised (like project revenues, or regulatory compliance costs) while others are much harder to so do (like the benefits associated with a stable climate, or avoided species loss, or low probability/high impact consequences such as radiation leakage from nuclear power stations). The difficulty in monetising these latter impacts can exacerbate the effect of discounting in 'weighing up' potentially disastrous future events – there is a risk that we both undervalue these impacts (the expected future costs at the time they occur), and then discount their present value. However, the valuation problem is distinct from discounting.

The fundamental decision is whether to attempt to monetise certain impacts, when uncertainty about expected values or outcomes is high, or whether to treat these factors as non-monetary considerations to be weighed in the balance alongside the benefit cost analysis of those factors that can readily be monetised. The absurdity of the view that all values should be monetised is readily apparent when human life is at risk. If a project (perhaps a new asbestos mine) was likely to generate significant economic value, but knowingly lead to hundreds or thousands of deaths over time, very few governments would require monetisation of the value of human life in order to make a decision about whether or not that project should proceed. Arguably a similar case can be made for climate change impacts, yet at this point there is a lack of agreement about the size or immanence of the threat.

Turning to the choice (or use) of discount rates, there are numerous different rationales offered for discounting – and, problematically, they do not always agree with each other conceptually. One paper refers to a 'small cottage industry' that is constantly generating new functional forms and explanations for discounting behaviours. Importantly, discounting behaviours and rates can be established through evidence-based, experimental and observational processes – although there is much debate about experimental design and the impact this may have on the results. Nevertheless, while individuals may vary in their discount rates, and there is some evidence that a given individual's discount rates may depend upon the context and also upon their attitudes towards risk, discounting is a real and observable behaviour.

The general observation is that most people display 'time preference'. That is, we tend to place a higher value on something which is available to, or is expected to affect us, or things we care about, in the short term when compared with something which is available to or affects us only in the longer term.

Amongst the many theories as to why such behaviour occurs, one key explanation is the availability of (real, or inflation adjusted) interest rates as a mechanism that change the value of at least money over time. Using a (practically) risk free Treasury bond, $100 not consumed today can with confidence be assumed to be worth, say, $104 next year. The choice whether to consume the $100 today or else to save it is informed by the awareness that it will be worth more in future. Real interest rates define a 'time value of money' that is independent of individual's values and judgements: a kind of yard-stick. Arguably this explanator for time preference only relates to monetary or instrumental values.

Other important considerations are individual (and potentially social or cultural) values that shape our view of the future, such as the degree to which we are altruistically-motivated or materially-motivated, and also our risk preferences. Some have argued that an 'innate' driver of discounting behaviours is an awareness (even subconscious awareness) of our own mortality (also known as 'dread risk'). Commonly-heard phrases such as 'I may not be here tomorrow', or 'get while the getting's good', or 'never do today what you can put off to tomorrow' (for unpleasant tasks, and an inversion of the original saying), all indicate time and risk preferences based on the inevitable uncertainty as to what the future will bring, including whether you personally will live long enough to find out.

Some argue that personal or social time preferences include 'kinship' or legacy considerations – concern for the welfare of our children and grandchildren, for example. If we place a high value on the interests of our children, or indeed on all human life, then we may not see a difference in kind between our interests and those of our grandchildren, or indeed others' grandchildren. Discounting the future well-being of your own offspring can seem counter-intuitive or repulsive, at least to some. This perspective leads to behaviours such as legacies, bequests and inheritance.

This long-term perspective may also be relevant to decisions about projects or policies that are expected to impact on climate change – since this raises the spectre of worsened living conditions for future generations, including our own offspring and all others. Some extend this to a concern for the welfare of all life, including non-human life, and a sense that we are responsible for the impacts of our decisions on all life, at all times, now and in the future. The latter represents an important challenge to the validity of benefit cost analysis, which deals with values that can be monetised, and these by definition are human and instrumental values only.

Yet such considerations must be weighed against the observational evidence. Rightly or wrongly, people do make decisions that may damage future generations or non-human life. Almost any consumption decision today may risk depriving a consumption possibility in the future; almost any decision – including to walk down the street and tread on an ant – involves risk to non-human life.

In short, discounting presents us with a conundrum. There is evidence that most people do discount the future, and yet we have evidence that our tendency to discount the future is causing or contributing to significant harm, which is likely to grow over time. This highlights the limitations inherent in relying on a single analytical technique as a basis for making good and responsible decisions. Using benefit cost analysis, there is a grave risk that we make decisions based on values that are easy to monetise, and ignore those that are not. This risk exists with or without benefit cost analysis, but the tendency to use benefit cost analysis as a key basis for government decision-making is deeply entrenched, including specifically for stringency-setting under the National Construction Code.

Another key concern, given our reliance on benefit cost analysis, is that results can easily be manipulated, through the choice not only of discount rates, but also which impacts to monetise, how those impacts are valued, probability weightings, the choice of input values (energy prices, carbon prices, etc.) and many other factors. The question arises, is there any basis for treating discount rates as a variable – as we commonly do – or should they be fixed, using experimental processes? Our instinct to use benefit cost analysis as a basis for making complex decisions is that, apparently, it simplifies those decisions into a single vector, cost effectiveness, with a clear tipping point (BCR = 1). Yet the risk is this technique only masks – or deliberately hides – complexity, denying the decision-maker's responsibility to make balanced and considered decisions.

So how to proceed? There are two practical perspectives. First, the choice of discount rate will only have a significant effect (i.e. change the 'preferred' option) if the underlying economics are marginal. A very low benefit cost ratio may be lifted a little by selecting a low discount rate, but if the BCR still does not exceed 1, then decision-makers may still reject the option. Conversely, a highly cost-effective pathway will remain so even with high discount rates. The choice becomes critical only where we strive to optimise…to push towards an outcome where we generate the maximum amount of change that can be economically justified, and that occurs where the BCR equals 1.

In the current context, where we are seeking to map the limits of cost effectiveness for a building energy performance pathway, and where the standard employed by the Australian Building Codes Board/COAG is that a stringency outcome should fall within the BCR range of 1 – 1.5, then discount rates will matter.

Second, despite all the argumentation above, the COAG Best Practice Regulation Guidelines, which apply to NCC energy performance stringency requirements inter alia, require that analyses use a reference real discount rate of 7%, and allows sensitivity analysis at 3% and 10%. This, therefore, is the common practice. The risk is that if the 'headline' results from this project were presented using a real discount rate lower than 7%, then they may be dismissed, particularly by those in government. Choosing a default discount rate of 7% will maximise the perceived credibility and impact of this project, and therefore we proceed on that basis.

Appendix C: Residential Energy Analysis – Tabular Form

The following tables summarise the detailed energy analysis results for the three residential archetypes under Climate Zones 2, 5 and 6. The results presented are the thermal energy consumption (MJ/m²/year). The **cooling or heating saving** presented in the tables refers to the difference between the thermal energy consumption of the baseline case and that of using individual technical options while the **rating change** refers to the difference of equivalent Star rating of the archetype using individual technical options with that of the baseline case.

C.1 Apartment Archetype

Table 85. Energy analysis results for the Apartment Archetype for Climate Zone 2

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m²/year)		Equivalent Star rating	Saving (MJ/m²/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	44.4	17.7	4.9	0.7	0.6	0	1.4	1.1	0.1	1.5	1.3	0.1	1.8	1.6	0.2
		Surface colour				0.4	-0.3	0	1.4	-0.8	0	1.5	-0.9	0			
	Infiltration	improve workmanship				4	8.3	0.8									
	External shading	Eave extension				1.2	-0.2	0	2.9	-0.4	0.1	3.1	-0.7	0.1	5.9	-1.7	0.2
		roller shutters				10.2	0	0.6									
	Thermal mass					8.8	0.8	0.5	4.7	1.1	0.3	12.3	1.3	0.9			
90º		Insulation	35.3	11.4	6	0.1	0.5	0	0.6	0.8	0.1	0.4	0.9	0.1	0.5	1.1	0.2

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m²/year)		Equivalent Star rating	Saving (MJ/m²/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	External wall	Surface colour				0.4	-0.3	0	0.8	-0.8	0	0.7	-1	-0.1			
	Infiltration	improve workmanship				0.3	6.2	0.6									
	External shading	Eave extension				0.1	-0.1	0	0.9	-0.3	0.1	1.6	-0.6	0.1	2.4	-1	0.1
		roller shutters				5.9	0	0.6									
	Thermal mass					5.3	2.5	0.8	3	2.8	0.6	7.2	3.9	1.2			
180°	External wall	Insulation	36.3	7.3	6.3	0.8	0.5	0	1.1	0.6	0.1	1.6	0.9	0.2	1.9	1.1	0.3
		Surface colour				0.7	-0.4	0	1.2	-0.9	0	1.7	-1.1	0.1			
	Infiltration	improve workmanship				-0.7	5.3	0.5									
	External shading	Eave extension				0.8	-0.4	0	1.5	-0.9	0.1	2.6	-1.4	0.1	3.7	-3	0.1

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m²/year)		Equivalent Star rating	Saving (MJ/m²/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		roller shutters				6.3	0	0.6									
	Thermal mass					4.8	1	0.6	1.5	1.4	0.3	4.3	1.6	0.6			
270º	External wall	Insulation	33.7	17.4	5.6	0.1	0.6	0	0.7	1.3	0.2	1	1.7	0.3	1.4	2	0.3
		Surface colour				0.6	-0.4	0	1.6	-1	0.1	1.7	-1.3	0			
	Infiltration	improve workmanship				0.8	9.2	0.9									
	External shading	Eave extension				1	0.1	0.1	2.2	-0.3	0.1	2.8	-0.6	0.2	4	-1.6	0.2
		roller shutters				5.4	0	0.5									
	Thermal mass					6.9	0.3	0.7	2.4	0.7	0.3	7.7	0.4	0.8			

Table 86. The energy analysis results for the Apartment Archetype for Climate Zone 5

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	24.6	28.4	5.1	0.3	0.9	0.1	0.9	1.8	0.2	1.1	2.4	0.2	1.1	2.8	0.3
		Surface colour				0.8	-0.6	0	0.8	-1.5	-0.1	1.3	-1.8	-0.1			
	Infiltration	improve workmanship				1.3	12.9	1.3									
	External shading	Eave extension				0.9	-0.3	0	1.4	-0.7	0	1.9	-1.1	0	3.5	-2.4	0.1
		roller shutters				4.9	0	0.3									
	Thermal mass					4.7	1.3	0.4	2.1	1.2	0.2	5.4	1.9	0.6			
90º	External wall	Insulation	21.9	17.9	6.3	0.2	0.4	0	0.5	0.9	0.1	0.7	1.2	0.1	0.8	1.5	0.2
		Surface colour				0.3	-0.7	-0.1	0.7	-1.5	-0.1	0.8	-1.9	-0.2			
	Infiltration	improve workmanship				-1.3	9.5	0.8									
	External shading	Eave extension				0.3	-0.3	0	0.8	-0.6	0	1.4	-1.2	0	1.9	-2	0
		roller shutters				2.8	0	0.3									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Thermal mass					3.3	3.2	0.6	2.1	3.7	0.6	4.7	5	1			
180º	External wall	Insulation	25.6	14	6.3	0.1	0.6	0.1	0.6	1.3	0.2	0.7	1.7	0.3	0.7	2.1	0.3
		Surface colour				0.6	-0.6	0	0.6	-1.6	-0.1	0.8	-2	-0.1			
	Infiltration	improve workmanship				-1	9.5	0.9									
	External shading	Eave extension				0.6	-0.5	0	1.3	-1.1	0	2	-1.8	0	3.1	-3.8	-0.1
		roller shutters				4.4	0	0.4									
	Thermal mass					4.2	1.4	0.6	1.9	1.8	0.4	5	2.6	0.8			
270º	External wall	Insulation	24.7	27.6	5.1	-0.1	1.1	0.1	0.3	2	0.2	0.9	2.6	0.3	0.9	3.1	0.3
		Surface colour				0.2	-0.7	0	0.6	-1.6	0	0.8	-1.9	0			
	Infiltration	improve workmanship				0.6	14	1.4									
		Eave extension				0.8	-0.4	0.1	1.2	-1	0.1	1.6	-1.5	0	2.6	-2.8	0

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	External shading	roller shutters				3.9	0	0.3									
	Thermal mass					5.2	0.3	0.5	1.3	0.2	0.1	5.8	0.4	0.5			

Table 87. The energy analysis results for the Apartment Archetype for Climate Zone 6.

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Ratin g chan ge
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	22	129.6	5.3	-0.2	3.7	0	0.2	7.1	0.1	0.4	9.3	0.2	0.5	11	0.3
		Surface colour				0.1	-1.5	-0.1	0.7	-3.6	-0.1	1	-4.3	-0.1			
	Infiltration	improve workmanship				-0.1	50.4	1.4									
	External shading	Eave extension				0.2	-1.3	-0.1	0.9	-2.5	-0.1	1.4	-3.8	-0.1	2.9	-7.5	-0.2

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		roller shutters				4	-0.1	0.1									
	Thermal mass					6.6	-0.1	0.1	4.3	1.4	0.1	8.9	0.8	0.2			
90º	External wall	Insulation	19.7	110.8	5.8	-0.1	3.2	0.1	0.4	6.2	0.1	0.7	8.1	0.3	0.8	9.6	0.3
		Surface colour				0.3	-1.8	0	0.7	-4.6	-0.1	1	-5.3	-0.1			
	Infiltration	improve workmanship				0.1	48.4	1.4									
	External shading	Eave extension				0.3	-1.2	0	0.8	-2.4	0	0.6	-3.5	-0.1	1.4	-7.4	-0.1
		roller shutters				3.8	-0.2	0.1									
	Thermal mass					6.9	2.3	0.3	5	4.6	0.3	9.2	4.5	0.4			
180º	External wall	Insulation	24.3	112.6	5.6	0	3.6	0.1	0.3	6.7	0.2	0.7	8.7	0.3	0.9	10.4	0.3
		Surface colour				0.2	-1.7	0	0.8	-4.2	0	1.1	-5	-0.1			

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year) Cooling	Load (MJ/m2/year) Heating	Equivalent Star rating	Saving (MJ/m2/year) Cooling	Saving (MJ/m2/year) Heating	Rating change	Saving (MJ/m2/year) Cooling	Saving (MJ/m2/year) Heating	Rating change	Saving (MJ/m2/year) Cooling	Saving (MJ/m2/year) Heating	Rating change	Saving (MJ/m2/year) Cooling	Saving (MJ/m2/year) Heating	Rating change
	Infiltration	improve workmanship				0.1	49.7	1.5									
	External shading	Eave extension				0.3	-1.3	0	0.7	-2.7	0	1.2	-4	0	2.8	-8	-0.1
	External shading	roller shutters				3.6	-0.1	0.1									
	Thermal mass					7.4	-0.5	0.2	3.3	1.9	0.2	9.3	1	0.3			
270º	External wall	Insulation	24	132.1	5.1	-0.1	3.9	0.1	0	7.3	0.2	0.3	9.5	0.3	0.6	11.2	0.3
270º	External wall	Surface colour	24	132.1	5.1	0.2	-1.3	0	0.6	-3.2	0	0.7	-3.8	0			
270º	Infiltration	improve workmanship	24	132.1	5.1	0.8	49.7	1.4									
270º	External shading	Eave extension	24	132.1	5.1	0.8	-1	0	1.3	-2.3	0	2.1	-3.4	0	3.8	-6.3	0
270º	External shading	roller shutters	24	132.1	5.1	2.7	0	0.1									
270º	Thermal mass		24	132.1	5.1	8	-1.2	0.2	3.4	-0.2	0.1	10.4	-1.2	0.3			

C.2 Attached Archetype

Table 88. The energy analysis results for the Attached Archetype for Climate Zone 2.

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	34	10.4	6.3	0	0.2	0	0.3	0.3	0	0.1	0.4	0	0.1	0.5	0
		Surface colour				0	-0.1	0	0.2	-0.2	0	0.5	-0.3	0	1	-0.4	0
	Roof	Roof surface type				0.5	-0.3	0	1	-0.7	0	1.8	-0.8	0			
		Surface colour				0.8	-0.3	0	0.6	-0.6	0	1.9	-0.8	0			
		Openness				0.7	-0.2	0	1	-0.2	0						
	Ceiling	Insulation				0.4	0.4	0	0.8	0.7	0	-0.2	0.9	0	-0.2	1	0
	Floor	Edge Insulation*															

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Under Slab Insulation				-2.6	-1.6	-0.4							-3.7	-1.8	-0.4
	Ventilation	Ceiling fan				16.7	-0.3	1.6									
	Infiltration	Improve workmanship				6.5	4.1	1.2									
	External shading	Eave extension				0.6	-0.5	0	1.1	-0.9	0	2.1	-1.3	0.1	2.8	-1.8	0
		roller shutters				1.9	0	0.2									
	Thermal mass					0.4	0.6	0	-1.5	-0.8	-0.2	-0.5	-0.2	-0.1			
90º	External wall	Insulation	60.6	7	4.6	0.4	0.2	0.1	0.8	0.3	0.1	1	0.4	0.1	0.7	0.5	0.1
		Surface colour				0.5	-0.1	0.1	1	-0.2	0.1	1.4	-0.3	0.1	1.7	-0.3	0.1

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Roof	Roof surface type				0.8	-0.2	0.1	2.1	-0.5	0.1	2.1	-0.6	0.1			
		Surface colour				0.5	-0.2	0.1	1.8	-0.5	0.1	2.3	-0.6	0.1			
		Openness				0.7	-0.1	0.1	0.9	-0.1	0.1						
	Ceiling	Insulation				0.9	0.5	0.1	1.3	0.7	0.2	0.7	0.9	0.1	0.4	1.1	0.1
	Floor	Edge Insulation*															
		Under Slab Insulation				-2	-0.3	-0.2							-2.1	-0.2	-0.2
	Ventilation	Ceiling fan				22.4	-0.1	1.7									
	Infiltration	Improve workmanship				10.9	5	1.1									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	External shading	Eave extension				2.5	-0.5	0.2	3.9	-1	0.2	6.7	-1.4	0.3	7.6	-1.9	0.3
		roller shutters				18.2	0	1.3									
	Thermal mass					1.2	0.7	0.2	1.3	0.8	0.2	2.9	1.5	0.3			
180º	External wall	Insulation	33.4	2.4	7.3	0.1	0.1	0	0.2	0.1	0	0.3	0.2	0	0.3	0.2	0
		Surface colour				0.2	0	0	0.1	0	0	0.3	-0.1	0	0.3	-0.1	0
	Roof	Roof surface type				-0.3	-0.1	-0.1	0.9	-0.2	0	1.1	-0.2	0.1			
		Surface colour				-0.1	-0.1	-0.1	0.9	-0.2	0	0.8	-0.2	0			
		Openness				-0.1	0	0	0.1	0	0						
	Ceiling	Insulation				0.1	0.2	0	0.2	0.4	0	0.2	0.5	0.1	0.2	0.6	0.1

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Floor	Edge Insulation*															
		Under Slab Insulation				-2.9	-0.1	-0.4							-3.6	0	-0.4
	Ventilation	Ceiling fan				15.4	-0.1	1.6									
	Infiltration	Improve workmanship				4.9	2	0.6									
	External shading	Eave extension*				0.4	-0.1	0	0.5	-0.2	0	1.2	-0.4	0.1	1.5	-0.5	0.1
		roller shutters				1.4	0	0.1									
	Thermal mass					0.4	-0.3	0.1	-2.3	0.6	-0.2	-1.5	1	-0.1			
270º		Insulation	64.7	5.1	4.5	0.5	0.2	0	0.2	0.3	0	0.5	0.3	0.1	0.8	0.4	0.1

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	External wall	Surface colour				0.3	-0.1	0	0.8	-0.1	0	0.9	-0.2	0	1	-0.2	0.1
	Roof	Roof surface type				0.1	-0.2	-0.1	0.6	-0.5	0	0.8	-0.6	0			
		Surface colour				0.1	-0.2	-0.1	0.5	-0.5	0	0.9	-0.6	0			
		Openness				0.2	-0.1	0	0.5	-0.2	0						
	Ceiling	Insulation				0.2	0.3	0	0.4	0.6	0.1	0.3	0.7	0.1	0.7	0.8	0.1
	Floor	Edge Insulation*															
		Under Slab Insulation				-3.3	-0.3	-0.2							-4.1	-0.3	-0.2
	Ventilation	Ceiling fan				23.2	-0.2	1.6									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Infiltration	Improve workmanship				9.4	3.9	0.8									
	External shading	Eave extension				3.8	-0.7	0.2	2.8	-0.4	0.1	5.6	-1	0.3	8.1	-1.3	0.4
		roller shutters				15.2	0	0.9									
	Thermal mass					0.9	0.5	0.1	1.1	0.5	0.1	2.4	0.8	0.2			

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Table 89. The energy analysis results for the Attached Archetype for Climate Zone 5.

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º		Insulation	17.8	18	6.8	0.3	0.3	0.1	0	0.6	0.1	0.2	0.7	0.1	0.3	1	0.1

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	External wall	Surface colour				-0.1	-0.1	0	0.2	-0.3	0	0.3	-0.4	0	0.3	-0.5	0
	Roof	Roof surface type				0.5	-0.5	0	0.5	-1.1	-0.1	0.5	-1.4	-0.1			
		Surface colour				0.3	-0.5	0	0.5	-1.1	0	0.5	-1.3	-0.1			
		Openness				0.4	-0.2	0	0.1	-0.4	0						
	Ceiling	Insulation				0.1	0.6	0.1	-0.1	1	0.1	-0.1	1.2	0.1	-0.7	1.4	0.1
	Floor	Edge Insulation*															
		Under Slab Insulation				-2	-1.9	-0.4							-2.9	-1.9	-0.3
	Ventilation	Ceiling fan				7.7	-0.3	0.8									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Infiltration	Improve workmanship				2.2	9.8	1.3									
	External shading	Eave extension				0.8	-0.6	0	1.2	-1.4	0	1.5	-2.1	0	1.8	-3	-0.1
		roller shutters				1.1	0	0.1									
	Thermal mass					-1.2	-1.5	-0.2	0	1.2	0.1	-0.5	-0.7	-0.1			
90º	External wall	Insulation	34.8	13.9	5.6	0.4	0.3	0	0.5	0.6	0	0.7	0.7	0.1	0.9	0.9	0.1
		Surface colour				0.4	-0.2	0	0.8	-0.4	0	0.9	-0.7	0	1.4	-0.9	0
	Roof	Roof surface type				0.8	-0.4	0	0.9	-0.9	0	2	-1.1	0			
		Surface colour				1	-0.4	0	1.2	-0.9	0	1.9	-1.1	0			

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Openness				0.6	-0.2	0	0.9	-0.3	0						
	Ceiling	Insulation				0.5	0.6	0.1	0.3	1	0.1	0.9	1.3	0.2	0.8	1.5	0.2
	Floor	Edge Insulation*															
		Under Slab Insulation				-2.9	0.3	-0.2							-3.8	0.7	-0.3
	Ventilation	Ceiling fan				12.2	-0.3	1.1									
	Infiltration	Improve workmanship				3.7	8.8	1.2									
	External shading	Eave extension				1.3	-0.8	0	3	-1.4	0.1	4.9	-2.1	0.2	6.3	-2.7	0.3
		roller shutters				11.3	0	1.1									
	Thermal mass					0.4	0.6	0	0.8	1.1	0.1	0.6	1.4	0.1			

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
180º	External wall	Insulation	18.6	5.4	8.1	0.1	0.1	0	0.5	0.3	0	0.5	0.3	0	0.6	0.4	0.1
		Surface colour				0.1	-0.1	0	0.5	-0.2	0	0.4	-0.2	0	0.6	-0.3	0
	Roof	Roof surface type				0.2	-0.2	0	0.9	-0.5	0	1.3	-0.5	0			
		Surface colour				0.4	-0.2	0	0.8	-0.4	0	1.3	-0.5	0			
		Openness				0.2	-0.1	0	0.6	-0.1	0						
	Ceiling	Insulation				0.1	0.4	0	0.6	0.6	0.1	0.4	0.8	0.1	0.6	0.9	0.1
	Floor	Edge Insulation*															
		Under Slab Insulation				-1.9	0.2	-0.2							-2.7	0.3	-0.3
	Ventilation	Ceiling fan															

Orientation	Design parameters		Baseline case Load (MJ/m2/year) Cooling	Baseline case Load (MJ/m2/year) Heating	Baseline case Equivalent Star rating	Level 1 Change Saving (MJ/m2/year) Cooling	Level 1 Change Saving (MJ/m2/year) Heating	Level 1 Change Rating change	Level 2 Change Saving (MJ/m2/year) Cooling	Level 2 Change Saving (MJ/m2/year) Heating	Level 2 Change Rating change	Level 3 Change Saving (MJ/m2/year) Cooling	Level 3 Change Saving (MJ/m2/year) Heating	Level 3 Change Rating change	Maximum Change Saving (MJ/m2/year) Cooling	Maximum Change Saving (MJ/m2/year) Heating	Maximum Change Rating change
	Infiltration	Improve workmanship				2.6	4.1	0.6									
	External shading	Eave extension				0.6	-0.2	0	1.3	-0.4	0	1.6	-0.5	0.1	2	-0.7	0.1
		roller shutters				1.1	0	0.1									
	Thermal mass					-0.4	1.2	0	0.3	0.8	0.1	0	1.9	0.1			
270º	External wall	Insulation	38.1	10.8	5.5	0.1	0.3	0.1	0.3	0.5	0.1	0.5	0.6	0.1	0.5	0.8	0.1
		Surface colour				0.4	-0.2	0.1	0.5	-0.4	0	0.5	-0.6	0	0.5	-0.7	0
	Roof	Roof surface type				0.3	-0.4	0	0.9	-0.9	0	1.4	-1.1	0.1			
		Surface colour				0.6	-0.4	0	1.1	-0.9	0.1	1.2	-1.1	0			

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Openness				0.4	-0.2	0	0.5	-0.3	0.1						
	Ceiling	Insulation				0.3	0.5	0.1	0.4	0.8	0.1	0.4	1	0.2	1	1.2	0.2
	Floor	Edge Insulation*															
		Under Slab Insulation				-2.9	0.3	-0.2							-4	0.4	-0.2
	Ventilation	Ceiling fan				12	-0.3	1.2									
	Infiltration	Improve workmanship				3	7.4	1.1									
	External shading	Eave extension				1.7	-0.7	0.1	2.9	-1.3	0.2	4.7	-1.9	0.3	6.4	-2.5	0.4
		roller shutters				8.7	-0.1	0.9									
	Thermal mass					1.7	0.3	0.2	0.9	0.6	0.2	2.2	0.6	0.3			

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Table 90. The energy analysis results for the Attached Archetype for Climate Zone 6.

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	10.4	125.8	5.8	0.1	1.6	0.1	0.3	2.7	0.1	0.3	3.4	0.1	0.4	4.1	0.1
		Surface colour				0.2	-0.6	0	0.2	-1.4	0	0.4	-2.1	0	0.4	-2.5	0
	Roof	Roof surface type				0.7	-1.3	0	1	-2.7	0	1.0	-3.3	0			
		Surface colour				0.6	-1.3	0	1	-2.6	0	1.1	-3.1	0			
		Openness				0.6	-0.9	0	0.5	-1.2	0						
	Ceiling	Insulation				0.9	2.2	0.1	0.6	3.6	0.1	1	4.5	0.1	1.2	4.9	0.1
	Floor	Edge Insulation*															

Orientation	Design parameters		Baseline case Load (MJ/m2/year)		Equivalent Star rating	Level 1 Change Saving (MJ/m2/year)		Level 1 Change Rating change	Level 2 Change Saving (MJ/m2/year)		Level 2 Change Rating change	Level 3 Change Saving (MJ/m2/year)		Level 3 Change Rating change	Maximum Change Saving (MJ/m2/year)		Maximum Change Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Under Slab Insulation				-1.7	4.5	0.1							-2.2	7.2	0.1
	Ventilation	Ceiling fan				3.4	-1.2	0.1									
	Infiltration	Improve workmanship				0.4	43.5	1.2									
	External shading	Eave extension				0.5	-2.9	-0.1	0.7	-5.4	-0.1	1	-8.1	-0.2	1.4	-11.1	-0.2
		roller shutters				1.1	-0.3	0									
	Thermal mass					1.1	-3.3	0	2.2	1.1	0.1	2.9	-1.9	0			
90º	External wall	Insulation	21.2	122.6	5.6	0.3	1.7	0.1	0.4	2.8	0.1	0.6	3.4	0.1	0.8	4.2	0.1
		Surface colour				0.3	-0.6	0	0.5	-1.2	0	0.9	-1.9	0	1.1	-2.3	0

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Roof	Roof surface type				0.3	-1	0	1.1	-2.2	0	0.6	-2.6	0			
		Surface colour				0.5	-1	0	1.1	-2.2	0	0.6	-2.5	0			
		Openness				0.2	-0.6	0	0.6	-0.9	0						
	Ceiling	Insulation				0.2	2.3	0.1	0.4	3.8	0.1	0.7	4.7	0.2	0.7	5.3	0.2
	Floor	Edge Insulation*															
		Under Slab Insulation				-2.1	6.2	0.1							-3.1	8.8	0.2
	Ventilation	Ceiling fan				4.5	-0.9	0.1									
	Infiltration	Improve workmanship				1.9	41.8	1.2									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	External shading	Eave extension				1	-2.2	0	1.9	-4.2	-0.1	2.7	-6.3	-0.1	3.2	-8.2	-0.2
		roller shutters				6.7	-0.1	0.2									
	Thermal mass					2.2	-0.9	0	2.4	0.9	0.1	4.8	-0.3	0.1			
180º	External wall	Insulation	10.1	99.2	6.5	0.1	1.6	0.1	0.1	2.8	0.1	0.1	3.5	0.1	0.2	4.3	0.2
		Surface colour				0.1	-0.6	0	0.2	-1.1	0	0.2	-1.7	0	0.4	-2	-0.1
	Roof	Roof surface type				0.3	-1	0	0.9	-2.2	0	1.1	-2.6	-0.1			
		Surface colour				0.5	-0.9	0	0.6	-2	0	1	-2.4	-0.1			
		Openness				0.2	-0.6	0	0.7	-0.9	0						
	Ceiling	Insulation				0.7	2.5	0.1	0.4	3.9	0.2	0.9	4.9	0.2	1.1	5.4	0.2

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Floor	Edge Insulation*															
		Under Slab Insulation				-1.7	7	0.2							-2.2	10	0.3
	Ventilation	Ceiling fan				3.2	-0.9	0.1									
	Infiltration	Improve workmanship				0.2	42.4	1.3									
	External shading	Eave extension				0.5	-1.9	0	0.8	-3.7	-0.1	1.1	-5.4	-0.1	1.6	-6.8	-0.1
		roller shutters				1	-0.3	0.1									
	Thermal mass					0.5	3.6	0.2	2	2.6	0.2	2.4	5.7	0.3			
270°		Insulation	21	120.1	5.7	0	1.7	0	0.1	2.8	0.1	0.2	3.5	0.1	0.4	4.3	0.1

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	External wall	Surface colour				-0.1	-0.5	0	0.1	-1.1	0	0.5	-1.7	0	0.4	-2.1	-0.1
	Roof	Roof surface type				0.1	-1.1	0	0.9	-2.3	-0.1	1	-2.7	-0.1			
		Surface colour				0.3	-1.1	0	1	-2.2	0	0.9	-2.7	-0.1			
		Openness				0.1	-0.8	0	0	-1	0						
	Ceiling	Insulation				0.4	2.3	0.1	0.6	3.7	0.1	1	4.5	0.1	1.1	5.1	0.1
	Floor	Edge Insulation*															
		Under Slab Insulation				-2.6	6.1	0.1							-3.6	8.8	0.1
	Ventilation	Ceiling fan				5	-0.9	0.1									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Infiltration	Improve workmanship				1.1	42	1.2									
	External shading	Eave extension				0.6	-2.1	-0.1	1.8	-4	-0.1	2.7	-5.8	-0.1	3.2	-7.6	-0.1
		roller shutters				5.6	-0.2	0.1									
	Thermal mass					1.5	-1.5	0	2.4	0.7	0.1	4	-1.1	0.1			

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

C.3 Detached Archetype

Table 91. The energy analysis results for the Detached Archetype for Climate Zone 2.

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	55.5	9.7	4.4	3.6	-0.2	0.2	4	-0.1	0.3	3.9	0.1	0.3	4.2	0.3	0.3
		Surface colour				0	-0.2	0	0.5	-0.4	0	1.3	-0.6	0	1.7	-0.7	0
	Roof	Roof surface type				0	0.1	0									
		Surface colour				0	0	0	1.4	-0.2	0	1.4	-0.3	0			
		Openness				0.2	-0.9	0	0.5	-1	0						
	Ceiling	Insulation				-0.1	0.8	0	0.3	1.3	0	0.2	1.6	0.1	0.5	1.9	0.2
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-20	-9.7	-1.2	-23.6	-11.5	-1.5	-24.9	-12.2	-1.5	-26	-12.5	-1.5

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Ventilation	Ceiling fan				16.5	-0.5	1.1									
	Infiltration	Improve workmanship				8.1	4.6	0.9									
	External shading	Eave extension				2.5	-0.2	0.1	3.8	-0.7	0.2	6.3	-1.1	0.4	8.2	-1.5	0.5
		roller shutters				15.7	-0.6	1									
	Thermal mass					-0.6	0.4	0	8.1	2.2	0.7	7.6	2.6	0.7			
90º	External wall	Insulation	58	10.1	4.3	4.2	-0.2	0.1	4.5	0	0.1	4.3	0.1	0.1	4.4	0.3	0.2
		Surface colour				0.9	-0.2	0	1	-0.4	0	1.6	-0.6	0	2.1	-0.7	0
	Roof	Roof surface type				0.6	0.1	0									
		Surface colour				0.3	0	0	1.3	-0.2	0	1.9	-0.3	0			
		Openness				0.6	-0.9	-0.1	0.6	-1.1	-0.1						

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Ceiling	Insulation				0.7	0.7	0	0.7	1.2	0.1	1.2	1.5	0.1	1.3	1.8	0.1
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-20.4	-8.6	-1.2	-24.9	-10.2	-1.4	-26.8	-10.7	-1.5	-27.5	-10.9	-1.5
	Ventilation	Ceiling fan				19.3	-0.4	1.2									
	Infiltration	Improve workmanship				9.2	4.6	0.8									
	External shading	Eave extension				2.3	-0.3	0.1	4.1	-0.5	0.1	6.5	-0.8	0.3	7.8	-1.1	0.4
		roller shutters				14	-0.5	0.8									
	Thermal mass					-0.4	0.2	-0.1	6.7	2	0.5	6.6	2.2	0.5			
180º	External wall	Insulation	66.8	9.9	3.8	4.5	-0.4	0.2	4.6	-0.3	0.2	4.9	-0.2	0.2	5.3	0	0.3
		Surface colour				0.5	-0.2	0.1	0.9	-0.5	0.1	1.5	-0.8	0.1	2	-1	0.1

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Roof	Roof surface type				0.1	0	0.1									
		Surface colour				0	0	0	1.8	-0.3	0.1	2.6	-0.4	0.1			
		Openness				0.5	-0.9	0	1	-1.1	0						
	Ceiling	Insulation				0.6	0.7	0.1	0.7	1.2	0.1	1	1.6	0.1	1.2	1.9	0.1
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-23.8	-9.2	-1.1	-28.4	-10.7	-1.2	-30.6	-11.4	-1.3	-31.5	-11.6	-1.4
	Ventilation	Ceiling fan				22.5	-0.6	1.3									
	Infiltration	Improve workmanship				9.3	4.7	0.8									
	External shading	Eave extension				2.4	-0.4	0.1	4.7	-0.8	0.2	6.7	-1.2	0.3	8.4	-1.6	0.4

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		roller shutters				16.1	-0.7	0.9									
	Thermal mass					-0.3	0.3	0	9.5	1.8	0.6	8.6	2.1	0.6			
270º	External wall	Insulation	65.8	11.9	3.8	4.6	-0.4	0.1	5	-0.2	0.1	5	0	0.2	5.7	0.1	0.3
		Surface colour				0.5	-0.2	0	1.3	-0.5	0	2.1	-0.8	0.1	2.4	-1	0.1
	Roof	Roof surface type				0.3	0.1	0									
		Surface colour				0.1	0	0	1.8	-0.2	0.1	2.5	-0.3	0.1			
		Openness				0.9	-0.9	0	1	-1	0						
	Ceiling	Insulation				0.6	0.8	0.1	1.1	1.4	0.1	1.5	1.8	0.1	1.9	2.1	0.1
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-23.1	-8.9	-1.1	-26.8	-10.7	-1.2	-28.5	-11.4	-1.3	-28.9	-11.7	-1.3

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Ventilation	Ceiling fan				21.5	-0.6	1.1									
	Infiltration	Improve workmanship				10.2	5.2	0.8									
	External shading	Eave extension				2.7	-0.4	0.1	4.5	-0.8	0.1	6.7	-1.2	0.2	8.7	-1.5	0.3
		roller shutters				19.5	-0.7	1									
	Thermal mass					-0.4	0.3	0	7.2	2.1	0.4	6.7	2.3	0.4			

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Table 92. The energy analysis results for the Detached Archetype for Climate Zone 5.

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	36.5	17.5	4.9	0.5	0.5	0	0.8	0.8	0	0.9	1	0	1.2	1.1	0
		Surface colour				0.4	-0.4	0	0.7	-0.8	-0.1	1.5	-1.4	0	1.7	-1.7	0
	Roof	Roof surface type				3.8	-0.8	0.2									
		Surface colour				0.2	0	0	1.1	-0.4	0	1.5	-0.6	0			
		Openness				0.9	-1	-0.1	1	-1.2	-0.1						
	Ceiling	Insulation				0.4	1.1	0	0.7	1.9	0.1	1.1	2.5	0.2	1.3	2.9	0.2
	Floor	Slab Insulation (Edge)*															

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Slab Insulation (Under)				-20.1	-9.3	-1.4	-23.9	-10.8	-1.5	-25.4	-11.3	-1.6	-25.8	-11.4	-1.6
	Ventilation	Ceiling fan				10.1	0	0.8									
	Infiltration	Improve workmans hip				3.8	7.4	0.9									
	External shading	Eave extension				2.2	-0.5	0	4.2	-1.1	0.2	5.9	-1.7	0.2	7	-2.4	0.3
		roller shutters				9	-0.1	0.6									
	Thermal mass					-0.5	0.6	0	3.9	3.3	0.5	3.2	3.9	0.5			
90º	External wall	Insulation	37.8	17.6	4.8	0.6	0.4	0	1.1	0.6	0.1	1.2	0.8	0.1	1.5	1	0.1
		Surface colour				0.4	-0.4	0	1.5	-0.9	0	2.3	-1.4	0	2.5	-1.7	0

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Roof	Roof surface type				3.2	-0.8	0.1									
		Surface colour				-0.1	-0.1	0	1.5	-0.5	0	2.1	-0.7	0.1			
		Openness				0.7	-1	-0.1	0.9	-1.3	-0.1						
	Ceiling	Insulation				0.3	1	0	0.5	1.7	0.1	0.6	2.2	0.1	1	2.6	0.1
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-19.3	-8.6	-1.3	-22.4	-9.9	-1.4	-24.2	-10.4	-1.5	-24.8	-10.5	-1.5
	Ventilation	Ceiling fan				11.7	0	0.9									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Infiltration	Improve workmanship				3.8	7.3	0.8									
	External shading	Eave extension				2	-0.5	0.1	4	-1.2	0.1	5.8	-1.6	0.2	7	-2.1	0.3
		roller shutters				8.6	-0.1	0.6									
	Thermal mass					-0.6	0.4	0	3	3.1	0.4	2.7	3.5	0.4			
180º	External wall	Insulation	41.4	17.9	4.5	0.4	0.4	0.1	0.5	0.7	0.1	0.5	0.9	0.1	0.9	1	0.2
		Surface colour				0.5	-0.4	0	1	-1	0	1.8	-1.6	0	2.3	-2	0
	Roof	Roof surface type				3.4	-0.9	0.2									
		Surface colour				-0.1	0	0	1	-0.4	0.1	1.8	-0.6	0.1			

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Openness				0.7	-1	0	0.9	-1.2	0						
	Ceiling	Insulation				0.2	1.2	0.1	0.4	2	0.2	0.7	2.6	0.2	0.7	3.1	0.3
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-20	-8.3	-1.1	-23.2	-9.7	-1.2	-24.7	-10.1	-1.3	-25.7	-10.3	-1.3
	Ventilation	Ceiling fan				12	0.1	0.9									
	Infiltration	Improve workmanship				4.5	7.7	0.9									
	External shading	Eave extension				1.9	-0.5	0.1	4	-1.2	0.2	5.5	-1.9	0.3	7	-2.7	0.3
		roller shutters				8.7	0	0.6									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Thermal mass					-0.5	0.6	0	4.2	2.8	0.4	3.6	3.4	0.4			
270º	External wall	Insulation	37.7	20.9	4.6	0.6	0.4	0	0.9	0.8	0.1	1	1	0.1	1.5	1.1	0.1
		Surface colour				0.6	-0.5	0	0.9	-1.1	0	2.2	-1.7	0	2.3	-2.1	0
	Roof	Roof surface type				3.4	-0.9	0.1									
		Surface colour				0	-0.1	0	1.2	-0.6	0	1.8	-0.8	0			
		Openness				1.1	-1.1	0	1.1	-1.3	0						
	Ceiling	Insulation				0.4	1.2	0.1	0.8	2	0.1	1	2.6	0.2	1.3	3.1	0.2
	Floor	Slab Insulation (Edge)*															

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Slab Insulation (Under)				-18.4	-8	-1.2	-22.4	-9.3	-1.3	-24.3	-9.8	-1.4	-25.3	-9.9	-1.4
	Ventilation	Ceiling fan				11.1	0	0.7									
	Infiltration	Improve workmanship				4.2	8.1	0.8									
	External shading	Eave extension				2.1	-0.6	0.1	4	-1.2	0.1	5.6	-1.6	0.2	7.5	-2.1	0.3
		roller shutters				10.1	-0.1	0.6									
	Thermal mass					-0.3	0.6	0	3.4	3.4	0.3	2.7	4	0.3			

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available.

Table 93. The energy analysis results for the detached archetype for Climate Zone 6.

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	External wall	Insulation	26.4	132.4	4.9	0.4	2.6	0	0.5	4.3	0.1	0.7	5.5	0.1	0.8	6.5	0.2
		Surface colour				0.4	-1.2	0	0.6	-2.5	0	0.9	-4.1	-0.1	1.2	-4.8	-0.1
	Roof	Roof surface type				-0.1	0.1	0									
		Surface colour				0	-0.1	0	0.7	-1.3	0	0.8	-1.8	0			
		Openness				-0.3	-2.6	-0.1	0	-3.1	-0.1						
	Ceiling	Insulation				0.3	4	0	0.5	6.8	0.2	0.7	8.9	0.2	0.8	10.5	0.3
	Floor	Slab Insulation (Edge)*															

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Slab Insulation (Under)				-17.9	1	-0.4	-21	2.6	-0.5	-22.4	3.5	-0.5	-23	4.3	-0.5
	Ventilation	Ceiling fan				2.8	0	0									
	Infiltration	Improve workmanship				1	33.6	0.9									
	External shading	Eave extension				1	-2.1	0	2.7	-4.7	0	3.8	-7	-0.1	5.1	-9.3	-0.1
		roller shutters				7.1	-0.3	0.2									
	Thermal mass					-0.7	3.5	0	0	0	0	0	0	0			
90º	External wall	Insulation	24	132.4	4.9	0.6	2.5	0.1	0.9	4.3	0.2	1.1	5.4	0.2	1.2	6.4	0.2
		Surface colour				0.7	-1.2	0	1	-2.4	0	1.5	-3.9	0	2	-4.7	0

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Roof	Roof surface type				0	0.1	0									
		Surface colour				0	-0.1	0	1	-1.3	0	1.1	-1.8	0			
		Openness				0.3	-2.6	0	0.4	-3.1	0						
	Ceiling	Insulation				0.5	3.9	0.2	0.9	6.8	0.2	1.2	8.8	0.3	1.3	10.4	0.4
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-17.1	1.5	-0.3	-20.1	3.1	-0.3	-21.4	4.2	-0.3	-22.1	5	-0.3
	Ventilation	Ceiling fan				3	0	0.1									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Infiltration	Improve workmanship				1.8	33.6	1									
	External shading	Eave extension				1.2	-2	0	2.7	-4.2	0	3.7	-6.5	0	4.6	-8.8	0
		roller shutters				6.1	-0.4	0.2									
	Thermal mass					-0.4	3.6	0.1	5.5	2.9	0.3	4.9	6.7	0.4			
180º	External wall	Insulation	23.9	136	4.9	0.3	2.5	0	0.7	4.2	0	0.8	5.4	0.1	0.9	6.3	0.1
		Surface colour				0.3	-1.4	0	0.8	-2.8	-0.1	1.2	-4.6	-0.1	1.3	-5.5	-0.1
	Roof	Roof surface type				-0.1	0.1	0									
		Surface colour				0	-0.1	0	0.6	-1.4	0	0.7	-1.9	0			

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Openness				-0.2	-2.5	-0.1	-0.1	-3.1	-0.1						
	Ceiling	Insulation				0.3	4.2	0	0.6	7.1	0.2	0.9	9.3	0.2	1	10.9	0.3
	Floor	Slab Insulation (Edge)*															
		Slab Insulation (Under)				-18.4	3.8	-0.3	-21.1	5.7	-0.4	-22.6	6.9	-0.4	-23.2	7.8	-0.4
	Ventilation	Ceiling fan				2.6	0	0									
	Infiltration	Improve workmanship				0.9	34.9	0.9									
	External shading	Eave extension				1	-2.2	-0.1	1.9	-4.8	-0.1	3.1	-7.4	-0.1	3.9	-9.9	-0.2
		roller shutters				5.5	-0.3	0									

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Thermal mass					-0.6	4	0	5	0.9	0.1	4.4	5.1	0.2			
270º	External wall	Insulation	25.6	138.8	4.8	0.5	2.6	0	0.7	4.2	0.1	0.8	5.4	0.1	1	6.3	0.1
		Surface colour				0.5	-1.3	0	0.8	-2.6	-0.1	1.3	-4.2	-0.1	1.8	-5.1	-0.1
	Roof	Roof surface type				0	0.1	0									
		Surface colour				0	-0.1	0	0.8	-1.4	0	1	-1.9	0			
		Openness				-0.1	-2.6	-0.1	0.1	-3.1	-0.1						
	Ceiling	Insulation				0.3	4.1	0.1	0.5	6.9	0.1	0.8	9.1	0.1	0.9	10.7	0.2
	Floor	Slab Insulation (Edge)*															

Orientation	Design parameters		Baseline case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
			Load (MJ/m2/year)		Equivalent Star rating	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change	Saving (MJ/m2/year)		Rating change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Slab Insulation (Under)				-17.6	2.8	-0.4	-20.3	4.5	-0.4	-21.5	5.6	-0.4	-22.2	6.4	-0.4
	Ventilation	Ceiling fan				3.1	0	0									
	Infiltration	Improve workmanship				1.1	34.4	0.9									
	External shading	Eave extension				1.1	-1.9	0	2.5	-4.1	-0.1	3.8	-6.3	-0.1	4.5	-8.6	-0.1
		roller shutters				7	-0.3	0.1									
	Thermal mass					-0.5	3.7	0	5	2	0.1	4.6	6	0.2			

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Appendix D: Residential Peak Load Data – Tabular Form

The following tables summarise the peak loads of the three residential archetypes with different changes under Climate Zones 2, 5 and 6. The results presented are the maximum electrical consumption (kW) over the course of a year, which was determined using an average heating and cooling coefficient of performance (COP) of 3.0. The **cooling or heating peak load saving** presented in the tables refers to the difference between the maximum electrical power consumption for the baseline case and that of using individual changes.

D.1 Apartment Archetype

Table 94. The peak load analysis results of the Apartment Archetype for Climate Zone 2 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	1.55	0.97	4.9	-0.09	0.03	-0.10	0.06	-0.09	0.08	-0.08	0.10
		Surface colour				-0.09	0.00	-0.07	-0.01	-0.07	-0.01		
	Infiltration	Improve workmanship				-0.01	0.35						
	External shading	Eave extension				-0.06	-0.01	0.06	-0.02	-0.26	-0.02	-0.17	-0.04
		roller shutters				-0.19	0.00						
	Thermal mass					-0.08	0.14	0.05	0.12	0.16	0.23		
90º	External wall	Insulation	1.49	0.77	6	0.02	0.03	0.03	0.06	0.03	0.07	0.04	0.09
		Surface colour				0.02	0.00	0.03	-0.01	0.04	-0.01		

Orientation	Design parameters		Baseline case Peak Load (kW) Cooling	Baseline case Peak Load (kW) Heating	Baseline case Equivalent Star rating	Level 1 Change Peak Load Saving (kW) Cooling	Level 1 Change Peak Load Saving (kW) Heating	Level 2 Change Peak Load Saving (kW) Cooling	Level 2 Change Peak Load Saving (kW) Heating	Level 3 Change Peak Load Saving (kW) Cooling	Level 3 Change Peak Load Saving (kW) Heating	Maximum Change Peak Load Saving (kW) Cooling	Maximum Change Peak Load Saving (kW) Heating
	Infiltration	Improve workmanship				-0.09	0.32						
	External shading	Eave extension				0.05	-0.01	-0.28	-0.02	-0.26	-0.02	-0.21	-0.06
	External shading	roller shutters				0.00	0.00						
	Thermal mass					-0.06	0.18	-0.39	0.07	-0.07	0.13		
180º	External wall	Insulation	1.68	0.74	6.3	0.02	0.04	0.04	0.06	0.05	0.07	0.06	0.09
	External wall	Surface colour				0.02	-0.01	0.05	-0.01	0.06	-0.01		
	Infiltration	Improve workmanship				0.15	0.37						
	External shading	Eave extension				0.02	-0.02	0.35	-0.04	0.11	-0.06	0.16	-0.10
	External shading	roller shutters				0.10	0.00						
	Thermal mass					0.41	0.10	0.06	0.04	-0.04	0.10		
270º	External wall	Insulation	1.82	0.93	5.60	0.02	0.03	0.04	0.06	0.05	0.07	0.05	0.09

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Surface colour				0.01	0.00	0.05	-0.01	0.05	-0.01		
	Infiltration	Improve workmanship				0.19	0.30						
	External shading	Eave extension				0.02	-0.01	0.05	-0.03	0.08	-0.02	0.14	-0.04
		roller shutters				0.27	0.00						
	Thermal mass					0.20	0.13	0.16	0.05	0.14	0.11		

Table 95. The peak load analysis results of the Apartment Archetype for Climate Zone 5 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	1.61	0.99	5.1	0.02	0.02	0.06	0.04	0.07	0.05	0.09	0.07
		Surface colour				0.05	0.00	0.05	-0.01	-0.09	-0.01		

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Infiltration	Improve workmanship				0.02	0.34						
	External shading	Eave extension				-0.39	0.00	-0.27	-0.01	-0.28	-0.01	-0.16	-0.02
		roller shutters				-0.07	0.00						
	Thermal mass					0.23	0.18	-0.05	0.09	0.25	0.11		
90º	External wall	Insulation	1.93	0.99	6.3	0.02	0.02	0.04	0.04	-0.02	0.05	0.00	0.06
		Surface colour				0.02	0.00	0.05	-0.01	0.06	-0.01		
	Infiltration	Improve workmanship				0.90	0.35						
	External shading	Eave extension				0.01	0.00	0.03	0.00	0.04	-0.01	0.00	-0.01
		roller shutters				0.25	0.00						
	Thermal mass					0.45	0.17	0.00	0.09	0.66	0.10		
180º	External wall	Insulation	1.60	1.01	6.3	0.18	0.02	0.30	0.04	0.07	0.05	0.09	0.06

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Surface colour				0.04	0.00	0.31	0.00	0.07	-0.01		
	Infiltration	Improve workmanship				0.33	0.31						
	External shading	Eave extension				0.02	0.00	0.04	-0.01	0.42	-0.01	0.46	-0.01
		roller shutters				-0.11	0.00						
	Thermal mass					0.40	0.13	-0.13	0.07	0.14	0.09		
270º	External wall	Insulation	1.68	1.01	5.10	0.02	0.69	0.46	0.71	0.45	0.72	0.47	0.73
		Surface colour				0.44	0.67	0.47	0.67	0.48	0.66		
	Infiltration	Improve workmanship				0.48	0.97						
	External shading	Eave extension				0.02	0.67	0.48	0.67	0.11	0.66	0.16	0.66
		roller shutters				0.07	0.67						
	Thermal mass					0.27	0.80	0.51	0.06	0.21	0.76		

Table 96. The peak load analysis results of the Apartment Archetype for Climate Zone 6 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	1.13	1.45	5.3	-0.20	0.03	-0.39	0.04	-0.38	0.06	-0.37	0.07
		Surface colour				-0.09	0.00	-0.07	-0.01	-0.06	-0.01		
	Infiltration	Improve workmanship				-0.34	0.44						
	External shading	Eave extension				-0.09	0.00	0.01	0.00	-0.07	-0.01	-0.47	-0.01
		roller shutters				-0.23	0.00						
	Thermal mass					-0.49	0.14	-0.43	0.05	-0.09	0.10		
90º	External wall	Insulation	1.44	1.45	5.8	0.00	0.02	0.11	0.04	0.07	0.06	0.13	0.07
		Surface colour				0.08	0.00	0.11	0.00	0.13	-0.01		

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Infiltration	Improve workmanship				-0.11	0.45						
	External shading	Eave extension				0.09	0.00	0.04	0.00	0.13	0.00	0.11	-0.01
		roller shutters				0.25	0.00						
	Thermal mass					-0.39	0.15	-0.42	0.07	-0.45	0.11		
180º	External wall	Insulation	1.50	1.47	5.6	0.33	0.02	-0.12	0.04	-0.10	0.05	-0.04	0.07
		Surface colour				-0.14	0.00	-0.12	0.00	-0.12	0.00		
	Infiltration	Improve workmanship				0.18	0.43						
	External shading	Eave extension				0.01	0.00	-0.14	0.00	-0.17	0.00	-0.27	-0.01
		roller shutters				-0.24	0.00						
	Thermal mass					0.31	0.13	-0.12	0.05	-0.22	0.10		
270º	External wall	Insulation	1.60	1.47	5.70	-0.01	0.15	-0.36	0.17	0.25	0.19	-0.15	0.20

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Surface colour				0.31	0.13	-0.39	0.13	-0.38	0.13		
	Infiltration	Improve workmanship				0.06	0.55						
	External shading	Eave extension				-0.18	0.13	-0.39	0.13	-0.37	0.13	-0.10	0.12
		roller shutters				0.16	0.13						
	Thermal mass					0.31	0.26	-0.11	0.04	-0.22	0.23		

D.2 Attached House Archetype

Table 97. The peak load analysis results of the Attached Archetype for Climate Zone 2 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	2.33	1.01	0.01	0.03	0.02	0.03	0.02	0.04	0.02	0.04
		Surface colour			0.01	0.00	0.02	0.00	0.02	-0.01	0.02	-0.01
	Roof	Roof surface type			0.03	0.00	0.07	0.01	0.05	0.00		
		Surface colour			0.03	0.00	0.03	0.01	0.04	0.00		
		Openness			0.02	0.00	0.04	0.01				
	Ceiling	Insulation			0.01	0.02	-0.01	0.03	0.01	0.05	0.06	0.05
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			0.01	-0.02					-0.01	-0.03
	Ventilation	Ceiling fan			0.32	0.01						
	Infiltration	Improve workmanship			0.01	0.30						

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	External shading	Eave extension			0.06	-0.03	0.08	-0.04	0.09	-0.07	-0.10	-0.08
		roller shutters			0.13	0.00						
	Thermal mass				-0.21	0.06	-0.36	-0.13	-0.34	-0.04		
90º	External wall	Insulation	3.68	0.98	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03
		Surface colour			0.01	0.00	0.02	0.00	0.03	-0.01	0.03	-0.01
	Roof	Roof surface type			0.05	0.00	0.07	-0.01	0.09	-0.01		
		Surface colour			0.04	0.00	0.06	-0.01	0.08	-0.01		
		Openness			0.05	0.01	0.08	0.00				
	Ceiling	Insulation			0.02	0.01	0.03	0.02	0.07	0.03	0.10	0.04
	Floor	Slab Insulation (Edge)*										

Orientation	Design parameters		Baseline case Peak Load (kW)		Level 1 Change Peak Load Decrease (kW)		Level 2 Change Peak Load Decrease (kW)		Level 3 Change Peak Load Decrease (kW)		Maximum Change Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Slab Insulation (Under)			-0.06	-0.04					-0.10	-0.05
	Ventilation	Ceiling fan			-0.10	0.00						
	Infiltration	Improve workmanship			-0.03	0.29						
	External shading	Eave extension			0.05	-0.01	0.13	-0.02	0.13	-0.04	0.27	-0.05
		roller shutters			1.15	0.00						
	Thermal mass				0.08	0.04	0.02	-0.10	0.13	-0.04		
180º	External wall	Insulation	2.27	0.74	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03
		Surface colour			0.01	-0.01	0.02	-0.01	0.03	-0.01	0.03	-0.01
	Roof	Roof surface type			0.02	-0.01	-0.02	-0.02	-0.02	-0.01		
		Surface colour			0.02	-0.01	-0.03	-0.01	-0.02	-0.01		
		Openness			0.02	-0.01	0.03	-0.01				

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Ceiling	Insulation			0.10	0.03	-0.08	0.05	-0.08	0.05	-0.06	0.06
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			-0.07	-0.01					-0.10	0.00
	Ventilation	Ceiling fan			0.13	-0.01						
	Infiltration	Improve workmanship			0.39	0.28						
	External shading	Eave extension			0.04	-0.01	-0.01	-0.02	0.00	-0.02	0.00	-0.03
		roller shutters			0.01	-0.01						
	Thermal mass				-0.02	0.05	-0.27	-0.11	-0.21	0.02		
270º	External wall	Insulation	2.81	0.80	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05
		Surface colour			0.01	0.01	0.03	0.00	0.05	0.00	0.05	-0.01

Orientation	Design parameters		Baseline case Peak Load (kW)		Level 1 Change Peak Load Decrease (kW)		Level 2 Change Peak Load Decrease (kW)		Level 3 Change Peak Load Decrease (kW)		Maximum Change Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Roof	Roof surface type			0.05	0.00	0.10	0.00	0.11	-0.01		
		Surface colour			0.05	0.00	0.10	0.00	0.11	0.00		
		Openness			0.04	0.01	0.07	0.00				
	Ceiling	Insulation			0.02	0.04	0.05	0.05	0.10	0.06	0.12	0.07
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			-0.10	0.01					-0.14	0.02
	Ventilation	Ceiling fan			-0.03	0.00						
	Infiltration	Improve workmanship			0.05	0.25						
	External shading	Eave extension			0.02	-0.01	0.08	-0.01	0.14	-0.02	0.20	-0.03
		roller shutters			0.34	0.01						

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Thermal mass				0.09	0.04	-0.14	0.03	-0.08	0.07		

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Table 98. The peak load analysis results of the Attached Archetype under Climate Zone 5 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	2.07	1.19	0.01	0.02	0.02	0.03	-0.12	0.04	-0.11	0.04
		Surface colour			0.01	0.00	0.01	0.00	-0.11	0.00	-0.10	-0.01
	Roof	Roof surface type			-0.15	0.00	-0.08	0.00	-0.34	-0.01		
		Surface colour			-0.18	0.00	-0.08	0.00	-0.42	-0.01		
		Openness			-0.12	-0.01	-0.11	0.00				

Orientation	Design parameters		Baseline case Peak Load (kW)		Level 1 Change Peak Load Decrease (kW)		Level 2 Change Peak Load Decrease (kW)		Level 3 Change Peak Load Decrease (kW)		Maximum Change Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Ceiling	Insulation			0.02	0.02	-0.22	0.04	-0.19	0.05	-0.18	0.05
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			-0.45	0.00					-0.15	0.01
	Ventilation	Ceiling fan			0.23	0.00						
	Infiltration	Improve workmanship			0.23	0.46						
	External shading	Eave extension			-0.12	-0.01	-0.11	-0.02	-0.11	-0.03	-0.11	-0.04
		roller shutters			0.03	0.00						
	Thermal mass				-0.08	0.10	-0.46	-0.05	-0.44	0.06		
90º	External wall	Insulation	3.77	1.25	0.03	0.02	0.14	0.03	0.15	0.03	0.15	0.04
		Surface colour			0.03	0.00	0.13	-0.01	0.16	-0.01	0.17	-0.01

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Roof	Roof surface type			0.06	0.00	0.09	0.00	0.12	-0.01		
		Surface colour			0.05	0.00	0.09	-0.01	0.11	-0.01		
		Openness			0.05	0.00	0.07	0.00				
	Ceiling	Insulation			0.01	0.01	0.04	0.03	0.07	0.04	0.08	0.05
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			0.03	-0.01					0.02	-0.01
	Ventilation	Ceiling fan			-0.12	0.00						
	Infiltration	Improve workmanship			-0.28	0.44						
	External shading	Eave extension			0.06	-0.03	0.08	-0.04	0.09	-0.07	-0.10	-0.08
		roller shutters			0.13	0.00						

Orientation	Design parameters		Baseline case Peak Load (kW)		Level 1 Change Peak Load Decrease (kW)		Level 2 Change Peak Load Decrease (kW)		Level 3 Change Peak Load Decrease (kW)		Maximum Change Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Thermal mass				-0.21	0.06	-0.36	-0.13	-0.34	-0.04		
180º	External wall	Insulation	1.95	1.14	0.01	0.02	-0.12	0.04	-0.12	0.04	-0.11	0.05
		Surface colour			0.01	0.00	-0.12	-0.01	-0.11	-0.01	-0.11	-0.01
	Roof	Roof surface type			0.01	0.00	0.06	0.00	0.10	-0.01		
		Surface colour			0.01	0.00	0.07	-0.01	0.02	0.00		
		Openness			0.00	0.00	0.06	0.00				
	Ceiling	Insulation			0.02	0.02	-0.05	0.04	-0.01	0.05	-0.02	0.07
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			-0.41	-0.01					-0.38	0.00
	Ventilation	Ceiling fan			-0.21	0.00						

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Infiltration	Improve workmanship			0.11	0.48						
	External shading	Eave extension			0.04	-0.01	-0.01	-0.02	0.00	-0.02	0.00	-0.03
		roller shutters			0.01	-0.01						
	Thermal mass				-0.02	0.05	-0.27	-0.11	-0.21	0.02		
270º	External wall	Insulation	3.20	1.25	0.00	0.02	-0.01	0.02	0.00	0.03	-0.02	0.04
		Surface colour			0.00	0.00	0.00	-0.01	0.00	-0.01	0.01	-0.01
	Roof	Roof surface type			0.00	-0.01	0.02	-0.01	0.03	-0.01		
		Surface colour			0.01	0.00	0.03	-0.01	0.04	-0.01		
		Openness			0.00	0.00	-0.01	0.00				
	Ceiling	Insulation			0.01	0.01	0.02	0.03	0.01	0.04	0.01	0.05
	Floor	Slab Insulation (Edge)*										

Orientation	Design parameters		Baseline case Peak Load (kW)		Level 1 Change Peak Load Decrease (kW)		Level 2 Change Peak Load Decrease (kW)		Level 3 Change Peak Load Decrease (kW)		Maximum Change Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Slab Insulation (Under)			-0.08	-0.01					-0.12	0.01
	Ventilation	Ceiling fan			0.04	0.00						
	Infiltration	Improve workmanship			-0.01	0.44						
	External shading	Eave extension			0.01	-0.01	0.06	-0.02	0.12	-0.03	0.04	-0.03
		roller shutters			0.40	0.00						
	Thermal mass				0.03	0.06	0.23	-0.06	0.37	0.01		

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Table 99. The peak load analysis results of the Attached Archetype for Climate Zone 6 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	2.43	2.01	0.02	0.02	0.03	0.02	0.00	0.03	0.01	0.04
		Surface colour			0.01	0.00	0.01	0.00	0.00	-0.01	0.00	-0.01
	Roof	Roof surface type			0.02	0.00	0.04	0.00	0.05	0.00		
		Surface colour			0.02	0.00	0.45	0.01	0.01	0.00		
		Openness			0.03	0.00	0.02	0.00				
	Ceiling	Insulation			0.42	0.01	0.14	0.03	0.01	0.05	0.29	0.05
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			-0.60	0.05					-0.62	0.07
	Ventilation	Ceiling fan			0.46	0.00						
	Infiltration	Improve workmanship			0.33	0.52						

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	External shading	Eave extension			0.01	-0.01	0.01	0.00	0.03	-0.01	0.05	-0.02
		roller shutters			0.01	0.00						
	Thermal mass				0.50	0.05	-0.20	-0.08	0.38	-0.03		
	External wall	Insulation			0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04
		Surface colour			0.03	0.00	0.02	0.00	0.03	0.00	0.03	0.00
	Roof	Roof surface type			-0.35	0.00	0.17	0.00	-0.18	0.00		
90º		Surface colour	3.25	2.09	0.16	0.00	0.18	0.00	-0.11	0.00		
		Openness			0.15	0.00	0.15	0.00				
	Ceiling	Insulation			0.02	0.02	-0.22	0.04	-0.20	0.04	-0.18	0.05
	Floor	Slab Insulation (Edge)*										

Orientation	Design parameters		Baseline case Peak Load (kW)		Level 1 Change Peak Load Decrease (kW)		Level 2 Change Peak Load Decrease (kW)		Level 3 Change Peak Load Decrease (kW)		Maximum Change Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Slab Insulation (Under)			-0.13	0.05					-0.51	0.06
	Ventilation	Ceiling fan			-0.01	0.00						
	Infiltration	Improve workmanship			-0.12	0.50						
	External shading	Eave extension			0.06	0.00	0.29	0.00	-0.25	-0.01	-0.10	-0.01
		roller shutters			0.95	0.01						
	Thermal mass				0.27	0.04	-0.48	-0.10	0.14	-0.06		
180º	External wall	Insulation	2.37	1.99	-0.01	0.02	0.41	0.02	-0.08	0.03	0.41	0.04
		Surface colour			-0.02	0.00	-0.01	0.00	0.41	0.00	0.41	0.00
	Roof	Roof surface type			-0.01	0.00	-0.04	-0.01	-0.05	0.00		
		Surface colour			0.05	0.00	-0.04	0.00	-0.04	0.00		
		Openness			-0.02	0.00	0.42	0.00				

Orientation	Design parameters		Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Ceiling	Insulation			0.40	0.01	-0.06	0.03	0.45	0.04	-0.03	0.05
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			-0.70	0.06					-0.62	0.07
	Ventilation	Ceiling fan			0.39	0.00						
	Infiltration	Improve workmanship			0.12	0.54						
	External shading	Eave extension			0.41	0.00	0.41	-0.01	0.43	-0.01	0.44	-0.01
		roller shutters			0.04	0.00						
	Thermal mass				0.36	0.05	-0.03	-0.07	-0.05	-0.01		
270º	External wall	Insulation	2.65	2.09	0.02	0.02	0.12	0.03	0.13	0.03	0.08	0.04
		Surface colour			0.01	0.00	0.03	0.00	0.12	0.00	0.01	0.00

Orientation	Design parameters		Baseline case Peak Load (kW)		Level 1 Change Peak Load Decrease (kW)		Level 2 Change Peak Load Decrease (kW)		Level 3 Change Peak Load Decrease (kW)		Maximum Change Peak Load Decrease (kW)	
			Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Roof	Roof surface type			0.04	0.00	0.15	0.00	0.13	0.00		
		Surface colour			0.03	0.00	0.14	0.01	0.09	0.00		
		Openness			0.02	0.00	0.21	0.00				
	Ceiling	Insulation			0.02	0.02	0.22	0.03	0.14	0.04	0.10	0.05
	Floor	Slab Insulation (Edge)*										
		Slab Insulation (Under)			-0.34	-0.05					-0.47	0.06
	Ventilation	Ceiling fan			0.42	0.00						
	Infiltration	Improve workmanship			0.27	0.49						
	External shading	Eave extension			0.12	0.00	0.13	-0.01	0.27	-0.01	0.11	-0.01
		roller shutters			0.23	0.00						

Orientation	Design parameters	Baseline case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
		Peak Load (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)		Peak Load Decrease (kW)	
		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Thermal mass			0.10	0.04	0.08	-0.10	0.07	-0.06		

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

D.3 Detached House Archetype

Table 100. The peak load analysis results of the Detached Archetype for Climate Zone 2 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	4.26	1.91	4.40	0.02	0.05	0.04	0.08	0.04	0.10	0.05	0.12
		Surface colour				0.02	-0.01	0.45	-0.01	0.42	-0.02	0.44	-0.03
	Roof	Roof surface type				0.21	-0.03						
		Surface colour				0.01	0.00	0.48	-0.01	0.52	-0.01		
		Openness				0.06	-0.06	0.08	-0.06				
	Ceiling	Insulation				0.03	0.08	0.05	0.13	0.47	0.18	0.48	0.21
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.33	-0.99	-0.49	-1.24	-0.46	-1.35	-0.55	-1.39

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Ventilation	Ceiling fan				0.12	0.00						
	Infiltration	Improve workmanship				0.64	0.58						
	External shading	Eave extension				0.27	-0.01	0.24	-0.04	0.07	-0.06	0.33	-0.08
		roller shutters				1.22	-0.01						
	Thermal mass					0.02	0.01	0.51	0.43	0.51	0.44		
90º	External wall	Insulation	3.86	1.90	4.30	0.18	0.05	0.20	0.08	0.08	0.10	0.09	0.12
		Surface colour				0.03	-0.01	0.21	-0.01	0.11	-0.03	0.13	-0.03
	Roof	Roof surface type				0.06	-0.03						
		Surface colour				0.00	0.00	0.08	-0.01	0.28	-0.01		
		Openness				0.20	-0.06	0.07	-0.06				
	Ceiling	Insulation				0.01	0.08	0.05	0.14	0.08	0.18	0.09	0.21

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.32	-0.99	-0.32	-1.24	-0.38	-1.35	-0.41	-1.39
	Ventilation	Ceiling fan				0.24	0.00						
	Infiltration	Improve workmanship				0.78	0.58						
	External shading	Eave extension				0.19	-0.01	0.09	-0.03	0.33	-0.05	0.34	-0.07
		roller shutters				0.87	-0.01						
	Thermal mass					0.22	0.02	0.92	0.42	0.90	0.43		
180º	External wall	Insulation	3.91	1.90	3.80	0.03	0.04	0.05	0.07	0.06	0.09	0.07	0.11
		Surface colour				0.03	-0.01	0.06	-0.02	0.09	-0.03	0.10	-0.04
	Roof	Roof surface type				0.09	-0.03						

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Surface colour				0.01	0.00	0.08	-0.01	0.11	-0.01		
		Openness				0.08	-0.06	0.09	-0.06				
	Ceiling	Insulation				0.04	0.08	0.07	0.14	0.09	0.18	0.02	0.21
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.33	-0.99	-0.27	-1.24	-0.42	-1.34	-0.45	-1.39
	Ventilation	Ceiling fan				0.06	0.00						
	Infiltration	Improve workmanship				0.27	0.58						
	External shading	Eave extension				0.06	-0.02	0.10	-0.04	0.15	-0.06	0.24	-0.07
		roller shutters				0.92	0.00						
	Thermal mass					0.00	0.02	0.35	0.43	0.35	0.44		

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
270º	External wall	Insulation	3.80	2.08	3.80	0.05	0.05	0.08	0.07	0.11	0.10	0.13	0.12
		Surface colour				0.05	-0.01	0.09	-0.02	0.15	-0.03	0.19	-0.03
	Roof	Roof surface type				0.14	-0.04						
		Surface colour				0.00	0.00	0.11	-0.01	0.15	-0.01		
		Openness				0.09	-0.06	0.11	-0.06				
	Ceiling	Insulation				0.05	0.08	0.08	0.13	0.11	0.18	0.11	0.21
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.42	-0.96	-0.54	-1.21	-0.59	-1.31	-0.62	-1.36
	Ventilation	Ceiling fan				-0.37	0.00						
	Infiltration	Improve workmanship				0.15	0.57						

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	External shading	Eave extension				0.05	-0.02	0.15	-0.04	0.06	-0.05	0.10	-0.07
		roller shutters				0.49	-0.01						
	Thermal mass					-0.01	0.01	0.63	0.43	0.62	0.45		

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Table 101. The peak load analysis results of the Detached Archetype for Climate Zone 5 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º		Insulation	4.23	2.31	4.90	0.05	0.04	0.07	0.06	0.09	0.08	0.11	0.10

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	External wall	Surface colour				0.02	-0.01	0.05	-0.01	0.09	-0.02	0.10	-0.02
	Roof	Roof surface type				0.05	-0.02						
		Surface colour				0.00	0.00	0.06	-0.01	0.09	-0.01		
		Openness				0.02	-0.03	0.03	-0.04				
	Ceiling	Insulation				0.05	0.05	0.09	0.10	0.12	0.12	0.14	0.15
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.66	-0.74	-0.35	-0.92	-0.66	-1.00	-0.70	-1.03
	Ventilation	Ceiling fan				-0.03	0.00						
	Infiltration	Improve workmanship				0.36	0.52						
		Eave extension				0.05	-0.01	-0.11	-0.02	0.12	-0.03	0.15	-0.05

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	External shading	roller shutters				0.45	0.00						
	Thermal mass					-0.01	0.02	0.43	0.26	0.41	0.28		
90º	External wall	Insulation	4.13	2.32	4.80	0.06	0.04	0.09	0.06	0.11	0.08	0.13	0.09
		Surface colour				0.03	-0.01	0.07	-0.01	0.11	-0.02	0.13	-0.02
	Roof	Roof surface type				0.09	-0.02						
		Surface colour				0.00	0.00	0.07	-0.01	0.09	-0.01		
		Openness				0.02	-0.03	0.04	-0.04				
	Ceiling	Insulation				0.06	0.05	0.10	0.09	0.12	0.12	0.14	0.15
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.15	-0.75	-0.29	-0.92	-0.59	-1.00	-0.63	-1.03

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Ventilation	Ceiling fan				-0.01	0.00						
	Infiltration	Improve workmanship				0.97	0.52						
	External shading	Eave extension				0.07	-0.01	0.12	-0.02	0.18	-0.03	0.26	-0.05
		roller shutters				1.06	0.00						
	Thermal mass					-0.01	0.02	0.85	0.27	1.06	0.29		
180º	External wall	Insulation	4.14	2.32	4.50	0.05	0.04	0.08	0.06	0.10	0.08	0.12	0.09
		Surface colour				0.02	-0.01	0.06	-0.02	0.10	-0.03	0.11	-0.03
	Roof	Roof surface type				0.10	-0.02						
		Surface colour				0.00	0.00	0.06	-0.01	0.09	-0.01		
		Openness				0.00	-0.03	0.02	-0.04				
	Ceiling	Insulation				0.05	0.05	0.09	0.10	0.12	0.12	0.14	0.15

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.20	-0.73	-0.36	-0.91	-0.67	-0.99	-0.69	-1.02
	Ventilation	Ceiling fan				-0.03	0.00						
	Infiltration	Improve workmanship				0.42	0.52						
	External shading	Eave extension				0.08	-0.01	0.12	-0.03	0.14	-0.04	0.20	-0.05
		roller shutters				0.55	0.00						
	Thermal mass					-0.03	0.02	0.80	0.26	0.25	0.29		
270º	External wall	Insulation	4.16	2.34	4.60	0.06	0.04	0.11	0.06	0.13	0.08	0.15	0.10
		Surface colour				0.04	-0.01	0.08	-0.01	0.13	-0.02	0.16	-0.02
	Roof	Roof surface type				0.08	-0.02						

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Surface colour				0.00	0.00	0.06	-0.01	0.09	-0.01		
		Openness				0.02	-0.03	0.04	-0.04				
	Ceiling	Insulation				0.05	0.06	0.09	0.10	0.12	0.12	0.14	0.15
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.19	-0.73	-0.35	-0.90	-0.66	-0.97	-0.69	-1.01
	Ventilation	Ceiling fan				-0.02	0.00						
	Infiltration	Improve workmanship				0.39	0.52						
	External shading	Eave extension				0.05	-0.01	0.11	-0.03	0.14	-0.04	0.18	-0.05
		roller shutters				0.37	0.00						
	Thermal mass					-0.01	0.02	0.80	0.26	0.89	0.28		

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Table 102. The peak load analysis results of the Detached Archetype for Climate Zone 6 (assuming a heating and cooling system COP of 3.0).

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	External wall	Insulation	3.59	3.73	4.90	0.02	0.03	0.17	0.05	0.18	0.07	0.19	0.08
		Surface colour				0.01	0.00	0.01	0.00	0.04	-0.01	0.05	-0.01
	Roof	Roof surface type				0.00	0.00						
		Surface colour				0.00	0.00	0.03	0.00	0.06	0.00		
		Openness				-0.01	-0.02	0.00	-0.03				
	Ceiling	Insulation				0.17	0.05	0.19	0.07	0.21	0.10	0.24	0.12
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.92	-0.57	-1.12	-0.73	-0.89	-0.80	-1.05	-0.82
	Ventilation	Ceiling fan				-0.04	0.00						
	Infiltration	Improve workmanship				0.19	0.52						

Orientation	Design parameters		Baseline case Peak Load (kW) Cooling	Baseline case Peak Load (kW) Heating	Baseline case Equivalent Star rating	Level 1 Change Peak Load Saving (kW) Cooling	Level 1 Change Peak Load Saving (kW) Heating	Level 2 Change Peak Load Saving (kW) Cooling	Level 2 Change Peak Load Saving (kW) Heating	Level 3 Change Peak Load Saving (kW) Cooling	Level 3 Change Peak Load Saving (kW) Heating	Maximum Change Peak Load Saving (kW) Cooling	Maximum Change Peak Load Saving (kW) Heating
	External shading	Eave extension				0.19	0.00	0.24	-0.01	0.01	-0.01	0.07	-0.02
		roller shutters				0.48	0.00						
	Thermal mass					-0.03	0.05	0.43	0.22	0.38	0.27		
90º	External wall	Insulation	3.11	3.73	4.90	0.14	0.03	0.17	0.05	0.19	0.07	0.20	0.08
		Surface colour				0.12	0.00	0.15	0.00	0.24	-0.01	-0.33	-0.01
	Roof	Roof surface type				0.00	0.00						
		Surface colour				0.00	0.00	0.15	0.00	0.18	0.00		
		Openness				0.00	-0.02	0.00	-0.03				
	Ceiling	Insulation				0.14	0.05	0.18	0.08	0.20	0.10	0.28	0.12
	Floor	Slab Insulation (Edge)*											

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
		Slab Insulation (Under)				-0.83	-0.57	-1.29	-0.74	-1.30	-0.80	-1.43	-0.83
	Ventilation	Ceiling fan				0.04	0.00						
	Infiltration	Improve workmanship				-0.20	0.52						
	External shading	Eave extension				-0.01	0.00	-0.16	-0.01	-0.24	-0.01	-0.20	-0.01
		roller shutters				0.21	0.00						
	Thermal mass					-0.04	0.05	-0.14	0.24	-0.18	0.28		
180º	External wall	Insulation	3.36	3.73	4.90	0.03	0.03	0.09	0.05	0.10	0.06	0.47	0.07
		Surface colour				0.02	0.00	0.09	-0.01	0.12	-0.01	-0.12	-0.01
	Roof	Roof surface type				0.00	0.00						
		Surface colour				-0.02	0.00	-0.13	0.00	-0.12	0.00		
		Openness				0.00	-0.02	0.00	-0.03				

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Ceiling	Insulation				0.02	0.05	-0.12	0.08	-0.09	0.10	-0.21	0.12
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.60	-0.57	-0.78	-0.73	-1.24	-0.80	-1.28	-0.82
	Ventilation	Ceiling fan				-0.32	0.00						
	Infiltration	Improve workmanship				0.12	0.53						
	External shading	Eave extension				-0.14	0.00	-0.08	-0.01	-0.01	-0.01	-0.11	-0.02
		roller shutters				0.45	0.00						
	Thermal mass					-0.11	0.05	0.16	0.23	0.21	0.27		
270º	External wall	Insulation	3.48	3.74	4.80	0.04	0.03	0.06	0.05	0.08	0.06	0.06	0.07
		Surface colour				0.02	0.00	0.05	-0.01	0.09	-0.01	0.25	-0.01

Orientation	Design parameters		Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
			Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
			Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Roof	Roof surface type				0.01	0.00						
		Surface colour				0.00	0.00	0.05	0.00	0.08	0.00		
		Openness				0.02	-0.02	0.02	-0.03				
	Ceiling	Insulation				0.05	0.04	0.09	0.07	0.02	0.10	0.03	0.11
	Floor	Slab Insulation (Edge)*											
		Slab Insulation (Under)				-0.65	-0.57	-1.12	-0.73	-1.12	-0.79	-1.19	-0.82
	Ventilation	Ceiling fan				-0.03	0.00						
	Infiltration	Improve workmanship				0.54	0.51						
	External shading	Eave extension				0.10	0.00	0.13	-0.01	0.06	-0.01	0.12	-0.02
		roller shutters				0.47	0.00						

Orientation	Design parameters	Baseline case			Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
		Peak Load (kW)		Equivalent Star rating	Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)		Peak Load Saving (kW)	
		Cooling	Heating		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Thermal mass				-0.04	0.05	0.43	0.22	0.41	0.27		

* Slab edge insulation to be re-modelled in updated version of AccuRate Sustainability when available

Appendix E: Supplementary Benefit-Cost Calculations

Residential Domestic Hot Water

Domestic hot water is a significant energy use within Australian homes, and indeed is dominant in mild climates where heating and cooling needs are limited. Australian homes currently use a mix of technologies for domestic hot water, including:

- Electric storage
- Instantaneous electric
- Gas storage
- Instantaneous gas
- Electric heat pump
- Solar – electric boosted
- Solar – gas boosted

For the purposes of this study, only electric options are being considered as this enables many building types to become net zero emission buildings through the use of PV. This however is only a reflection of the scenario development process and is not a recommendation against gas DHW per se. A full Code development process would need to properly address the complex issues of the electricity/gas question.

Scenario Formulation

The available electric DHW technologies have been characterised as listed in Table 103, noting the Efficiency COP is the number of units of hot water produced per unit of energy put in, not including standing losses. It is noted that the actual efficiency of solar varies widely based on the installation and climate zone, and the efficiency of heat pump units is temperature dependent

Table 103. Electric DHW technologies considered.

Technology	Description	Effective Efficiency (COP)
Electric storage	Direct electric heating elements in a storage tank.	1.0
Standard Heat Pump	HCFC refrigerant heat pump with storage tank. Examples: Rheem MPi series	3.0
High Performance Heat Pump	CO2 refrigerant heat pump with storage tank. Examples: Sanden EcoPlus	4.5
Solar with electric boost	Roof mounted solar panel/storage tank unit. Examples: Rheem Hiline series	4.0

For the townhouse and detached house archetypes, all of the nominated technologies are viable. For apartments, however, only direct electric heating is viable as a technology for DHW on an individual apartment basis; other technologies require a centralised system (which is common practice, albeit typically gas fired, in larger apartment buildings). As it is beyond the scope of this study to assess centralised DHW versus individual unit DHW, and as it is possible for heat pump and solar technologies to be used with centralised systems, we have elected not to analyse DHW for apartments, and instead extrapolate the results for the other archetypes to the apartment case.

Assuming a townhouse occupancy of 3 persons and a detached house occupancy of 5 persons, both can be served adequately using a system of any technology with approximately 300-325 litre storage. Costs vary but based on a survey of prices available on the web it is possible to characterise costs as follows:

Technology	Sample System	Capital Cost
Electric storage	3.6kW direct electric heating elements in a 315 litre storage tank.	$1,200
Standard Heat Pump	R134a heat pump plus 3.6kW booster elements in a 325 litre storage	$3,000
High Performance Heat Pump	CO2 pump with 315 litre storage tank	$4,800
Solar with electric boost	300 litre roof mounted solar panel/storage tank unit with 3.6kW boost.	$4,500

Based on work by Whaley et al, annual standing losses from storage systems have been estimated at around 1.8 kWh/day. The same reference identifies average hot water use as 39 litre per person per day; for the purposes of the current calculation, a 40°C temperature rise has been assumed. In practice this varies with inlet temperature and thus with climate zone; however this is a second order factor and has been disregarded for the purpose of the current calculation.

Based on these assumptions the calculated energy use figures are as shown in Table 104 and Table 105.

Table 104. DHW energy use calculations for the townhouse

Technology	Annual water use (litres)	Water use energy (kWh_e)	Standing losses (kWh_{th})	Standing losses (kWh_e)	Annual energy use (kWh_e)
Direct Elec	42705	1993	664	664	2657
Standard HP	42705	664	664	221	886
Hi Perf HP	42705	443	664	148	590
Solar DHW	42705	498	664	166	664

Table 105. DHW calculations for the detached house.

Technology	Annual water use (litres)	Water use energy (kWh_e)	Standing losses (kWh_{th})	Standing losses (kWh_e)	Annual energy use (kWh_e)
Direct Elec	71175	3322	664	664	3986

Technology	Annual water use (litres)	Water use energy (kWh$_e$)	Standing losses (kWh$_{th}$)	Standing losses (kWh$_e$)	Annual energy use (kWh$_e$)
Standard HP	71175	1107	664	221	1329
Hi Perf HP	71175	738	664	148	886
Solar DHW	71175	830	664	166	996

It is noted that there is a significant difference in the peak demand from each of these systems. However, as all are typically connected to ripple or off-peak control, no allowance has been included in the economic analysis for the impacts on network infrastructure.

A 15 year lifespan has been assumed for all systems.

Results – Baseline Analysis

All three upgraded technologies are cost effective relative to direct electric heating, as shown in Figure 41.

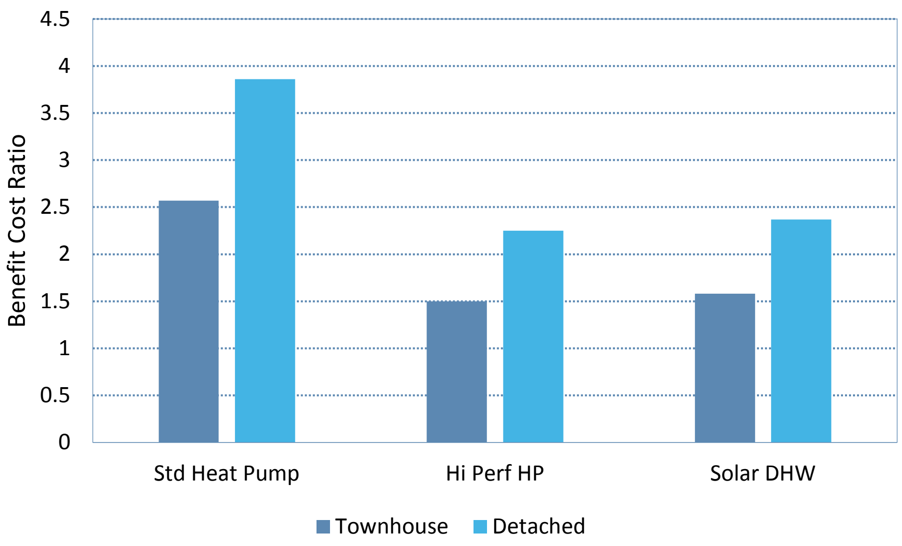


Figure 41. Benefit cost results for DHW technologies relative to direct electric.

However, the cost benefit for high performance heat pumps and solar DHW relative to standard heat pump is not attractive, at 0.43/0.39 (HP/solar respectively) for townhouses and 0.64/0.58 for the detached house.

Based on these results, the appropriate level of stringency for DHW based on current economics is taken to be that of standard heat pump technology.

7.1.1.10 E.3.1 Future Economic Scenario

The high performance heat pump currently carries a significant price premium relative to the standard heat pump, and yet comprises essentially the same technological components while using a different refrigerant (albeit at higher pressure). It is reasonable to expect, therefore that the real cost of the high performance heat pump will reduce significantly and production volumes and market competition increase. Given the 85% phase down of R134a over the next 20 years, it is reasonable to project that the cost of the high performance units will reduce to 110% of the standard heat pump over the next 10 years.

Appendix F: Residential Lighting Simulation Screenshots

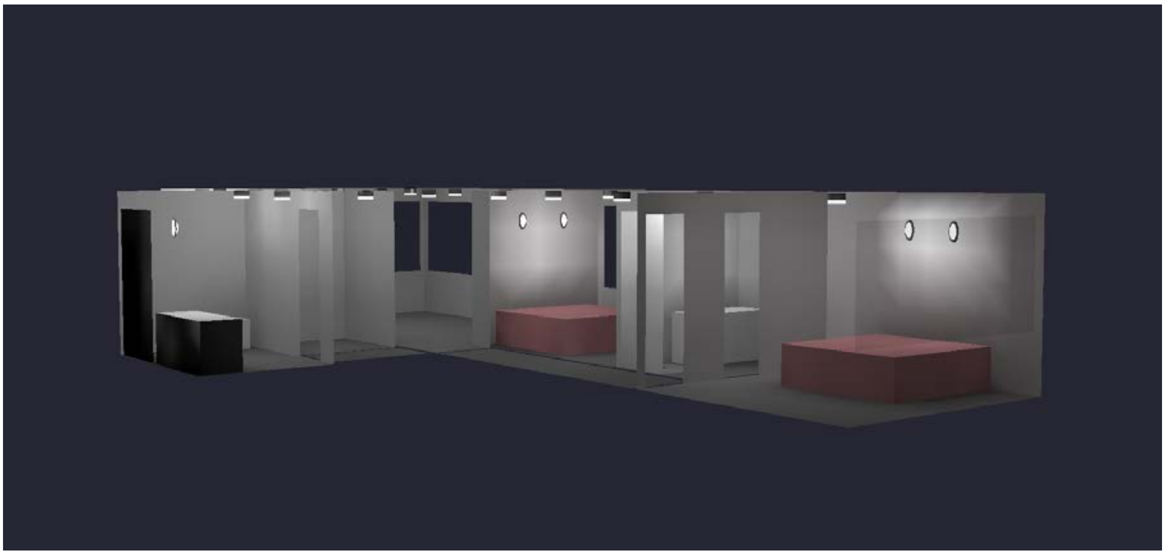


Figure 42. Apartment model – north east isometric view of rendered simulation

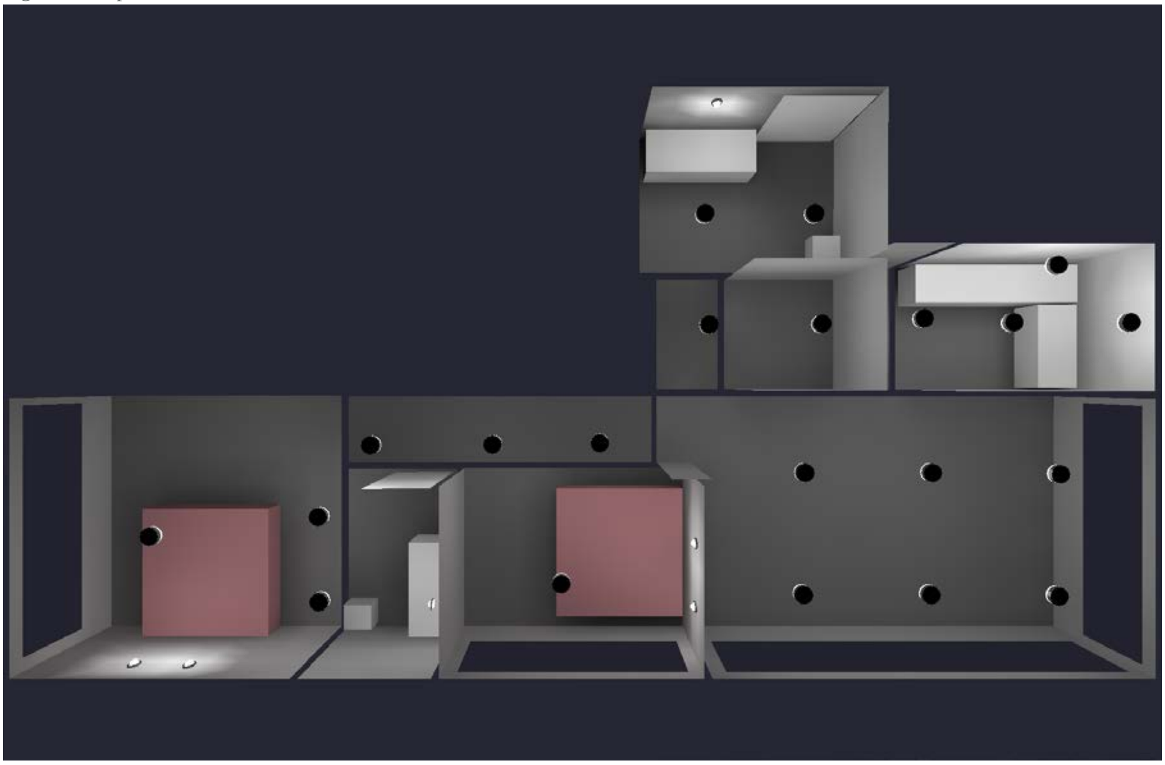


Figure 43. Apartment model – plan view of rendered simulation.

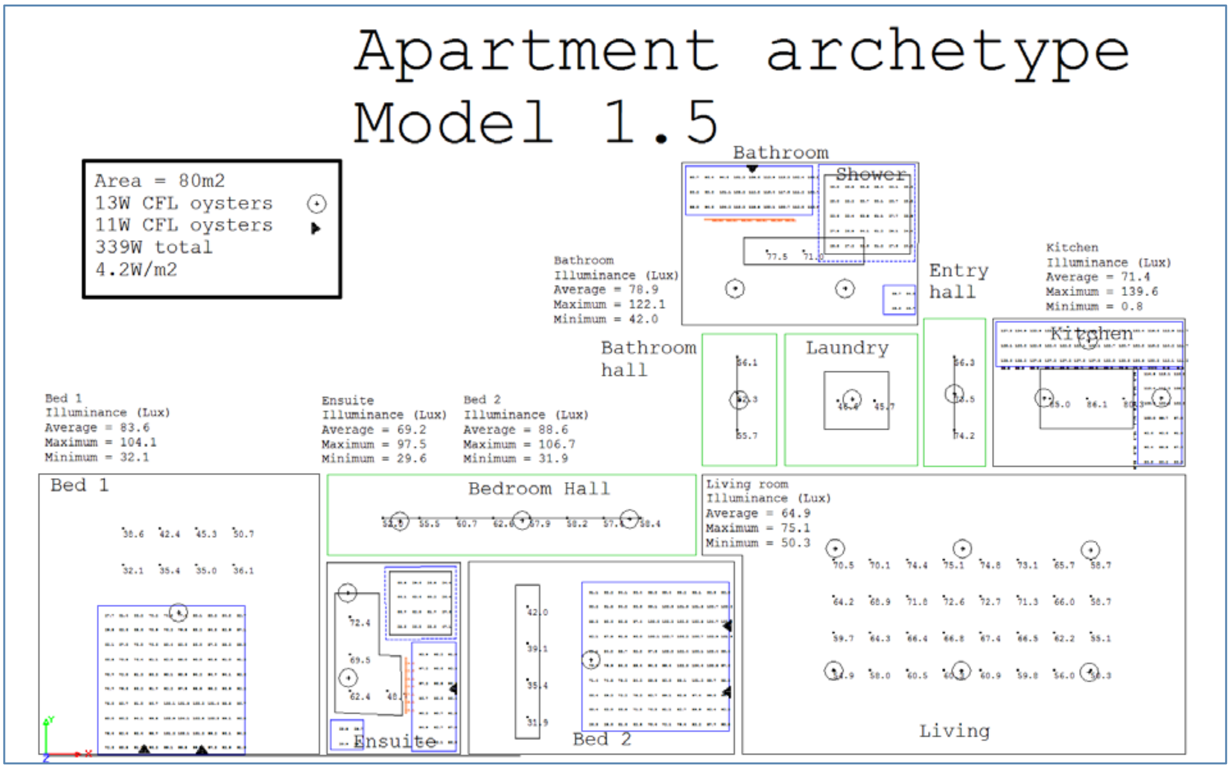


Figure 44. Apartment model 1.5 (CFL base case).

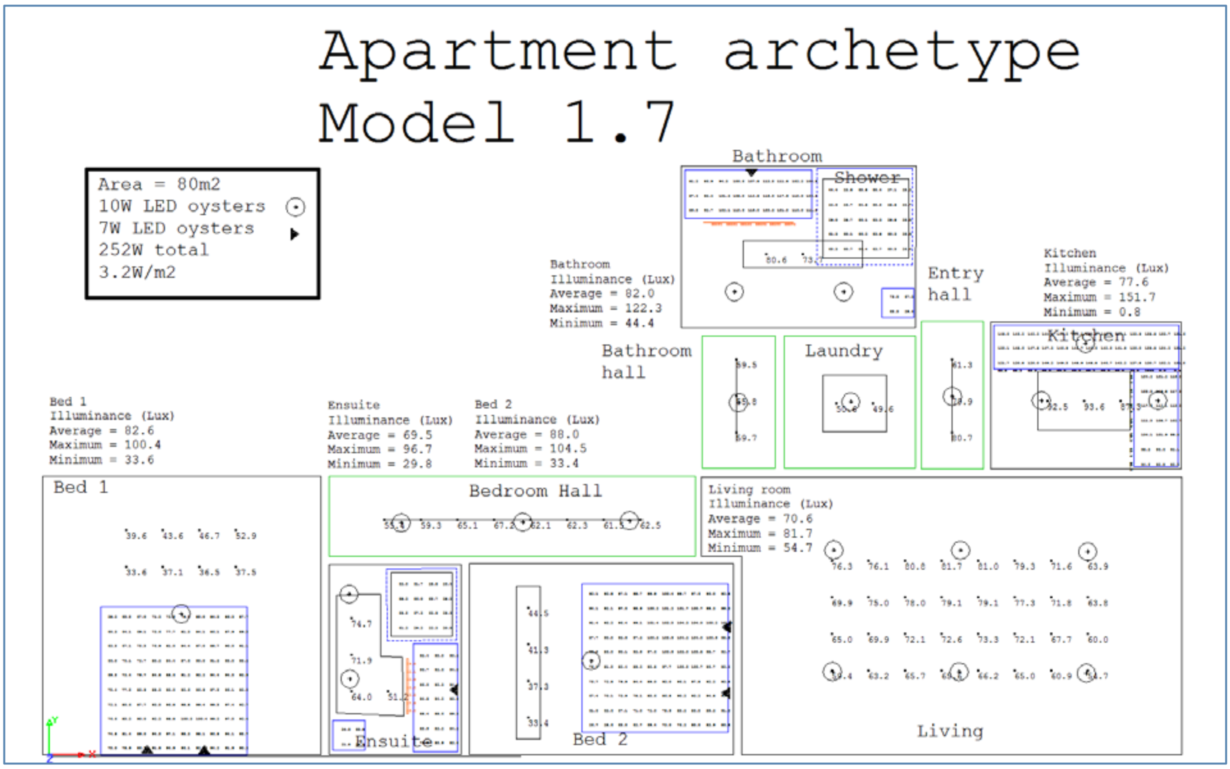


Figure 45. Apartment model 1.7 (LED case).

Figure 46. Detached house model – south west isometric view of rendered simulation.

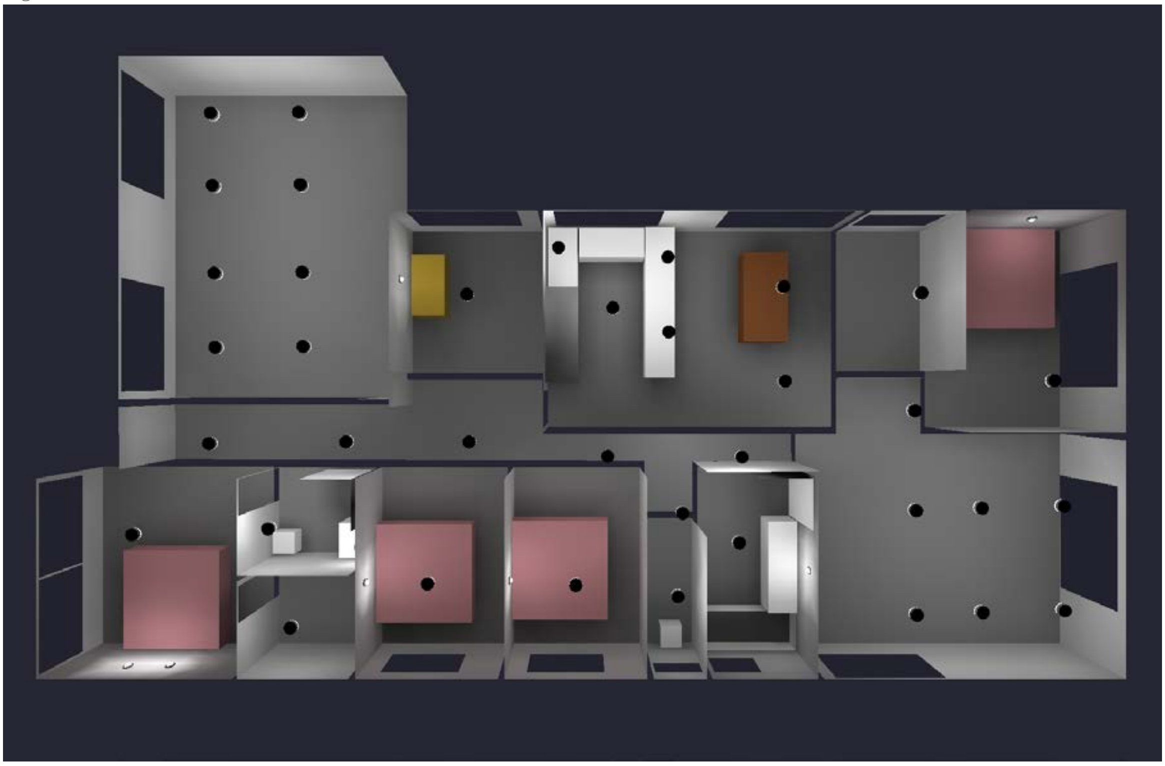


Figure 47. Detached house model – plan view of rendered simulation.

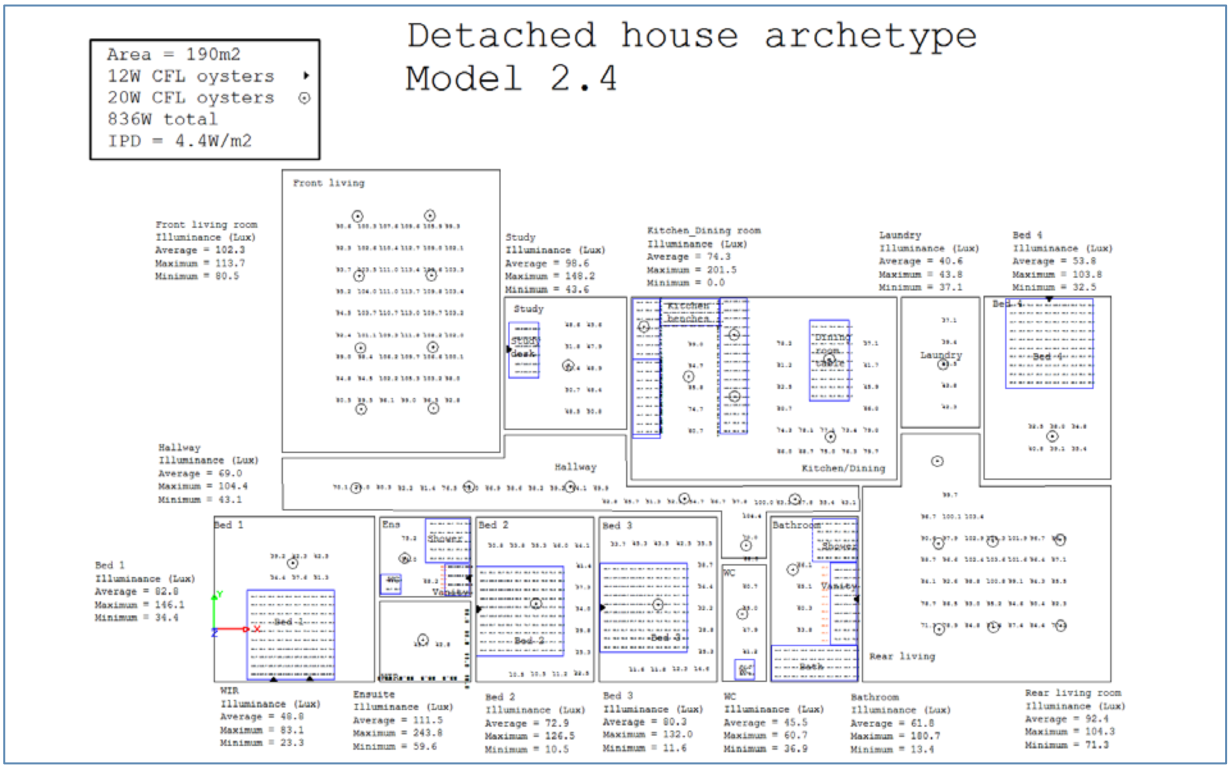


Figure 48. Detached house model 2.4 (CFL base case).

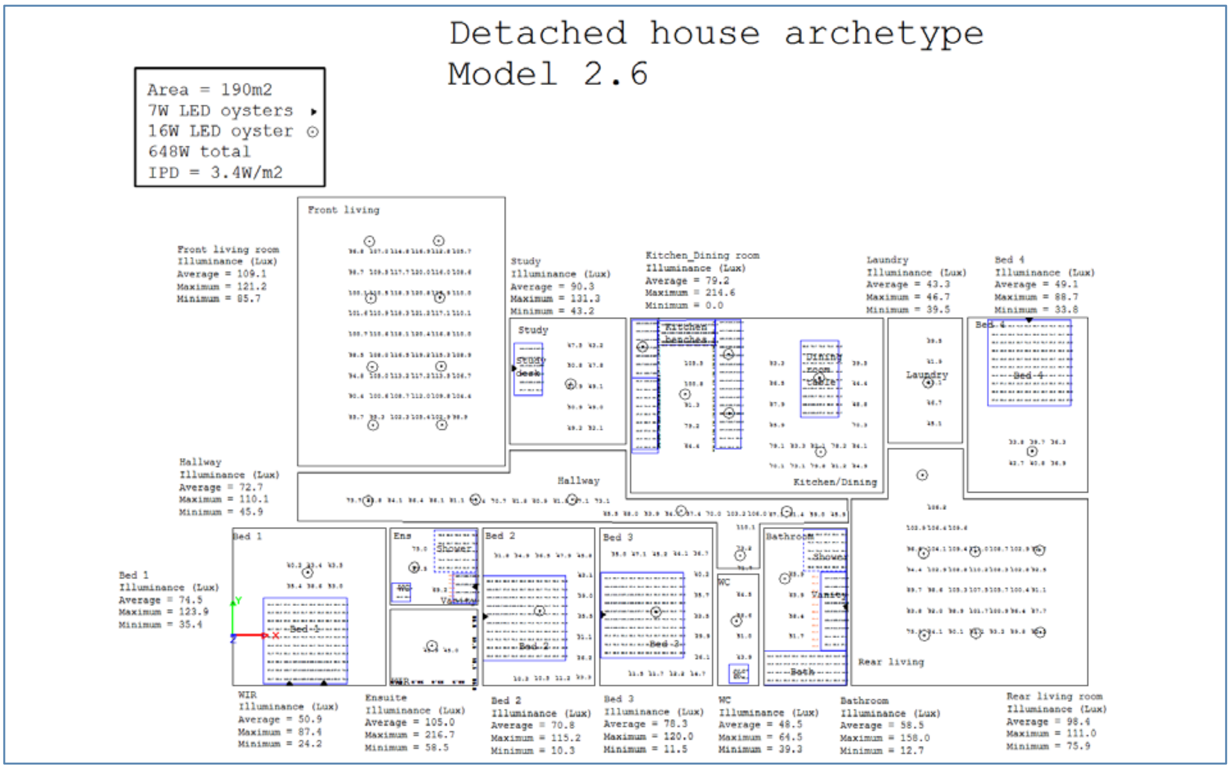


Figure 49. Detached house model 2.6 (LED case)

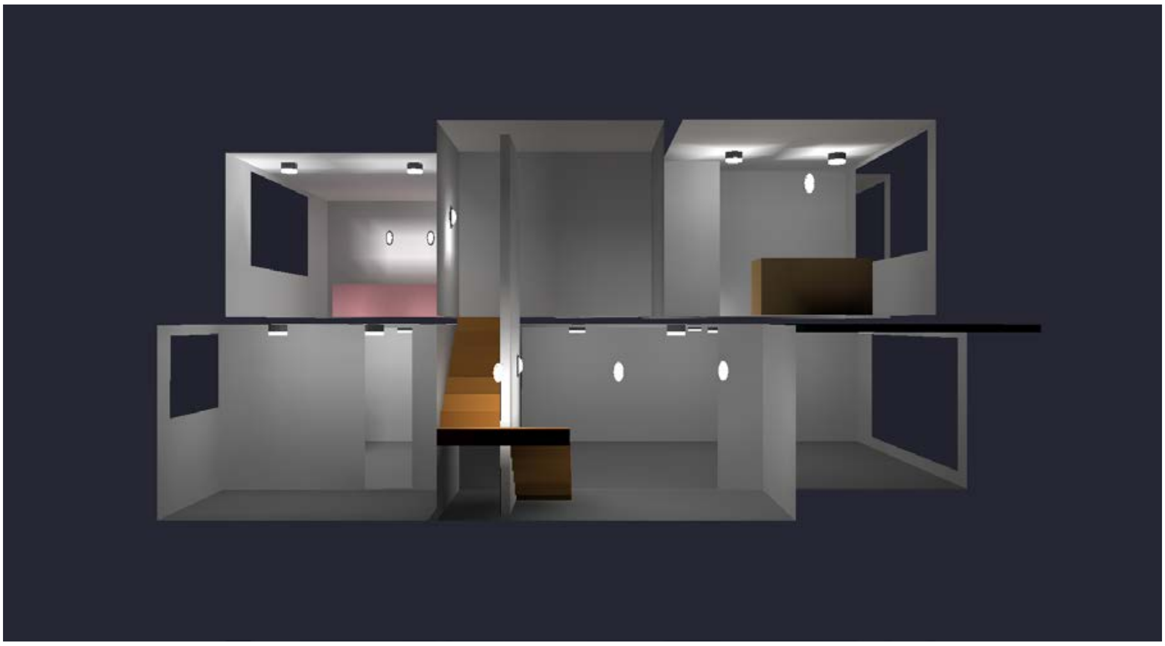


Figure 50. Attached house model – east elevation of rendered simulation.

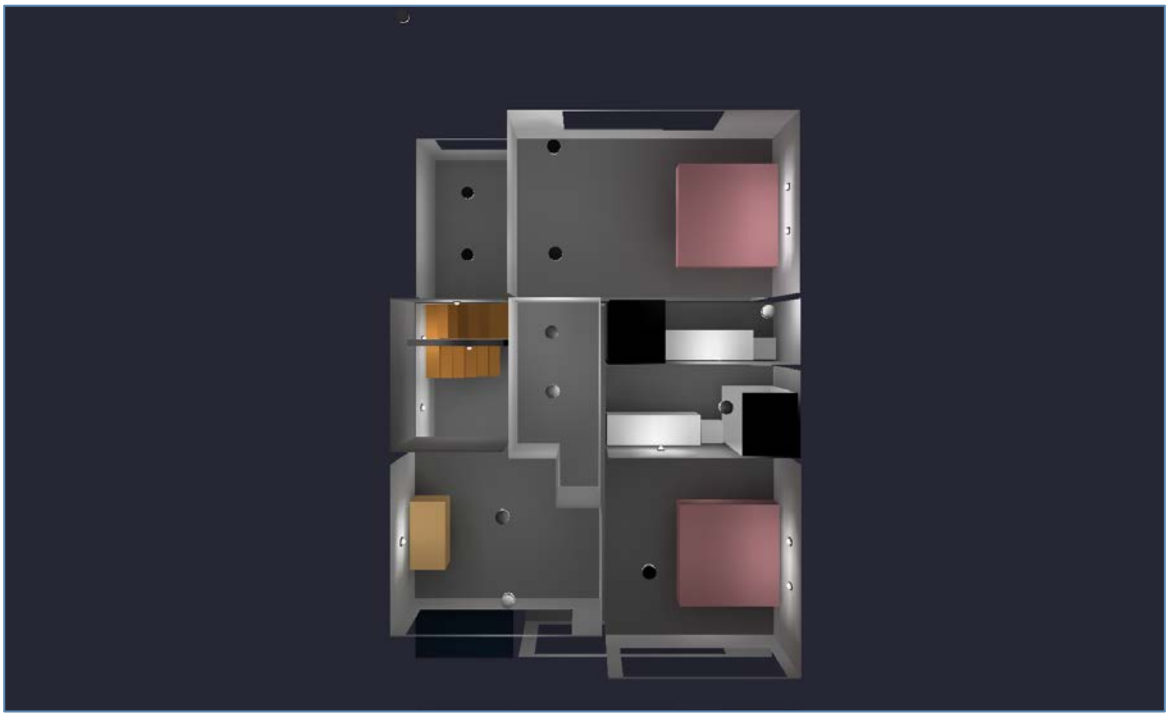


Figure 51. Attached house model – plan view of rendered simulation – 1st floor plan with ground floor laundry and stairs visible on left.

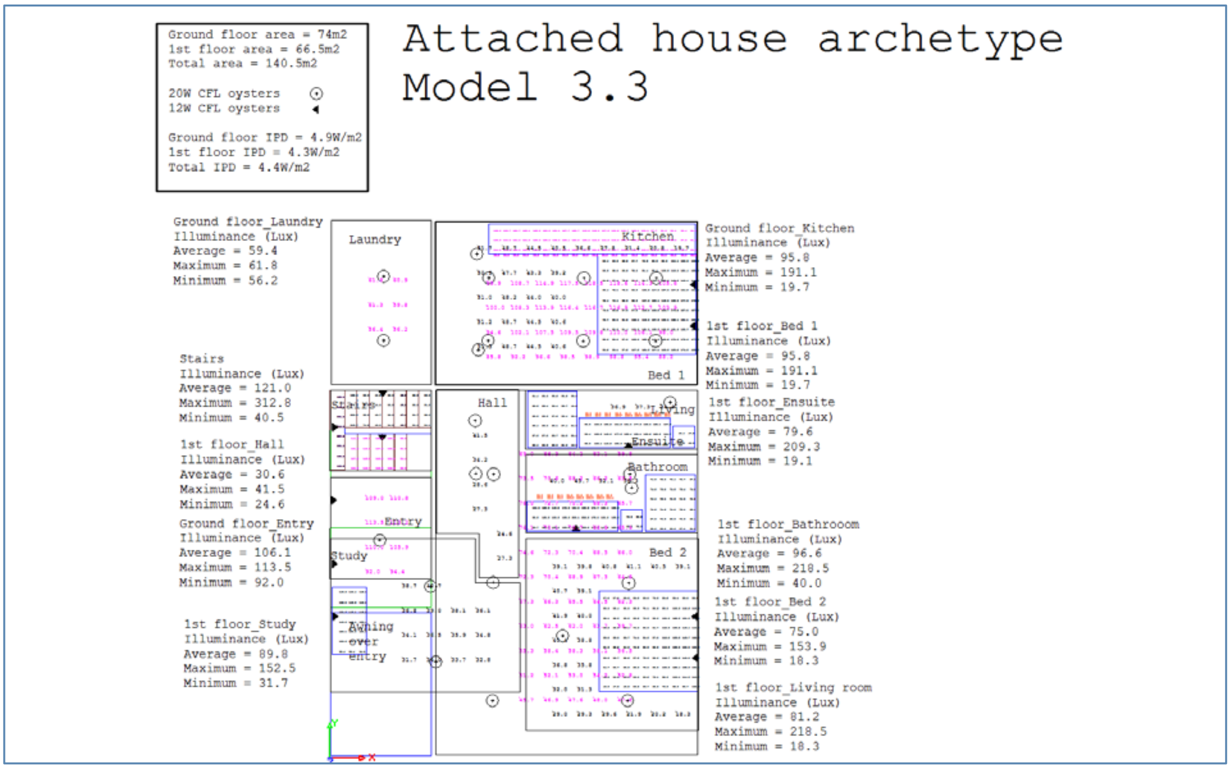


Figure 52. Attached house model 3.3 (CFL base case).

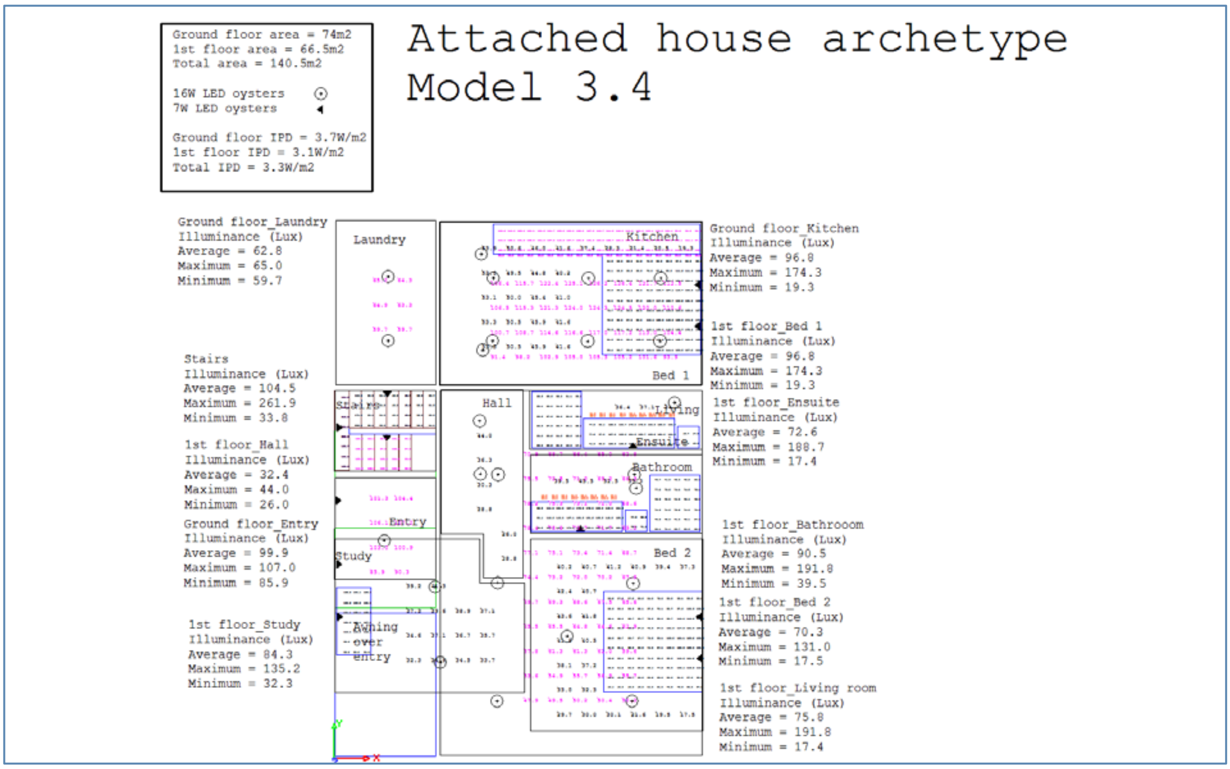


Figure 53. Attached house model 3.4 (LED case)

Appendix G: Air Tightness and Infiltration Rates in Residential Archetypes

G.1 Introduction

To ascertain the impact of air tightness improvements the baseline archetype models were developed with air tightness values that approximately matched the average from blower door survey data made available by the CSIRO in their report “House Energy Efficiency Inspections Project” (Ambrose & Syme 2015, p10).

To ensure that the 15ACH at 50Pa data was representative of buildings in the present NCC Trajectory project, only the city-by-city mean values provided by Ambrose and Syme for newly constructed buildings (up to 3 years old) were averaged. Thus, it could be inferred that the buildings in this dataset were built close to current NCC energy performance standards (noting that 6 Star NatHERS applied in most jurisdictions, with some less stringent requirements used in others). The resultant average air change rate was then calculated to be approximately 15 ACH at 50 Pa.

The UOW team developed a method to estimate the impact of improving the airtightness of the building envelope on the energy and thermal performance of a new dwelling; this method is outlined in some detail below. The infiltration rates in the three archetype buildings were adjusted in Accurate by the addition of wall vents so as to implement a baseline air tightness level of close to the target value of 15ACH at 50Pa. However, it should be noted that it was not always possible to match this value exactly in the AccuRate Sustainability simulation tool, due to the nature of the in-built infiltration algorithms.

G.2 Method

In order to achieve the targeted infiltration rate in the base case models, the following procedure was carried out.

1. The infiltration rate $\overline{\mathrm{ACH}}_{\mathrm{archetype}}$ of the AccuRate archetype base case model was calculated using the information provided in Chen’s documentation *Infiltration Calculations in AccuRate V2.0.2.13* (Chen, 2013):

    a. The natural infiltration rate of a given zone, ACH_{zone}, in units of air changes per hour, is a function of the instantaneous wind and thermal effects imposed in the building. Using Chen’s approach this was calculated using the formula $\mathrm{ACH}_{zone} = A + B\upsilon$, where A is a constant that accounts for the ‘stack’ (thermal) ventilation effects and B is a constant used to model the effects of wind. A and B are functions of the number, size and type of penetrations in the envelope of each zone/space and can be extracted directly from the AccuRate Scratch file.

    b. υ is dependent on the wind speed derived from the AccuRate weather file and the terrain factor, $f = a\left(\frac{h_b}{10}\right)^b$, where a and b depend on the terrain category, and are specified as 0.67 and 0.25 for a suburban area. The height of the eaves h_b (m) for the Attached townhouse and Detached house, was taken as 2.4m while it was taken as the mid-height of the zone above the ground for the Apartment archetype (4.35m) due to this archetype being higher than 9m.

    c. The hour-by-hour wind speeds from the Climate Zone 5 weather file over an entire year were then used to calculate the hour-by-hour natural air change rates in each zone using $\mathrm{ACH}_{zone} = A + B\upsilon$, and hence the annual average for each zone, $\overline{\mathrm{ACH}}$.

    d. The annual average natural air change rate, $\overline{\mathrm{ACH}}_{\mathrm{archetype}}$, was then calculated as the volume-weighted average of all the zones in the house.

    e. Climate Zone 5 was initially employed in these calculations for the purposes of controlling the permeability of the envelope to achieve the target air change rate.

2. The equivalent building envelope permeability (i.e. under a blower door test conditions), ACH_{50}, was calculated by utilizing an correlation that is commonly used in the air tightness industry whereby $ACH_{50} \approx 20 \times ACH$ (Sherman, 1987). It should be noted that despite the fact that this correlation is widely accepted (CIBSE, 2000; Egan, 2011), it is an approximation to reality and does not take account of many factors such as wind shielding or the type of air leaks.

3. Wall vents were added in all zones in AccuRate so as to achieve an infiltration rate as close as possible to 15ACH at 50Pa, i.e. $\overline{\text{ACH}}_{\text{archetype 50}} \approx 15\text{ACH}_{50} \pm 5\%$. If the value obtained was larger than $15\text{ACH}_{50} + 5\%$, the wall vents in the zones were progressively removed. This wall vent removal process was typically undertaken first in the zones with an exhaust fan, which led to the three archetype with at least one exhaust fan, wall vent or both in all zones (with the exception of the 'Walk in Robe' of the Detached house archetype).
4. Thereafter, to assess the building performance when the building was 'well sealed' all the wall vents were removed and the exhaust fans were 'sealed' (i.e. in practice this means an exhaust fan that incorporates a sealing device of some sort) as specified in the National Construction Code. This resulted in infiltration rates that ranged from 5.4 ACH_{50} to 5.9 ACH_{50} for the three archetypes in Climate Zone 5.

G.3 Summary of Estimated Air Change Rates in Archetypes

The purpose of undertaking the process above was to provide reasonably consistent ACH_{50} values across the three archetypes so that the impact on heating and cooling energy consumption of improving air tightness could be determined with greater confidence than an alternative *ad hoc* approach.

The same number and size of vents in each archetype were maintained across all three climate zones, so that the relative change in the air-tightness performance of the base case, and higher stringency, archetypes could be compared easily across climate zones.

The following table summarises the calculated air change rates using the method outlined above for the three archetypes and wind speed data from each of the three AccuRate weather files, and for each of the three infiltration options tested using the approach in Section G.2.

Note that the Apartment and the Attached Townhouse each had 2 exhaust fans, while the Detached House had 6 exhaust fans. Note also that option 'a) ACH with vents and unsealed exhaust fans' corresponds to the Baseline I case in the 1-D stringency analysis, and option 'c) ACH with no vents sealed and sealed exhaust fans' corresponds to the Level 1 stringency case.

Table 106. Summary of the equivalent infiltration air change rates (ACH_{50}) determined for each archetype and climate zone using the method summarised above.

	Estimated Air Change per Hour (ACH_{50})			% change compared to a) i.e. (b-a)/a or (c-a)/a		
CZ2	Apartment	Attached	Detached	Apartment	Attached	Detached
a) ACH with vents and unsealed exhaust fans	17.6	16.7	16.1			
b) ACH with vents and sealed exhaust fans	14.4	14.6	11.8	18.2%	12.6%	26.7%
c) ACH with no vents sealed and sealed exhaust fans	6.7	6.1	6.1	53.5%	58.2%	48.3%
CZ5	Apartment	Attached	Detached	Apartment	Attached	Detached
a) ACH with vents and unsealed exhaust fans	15.2	14.3	14.4			
b) ACH with vents and sealed exhaust fans	12	12.2	10.1	21.1%	14.7%	29.9%
c) ACH with no vents sealed and sealed exhaust fans	5.9	5.4	5.5	50.8%	55.7%	45.5%
CZ6	Apartment	Attached	Detached	Apartment	Attached	Detached
a) ACH with vents and unsealed exhaust fans	18.5	17.6	16.7			
b) ACH with vents and sealed exhaust fans	15.3	15.5	12.4	17.3%	11.9%	25.7%
c) ACH with no vents sealed and sealed exhaust fans	7	6.4	6.3	54.2%	58.7%	49.2%

G.4 References

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Appendix H: Residential Photovoltaics (PV) Analysis

The benefit of using PV systems for the attached and detached residential archetypes was analysed using online PVWatts calculator[44] developed by US National Renewable Energy Laboratory (NREL). This calculator estimates the electricity production and energy value of a grid-connected roof or ground-mounted photovoltaic system based on default inputs or user-defined inputs about the system's location, basic design parameters, and system economics.

In this analysis, the PV system was assumed to be installed on the north, east and west roofs of the detached and attached archetypes. The analysis was carried out for three Climate Zones 2, 5 and 6, and four different orientations. The hip type roof was considered for both archetypes. The specifications of the PV systems used are summarised in Table 107. Table 108 summarises the available roof areas and roof pitch of both the detached and attached archetypes and the DC system size installed when the orientation of the house was 0º. In order to simplify the PV analysis, the North and South facing roof sections were assumed to be the average of the two areas (80 m^2 for the detached archetype, 14.5 m^2 for the attached archetype), as were the East and West facing sections (37 m^2 for the detached archetype and 29 m^2 for the attached archetype). A usable roof space factor of 0.5 (for detached) and 0.4 (for attached) was used to determine the maximum DC system size (in increments of panel size).

Table 107. Specifications of the PV systems used.

Module type	**Standard (Efficiency: ~15%)**
Array type	Fixed (roof mount)
System losses (%)	14
Invert efficiency (%)	96
DC to AC size ratio	1.1

Table 108. Roof areas of the Attached and Detached houses (0 degree orientation).

Section of Roof	Detached house			Attached house		
	Roof area (m^2)	Roof pitch (º)	DC system size* (kW)	Roof area (m^2)	Roof pitch (º)	DC system size (kW)
North Facing	77	23	6.0	14.5	23	0.75
East Facing	40	23	2.75	29.1	23	1.75
South Facing	84	23	-	14.5	23	-
West Facing	34	23	2.75	29.1	23	1.75

* Size (kW) = Array Area (m²) × 1 kW/m² × Module Efficiency (%), based on average roof sizes of 80m^2 and 37m^2 for North/South and East/West facing roof sections for detached archetype.

For PV analysis Climate Zones 2, 5 and 6 were represented by weather data from Brisbane, Sydney, and Melbourne coordinates to establish nominal solar irradiance levels. It was assumed that there was no shading from nearby buildings/objects, roof sections, or other roof mounted equipment.

[44] http://pvwatts.nrel.gov/pvwatts.php

Table 109 to Table 111 summarises the AC output of the PV system when the detached archetype was oriented at 0°, 90°, 180°, and 270°, respectively. As expected, for the same climate zone, the monthly AC output of the PV system was quite different. A higher PV output can be achieved when the baseline house was oriented at 90° or 270°, in comparison to that was oriented at 0° or 180°, due to the capacity of roof area to install a larger system. The AC output of the PV system also varied greatly with the variation in climate zones. The annual AC output of the PV system in this detached archetype for Climate Zones 2, 5 and 6 were 20,010 kWh, 18,036 kWh and 17,745 kWh respectively, when the house was oriented at 90° or 270° and with a DC system size of 14.75 kW.

Table 109. The electricity generation of the Detached Archetype – Climate Zone 2.

Month	Detached Climate Zone 2					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	875	807	1682	401	1761	2162
February	721	634	1355	331	1384	1715
March	788	636	1424	361	1388	1749
April	675	504	1179	309	1101	1410
May	568	398	966	260	869	1129
June	570	371	941	261	809	1070
July	664	436	1100	304	950	1254
August	771	542	1313	353	1182	1535
September	849	656	1505	389	1431	1820
October	827	702	1529	379	1532	1911
November	838	762	1600	384	1662	2046
December	890	826	1716	408	1801	2209
Annual (kWh)	**9036**	**7274**	**16310**	**4140**	**15870**	**20010**
DC System Size (kW)	**6**	**5.5**	**11.5**	**2.75**	**12**	**14.75**

Table 110. The electricity generation of the Detached Archetype – Climate Zone 5.

Month	Detached Climate Zone 5					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	846	762	1608	388	1662	2050
February	739	627	1366	339	1369	1708
March	669	530	1199	306	1157	1463
April	617	436	1053	283	951	1234
May	482	316	798	221	691	912
June	496	299	795	227	653	880
July	530	326	856	243	712	955
August	636	426	1062	291	931	1222
September	762	570	1332	349	1242	1591
October	856	704	1560	392	1537	1929
November	827	732	1559	379	1596	1975
December	866	788	1654	397	1720	2117
Annual (kWh)	**8326**	**6516**	**14842**	**3815**	**14221**	**18036**
DC System Size (kW)	**6**	**5.5**	**11.5**	**2.75**	**12**	**14.75**

Table 111. The electricity generation of the Detached Archetype – Climate Zone 6.

Month	Detached Climate Zone 6					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	959	847	1806	439	1848	2287
February	829	690	1519	380	1504	1884
March	810	620	1430	371	1354	1725
April	623	429	1052	286	935	1221
May	418	268	686	192	586	778
June	400	234	634	183	510	693
July	427	266	693	196	581	777

August	550	371	921	252	811	1063
September	632	476	1108	289	1038	1327
October	849	693	1542	389	1513	1902
November	831	724	1555	381	1580	1961
December	882	790	1672	404	1723	2127
Annual (kWh)	**8210**	**6408**	**14618**	**3762**	**13983**	**17745**
DC System Size (kW)	**6**	**5.5**	**11.5**	**2.75**	**12**	**14.75**

Table 112 to Table 114 summarises the AC output of the PV system when the attached house was oriented at 0°, 90°, 180°, and 270°, respectively. Similar monthly and climate zone variation as that observed in the detached house was also observed. A higher PV output can be achieved when the baseline attached house was oriented at 0° or 180°, in comparison to that was oriented at 90° or 270°. The annual AC output of the PV system in this attached house under Climate Zones 2, 5 and 6 were 5,756 kWh, 5,187 kWh and 5,106 kWh respectively, when the house was oriented at 0° or 180° with a DC system size of 4.25 kW.

Table 112. The electricity generation for the Attached archetype – Climate Zone 2.

Month	Attached Climate Zone 2					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	109	514	623	255	220	475
February	90	404	494	210	173	383
March	98	405	503	230	174	404
April	84	321	405	197	138	335
May	71	253	324	166	108	274
June	71	237	308	166	101	267
July	83	276	359	194	118	312
August	96	345	441	225	148	373
September	106	417	523	248	178	426
October	103	447	550	241	192	433
November	105	485	590	244	208	452
December	111	525	636	260	225	485

Annual (kWh)	1127	4629	5756	2636	1983	4619
DC System Size (kW)	0.75	3.50	4.25	1.75	1.50	3.25

Table 113. The electricity generation for the Attached Archetype – Climate Zone 5.

Month	Attached Climate Zone 5					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	106	485	591	247	208	455
February	92	400	492	216	171	387
March	84	337	421	195	145	340
April	77	278	355	180	119	299
May	60	201	261	141	86	227
June	62	190	252	145	82	227
July	66	208	274	155	89	244
August	79	271	350	185	116	301
September	95	363	458	222	155	377
October	107	448	555	250	192	442
November	103	465	568	241	199	440
December	108	502	610	253	215	468
Annual (kWh)	**1039**	**4148**	**5187**	**2430**	**1777**	**4207**
DC System Size (kW)	**0.75**	**3.50**	**4.25**	**1.75**	**1.50**	**3.25**

Table 114. The electricity generation for the Attached archetype – Climate Zone 6.

Month	Attached Climate Zone 6					
	0° and 180°			90° and 270°		
	North	East + West	Total	North	East + West	Total
January	120	539	659	280	231	511
February	104	439	543	242	188	430
March	101	395	496	236	169	405
April	78	273	351	182	117	299
May	52	171	223	122	73	195

June	50	149	199	117	64	181
July	53	170	223	125	73	198
August	69	237	306	161	101	262
September	79	303	382	184	130	314
October	106	442	548	248	189	437
November	104	460	564	242	198	440
December	110	502	612	257	216	473
Annual (kWh)	**1026**	**4080**	**5106**	**2396**	**1749**	**4145**
DC System Size (kW)	**0.75**	**3.50**	**4.25**	**1.75**	**1.50**	**3.25**

In order to determine the approximate export ratio (kWh export / kWh generated) of the installed PV systems the average daily generation profile for each PV configuration and orientation, across all three climate zones, was compared to the average daily demand profile of the detach and attached archetypes (apartment archetype excluded from PV analysis at this stage of project). To create the average daily demand profile, the lighting, domestic hot water and total heating/cooling demand were summated. The lighting profile was assumed to follow NatHERS protocol, direct electric domestic hot water was assumed to be spread evenly over each 24hr period, and heating and cooling demand were extracted from the energy analysis results. No allowance was given to appliance loads beyond that associated with additional heating and cooling requirements, and all demand and generation was assumed to be consumed or delivered at unity power factor. The lack of appliance loads is a conservative assumption that will be addressed in the final report. This further work will also identify the optimum PV capacity for each archetype based on the maximum available capacity and empirical data on the average rates of export as the ratio of PV array to household energy use is varied.

Table 115. Export ratio for PV generation system on Detached archetype.

PV panel configuration and rating	Export Ratio
2.75kW of North facing PV panels only	37%
6.0kW of North facing PV panels only	64%
2.75kW of North facing PV panels, and 12.0kW of East and West facing panels	82%
6.0kW of North facing PV panels, and 5.5kW of East and West facing panels	79%

Table 116. Export ratio for PV generation system on Attached archetype.

PV panel configuration and rating	Export Ratio
0.75kW of North facing PV panels only	1%

1.75kW of North facing PV panels only	39%
0.75kW of North facing PV panels, and 3.5kW of East and West facing panels	61%
1.75kW of North facing PV panels, and 1.5kW of East and West facing panels	56%

Export ratios of 0% and 100% will be utilised for the initial cost benefit analysis in order to provide the boundary cost benefit results. Export ratios of Table 115 and Table 116 will then be utilised to establish the scenario level changes between the boundary results. It is noted that export ratios could be reduced, increasing the cost benefit of PV further, if loads such as domestic hot water and other appliances could be shifted to operate within the periods of high solar irradiance.

Appendix I: Multi-Dimensional Stringencies Scenario Results

I.1 Specification for Baselines, Glazing and Multi-dimensional Analyses

Following discussions between CWA, UOW and Energy Action, and recent input from other experts and stakeholders, the UOW NCC trajectories team adjusted the glazing of the specific building archetypes to generate baselines archetypes and energy simulation results against the following baselines.

- Changes to glazing in the 1-D archetype glazing types are to be made to ensure that all archetypes are DTS-compliant for at least one building orientation, for all three archetypes, in all three climate zones.
- Two baseline archetypes with appropriate glazing types for the multi-dimensional analyses are to be developed such that the archetypes are 6-Star compliant for at least one building orientation, for all three archetypes, in all three climate zones, i.e.:
    - Using the minimum WWR for daylighting purposes (A_{window}>10% of floor area);
    - With a larger WWR reflecting some current architectural practice (noting that this task represents significant extra work as compared to original project scope).

Based on the discussions UOW proposes the following approach and scope of work from here.

I.2 Overview of Multi-dimensional Analysis and Outputs

UOW have produced extensive tables of energy performance for the baseline 1-D archetypes, and with associated individual higher stringency building elements included.

The major outputs from the future multi-dimensional analyses is essentially be two sets of summary tables shown schematically below.

Each set of tables includes variations for each archetype and climate zone (CZ), i.e. 3 x 3 tables, each with 4 (orientations) x 3 (new Accurate models) sets of results = 108 models.

Table 117. Summary of Energy Performance/Equivalent Star Rating using a 'minimum WWR + 6-Star compliance' Baseline II archetype design for multi-dimensional analysis.

Orien-tation (°)	Baseline I results DTS compliant	Baseline II (Multi-dimensional) results: • Glazing/WWR chosen for both 6-Star and 10% of floor area minimum daylighting compliance. • All other building elements as for the Baseline I (DtS compliant). • Glazing not necessarily DTS compliant. • The glazing type chosen for a given archetype and climate zone will be applied to all windows (i.e. same on all facades of the house).	Economic stringencies package results • The initial stringency packages defined to date do not include glazing upgrades. • If it is agreed that further simulations including glazing upgrades in the packages are required, they will be informed by the separate Glazing Analysis work.	Ambitious stringencies package results • ditto
0	(MJ/m²/y) (kWh/m²/y) (Star Rating)			
90, etc.				

Table 118. Summary of Energy Performance/Equivalent Star Rating using a 'increased WWR + 6-Star compliance' Baseline III archetype design for multi-dimensional analysis.

Orien-tation (°)	Baseline I results	Baseline III (Multi-dimensional) Results • Glazing chosen to be more representative of current practice (e.g. WWR_{min}+20%) • 6-Star compliant. • Glazing not necessarily DTS compliant. • All other building elements as for the 1-D baseline (DtS compliant). • The glazing type chosen for a given archetype and climate zone will be applied to all windows (i.e. same on all facades of the house).	Economic stringencies package results • These initial stringency packages do not include glazing upgrades. • If it is agreed that further simulations including glazing upgrades in the packages are required, they will be informed by the separate Glazing Analysis work.	Ambitious stringencies package results • ditto
0	(MJ/m²/y) (kWh/m²/y) Equivalent Star rating			
90, etc.				

Table 119. Multi-Dimensional Scenario Heating & Cooling Energy using Baseline II.

Archetype	Climate Zone	Orientation	DtS Glazing[1]	Basline I (1-D) (15ACH at 50Pa) *				Baseline II (WWR$_{min}$) (15ACH at 50Pa)**				Economic Stringency Case***				Ambitious Stringency Case****				Economic – change relative to Baseline II				Ambitious – change relative to Baseline II			
				Heating Energy (MJ/m^2/y)	Cooling Energy (MJ/m^2/y)	Electrical Energy (kWh/m^2/y)	Equiv. Star rating	Heating Energy (MJ/m^2/y)	Cooling Energy (MJ/m^2/y)	Electrical Energy (kWh/m^2/y)	Equiv. Star rating	Heating Energy (MJ/m^2/y)	Cooling Energy (MJ/m^2/y)	Electrical Energy (kWh/m^2/y)	Equiv. Star rating	Heating Energy (MJ/m^2/y)	Cooling Energy (MJ/m^2/y)	Electrical Energy (kWh/m^2/y)	Equiv. Star rating	Electrical Energy	Equiv Star improv	Avg energy improv	Avg Star improv	Electrical Energy	Equiv Star improv	Avg energy improv	Avg Equiv Star improv
Apartment	CZ 2	0	n	17	43	5.6	4.9	16.1	29.8	4.3	6.1					6.3	29.8	3.3	7.1					-21%	1.0	-11%	0.6
		90	y	10.8	32.2	4.0	6.3	7.3	28.6	3.3	6.8					3	32.7	3.3	7.1					-1%	0.3		
		180	y	6.9	34.4	3.8	6.4	8.1	30.6	3.6	6.8					1.6	34.7	3.4	7.1					-6%	0.3		
		270	n	15.6	33.5	4.5	5.8	16.3	31.5	4.4	5.9					6.2	34.1	3.7	6.6					-16%	0.7		
	CZ 5	0	n	27.3	25	4.8	5.1	25.5	20.4	4.3	5.6					10.6	22.8	3.1	6.9					-27%	1.3	-20%	0.9
		90	y	15.9	22.3	3.5	6.4	14.2	21.3	3.3	6.7					5.3	27.1	3.0	6.9					-9%	0.2		
		180	y	12.4	25.7	3.5	6.4	13.3	24.6	3.5	6.4					3.7	26.5	2.8	7.2					-20%	0.8		
		270	n	25.1	24.6	4.6	5.3	24.5	26.3	4.7	5.2					10.6	27.5	3.5	6.4					-25%	1.2		
	CZ 6	0	n	116.5	22.1	12.8	5.6	105	22.6	11.8	5.9	63.7	27.2	8.4	6.9	53.2	27.2	7.4	7.3	-29%	1.0	-35%	1.3	-37%	1.4	-38%	1.4
		90	y	94.2	21.4	10.7	6.2	87.6	22.3	10.2	6.4	38.6	26.3	6.0	7.8	38.6	25.6	5.9	7.8	-41%	1.4			-42%	1.4		

		180	y	93.8	24.4	10.9	6.1	90.3	25.9	10.8	6.2	41.4	31.5	6.8	7.5	41.4	30.5	6.7	7.5	-37%	1.3			-38%	1.3		
		270	n	118.9	23.9	13.2	5.4	110.1	25.5	12.6	5.7	59.2	30.2	8.3	7	59.2	29.4	8.2	7	-34%	1.3			-35%	1.3		
Attached	CZ 2	0	n	13.7	38.1	4.8	5.7	10.4	33.3	4.0	6.4	10.4	16.8	2.5	8.1	3.8	14.1	1.7	9.2	-38%	1.7	-40%	1.9	-59%	2.8	-57%	2.7
		90	n	8.4	60.5	6.4	4.6	6.6	50.6	5.3	5.3	6.6	27.6	3.2	7.4	1.6	23.3	2.3	8.4	-40%	2.1			-56%	3.1		
		180	y	3.2	34.7	3.5	7.1	2.6	30.3	3.0	7.6	2.6	16.1	1.7	9.1	0.3	13.5	1.3	9.6	-43%	1.5			-58%	2.0		
		270	n	6.2	63.7	6.5	4.5	5.7	51.3	5.3	5.3	5.7	28.9	3.2	7.4	1.1	25	2.4	8.3	-39%	2.1			-54%	3.0		
	CZ 5	0	n	23.4	20	4.0	6.1	18.7	18.5	3.4	6.7	18.7	9.4	2.6	7.7	7.6	8.6	1.5	8.8	-24%	1.0	-28%	1.0	-56%	2.1	-56%	2.0
		90	n	15.7	34.8	4.7	5.4	13.4	26.5	3.7	6.4	13.4	16.1	2.7	7.4	4.2	13.4	1.6	8.7	-26%	1.0			-56%	2.3		
		180	y	6.8	20.3	2.5	7.8	6	16.8	2.1	8.2	6	9	1.4	8.9	1.1	8.0	0.8	9.7	-34%	0.7			-60%	1.5		
		270	n	12.8	35.4	4.5	5.6	12.2	27.6	3.7	6.4	12.2	16.5	2.7	7.6	3.4	15.3	1.7	8.6	-28%	1.2			-53%	2.2		
	CZ 6	0	n	99.4	8	9.9	6.6	114.4	8.1	11.3	6.2	70.7	8.3	7.3	7.4					-36%	1.2	-37%	1.2				
		90	n	94.6	15.9	10.2	6.5	109.7	13	11.4	6.2	67.4	12.4	7.4	7.4					-35%	1.2						
		180	y	74.7	7.6	7.6	7.4	95.5	7.6	9.5	6.8	51.9	7.7	5.5	8.1					-42%	1.3						
		270	n	93.9	15.8	10.2	6.6	111	12.9	11.5	6.2	68.1	12.7	7.5	7.4					-35%	1.2						
Detached	CZ 2	0	y	8.4	32.8	3.8	6.3	9.3	29.4	3.6	6.5	2.8	16.6	1.8	8.8	2.8	13.2	1.5	9.2	-50%	2.3		2.5	-59%	2.7		2.9

		90	y	8.4	37.1	4.2	5.9	8.2	35.4	4.0	6.0	2.5	19.6	2.0	8.4	2.6	15.1	1.6	8.9	-49%	2.4	-51%		-59%	2.9	-60%	
		180	y	8.8	40.4	4.6	5.5	8.1	36.2	4.1	5.9	2.2	19.2	2.0	8.5	2.2	15.6	1.6	8.9	-52%	2.6			-60%	3.0		
		270	y	9.8	39.2	4.5	5.5	9.9	34.8	4.1	5.9	3.0	18.2	2.0	8.5	3.0	14.2	1.6	9.0	-53%	2.6			-62%	3.1		
		0	y	15.2	41.3	5.2	4.7	15.4	24.3	3.7	6.1	5.3	14	1.8	8.3	5.3	11	1.5	8.6	-51%	2.2	-51%	2.3	-59%	2.5	-58%	2.6
		90	y	15.7	43.1	5.4	4.6	14.6	26.4	3.8	5.9	4.9	15.5	1.9	8.2	4.9	12.4	1.6	8.5	-50%	2.3			-58%	2.6		
		180	n	16	47.1	5.8	4.3	14.7	28	4.0	5.8	4.6	16.5	2.0	8.2	4.6	13.1	1.6	8.4	-51%	2.4			-59%	2.6		
	CZ 5	270	y	18.7	42.7	5.7	4.4	17.1	25.7	4.0	5.8	6.4	15	2.0	8.1	6.5	12.7	1.8	8.3	-50%	2.3			-55%	2.5		
		0	y	96.2	17	10.5	6.1	103.4	9.1	10.4	6.2	58.3	7.9	6.1	7.6	58.5	7.1	6.1	7.7	-41%	1.4	-42%	1.5	-42%	1.5	-42%	1.5
		90	y	96.2	14.6	10.3	6.2	101.3	8.3	10.1	6.3	56.4	6.4	5.8	7.8	56.5	5.6	5.8	7.8	-43%	1.5			-43%	1.5		
		180	n	99.2	15.2	10.6	6.1	102.1	8.9	10.3	6.2	56.4	7.5	5.9	7.7	56.6	6.5	5.8	7.8	-42%	1.5			-43%	1.6		
	CZ 6	270	n	101.3	16.3	10.9	6	104.9	9.2	10.6	6.1	60.3	8.1	6.3	7.6	60.4	7	6.2	7.6	-40%	1.5			-41%	1.5		

Notes:

[1] At least one orientation of each archetype in a given climate zone had to be DtS compliant (either Glazing Calculator for Detached or Attached, or equivalent 6 Star for Apartment). This column shows which orientations did/did not comply.

* Baseline I glazing: same glazing used for all orientations for a given archetype/climate zone; Detached and Attached glazing was chosen to meet DtS glazing calculator requirements for at least one orientation; Apartment glazing required to achieve equivalent 6 Star for at least one orientation.

** Glazing/WWR chosen for both 6-Star and 10% of floor area minimum daylighting compliance. All other building elements as for the Baseline I. Not necessarily DtS compliant for glazing. The glazing type is the same for all windows of the house for a given climate zone/archetype.

*** Economic Stringencies applied to Basline II. Economic stringencies for apartment archetype included infiltration for Climate Zone 6 only (no other stringencies were economic). PV not included in energy results.

****Ambitious Stringencies applied to Baseline II.

Table 120. Multi-Dimensional Scenario Peak Heating & Cooling Power using Baseline II

Archetype	Climate Zone	Orientation	Baseline I**		Baseline II (WWR_{min})***		Economic Stringency Case****		Ambitious Stringency Case*****	
			Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*
Apartment	CZ 2	0	0.98	1.93	0.80	1.12			0.42	1.45
		90	0.77	1.72	0.62	1.38			0.30	1.18
		180	0.62	1.77	0.69	1.26			0.29	1.30
		270	0.92	1.91	0.80	1.40			0.46	1.70
	CZ 5	0	1.02	1.86	0.86	1.84			0.46	1.07
		90	1.02	1.34	0.86	1.73			0.46	1.58
		180	1.03	1.52	0.87	1.63			0.50	1.32
		270	1.05	1.70	0.90	1.53			0.55	1.18
	CZ 6	0	1.41	1.66	1.23	1.77	0.80	1.07	0.75	1.67
		90	1.38	1.69	1.23	1.60	0.74	1.64	0.74	1.66
		180	1.42	1.43	1.26	1.77	0.79	1.68	0.79	1.00
		270	1.43	1.82	1.27	1.63	0.82	1.59	0.82	1.52
Attached	CZ 2	0	1.12	2.27	0.98	2.19	0.98	2.35	0.62	2.13

Archetype	Climate Zone	Orientation	Baseline I**		Baseline II (WWR_{min})***		Economic Stringency Case****		Ambitious Stringency Case*****	
			Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*
		90	1.07	3.64	0.90	2.82	0.91	2.75	0.59	2.33
		180	0.78	2.48	0.78	1.96	0.78	1.87	0.32	1.75
		270	0.84	2.60	0.69	2.29	0.69	2.75	0.39	2.58
	CZ 5	0	1.25	2.45	1.00	2.33	1.00	1.92	0.58	1.74
		90	1.30	3.58	1.05	2.59	1.04	2.36	0.61	2.48
		180	1.23	2.05	0.97	1.81	0.97	2.00	0.52	1.45
		270	1.31	3.08	1.06	2.53	1.06	2.22	0.62	2.13
	CZ 6	0	1.61	2.22	1.76	1.90	1.24	1.33		
		90	1.67	2.66	1.81	2.02	1.31	1.64		
		180	1.57	1.79	1.75	1.69	1.22	1.38		
		270	1.66	2.37	1.82	1.81	1.31	1.62		
Detached	CZ 2	0	1.54	2.89	1.69	2.82	0.94	2.22	0.94	1.91
		90	1.50	2.30	1.53	2.59	0.81	2.37	0.81	1.69

Archetype	Climate Zone	Orientation	Baseline I**		Baseline II (WWR_{min})***		Economic Stringency Case****		Ambitious Stringency Case*****	
			Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*
		180	1.51	2.79	1.44	2.35	0.74	2.21	0.74	1.64
		270	1.65	2.84	1.59	2.49	0.89	2.32	0.89	1.80
	CZ 5	0	2.27	4.40	1.96	3.51	1.18	2.56	1.18	2.17
		90	2.28	3.98	1.95	3.16	1.16	2.63	1.16	2.12
		180	2.28	4.31	1.93	3.55	1.13	2.39	1.14	2.82
		270	2.29	4.32	1.96	3.20	1.18	2.17	1.18	2.68
	CZ 6	0	2.96	2.94	2.89	2.46	2.07	1.73	2.07	1.65
		90	2.96	2.77	2.87	2.24	2.04	1.71	2.04	1.55
		180	2.96	2.51	2.85	2.09	2.01	1.78	2.01	1.77
		270	2.97	2.71	2.88	2.31	2.06	1.62	2.06	1.63

Notes:

* All values are in kW where the conversion assumes a heating/cooling system COP of 3 (nominal).

** Baseline I glazing met DtS requirements for the attached and detached houses and equivalent 6 Star performance requirement for the apartment.

*** Glazing/WWR chosen for both equivalent 6-Star and 10% of floor area minimum daylighting compliance. All other building elements as for the Baseline I. Not necessarily DtS compliant for glazing. The glazing type is the same for all windows of the house for a given climate zone/archetype.

**** Economic Stringencies applied to Baseline II. Economic stringencies for apartment archetype included infiltration for Climate Zone 6 only (no other stringencies were economic). PV not included in energy results.

*****Ambitious Stringencies applied to Baseline II.

Table 121. Multi-Dimensional Scenario Heating & Cooling Energy using Baseline III.

Archetype	Climate Zone	Orientation	Baseline I (1-D) (15ACH at 50Pa)*					Baseline III (Increased WWR) (15ACH at 50Pa) **				Economic Stringency Case***				Ambitious Stringency Case****				Economic - change relative to Baseline III				Ambitious - change relative to Baseline III			
			DtS Glazing[1]	Heating Energy (MJ/m²/y)	Cooling Energy (MJ/m²/y)	Electrical Energy (kWh/m²/y)	Equiv. Star rating	Heating Energy (MJ/m²/y)	Cooling Energy (MJ/m²/y)	Electrical Energy (kWh/m²/y)	Equiv. Star rating	Heating Energy (MJ/m²/y)	Cooling Energy (MJ/m²/y)	Electrical Energy (kWh/m²/y)	Equiv. Star rating	Heating Energy (MJ/m²/y)	Cooling Energy (MJ/m²/y)	Electrical Energy (kWh/m²/y)	Equiv. Star rating	Electrical Energy	Equiv Star improv	Avg energy improv	Avg Star improv	Electrical Energy	Equiv Star improv	Avg energy improv	Avg Equiv Star improv
Apartment	CZ 2	0	n	17	43	5.6	4.9	18.1	35.2	4.9	5.4					8.6	32.7	3.8	6.4					-23%	1.0	-17%	0.8
		90	y	10.8	32.2	4.0	6.3	10.7	29.9	3.8	6.6					4.5	30	3.2	7.3					-15%	0.7		
		180	y	6.9	34.4	3.8	6.4	7.2	30.1	3.5	6.9					2.5	31.5	3.1	7.3					-9%	0.4		
		270	n	15.6	33.5	4.5	5.8	16.4	32.6	4.5	5.8					7.3	31.4	3.6	6.8					-21%	1.0		
	CZ 5	0	n	27.3	25	4.8	5.1	27.4	21.6	4.5	5.4					13.4	20	3.1	6.9					-32%	1.5	-26%	1.2
		90	y	15.9	22.3	3.5	6.4	16.4	20.9	3.5	6.5					6.8	22.4	2.7	7.3					-22%	0.8		
		180	y	12.4	25.7	3.5	6.4	12.6	22.6	3.3	6.7					4.3	22.9	2.5	7.6					-23%	0.9		
		270	n	25.1	24.6	4.6	5.3	25.6	23.3	4.5	5.4					11.6	23	3.2	6.8					-29%	1.4		
	CZ 6	0	n	116.5	22.1	12.8	5.6	104.7	29	12.4	5.7	68.1	31.1	9.2	6.7	57.9	30.5	8.2	7	-26%	1.0	-33%	1.2	-34%	1.3	-36%	1.3
		90	y	94.2	21.4	10.7	6.2	83.3	30.6	10.5	6.3	42	31.7	6.8	7.4	42	30.1	6.7	7.5	-35%	1.1			-37%	1.2		

		180	y	93.8	24.4	10.9	6.1	82.9	28.8	10.3	6.3	41.5	29.9	6.6	7.6	41.5	27.9	6.4	7.6	-36%	1.3			-38%	1.3		
		270	n	118.9	23.9	13.2	5.4	104.8	29.7	12.5	5.7	59.3	29.7	8.2	7	59.3	27.3	8.0	7.1	-34%	1.3			-36%	1.4		
Attached	CZ 2	0	n	13.7	38.1	4.8	5.7	12.4	42.7	5.1	5.4	12.4	21.7	3.2	7.4	6.2	18.1	2.3	8.4	-38%	2.0	-37%	1.8	-56%	3.0	-50%	2.6
		90	n	8.4	60.5	6.4	4.6	7.2	73.7	7.5	3.9	7.2	49	5.2	5.4	2.8	43.2	4.3	6.3	-31%	1.5			-43%	2.4		
		180	y	3.2	34.7	3.5	7.1	3.3	40.3	4.0	6.4	3.3	20.6	2.2	8.4	0.9	17.7	1.7	9.1	-45%	2.0			-57%	2.7		
		270	n	6.2	63.7	6.5	4.5	5.6	80.1	7.9	3.8	5.6	50.9	5.2	5.4	1.9	45.8	4.4	6.1	-34%	1.6			-44%	2.3		
	CZ 5	0	n	23.4	20	4.0	6.1	21.2	23.6	4.1	5.9	21.2	12.9	3.2	6.9	11.3	11.1	2.1	8.2	-24%	1.0	-29%	1.2	-50%	2.3	-48%	2.1
		90	n	15.7	34.8	4.7	5.4	13.6	45.3	5.5	4.9	13.6	28.7	3.9	6.2	5.9	25.9	2.9	7.2	-28%	1.3			-46%	2.3		
		180	y	6.8	20.3	2.5	7.8	6.6	23.3	2.8	7.4	6.6	12.8	1.8	8.4	2.2	11.3	1.3	9.1	-35%	1.0			-55%	1.7		
		270	n	12.8	35.4	4.5	5.6	10.9	47.7	5.4	4.9	10.9	31.6	3.9	6.2	4.1	29.7	3.1	7	-27%	1.3			-42%	2.1		
	CZ 6	0	n	99.4	8	9.9	6.6	130.1	15.9	13.5	5.6	89.7	15	9.7	6.7					-28%	1.1	-29%	1.1				
		90	n	94.6	15.9	10.2	6.5	124.6	30.5	14.4	5.4	85.3	28.7	10.6	6.4					-26%	1.0						
		180	y	74.7	7.6	7.6	7.4	103.4	15.3	11.0	6.3	64.4	14.4	7.3	7.4					-34%	1.1						
		270	n	93.9	15.8	10.2	6.6	124.3	30	14.3	5.4	84.7	28	10.4	6.4					-27%	1.0						
Detached	CZ 2	0	y	8.4	32.8	3.8	6.3	9.7	34.2	4.1	6.0	3.3	20.7	2.2	8.2	3.3	15.6	1.8	8.8	-45%	2.2		2.5	-57%	2.8		3.1

		90	y	8.4	37.1	4.2	5.9	9.5	40.0	4.6	5.4	3.7	23.0	2.5	7.9	2.1	18.8	1.9	8.6	-46%	2.5	-47%		-58%	3.2	-58%	
		180	y	8.8	40.4	4.6	5.5	8.8	43.7	4.9	5.3	3.1	24.6	2.6	7.8	2.9	18.9	2.0	8.4	-47%	2.5			-58%	3.1		
		270	y	9.8	39.2	4.5	5.5	11.1	40.7	4.8	5.3	4.3	22.6	2.5	7.9	3.5	18.0	2.0	8.5	-48%	2.6			-58%	3.2		
	CZ 5	0	y	15.2	41.3	5.2	4.7	17.7	23.4	3.8	5.9	7.6	13.9	2.0	8.1	7.6	10	1.6	8.4	-48%	2.2	-47%	2.3	-57%	2.5	-56%	2.7
		90	y	15.7	43.1	5.4	4.6	17	26	4.0	5.7	7.5	15.5	2.1	7.9	6	13.2	1.8	8.3	-47%	2.2			-55%	2.6		
		180	n	16	47.1	5.8	4.3	16.4	26.9	4.0	5.7	6.9	15.5	2.1	8	6.9	11.9	1.7	8.4	-48%	2.3			-57%	2.7		
		270	y	18.7	42.7	5.7	4.4	19.8	25.8	4.2	5.4	8.9	15.9	2.3	7.7	7.1	13.3	1.9	8.2	-46%	2.3			-55%	2.8		
	CZ 6	0	y	96.2	17	10.5	6.1	99.6	17.2	10.8	6	58	15.2	6.8	7.4	58.1	13.4	6.6	7.4	-37%	1.4	-38%	1.4	-39%	1.4	-39%	1.5
		90	y	96.2	14.6	10.3	6.2	97.7	16.1	10.5	6.1	56.1	13.8	6.5	7.5	55.6	12.2	6.3	7.6	-39%	1.4			-40%	1.5		
		180	n	99.2	15.2	10.6	6.1	97.4	16.7	10.6	6.1	55.8	14.7	6.5	7.4	56.2	12.2	6.3	7.6	-38%	1.3			-40%	1.5		
		270	n	101.3	16.3	10.9	6	102.3	16.8	11.0	5.9	60.4	15	7.0	7.3	61.3	11.7	6.8	7.4	-37%	1.4			-39%	1.5		

Notes:

[1] At least one orientation of each archetype in a given climate zone had to be DtS compliant (either Glazing Calculator for Detached or Attached, or 6* for Apartment). This column shows which orientations did/did not comply.

* Baseline I glazing: same glazing used for all orientations for a given archetype/climate zone; Detached and Attached glazing was chosen to meet DtS glazing calculator requirements for at least one orientation; Apartment glazing required to achieve equivalent 6 Star for at least one orientation.

** Glazing chosen to be more representative of current practice (e.g. Baseline II +20%). Glazing/WWR chosen for both 6-Star and 10% of floor area minimum daylighting compliance. All other building elements as for the Baseline I. The glazing type is the same for all windows of the house for a given climate zone/archetype.

*** Economic Stringencies applied to Baseline III. Economic stringencies for apartment archetype included infiltration for Climate Zone 6 only (no other stringencies were economic). PV not included in energy results.

****Ambitious Stringencies applied to Baseline III.

Table 122. Multi-Dimensional Scenario Peak Heating & Cooling Power using Baseline III.

Archetype	Climate Zone	Orientation	Baseline I (1-D)**		Baseline III (Increased WWR)***		Economic Stringency Case****		Ambitious Stringency Case*****	
			Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*	Peak Heating Power (kW)*	Peak Cooling Power (kW)*
Apartment	CZ 2	0	0.98	1.93	0.90	1.85			0.57	1.62
		90	0.77	1.72	0.67	1.93			0.39	1.71
		180	0.62	1.77	0.66	1.75			0.41	1.59
		270	0.92	1.91	0.90	1.84			0.58	1.77
	CZ 5	0	1.02	1.86	0.97	1.83			0.64	1.58
		90	1.02	1.34	0.97	1.78			0.63	1.48
		180	1.03	1.52	0.99	1.86			0.67	1.58
		270	1.05	1.70	1.01	1.44			0.72	1.41
	CZ 6	0	1.41	1.66	1.34	1.93	0.98	1.75	0.93	1.79
		90	1.38	1.69	1.33	2.10	0.88	1.72	0.88	1.67
		180	1.42	1.43	1.36	1.56	0.94	1.47	0.94	1.53
		270	1.43	1.82	1.41	2.12	1.02	1.91	1.02	1.83
Attached	CZ 2	0	1.12	2.27	1.14	2.41	1.14	2.28	0.84	2.62

		90	1.07	3.64	1.05	4.23	1.05	4.31	0.77	4.19
		180	0.78	2.48	0.85	2.52	0.85	2.37	0.61	2.32
		270	0.84	2.60	0.90	3.21	0.90	3.36	0.67	3.09
	CZ 5	0	1.25	2.45	1.34	2.73	1.34	2.74	0.97	2.29
		90	1.30	3.58	1.38	4.33	1.38	4.13	0.98	3.66
		180	1.23	2.05	1.30	2.52	1.30	2.28	0.86	2.35
		270	1.31	3.08	1.40	3.66	1.40	3.23	0.99	3.17
	CZ 6	0	1.61	2.22	2.18	2.50	1.71	2.22		
		90	1.67	2.66	2.27	4.03	1.81	3.74		
		180	1.57	1.79	2.17	2.30	1.66	2.37		
		270	1.66	2.37	2.28	3.53	1.81	2.77		
Detached	CZ 2	0	1.54	2.89	1.62	3.16	0.91	2.30	0.91	2.11
		90	1.50	2.30	1.61	3.39	0.91	2.46	0.91	2.25
		180	1.51	2.79	1.49	2.99	0.88	2.13	0.89	1.97
		270	1.65	2.84	1.61	2.75	0.92	2.86	0.92	1.94

	CZ 5	0	2.27	4.40	1.93	3.66	1.24	2.44	1.25	2.08
		90	2.28	3.98	1.92	3.75	1.22	2.55	1.22	2.33
		180	2.28	4.31	1.90	3.54	1.20	2.40	1.20	2.22
		270	2.29	4.32	1.94	3.36	1.24	2.50	1.24	2.50
	CZ 6	0	2.96	2.94	3.03	2.81	2.27	2.50	2.27	2.59
		90	2.96	2.77	3.01	3.00	2.24	2.82	2.24	2.80
		180	2.96	2.51	2.99	2.83	2.20	2.76	2.20	1.96
		270	2.97	2.71	3.02	2.68	2.26	2.14	2.26	2.25

Notes:

* All values are in kW where the conversion assumes a heating/cooling system COP of 3 (nominal).

** Baseline I glazing met DtS requirements for the attached and detached houses and equivalent 6 Star performance requirement for the apartment.

*** Glazing/WWR chosen for both equivalent 6-Star and 10% of floor area minimum daylighting compliance. All other building elements as for the Baseline I. Not necessarily DtS compliant for glazing. The glazing type is the same for all windows of the house for a given climate zone/archetype.

**** Economic Stringencies applied to Baseline III. Economic stringencies for apartment archetype included infiltration for Climate Zone 6 only (no other stringencies were economic). PV not included in energy results.

***** Ambitious Stringencies applied to Baseline III.

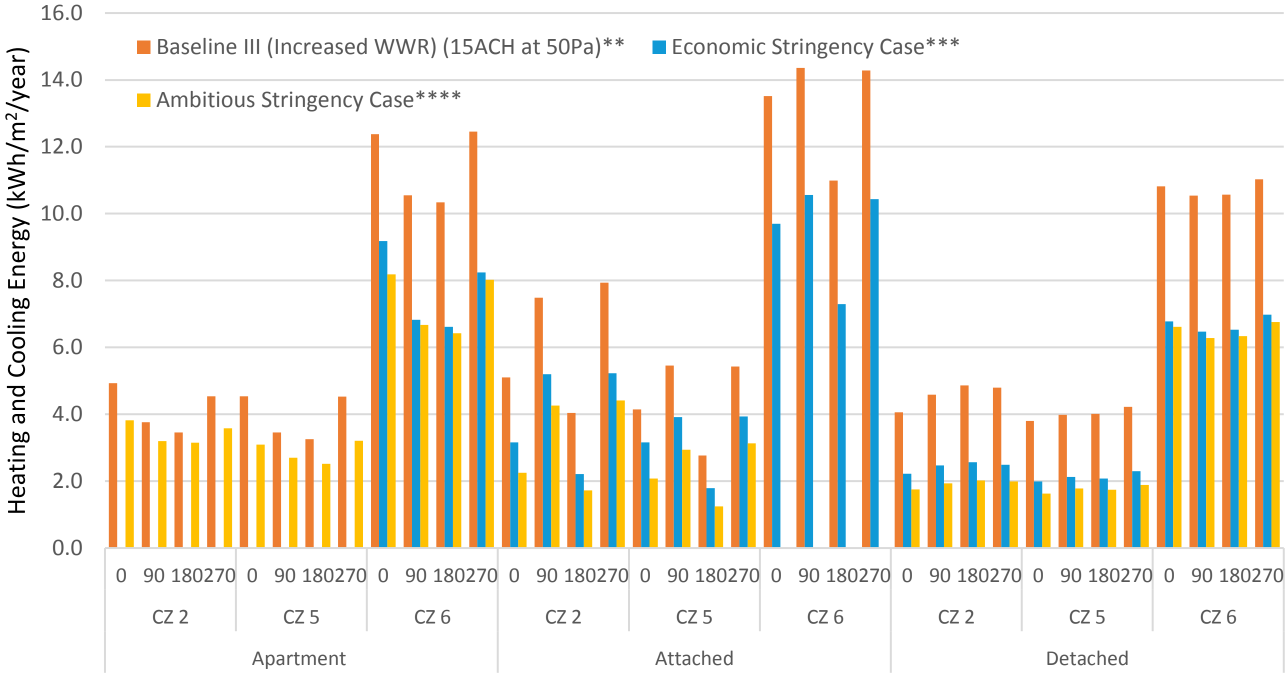


Figure 54. Heating and Cooling Energy (Total) across each archetype for the Baseline III (Increased WWR), Economic Stringency and Ambitious Stringency Cases

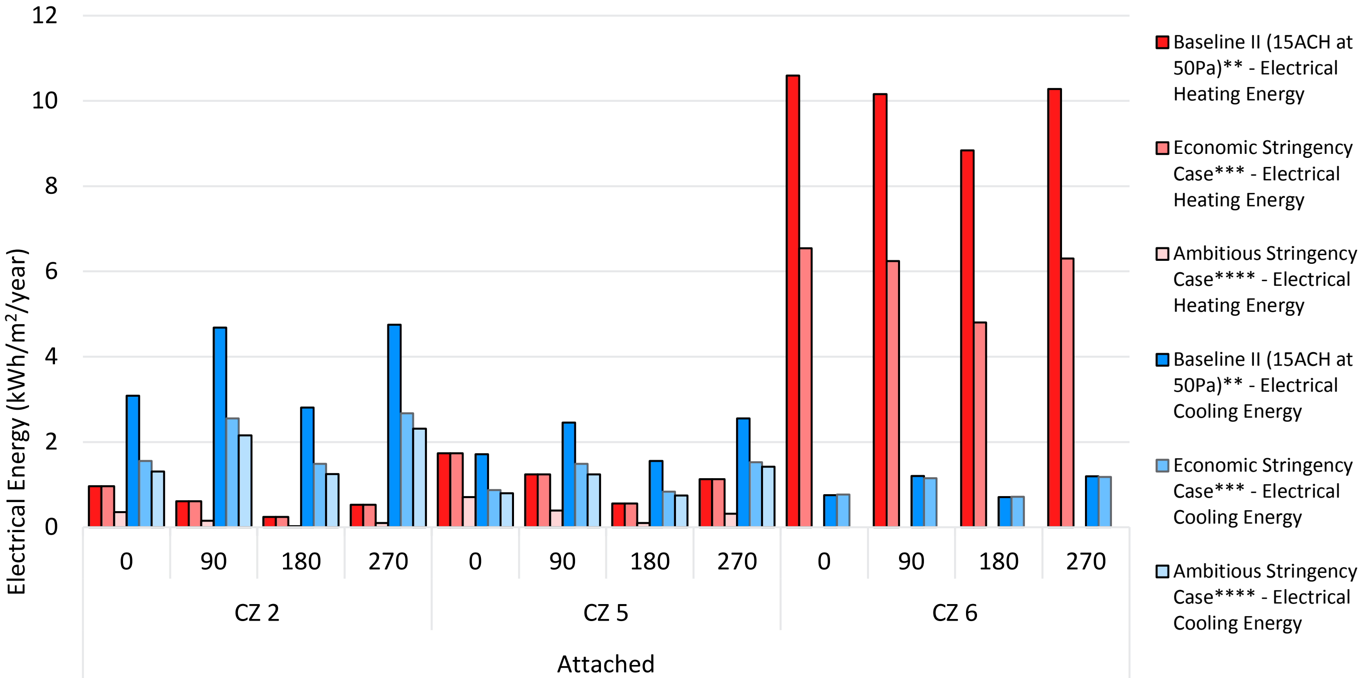


Figure 55. Heating and Cooling Energy (Separated) for Attached archetype for the Baseline II (WWR_{min}), Economic Stringency and Ambitious Stringency Cases

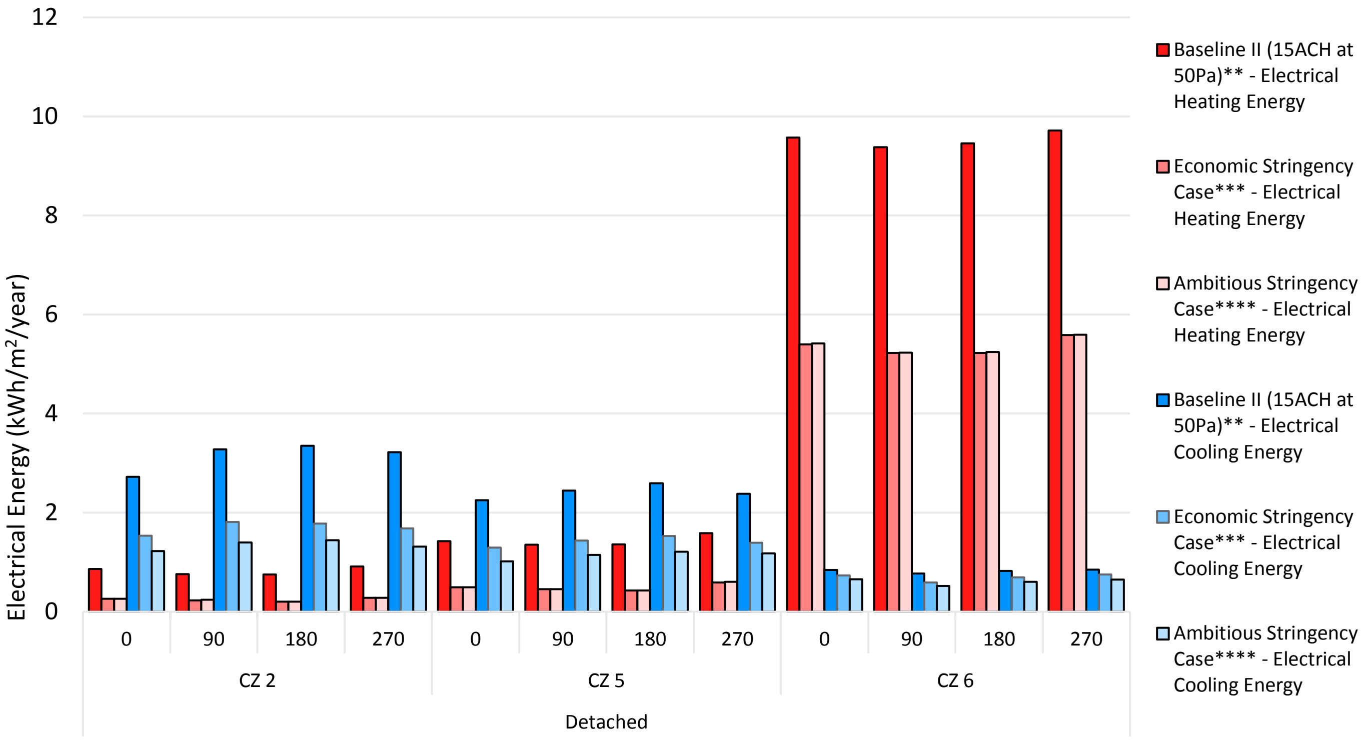


Figure 56. Heating and Cooling Energy (Separated) for Detached archetype for the Baseline II (WWR_{min}), Economic Stringency and Ambitious Stringency Cases

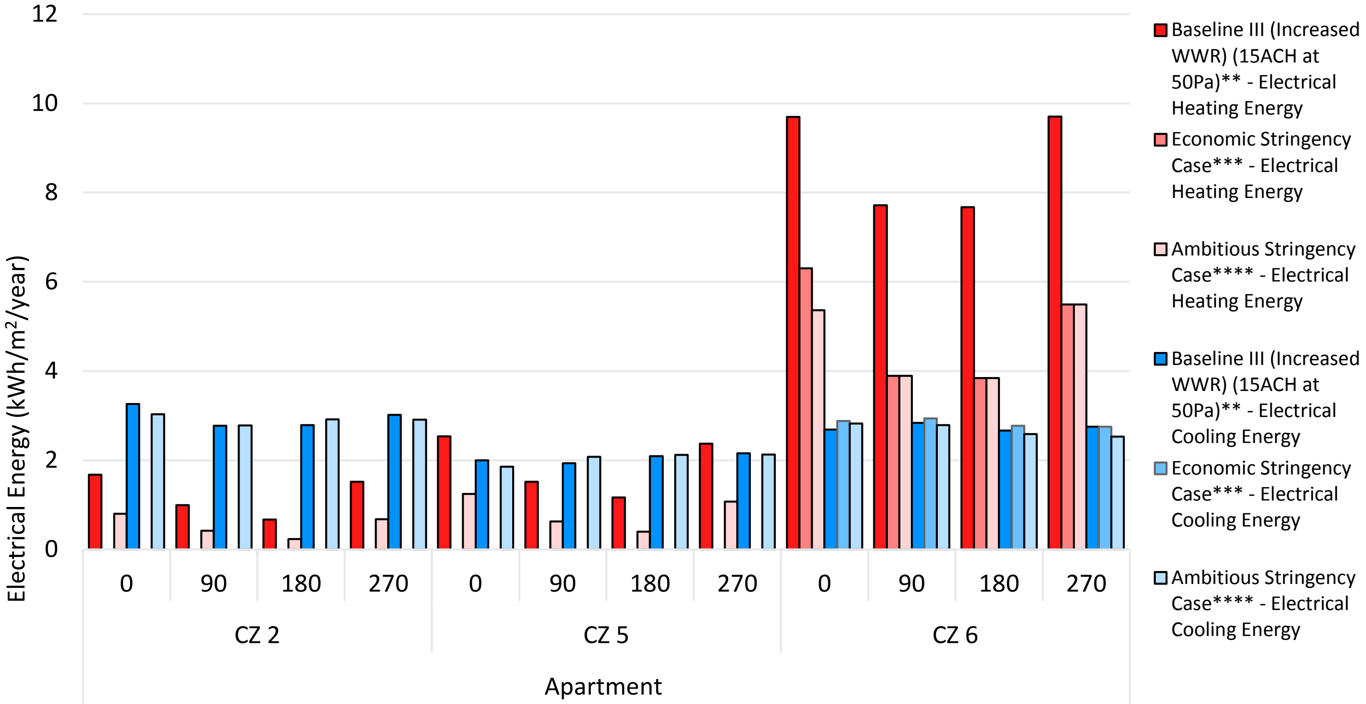


Figure 57. Heating and Cooling Energy (Separated) for Apartment archetype for the Baseline III (Increased WWR), Economic Stringency and Ambitious Stringency Cases

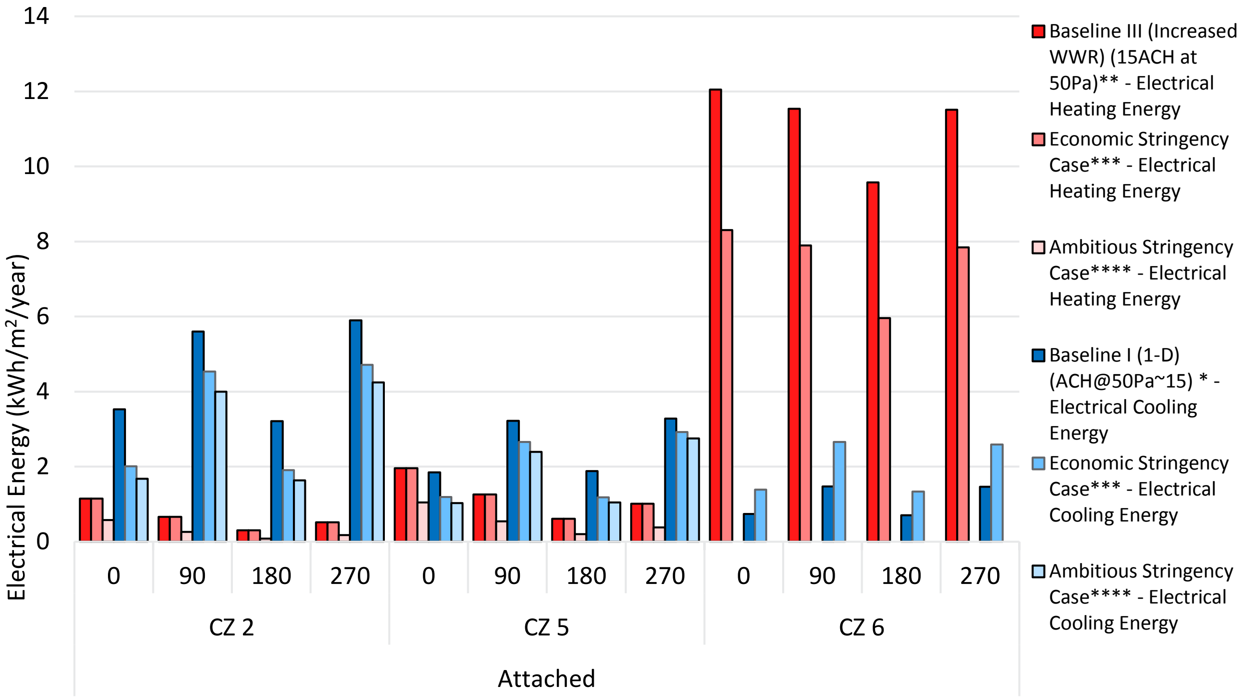


Figure 58. Heating and Cooling Energy (Separated) for Attached archetype for the Baseline III (Increased WWR), Economic Stringency and Ambitious Stringency Cases.

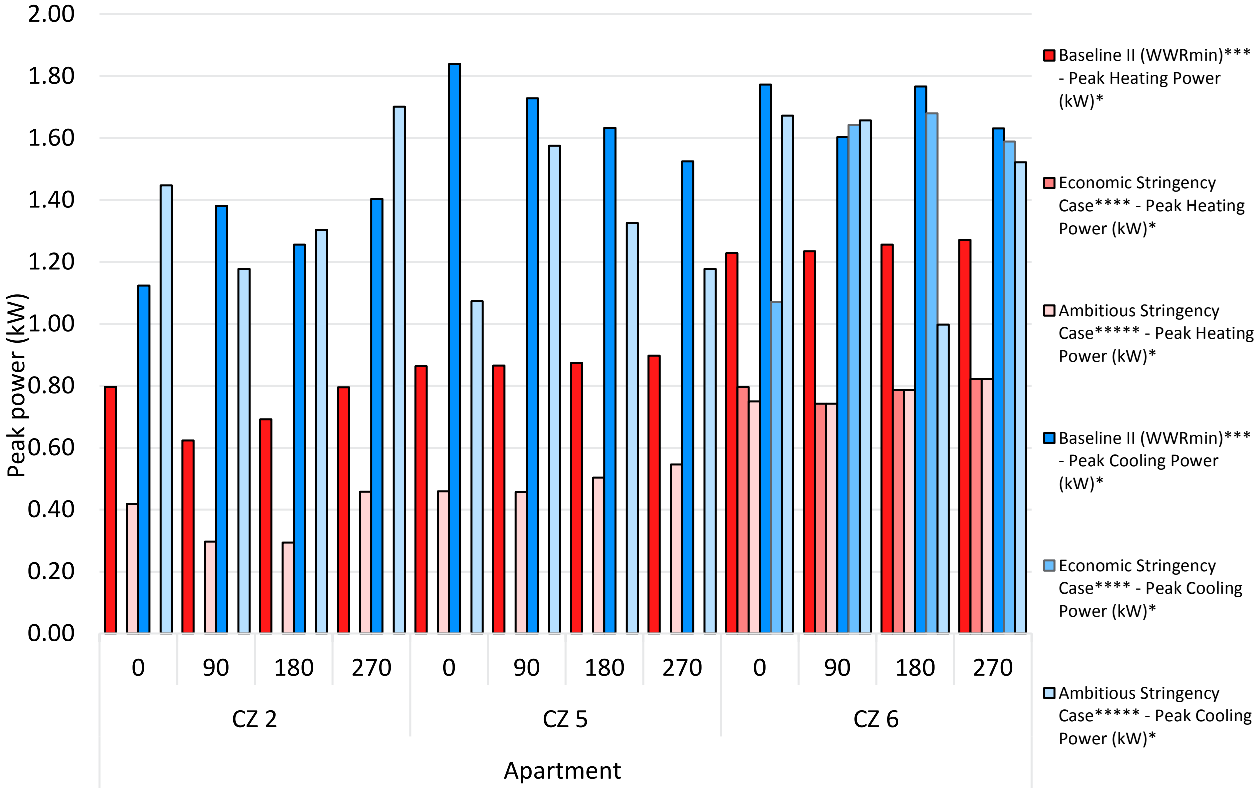


Figure 59. Heating and Cooling Peak Power (Separated) for Apartment archetype for the Baseline II (WWR_{min}), Economic Stringency and Ambitious Stringency Cases

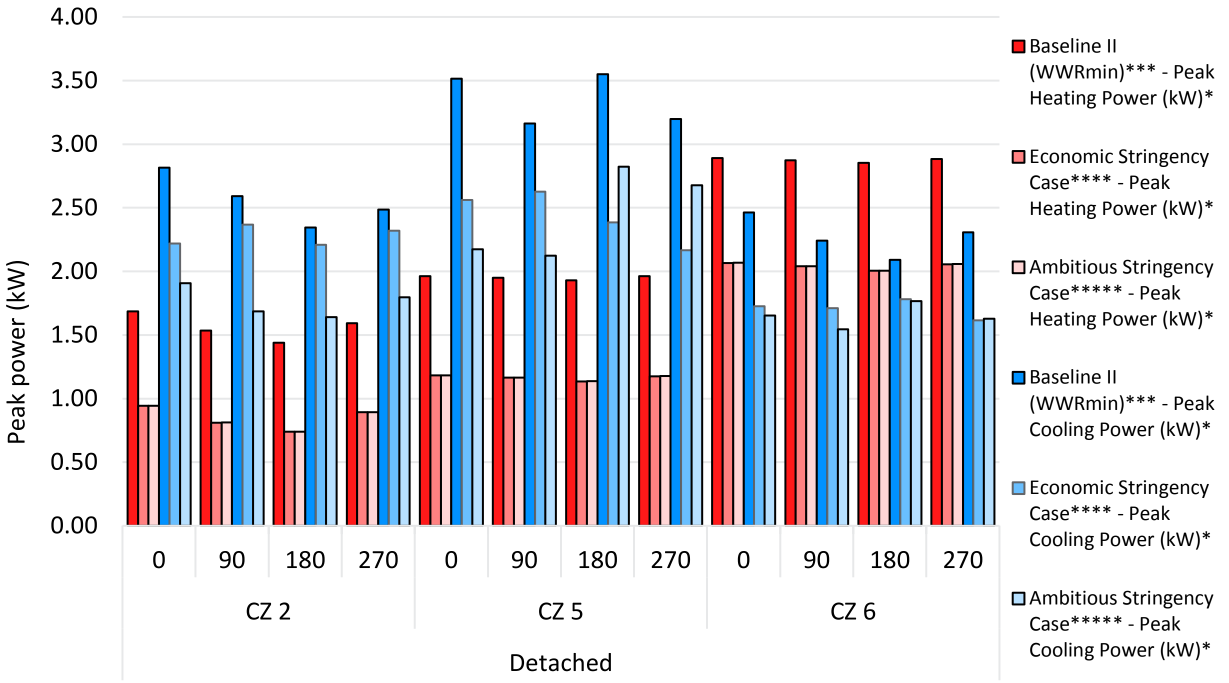


Figure 60. Heating and Cooling Peak Power (Separated) for Detached archetype for the Baseline II (WWR_{min}), Economic Stringency and Ambitious Stringency Cases

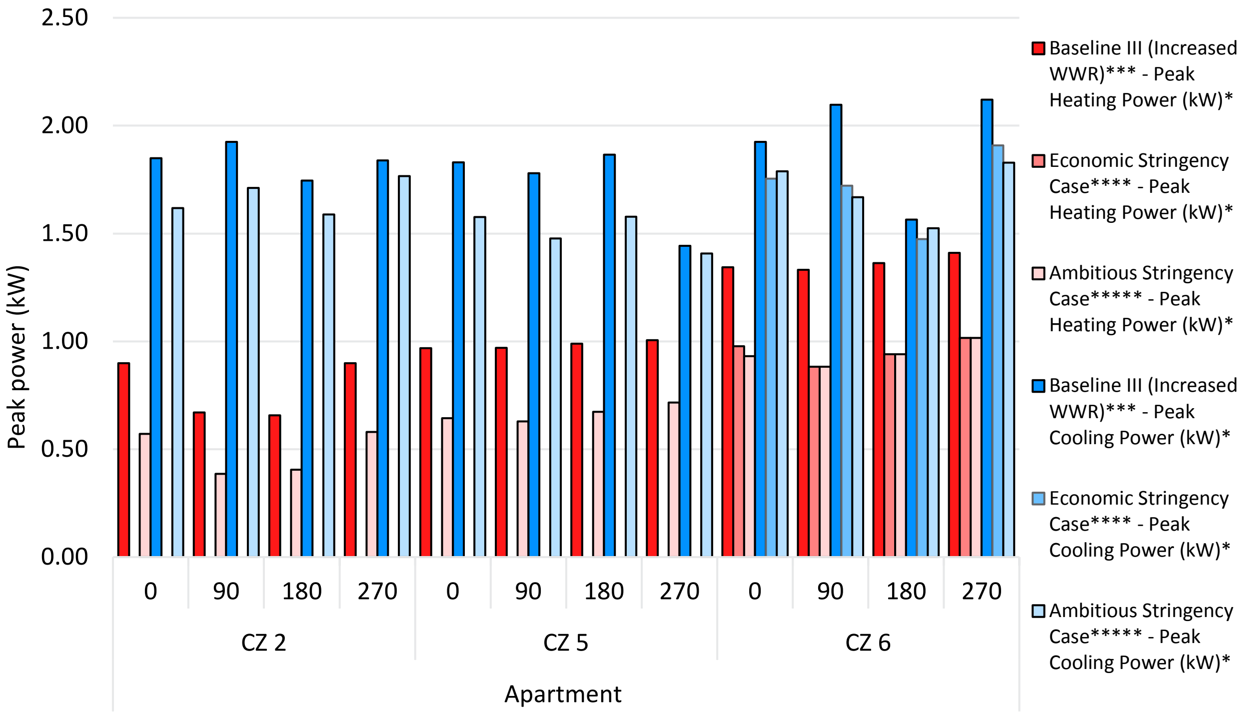


Figure 61. Heating and Cooling Peak Power (Separated) for Apartment archetype for the Baseline III (Increased WWR), Economic Stringency and Ambitious Stringency Cases.

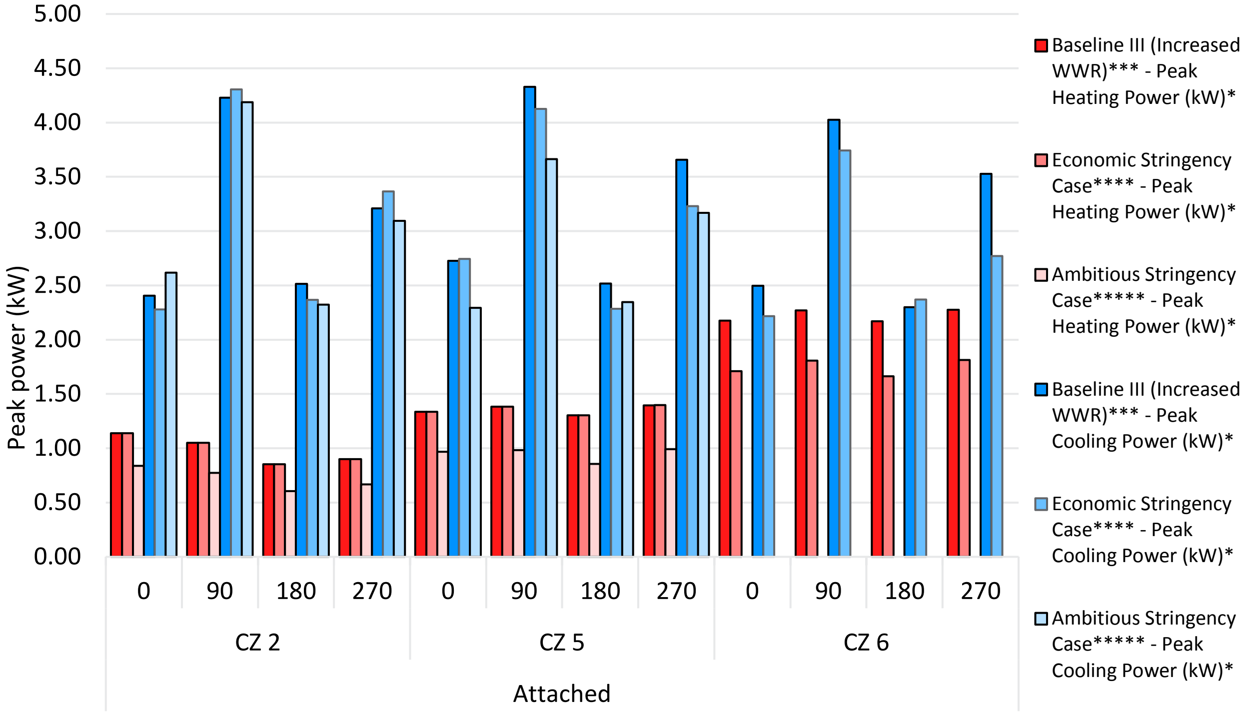


Figure 62. Heating and Cooling Peak Power (Separated) for Attached archetype for the Baseline III (Increased WWR), Economic Stringency and Ambitious Stringency Cases.

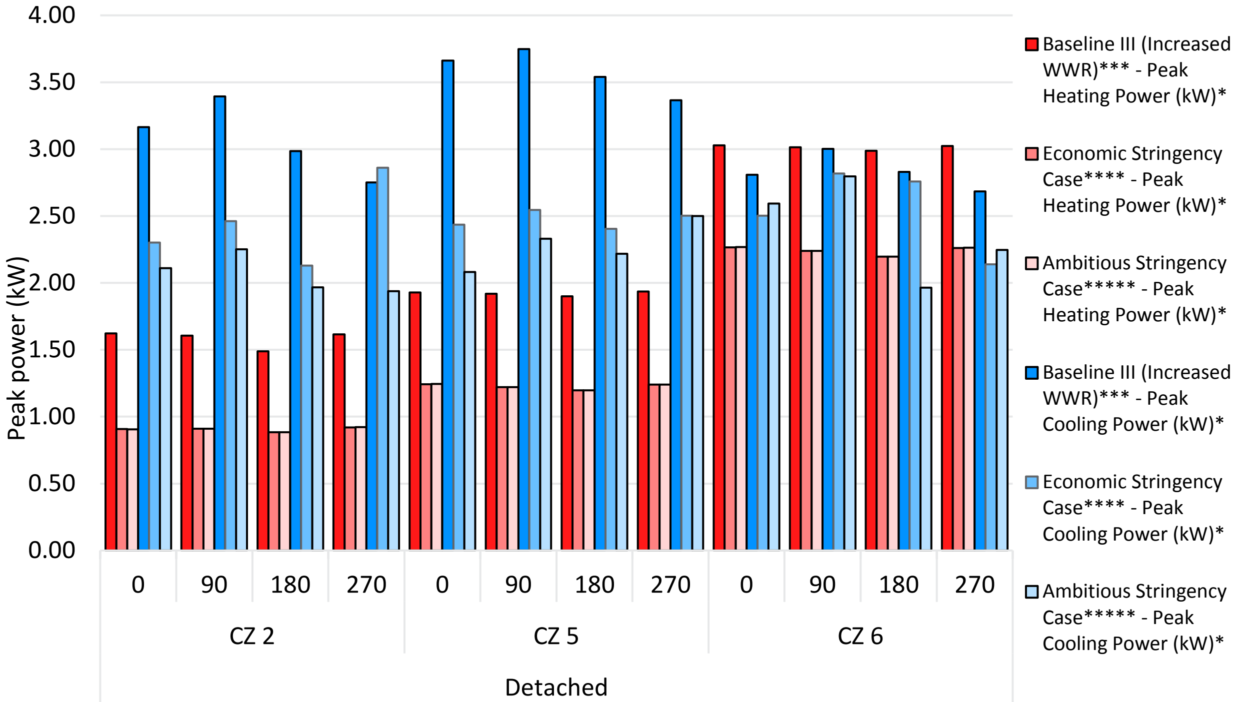


Figure 63. Heating and Cooling Peak Power (Separated) for Detached archetype for the Baseline III (Increased WWR), Economic Stringency and Ambitious Stringency Cases.

I.3 Benefit Cost Analysis Results for Multi-Dimensional Scenarios

The results in this Interim Report are based on assessment of measures that are cost-effective when considered individually. Further work will be done by the Trajectory Project team to analyse the interactions between measures when they are applied together. The team is also undertaking ongoing analysis of glazing opportunities, which have been excluded from the results presented here. These updated results will be presented in the Final Report to be published in mid-2018, with scenarios optimised to get benefit cost ratios closer to 1-1.5. However, this follow-up analysis will not impact on the cost-effectiveness of each individual measure.

7.1.1.11 I.3.1 Economic assumptions

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

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

A discount rate of seven per cent is used.

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

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

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

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

7.1.1.12 I.3.2 Key results

Table 123 summarises the costs and benefits for the combination of measures that were determined to be individually cost-effective for each archetype in each climate zone. The cost premiums for combined measure is calculated as the upfront capital costs of the individual measures, minus savings associated with downsizing heating and cooling equipment and network benefits associated with reduced peak demand.

Table 123. Multi-Dimension Benefit Cost Analysis Summary - Without Glazing.

Attached Archetype, Climate Zone 2

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 3,000		486	2.32				
Economic Stringency	$ 3,656	$ 111	292	2.43	1.27	1.47	1.62	1.77
Ambitious	$ 6,256	-$ 114	211	2.20	0.44	0.51	0.56	0.61

Attached Archetype, Climate Zone 5

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 3,000		356	2.32				
Economic Stringency	-	-	-	-	-	-	-	-
Ambitious	$ 6,010	-$ 355	157	1.95	0.38	0.44	0.48	0.52

Attached Archetype, Climate Zone 6

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 3,000		1,203	1.86				
Economic Stringency	$ 3,570	-$ 354	763	1.49	10.23	11.84	12.66	13.58
Ambitious	-	-	-	-	-	-	-	-

Detached Archetype, Climate Zone 2

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 5,854		693	2.56				
Economic Stringency	$ 8,551	-$ 271	340	2.28	0.73	0.84	0.93	1.01
Ambitious	$ 9,891	-$ 773	278	1.76	0.64	0.74	0.81	0.88

Detached Archetype, Climate Zone 5

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 5,854		672	3.36				
Economic Stringency	$ 8,309	-$ 887	333	2.44	1.09	1.26	1.37	1.48
Ambitious	$ 10,109	-$ 873	286	2.45	0.57	0.66	0.73	0.79

Detached Archetype, Climate Zone 6

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 6,047		1,809	2.28				
Economic Stringency	$ 7,971	-$ 547	1,056	1.71	2.74	3.17	3.47	3.76

Ambitious	$ 9,771	-$ 605	1,045	1.65	1.23	1.42	1.56	1.70

Apartment Archetype, Climate Zone 2

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 3,000		283	1.29				
Economic Stringency	-	-	-	-	-	-	-	-
Ambitious	$ 5,600	$ 112	250	1.41	0.06	0.07	0.08	0.09

Apartment Archetype, Climate Zone 5

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 3,000		286	1.68				
Economic Stringency	-	-	-	-	-	-	-	-
Ambitious	$ 5,370	-$ 379	226	1.29	0.15	0.18	0.19	0.21

Apartment Archetype, Climate Zone 6

Scenario	Capital Cost (not inc network adjustments)	Network adjustments to capital cost	Energy Use (kWh)	Peak Demand (kW)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years
WWRmin	$ 3,000		823	1.69				

Economic Stringency	$ 3,800	-$ 191	535	1.50	2.37	2.74	3.00	3.26
Ambitious	$ 5,600	-$ 223	514	1.46	0.65	0.75	0.83	0.90

Appendix J: Residential Model Development Issues and Responses

Issue/Comment from Technical Advisory Group (TAG)	Response
What is the rationale behind archetypes being used to create the baseline energy consumption? Recommend using NCC 2016 as the energy baseline for relevance.	The baseline energy consumption has been adjusted and is now determined from the archetypes with design modifications applied to ensure compliance with NCC 2016, via deemed-to-satisfy measures.
Fine to use the 10 year old plan for apartment as long as it meets requirements for good design, such as in the new apartment design guidelines in Victoria. If not, it should be updated.	Apartment archetype has been adjusted slightly to accommodate changes suggested during TAG. Major change was to reduce size.
I think [NatHERS Protocol] or [International Protocol] would be most suitable. [NatHERS Protocol] is what sets current minimum requirements, whereas [International Protocol] has the advantage of being an international protocol, so would help give validation. A [custom protocol] is to open to criticism.	NatHERS protocol is the default protocol in the software being utilised. As it has been a common benchmark for a number of years, as per discussion during the TAG meeting, it will be adopted for the default occupancy schedule during modelling.
Given surface area to volume ratio is the primary metric used to select building archetypes to 'bracket' the housing stock, it is important for reporting of the modelling to specify the surface area to volume ratio for each model	Effective surface area to volume ratio information was included in previously provided Technical Advisory Group reports. This has been added to archetype details section of Interim Report.
The size of eaves for all building types should be reviewed against current design practices	Current eaves considerations align with construction drawings provided by TAG as representative of typical designs. It was noted that size of eave will vary between developments and climates.
Concern that the apartment area is on the large side, i.e. higher surface area to volume ratio than typical apartments	Apartment size has been reduced to align with statistics based on perceived apartment sizes in NSW and Victoria (data from other states not readily available).
There are some concerns about the way NatHERS models heat transfer through large windows which may be particularly relevant for the apartment archetype modelling	Feedback is that NatHERS software (e.g. AccuRate) has trouble with scaling up windows and accounting for higher-performance glazing for large window sizes. This has been referred to the CSRIO. Preliminary checks on this issue indicated that the order of magnitude of error is not critical to this analysis, and thus the impact of this issue is second order and not fundamental to the project outcomes..

Issue/Comment from Technical Advisory Group (TAG)	Response
Infiltration – When you do the cost:benefit analysis, don't assume that extra materials (internal air barrier wraps etc.) and labour are required to achieve 5.8 ACH@50Pa. We achieve levels of air tightness between 3 and 8 ACH@50Pa using standard construction and simply getting the builders to pay attention to detail on all gyprock junctions and penetrations.	On infiltration, we are assuming an essentially nil cost for this, for the reasons outlined. We have allowed for the incremental cost of the pressurisation testing only.
When undertaking the cost benefit analysis, can there be some indication that the WA energy price projections have been taken into account? WA operates its own electricity grid, and the cost of electricity is determined on state-based needs.	The analysis we are undertaking at the moment (for the Interim Report) is based on national averages. Energy price projections will be factored in by CSIRO for the next phase of modelling where we develop up the forward trajectories. This will be included in the Final Report.
The building archetypes seem generally reflective of WA building practices. However, in the detached house, the overwhelming construction is double brick in WA. This would have a big impact on the outcomes in terms of thermal mass. If there can be something done to see if double brick makes any material difference, that would be great.	As our analysis is done using estimates at the national level, we have limited plans to model specific variations by state/territory. We do recognise the double brick construction in WA and are considering the impacts of increased thermal mass.
The high performance double glazing should not be composite framed with low SHGC. This doesn't make any sense in Climate zone 7 and wouldn't in 6 either. We need to be maximising SHGC in these heating dominated climates over winter (and shading windows externally over summer). We use high transmission lowE coatings to maintain an SHGC of above 0.4.	The team has added an additional window option with U-value of 2.9W/m^{2}K and SHGC of 0.51.
The reporting should make clear whether energy and load figures are thermal or electrical results. Note that a COP of 3 is assumed for all heating and cooling equipment in the base case	Noted in the Interim Technical Report
Eaves should only be investigated in a single direction, not across all for facades	Eaves analysis has been updated to look at extending eaves only in a single orientation

Issue/Comment from Technical Advisory Group (TAG)	Response
It was suggested to reduce PV system sizing to a level that is likely to be seen in practice, working with limitations of building orientation, government subsidies and grid connection limits	PV system size has been adjusted as suggested
Potential glitches in the AccuRate software for slab edge insulation	There was a known issue with software for modelling slab edge insulation. This was previously reported as being specific to colder climate zones and therefor was unlikely to impact the presented energy results in a significant way for preliminary analysis (which only included CZ2, CZ5 and CZ6). Energy analysis results related to slab insulation have been omitted from this report. The software issue has subsequently been corrected in latest version of software, which will be used for the Final Report.
Peak load for building may not happen at the same time as peak load for the grid	We are taking peak demand as occurring at the time of thermal peak demand for the HVAC system under an assumption that this this will either be at the grid daytime peak or at the 8pm residential peak because an evening occupant has only just turned the system on. Lighting is assessed as being at residential peak, 8pm
Peak load may be higher if we use different occupancy profiles from NatHERS Protocol, e.g. when people return home to a hot, unconditioned house after work	Short-term stringency analysis uses NatHERS Protocol. We will consider adjusting for forward trajectory to test sensitivity
Should include labour costs for HVAC where there is a step change in system type, e.g. when stepping down from ducted to split system	To be investigated for Stage 2 of the project.
Ceiling fans: the network savings that adjust the capital cost in Climate Zone 5 are significantly higher than other dwelling types and other climate zones, making the outcome cost negative. Please double-check the results.	The simulation results have been checked and appear correct – the improvement is much higher for detached in CZ5 than for other scenarios.
Are we going to look at the combination of air-tightness and HRV? Heat recovery ventilation is a completely immature market in Australia, so we'd have to apply some learning rates to current pricing, to reflect economies of scale, if we did.	HRV is currently not able to be modelled in the existing software, however a module is currently under development. HRV was identified as a technology to potentially be investigated in next phase of project.

Issue/Comment from Technical Advisory Group (TAG)	Response
How are we dealing with the large variation in starting point star ratings by state?	A common 6 Star baseline is being used at this stage, which does not factor in state variations.
We are showing a big cost jump to go to the next increment of R3.5 – is that real?	The majority of the first R3.5 is achieved using glass fibre batts in the stud wall, the additional insulation is from extruded polystyrene boards, which have a much higher cost.
For DHW, the least cost option for people with access to gas is usually instantaneous gas, or electric storage where gas is not available. I'm not aware that any form of heat pump is needed to comply with NCC2016. If instantaneous gas or electric storage were the base cases, moving to any heat pump or solar would then be cost effective and also save a lot of energy.	The modelling assumes zero gas. The Code already severely limits the situations in which gas can be used, to the point that it can't really be considered to be a viable DTS solution. As a result we have gone the next step up (HP, also broadly equivalent to gas plus solar) as the baseline.
Floors are modelled with 200 mm concrete. Residential slab on ground is usually 100 mm. Suspended slabs in apartments are typically 150 mm thick. Note that ratings do not take into account the additional concrete thickness provided beams. This adds additional thermal mass to the dwellings which will overstate their performance.	The impact of decreasing the concrete floor thickness increased the total energy consumption moderately, by approximately 2.5%. This impact is attributed to the decrease of the thermal mass, which increased the heating load and generally decreased the cooling load across all climates. Apartment slab remains as 200mm as this aligns with example drawings as previously provided by TAG. Attached suspended slab is already 150mm. Ground floor slab to be adjusted to be 100mm (previously 200mm). Detached ground slab to be adjusted to 100mm (previously 200mm).
The floor covering applied to carpeted floors uses only an underlay. Underlay plus carpet should be used. The additional thermal resistance of the carpet further decouples the thermal mass in the slab from the air in the rooms and significantly reduces ratings (0.5 stars + in the Detached dwelling).	The impact of incorporating a carpet in the model had a substantial impact on the energy performance in CZ 2 across all archetypes. This is ascribed to the increase of the thermal resistance between the inside of the archetype and the thermal mass. This, in turn, resulted in the thermal mass being less effective. The highest change was in the detached house with a maximum 15% increase in the energy consumption for CZ2. On average, the increase of the energy consumption across all archetypes in CZ2 was approximately 11%.

Issue/Comment from Technical Advisory Group (TAG)	Response
Eave modelling is not applied as required by AccuRate data input requirements or Tech Note 1..	The testing of CZ2 found hardly any difference between the technique used and the correct implementation of eaves via employing the horizontal offset. The attached townhouse had a slightly larger impact as the baseline case, due to the eaves extended longer (the length was larger) than what is currently implemented in this change. This change translated into a moderate increase for the attached townhouse of 3.3% in the energy consumption compared to the Baslien I (1-D) case. All models have been corrected to model eaves as suggested.
The hallways in the apartment have been included in the adjacent zones. This is not allowed by Tech Note 1 which requires them to be modelled as separate zones	The apartment archetype has been rezoned. The re-zoning of the apartment resulted in the inclusion of the hallway, the decrease of the living area and the slightly increase of the kitchen. These modifications leaded to an average 1.5% energy increase compared to the Baseline I (1-D) case (which was the incorrectly zoned apartment).
Detached dwelling was incorrectly zoned. The entry/hall zone extends through the Living room. This may be typical of how commercial buildings are zoned, but is not allowed in Tech Note 1 because this type of zoning cannot be properly represented by the of the cross-flow ventilation algorithms in NatHERS tools	The detached archetype has been rezoned. The rezoning of the corridor and living room showed a slightly increase in the energy consumption. An average of 3% increase in comparison with the Baseline I (1-D) case was found.
Based on Technical Note 1, the usage of the [attached archetype] zones named Entry, Study and Bathroom have been re-specified. These usages were day time for Entry and Bathroom (as opposed to night time) and bedroom usage for the study.	The attached archetype has been rezoned. The results showed a small increase in the energy consumption, which translated into an average of 4% energy consumption increase compared to the Baseline I (1-D) case. This difference is mostly attributed to the thermostats schedules being different between day and night time.
Ceiling fans are included in several ratings for the attached but are not required by the NCC. If they are not included in CZ1 to CZ5, window openable area must be larger. It is not clear which is the worst case in terms of energy loads. This may need further consideration.	This item did not involve any modelling but it was needed to ensure that the air movement and ventilation provisions were met. It was found that the required openable area of the archetypes to comply with the air movement and ventilation provisions is less than the existing window openable area. Models were not modified but explanation provided in air movement table.
The project should undertake a relatively small, but representative, sample of simulations to test the impact of the change in archetype/glazing baselines on the change in energy savings for the increase in stringency of a single building element/parameter.	Modelling checks were completed. Results demonstrated (with some caveats) that the findings from the original single-dimensional analysis (with some scenarios glazing not being DtS for any orientation) provided a sufficiently robust set of results for the subsequent benefit cost analysis and prioritisation of building element performance upgrades.

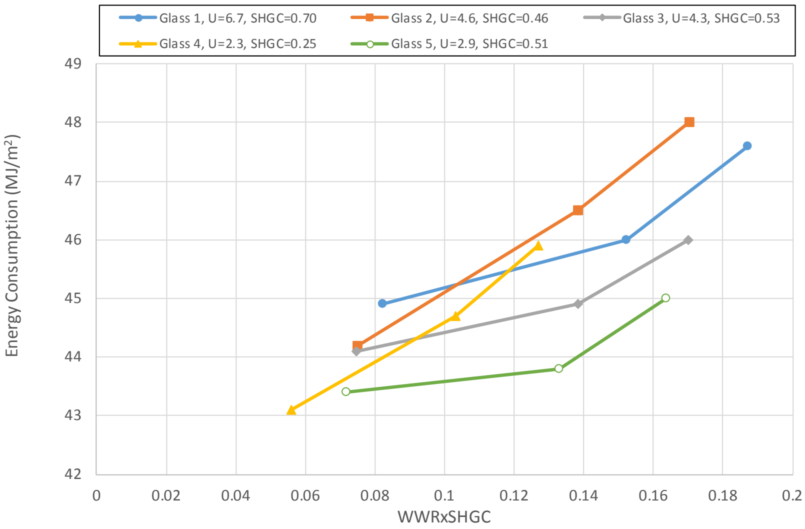
Appendix K: Commercial Model Development Issues and Responses

Issue/Comment from Technical Advisory Group (TAG)	Response
Does IES provide a 3D model of floor slab heat transfer? This is very important for smaller buildings, in particular.	IES can model floor slabs using the ISO13370 3D methodology. This will be used in the modelling.
Should the modelling allow for significant changes in building form, such as an H-floorplate office with high daylight access, in response to the increased demand for efficiency?	Design responses of this nature tend to be very site and application specific and are difficult to extrapolate (and even more difficult to phrase as regulation). As a result, only the most generic design changes are covered in this study (such as changing window size, adding shading/light shelves and adding mass) as these have the potential to be codified. In an NCC context, smarter and more holistic design solutions are encouraged via the use of performance methods (e.g. JV3).
Internal heat loads for the office example are of the order of 150W/person, these seem high?	The internal load assumptions are $11W/m^2$ and 1 person per $14m^2$, giving a total of 154 W/person as noted. Bear in mind that this isn't just a computer – it is also a share of printer, coffee machine, etc etc. From a holistic perspective, though, it's just a load – and we are trying to represent a medium-to-high load space as part of a spectrum of commercial building types. As the numbers match current recommendations for NCC2019 JV3 modelling, we consider it best to make no changes.
How will changes in energy prices plus peak/off-peak considerations be dealt with?	We are currently proposing to use a single flat rate tariff based on AEMO projections. However, for measures that are identified as being not immediately economic, we will be assessing the degree of movement in price and analysis assumption needed to make the measure economic. In terms of peak/off-peak rates, this is a level of detail that it's not practical for us to consider in this study. The relativity of these rates is also likely to change – in ways at this point open to wide debate - as the grid generation mix changes.
Can tighter lighting control be considered?	The lighting scenarios have been updated to incorporate increasing levels of occupancy sensing. Daylight control is considered under the daylighting scenarios.

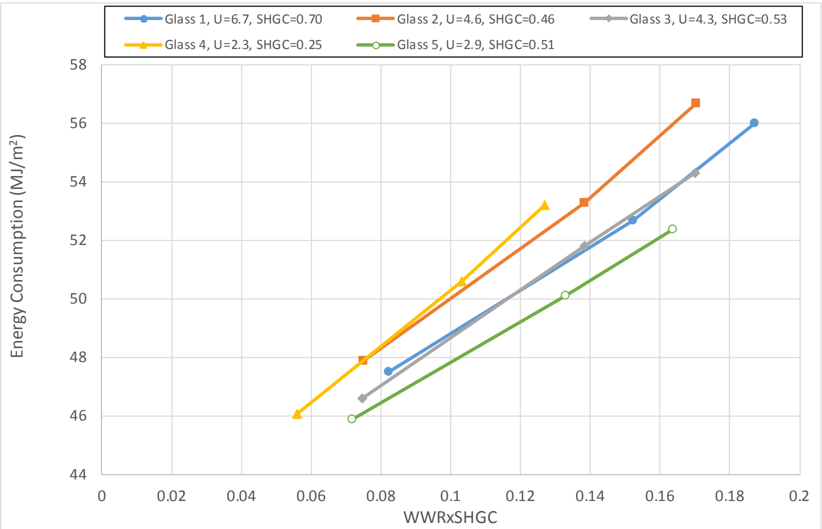
Issue/Comment from Technical Advisory Group (TAG)	Response
The shop archetype seems small – typical big box retail is 3000-4000m^2 and has essentially no windows.	The shop is really representing a place in a spectrum of building envelope exposure, and making the building larger would do little other than marginally shifting the position of the archetype within this spectrum. However the glazing point is a good one and we have modified the archetype to reflect this
Apartments are a commercial building type and should be covered under this work rather than the residential component	ABCB considers that the actual apartments are covered by Vol 2 of the Code, while the common area of apartment buildings is covered by Vol 1; we are working within this interpretation. As the common area energy use is dominated by lighting, lifts and HVAC, it is considered to be adequately captured from a measures perspective within the range of commercial archetypes being considered in this study.
The 5% daylight factor used to determine the underlying NCC2019 glazing provisions is insufficient to guarantee amenity, particularly with respect to glare.	Detailed glare design is highly specific and outside the scope of this study. However as we develop the trajectory models we will consider glare issues and endeavour to integrate appropriate design responses into the model where we think this will have a material impact on the results.
Behaviour of electrochromic glazing not reflective of function in reality	Electrochromic glazing can be controlled based on external inputs – in this case outdoor temperature – and thus can be modelled with a good level of certainty. We believe that the issue raised refers to thermochromic glazing (which passively responds to substrate temperature, and thus suffers from significant uncertainty in actual operation).

Appendix L: Residential Glazing Analysis Summary

The Glazing Energy Analysis was extremely extensive including the simulation of 548 scenarios. This data was plotted in over 216 graphs, and subsequently incorporated in the ongoing benefit cost analysis. An example of a typical graph is shown in Figure 64 where the change in energy consumption as a result of changing window sizes and glazing on the Principal Façade of the Detached archetype.



- South



- West

Figure 64. Two example plots of changes in total heating and cooling annual energy consumption as a function of the characteristics of the glazing in the Principal Façade of the Detached Archetype in Climate Zone 2: a) south-facing façade; b) west-facing. The horizontal axis indicates the effective solar transmission index for the wall as a whole, which is defined as the product of the window-to-wall ratio and the solar heat gain coefficient of the glazing (WWRxSHGC).

Climate Zone	Building Orientation	Principal Façade Orientation	Base Case	Energy Savings (Heating/Cooling) **MJ/m^2**																	
			Glass 1	Glass 1		Glass 2			Glass 3			Glass 4			Glass 5			Glass 6			
			WWRmin	WWRmin +10%	WWRmin +15%	WWRmin	WWRmin +10%	WWRmin +15%	WWRmin	WWRmin +10%	WWRmin +15%	WWRmin	WWRmin +10%	WWRmin +15%	WWRmin	WWRmin +10%	WWRmin +15%	WWRmin	WWRmin +10%	WWRmin +15%	
2	0	South	44.9	-1.1	-2.7	0.7	-1.6	-3.1	0.8	0.0	-1.1	1.8	0.2	-1.0	1.5	1.1	-0.1	—	—	—	
2	90	West	47.5	-5.2	-8.5	-0.4	-5.8	-9.2	0.9	-4.3	-6.8	1.4	-3.1	-5.7	1.6	-2.6	-4.9	—	—	—	
2	180	North	53.0	-0.3	-0.2	0.6	1.3	1.9	1.1	1.0	2.4	2.6	4.2	5.0	1.6	1.9	2.9	—	—	—	
2	270	East	53.4	-3.3	-4.8	0.9	-2.3	-5.0	0.8	-0.6	-2.3	3.5	3.4	2.8	1.9	1.1	-0.2	—	—	—	
5	0	South	37.4	-1.7	-2.7	0.0	-1.8	-3.1	0.8	-0.3	-0.7	1.1	-0.2	-0.7	—	—	—	—	—	—	
5	90	West	38.0	-2.7	-5.7	0.1	-4.2	-6.5	0.9	-1.5	-4.1	1.1	-1.4	-3.4	—	—	—	—	—	—	
5	180	North	40.1	0.8	0.7	0.2	0.6	-0.2	0.7	1.4	1.6	0.6	1.5	1.7	—	—	—	—	—	—	
5	270	East	40.8	-2.1	-4.6	0.4	-2.6	-5.9	1.2	-0.2	-2.2	1.7	0.6	-0.7	—	—	—	—	—	—	
6	0	South	132.7	-5.1	-8.2	-0.3	-6.4	-9.7	2.8	0.0	-1.9	—	—	—	—	—	—	4.3	2.7	1.4	
6	90	West	128.0	-4.9	-8.3	-1.4	-7.5	-11.6	1.7	-1.0	-3.4	—	—	—	—	—	—	3.3	2.1	0.2	
6	180	North	131.3	0.2	-0.7	-1.1	-2.8	-5.1	1.5	3.5	3.0	—	—	—	—	—	—	2.9	6.0	6.1	
6	270	East	136.7	-3.2	-5.7	-0.6	-5.2	-8.0	2.4	0.9	-0.3	—	—	—	—	—	—	3.6	3.5	2.7	

Figure 65. An example of consolidated energy savings data compared to the baseline case that result from making changes to the glazing in the Principal Façade of the Detached Archetype.

Appendix M: Example Residential Glazing Calculator Results for Baseline Archetype

Glazing types for baseline models were initially based on details of typical windows as provided by the Technical Advisory Group (TAG). This was later adjusted to ensure better alignment with the Code DtS requirements. DtS requirements for glazing were determined using the NCC Glazing Calculator Spreadsheet ensuring that glazing met DtS requirements for at least one orientation for each archetype, in each climate zone.

As an example the Glazing Calculator results for the Attached Archetype in Climate Zone 2 across the four cardinal orientations (0°, 90°, 180° and 270°) are provided below. The glazing for the Attached Archetype satisfies the Glazing Calculator requirements for the 180° orientation.

Attached – Climate Zone 2 – Orientation 0° – Ground Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_0_Ground_Floor *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**
Climate zone: **2**

CONSTANTS: C_U 18.387; C_{SHGC} 0.075

Storey: **1**
Floor Construction / Area: Direct contact **64m²**; Suspended
Air Movement: **1.1 x Std**
Area of storey: **64m²**
Area of glazing *14.6m² (23% of area of storey)*

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

ALLOWANCES: C_U(only) **18.4**; C_{SHGC} x Area **4.8**

Number of rows for table below **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	*Conductance - FAILED*		Solar heat gain - PASSED	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	Laundry	N	1.00	1.50		6.70	0.57	0.45	1.40	0.32	0.42	1.50	2.02	10% of 107%	0.4	11% of 71%
2	Kitchen	N	1.50	2.02		6.70	0.57	0.45	1.90	0.24	0.46	3.03	4.07	21% of 107%	0.8	23% of 71%
3	Living	S	2.00	4.04		6.70	0.57	0.90	2.40	0.38	0.41	8.08	10.86	55% of 107%	1.9	56% of 71%
4	Entry	S	2.00	1.00		6.70	0.57	1.50	2.20	0.68	0.31	2.00	2.69	14% of 107%	0.4	11% of 71%
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Attached – Climate Zone 2 – Orientation 0° – First Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_0_First_Floor *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**

Climate zone: **2**

	C_U	C_{SHGC}
CONSTANTS	18.387	0.075

Storey: **1**

Air Movement: **1.1 x Std**

Floor Construction / Area:

- Direct contact: **64m²**
- Suspended:
- Area of storey: **64m²**
- *Area of glazing* *11.6m² (18% of area of storey)*

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

	C_U(only)	C_{SHGC} x Area
ALLOWANCES	18.4	4.8

Number of rows for table below **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES - OK (if inputs are valid)			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		Solar heat gain - PASSED	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	Bed1	n	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.46	4.55	6.30	39% of 88%	1.2	38% of 64%
2	Study	s	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.48	4.55	6.30	39% of 88%	1.2	40% of 64%
3	Bed2	s	1.12	2.28		6.70	0.57	0.45	1.53	0.29	0.45	2.55	3.54	22% of 88%	0.7	21% of 64%
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If inputs (including air movement levels) are valid ✓

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Attached – Climate Zone 2 – Orientation 90° – Ground Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_90_Ground_Floor *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**

Climate zone: **2**

	C_U	C_{SHGC}
CONSTANTS	18.387	0.075

Storey: **1**

Air Movement: **1.1 x Std**

Floor Construction / Area:
- Direct contact: **64m²**
- Suspended:
- Area of storey: **64m²**
- *Area of glazing* *14.6m² (23% of area of storey)*

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

	C_U(only)	C_{SHGC} x Area
ALLOWANCES	18.4	4.8

Number of rows for table below **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES				
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - FAILED		Solar heat gain - FAILED		
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used	
1	Laundry	e	1.00	1.50		6.70	0.57	0.45	1.40	0.32	0.80	1.50	1.98	10% of 106%	0.7	10% of 143%	
2	Kitchen	e	1.50	2.02		6.70	0.57	0.45	1.90	0.24	0.89	3.03	4.01	21% of 106%	1.5	22% of 143%	
3	Living	w	2.00	4.04		6.70	0.57	0.90	2.40	0.38	0.85	8.08	10.69	55% of 106%	3.9	57% of 143%	
4	Entry	w	2.00	1.00		6.70	0.57	1.50	2.20	0.68	0.63	2.00	2.65	14% of 106%	0.7	11% of 143%	
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Attached – Climate Zone 2 – Orientation 90° – First Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_90_First_Floor — *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**

Climate zone: **2**

	C_U	C_{SHGC}
CONSTANTS	18.387	0.075

Storey: **1**

Floor Construction — Area
- Direct contact: **64m²**
- Suspended:
- Area of storey: **64m²**
- *Area of glazing*: *11.6m² (18% of area of storey)*

Air Movement: **1.1 x Std**

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

	C_U (only)	C_{SHGC} x Area
ALLOWANCES	18.4	4.8

Number of rows for table below: **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		*Solar heat gain - FAILED*	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	Bed1	e	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.89	4.55	6.75	39% of 94%	2.3	37% of 128%
2	Study	w	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.97	4.55	6.75	39% of 94%	2.5	41% of 128%
3	Bed2	w	1.12	2.28		6.70	0.57	0.45	1.53	0.29	0.92	2.55	3.79	22% of 94%	1.3	22% of 128%
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Attached – Climate Zone 2 – Orientation 180° – Ground Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_180_Ground_Floor *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**

Climate zone: **2**

	C_U	C_{SHGC}
CONSTANTS	18.387	0.075

Storey: **1**

Air Movement: **1.1 x Std**

Floor Construction / Area: Direct contact **64m²**; Suspended; Area of storey 64m²

Area of glazing 14.6m² (23% of area of storey)

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

	C_U (only)	C_{SHGC} x Area
ALLOWANCES	18.4	4.8

Number of rows for table below **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES - OK (if inputs are valid)			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		Solar heat gain - PASSED	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	Laundry	s	1.00	1.50		6.70	0.57	0.45	1.40	0.32	0.44	1.50	1.32	10% of 70%	0.4	11% of 71%
2	Kitchen	s	1.50	2.02		6.70	0.57	0.45	1.90	0.24	0.48	3.03	2.66	21% of 70%	0.8	24% of 71%
3	Living	n	2.00	4.04		6.70	0.57	0.90	2.40	0.38	0.40	8.08	7.09	55% of 70%	1.8	54% of 71%
4	Entry	n	2.00	1.00		6.70	0.57	1.50	2.20	0.68	0.31	2.00	1.76	14% of 70%	0.4	10% of 71%
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If inputs (including air movement levels) are valid ✓

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Attached – Climate Zone 2 – Orientation 180° – First Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_180_First_Floor *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**

Climate zone: **2**

	C_U	C_{SHGC}
CONSTANTS	18.387	0.075

Storey: **1**

Floor Construction / Area: Direct contact **64m²**; Suspended; Area of storey **64m²**

Air Movement: **1.1 x Std**

Area of glazing *11.6m² (18% of area of storey)*

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

	C_U(only)	C_{SHGC} x Area
ALLOWANCES	18.4	4.8

Number of rows for table below **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES - OK (if inputs are valid)			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		Solar heat gain - PASSED	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	Bed1	S	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.48	4.55	4.69	39% of 65%	1.2	41% of 64%
2	Study	N	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.46	4.55	4.69	39% of 65%	1.2	39% of 64%
3	Bed2	N	1.12	2.28		6.70	0.57	0.45	1.53	0.29	0.43	2.55	2.64	22% of 65%	0.6	21% of 64%
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IMPORTANT NOTICE AND DISCLAIMER IN RESPECT OF THE GLAZING CALCULATOR ***If inputs (including air movement levels) are valid***

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Attached – Climate Zone 2 – Orientation 270° – Ground Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_270_Ground_Floor *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**

Climate zone: **2**

	C_U	C_{SHGC}
CONSTANTS	18.387	0.075

Storey: **1**

Air Movement: **1.1 x Std**

Floor Construction — Area

Direct contact: **64m²**

Suspended:

Area of storey: **64m²**

Area of glazing *14.6m² (23% of area of storey)*

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

	C_U(only)	C_{SHGC} x Area
ALLOWANCES	18.4	4.8

Number of rows for table below **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	*Conductance - FAILED*		*Solar heat gain - FAILED*	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	Laundry	W	1.00	1.50		6.70	0.57	0.45	1.40	0.32	0.90	1.50	2.07	10% of 110%	0.8	12% of 137%
2	Kitchen	W	1.50	2.02		6.70	0.57	0.45	1.90	0.24	0.97	3.03	4.18	21% of 110%	1.7	26% of 137%
3	Living	E	2.00	4.04		6.70	0.57	0.90	2.40	0.38	0.75	8.08	11.15	55% of 110%	3.5	53% of 137%
4	Entry	E	2.00	1.00		6.70	0.57	1.50	2.20	0.68	0.56	2.00	2.76	14% of 110%	0.6	10% of 137%
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Attached – Climate Zone 2 – Orientation 270° – First Floor

Report from CalculatorGlazingVolTwo2014_Attached_Climate2_Baseline_270_First_Floor — *printed 7/12/2017*

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: **Attached Townhouse**

Climate zone: **2**

	C_U	C_{SHGC}
CONSTANTS	18.387	0.075

Storey: **1**

Air Movement: **1.1 x Std**

Floor Construction / Area: Direct contact **64m²**; Suspended; Area of storey 64m²; *Area of glazing* *11.6m² (18% of area of storey)*

Wall insulation option chosen for 3.12.1.4: ***No wall insulation concession used***

	C_U (only)	C_{SHGC} x Area
ALLOWANCES	18.4	4.8

Number of rows for table below **11** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		*Solar heat gain - FAILED*	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area / winter access	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	Bed1	w	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.97	4.55	6.89	39% of 96%	2.5	42% of 126%
2	Study	e	1.50	3.03		6.70	0.57	0.45	1.90	0.24	0.89	4.55	6.89	39% of 96%	2.3	38% of 126%
3	Bed2	e	1.12	2.28		6.70	0.57	0.45	1.53	0.29	0.83	2.55	3.87	22% of 96%	1.2	20% of 126%
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